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CONTENTS

Nutritional management in oilseeds : Present status and future strategies

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ABSTRACT

A review of the recently published information on the nutritional aspects of oilseed crops in relation to their yield and quality reveals a substantial scope for increasing their production in the country. National self-sufficiency of edible oil would be enhanced if the productivity of the oilseed crops on marginal soils under rainfed conditions is increased through adoption of improved management technology and improved germplasm. This warrants intensive research efforts in these areas. Applying mineral fertilizers in balanced amounts and in an integrated manner by combining with bulky organic manures and crop residues can ensure sustainable production at higher productivity and higher quality level of the oilseed crops. For optimum utilization of other essential inputs, fertilizer requirements need to be fine tuned, especially in oilseed-based cropping systems and intercropping systems. Besides making best use of the applied nutrients, such management practices can substantially benefit the major cereal crops from the fixed-N, if the accompanying oilseed crop happens to be a leguminous like soybean and groundnut. Combining a cheap source of sulphur with other basic nutrients like nitrogen, phosphorus and potassium and required micronutrients like zinc is very essential in case of oilseeds for both yield and higher oil production under irrigated as well as rainfed conditions. To make best use of the soil-derived phosphorus, inoculation with naturally occurring phosphorus solubalizing micro-organism can be successfully employed.

Key words: Fertilizer requirements, Integrated nutrient management, Oilseeds

Production of oilseed crops occupies a unique place in the strategic national programme of food security. This is because of the consistent shortfall in their availability to meet the minimum *per capita* needs of the population. Current availability of edible oil in the country is only 20 g/day/capita as against the balanced nutritional requirement of 30g/day/head (Economic Survey, 2006-07). To meet the vegetable oil needs of the country at the optimum consumption level, we have to increase our production from present level of 20 m. t. to about 50 m. tonnes by 2020 (Hegde, 2005). At present, oilseed crops are grown over an area of 27.56 m. ha. with total production of 27.72 m. t. (2008-09). There could be several reasons for their low production. Oilseeds are mostly grown under rainfed conditions on marginal lands, which are considered unsuitable for the production of high-input cereal crops. Most of such lands are inhabited by resource-poor farmers who can rarely afford to use minimum nutrients required in balanced proportions. Slow pace in the productivity growth in oilseeds has been, thus often linked to imbalanced and inadequate nutrient application to these highly energy rich crops. Major oilseed growing states are Madhya Pradesh, Rajasthan, Maharashtra, Gujarat, Andhra Pradesh, Karnataka and Uttar Pradesh. Gross cropped area under oilseed crops is 17.725 m. ha., of which only 62% of the area is treated with fertilizers. On national average for all oilseed crops, only 52.5 kg/ha nutrients (NPK) are applied as against 140 kg/ha for rice and 160 kg/ha for wheat. In all the oilseed crops, S nutrition occupies a unique position as it is involved in the oil synthesis while N plays a key role in their production, but more so in non-legume oilseed crops (Aulakh and Pasricha, 1988; Aulakh *et al.*, 1990b; Aulakh *et al.*, 1997). Its deficiency in crops has been accentuated by increased use of S-free nitrogenous and phosphatic fertilizers in the country (Pasricha and Abrol, 2003). Their productivity can be enhanced by judicious use of nutrients integrated with bulky organic manures and adoption of improved management technologies in relation to increased storage and conservation of moisture in the root zone of soil (Aulakh *et al.*, 1987; Pasricha and Aulakh, 1989; Pasricha and Bahl, 1997; Pasricha and Tandon, 1990). Soybean, groundnut, rapeseed-mustard, sunflower, sesame, linseed and castor are some of the important annual oilseed crops, which have value for human consumption and industrial use. In this review, attempt has been made to consolidate the latest information on the nutritional aspect of these crops by highlighting the role mineral fertilizers and bulky organic materials in increasing productivity of oilseeds on a sustainable basis.

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SOYBEAN

Soybean is the most important oilseed crop grown in an area of 96.87 m. ha in the world and 9.51 m. ha in India. Current productivity of soybean is very poor both under irrigated (1827 kg/ha) and rainfed (1338 kg/ha) conditions. The projected area in the world in 2025 under rainfed conditions is slated to increase to 60.83 m. ha with productivity of 1765 kg/ha. But under irrigated conditions, the projected area would decrease to 37.80 m. ha with productivity of 2317 kg/ha (Rosegrant *et al.*, 2002). Thus, there is a lot of scope of improvement in its productivity (Chauhan and Joshi, 2005). Soybean is highly energy rich crop with 18-22% oil content and 40-44% protein and as such is termed as a miracle crop. Its use in preparation of soyamilk and soy cheese makes it an important crop to provide relatively cheaper protein to the poor section of the people at a relatively low price. After extraction of oil, the meal of soybean is a very good source of poultry feed. The crop has been rated as industrially vital and economically highly viable in the central part and elsewhere in the country (Singh *et al.*, 2001). Its oil is a rich source of desired poly-unsaturated fatty acids, especially omega-6 and omega-3 fatty acids (Chauhan *et al.*, 1988). India ranks fifth in the world with respect to soybean acreage and production. Madhya Pradesh, Maharashtra and Rajasthan are the major soybean growing states in the country. In Madhya Pradesh and Maharashtra, it is grown on Vertisols. Currently soybean-wheat rotation (irrigated) and soybean-chickpea (rainfed) are the two main soybean-based production systems followed in the country.

Nitrogen requirements: The widespread adoption of soybean is due to its ability to meet a portion of its N requirement through symbiotic fixation of atmospheric N and its potential to fit well as an intercrop with a number of major crops of the region. Soybean has high demands for N which can exceed 92 g/kg seed at its optimum yield (Flannery, 1986). All popularly grown cultivars of this crop may not have an effective mechanism of symbiotic N_2 fixation to meet its entire N requirement. Ability of soybean crop to fix N_2 decreases as the seed development stage advances, whereas the requirement of N at seed development stage remains relatively high. Any addition of fertilizer N at this stage, therefore, is sure to improve yield and quality of the produce. Yadav and Chandel (2003) observed highest seed yield of 3.25 t/ha of soybean with 40 kg N/ha at 60 days after sowing + 20 kg N/ha at 75 days after sowing along with 35 kg P/ha applied as the basal dose at the time of sowing. Supply of N from outside in the form of fertilizer is, however, very tricky. A slightly excessive amount applied may result in increased vegetative growth resulting in decreased yield. According to Hanway and Weber (1971), half of the N in mature soybean seeds is cornered from different parts of the plant as translocated N while the rest half comes from soil and symbiotically fixed N in root nodules of the plant (Papastylianou, 1986). For balanced nutrition, legumes have a higher requirements of S. Its requirement becomes more prominent oilseed legume crops like in soybean and groundnut. Application of N beyond 300 kg/ha can depress nodulation in soybean (Singh and Bansal, 2000), leading to decrease in N-fixation symbiotically. N-fixation and applied fertilizer N complement each other to meet high N requirement of this crop (Tanaka, 1983). For its N_2 fixation, optimum level of available copper content in soil is necessary. Barik and Chandel (2002) studied the effect of Cu nutrition on the nodulation, leg-haemoglobin content, and N uptake of commonly cultivated soybean varieties. Application of 2.5 kg Cu/ha as copper sulphate significantly increased nodule/plant, their dry weight and their leg-haemoglobin content by 11, 11 and 21%, respectively. Effect of Cu was more conspicuous in crop variety AK-416. This shows that plants receiving adequate Cu raised the efficiency of energy producing systems and enzymes essential for metabolism directly involved in N_2 fixation (Hallsworth *et al.*, 1964). Total N uptake was significantly affected by Cu application and the variety PK-416 showed the highest uptake of 186.5 kg N/ha.

Phosphorus requirements: Although P plays a key role in the nutrition of soybean, but its use in the rainfed soybean crop is constrained by its low efficiency (<25%). A major portion of the applied source is converted to less soluble P sources in soil and become unavailable to crop plants. Solubalizing this fixed form of P through application of FYM or solubalizing organism is a valuable option to augment its availability in easily assimiable form by the crops. Gautam *et al.* (2003) evaluated the effect of phosphate solubalizing micro-organisms (*Pseudomonas*) coupled with FYM and *Bradyrhizobium japonicum* in rainfed soybean. They observed a 22 to 34% increases in seed yield of soybean. Increase in seed yield due to inoculation with *B. japonicum* (Dubey, 1999), and *Rhizobium* (Raychaudhari *et al.*, 1997) has also been observed. It was concluded that use of microbes in conjunction with FYM was beneficial for making use of applied and native P to increase the yield of soybean. Phosphorus enrichment of compost owing to addition of low grade rock phosphate available abundantly in several parts of the country, in association with P-solubalizing fungi (*Aspergillus avavamore*) accelerates the process of composting as well as improvement in its quality (Singh *et al.*, 1992; Singh, 2000). Namdeo *et al.* (2003) used P enriched compost for improving the yield of soybean on Vertisols of Madhya Pradesh. They observed that application of 60 kg P_2O_5/ha either as 12.5% Jhabua rock-phosphate-charged phospho-compost @2.5 t/ha or 25% Jhabua rock phosphate @1.5 t/h exhibited statistically identical performance for growth and yield parameters of soybean and were significantly superior to the control. Both the phospho- composts were as effective as application of 60 kg P_2O_5/ha supplied through single super phosphate. This study would have given clear superiority of enriched compost, had there been a treatment of 60 kg P_2O_5/ha + 2.5 t or 1.5 t/ha of compost. Phosphorus present in soil in organic combinations such as esters are readily available to plants. However, its importance as a source of available P is largely determined by the rate of its solubalization to release inorganic form of P. Activity of enzyme phosphatase controls the rate of hydrolysis of organic P. Utilization of such forms of P also depends to some extent on the soybean genotypes which can influence the phosphatase activity in soil (Zoysa *et al.*, 1999). Variation in the phosphatase activity in the soil on P-utilization efficiency and depletion of organic P in soybean genotype could be due differential root pattern. Genotypes with higher P concentrating capacity were found to be related with root surface area (Ramesh *et al.*, 2004).

Potassium requirements: Potassium is considered as one of the nutrients which not only improves yield but is also involved very actively in the metabolic processes in the plant system (Bahl and Pasricha, 1995; Basseto *et al.*, 2007). In long-term field experiments, Rupa *et al.* (2003) observed decline in the yields as a result of K deficiency. Wanjari *et al.* (2004) reported an increase in yield of soybean with K-application when grown in different production systems. The recovery and physiological and internal use efficiency of K were higher in the late sown soybean compared to the timely planted crop in the Malwa region of Madhya Pradesh. Significantly higher net returns were reported with 50 kg K/ha, while maximum B: C ratio was associated with 33 kg K/ha. All the 3 genotypes tested differed significantly among themselves with regard to K-use efficiency. The economic optimum level of K for planting time and soybean genotypes ranged from 37-39 kg K/ha. Increase in yield of soybean observed was 13.5, 25.2, and 35.6% through application of 17, 33, and 50 kg K/ha, respectively, over control (1.965 t/ha) (Billore *et al.*, 2009). Vyas *et al.* (2007) also reported similar increase in yield with graded levels of K application. Yadav (2003) reported a fall in agronomic efficiency and partial factor productivity in K application rates above 50 kg K/ha. Billore *et al.* (2009) also reported genetic variation in recovery of K, efficiency, physiological efficiency, and internal K use efficiency being maximum with JS93-05, followed by NRC7, and least in JS335.

Sulphur requirements: Like all the grain legumes, soybean also responds markedly to S application. This is more so because it is both a grain legume as well as an oilseed crop. Extent of response to this nutrient, however, is determined to some extent whether the crop is irrigated or rainfed. In irrigated soybean, the response to applied S may not be glaring especially when the source of irrigation is ground water. Most of the underground waters contain significant amounts of S which can meet the S requirement of the crop. However, rainfed crop must receive adequate quantity of this element in balanced fertilization for optimum yields. Chaurasia *et al.* (2009) in a comparison of different S sources reported that application of 30 kg S/ha through single super phosphate gave the highest seed yield (2.129 t/ha) as compared to gypsum (2.075 t/ha) and pyrite (1.954 t/ha). Oil content (19.9%) and oil yield (430 kg/ha) were also highest in the single super phosphate treated plots. Pyrite has proved the poorest of the three sources (Table 1). This is because, unlike other two sources, S in pyrite (FeS_2) is present in sulphide form which must be oxidized to sulphate before it can be taken up by the crop. Similar results have been earlier reported by Aulakh *et al.* (1980a) and Pasricha *et al.* (1990) for groundnut.

Table 1. Yield and quality of soybean as influenced by source and level of sulphur application (Chaurasia *et al.*, 2009)

Source	Yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)
Gypsum	2075	19.3	410
Pyrite	1954	18.8	370
Single super phosphate	2129	19.9	430
S levels (kg/ha)			
No-S	1728	18.6	325
10	1891	18.9	363
20	2071	19.4	408
30	2270	19.8	456
40	2294	20.2	470

Combined use of nutrients for balanced nutrition: In general, soybean can experience N deficiency at pod filling stage like all other grain legumes and ultimately causing reduction in seed yield (Mahadkar and Saraf, 1992). It also has high S requirement which if available in requisite amounts, improves N utilization in the plant system (Pasricha and Randhawa, 1975). Vyas *et al.* (2006) in a study on the effect of balanced and continuous supply of N and S reported that productivity and energy budgeting of soybean were significantly affected. An application 20 kg N/ha in combination with 40 kg S/ha gave highest yield of 2212 kg/ha over 1742 kg/ha in control (N_0S_0) in soybean genotypes in Malwa region of Madhya Pradesh. In a three-year experiment on soybean, highest seed yield was obtained as a result of combined application of 25 kg N, 80 kg P_2O_5 and 40 kg S/ha (Aulakh *et al.*, 1990a). Maximum oil yield of 412 kg/ha was produced with this combination of N, P and S as compared to only 111 kg/ha in control. This also resulted in plump and shining seeds with increased protein content. The protein content increased from 27.1% in control to 33.1% with $N_{25}P_{80}S_{40}$. The increase in oleic/linoleic acid ratio with increasing levels of P applied and 25 kg N and 40 kg S/ha, indicated improvement in the quality of soybean.

Nutrient requirement in soybean-based crop rotations: Most of the rainy season crops grown in rotation with wheat either do not respond or respond partially to direct application of fertilizer P because these crops can efficiently meet their P requirements from the residual P in the soil. Soybean is the only exception in this regard which is very poor efficient in using P from soil (Aulakh *et al.*, 2003) and a high dose of 80 kg P_2O_5/ha has to be applied for optimum yield, but when it follows wheat which has received the recommended level of P (60 kg P_2O_5/ha), its application to soybean can be decreased by only 25% i.e., instead of 80 kg P_2O_5/ha, an application 60 kg P_2O_5/ha will serve the purpose. Unlike other rainy season crops, P application cannot be completely omitted in this case (Aulakh *et al.*, 2003). Soybean-wheat is an important cropping system followed in Vertisols in the semi-arid and tropical region of the country. Legume-cereal cropping system helps in maintaining health of the soil (Dhama and Sinha, 1985). Productivity of this system is highly unstable because of low use of chemical fertilizers in a highly imbalanced manner under situations of uncertain amount and distribution of rains in this region. In deep Vertisols in central India, predominant cropping system is soybean in rainy season (July-October) and wheat in winter season (November-March). Continuous adoption of mono-culture of soybean-wheat rotation is perhaps responsible for its declining productivity because of mining of certain specific nutrient elements (Nimje, 2003). Breaking sequence with maize, chickpea, pigeonpea or Indian mustard is necessary to break the monotony. Amongst the grain legumes, soybean is the most energy-rich crop with high content of protein and oil. As such, it is most exhaustive crop. It has high demand for N and P. Phosphorus proves more efficient if applied to wheat crop in the rotation (Aulakh *et al.*, 1990a). Following soybean crop still requires high amount of P (60 kg P_2O_5/ha). Rao *et al.* (1995) reported that P applied to soybean has sufficient residual effect on the following wheat crop.

In a study, on the performance of different soybean-based cropping systems as influenced by varying levels P under rainfed conditions, Nimje (2003) observed that soybean yield equivalent of pigeonpea-wheat was 4.9 t/ha, followed by soybean-chickpea (4.8 t/ha) were significantly higher than the soybean-wheat (4.6 t/ha) and maize-wheat (3.9 t/ha). Soybean-chickpea sequence proved more economical and gave returns of ₹ 2,808/ha. Benefit: cost ratio was also significantly higher in soybean-chickpea (2.86) than soybean-wheat (2.21). Phosphorus application at 19.5 and 39 kg P/ha gave significantly higher soybean seed (t/ha) equivalent yield of 30 and 50.6% over control, respectively (Table 2). Durum wheat has relatively less irrigation requirements and can be successfully grown under these conditions in rotation with soybean (Bahera and Thakur, 1999). Although P is the most important nutrient for legume crops, but due to high price, its use in rainfed soybean is not warranted because of unsure nature of rainfed crop.

Table 2. Soybean seed-equivalent yield, net returns and benefit: cost ratio as influenced by cropping sequence and level of phosphorus application (mean of 3 years data, 1997, 1998, 1999) (Nimje, 2003)

Cropping sequence/P-levels	Yield (t/ha)			Net monetary returns (₹/ha)	Benefit : cost ratio
	Rainy season	Winter season	Total		
Maize-wheat	1.85	2.06	3.91	20,732	1.97
Soybean-wheat	1.79	2.87	4.66	25,669	2.21
Soybean-chick pea	1.67	3.19	4.86	28,808	2.86
Soybean-mustard	1.72	2.34	4.06	21,808	2.04
Pigeon pea-wheat	2.48	2.48	4.96	27,173	2.61
P-applied (kg/ha)					
No-P	1.55	1.97	3.52	17,430	1.63
19.5	1.96	2.61	4.57	25,270	2.24
39.0	2.22	3.14	5.36	31,030	2.61

There exists large deposit of phosphate rock in the southern Rajasthan. Phosphorus in apatite form in phosphate rock is highly insoluble and its P is not available to plants when applied to soil especially in non-acidic high pH soils. However, when applied in combination with acidic P fertilizers like single super phosphate, organic materials and P-Solubalizing micro-organisms, its solubility increases Tanwar and Shaktawat (2003) studied integrated P management in soybean-wheat cropping system by incorporating locally available P sources. Phosphorus application through single super phosphate significantly increased yield and oil content in soybean. However, application of half of P through SSP and half through Udaipur rock phosphate gave yield that were significantly higher than control, but lower than SSP alone. The effect of Udaipur rock phosphate seemed negligible and whatever increase in yield was observed can be ascribed to SSP added along with rock phosphate. Phosphorus solubalizing organisms were far less effective than FYM when applied along with rock phosphate. Combining P solubalizers with FYM did not prove more effective either. FYM applied to soybean had significant effect on the yield of following wheat crop but it responded more to direct application of P in the soluble form. Application of P-solubalizers with phosphate rock seems more effective in the following wheat crop.

Light textured soils of Uttarakhand are low in available K (Ghosh and Hasan, 1976). Soybean-wheat rotation under rainfed conditions of Uttarakhand and has been found profitable (Kundu *et al.*, 1990). In legume-cereal crop sequence, cereal mines soil K more effectively, when K is present in critical amounts in the soil, the following legume crops may suffer from its deficiency. Legume crop depends more on readily available applied fertilizer K (Srinivasa Rao *et al.*, 1999). Singh *et al.* (2001), in a long-term study reported that continuous cropping with soybean and wheat in that sequence for 7 years led to a negative K balance in a Vertisols which are otherwise known to be rich in available K (Datta *et al.*, 2010). This has happened even at regular annual application of 66 kg K/ha. Ved Prakash *et al.* (2002) reported the results of a long-term experiment (Table 3). They worked out response patterns of soybean-wheat to applied K in relation to advancing years of cultivation. Average yield data of 27 years showed significant response to K resulting in increase in yield of soybean up to 70%, and 20% increase in yield of wheat due to residual effect of K. Average yield response of soybean ranged from 7.2 to 11.7 kg seed yield/kg K during 1973-79, and it increased to 22.7-25.7 kg seed/kg K during the period from 1986-96. Yield response of succeeding wheat to residual K also showed similar increasing trend with time. Soil analysis after 27 years of soybean-wheat rotation showed a net negative K balance in soil (0-45 cm). On the other hand, application of recommended levels of NPK along with 10 t/ha of FYM to soybean sustained not only higher yields but also resulted in buildup of extractable K (26.7 kg K/ha).

Table 3. Response patterns of soybean-wheat to nutrients and in combination with FYM in relation to advancing years of cultivation (Ved Prakash *et al.*, 2002)

Treatment	Yield (kg/ha)*		Change in soybean yield (kg/ha)		Change in wheat yield (kg/ha)	
	Soybean	Wheat	1973-77	1995-99	1974-78	1996-2000
$N_{20}K_{33}$	583	711	970	311	716	728
$N_{20}P_{35}$	623	801	1055	285	808	818
$N_{20}P_{35}K_{33}$	876	917	1410	482	965	868
$N_{20}FYM_{10}$	1489	1119	1650	1049	1044	1057

*Mean of 27 years data

Nutrient requirement of soybean as intercrop: Productivity of soybean is either constant or declining in the central India, the dominant soybean growing region of the country. Sorghum on the other hand can more effectively resist the drought conditions and make best use of the available water as it has C_4 photosynthetic mechanism. Intercropping of soybean with sorghum and other such crops is now considered as one of the most effective management practices for increasing the overall production of oilseed crops in the country. This practice helps in optimizing crop productivity and efficiency of basic and external resources. Singh *et al.* (2003) investigated the integrated nutrient management of soybean+sorghum-wheat grown in multiple intercropping systems in Vertisols. Application of 75% of recommended NPK fertilizers along with 5 t/ha of FYM recorded the highest yield of soybean along with yield and quality of intercropped sorghum. Wheat under legume-cereal intercropping system (soybean-wheat) had better quality in terms of protein (12.2%), methionine (1.4g/16 g N) and tryptophan content (1.37 g/16 g N) as compared to wheat crop grown under cereal-cereal (sorghum-wheat) cropping system. Bandopadhyay *et al.* (2004) tried to partially substitute sorghum for soybean to overcome the situation of complete crop failure in years of erratic rains. In such a system, cereal (sorghum) has high requirement for N while legume (soybean) can take care of its N requirement through symbiotic fixation of molecular N (Yadav *et al.*, 1998). Intercropping, especially cereal+ legume combination can increase production and productivity by better utilization of available source, thereby, help in minimizing risk and bringing stability under rainfed conditions (Chatterjee and Mandal, 1992). Ramesh *et al.* (2003) found that under low fertility level (N_0), soybean+sorghum intercropping system was more productive and remunerative; however, at higher fertility level (N_{100}), sole sorghum was more remunerative. At higher levels of N, excessive vegetative growth in legumes is responsible for low yield. Singh *et al.* (2001) and Chatopadhyay *et al.* (2001) reported a significant correlation between crop yield and seasonal evapotranspiration. By manipulating irrigation and nutrient application practices, the evapotranspiration can be optimized to attain maximum yields. The seasonal evapotranspiration showed a quadratic relationship with total drymatter yield in soybean grown as sole or as intercrop with sorghum. Optimum seasonal evapotranspiration for maximum drymatter yield was found to be 605.5 mm for soybean as sole crop and 576.2 mm for sorghum + soybean grown as intercrops.

Intercropping of soybean with pigeonpea has been reported to offer improved production system (Billore and Joshi, 2004) than its sole cropping in the central India. Such a system has lesser risk components by ensuring adequate yield of at least of one of the crops under aberrant weather conditions (Rao and Willey, 1980). Growing sesame and soybean as intercrop with balanced nutritional management can achieve higher productivity of these oilseed crops (Mondal *et al.*, 2001). Most of the work on intercropping has been done in relation to row spacing/row ratio, but such management may have different nutrient requirements as well. Total oil yield (soybean oil yield + sesame oil yield) was 484 kg/ha in intercropping, while sole crops individually gave an oil yield of 288 kg in case of soybean and 339.5 kg/ha in case of sesame. Similarly, the yield of rainy season intercropping of soybean with sesame were higher at 448 kg/ha than sole crops at 296 kg/ha for soybean and 320 kg/ha for sesame, as mean of three years oil yield data. Maximum combined oil yield was observed with combined application of 40 kg/ha N and 80 kg/ha K at the time of sowing. Similar findings have been earlier reported by Deshmukh *et al.* (1994) and Lal *et al.* (1995).

Vyas *et al.* (2006) attempted to understand nutritional requirement of such system through integrated nutrient use. They evaluated productivity and economic advantage as influenced by different fertility levels in soybean-pigeonpea intercropping system. They reported highest yield of 1937 kg/ha for soybean and 1632 kg/ha for pigeon pea with 75% of the recommended fertilizers + 5 t/ha of FYM. Soybean yield with 75 and 100% of recommended levels of fertilizers alone were 1657 kg/ha, and 1860 kg/ha, respectively. Although, soybean yield decreased by 18-36% under intercropping but combined yield of soybean and pigeonpea as equivalent of soybean per unit land area w higher than the sole yield of either crop per unit land area

Integrated nutrient management: Lack of adoption integrated approach and sub-optimal unbalanced nutrition soybean crop under on-farm conditions is a major factor f lower yield realization in the country. The nutrient imbalan due to deficit supplementation of nutrients by organ manures is cause for lower yields (Katyal and Reddy, 199 Both S and K along with N are crucial for long-term hi productivity, however, stability in productivity can only affected with long-term use of bulky organic manures wi these nutrients. Crop response as sole or in cropping syste to applied nutrients is, however, determined by nati nutrient supplying power of the soil. It also depends up crop requirement and eco-edaphic factors besides agronom management practices. Consistent use of organic manur and crop residues in conjunction with fertilizer nutrients n only help to stabilize the production system but al improves soil quality by protecting soil health again degradation. Billore *et al.* (2005) observed that conjuncti use of soybean residue @ 5 t/ha + 5 t FYM/ha + Zn @ kg/ha applied to soybean only was most productive (26 kg/ha soybean yield equivalent). Enhancement of soybe yield (Bisht and Chandel, 1996) has been reported wi consistent use of organic materials in combination wi mineral fertilizers.

Deficiency of Zn, B, and Mo are more widespread th other micronutrients which limit the productivity of soybe in Madhya Pradesh. Billore and Joshi (2005) evaluated t application of micro- and major nutrients with FYM on t productivity of soybean-wheat cropping system. Th reported that application of FYM @ 10 t/ha applied in t rainy season was more effective in total productivity of t system, which was confirmed by highest value (0.82) sustainable yield index. They analysed stability index a indicated that application of Zn @ 5 kg/ha to soybean (0.9 FYM @ 10 t/ha (0.92) and integration (1.06) gave stabili of this production system over years.

Hegde *et al.* (1993) reported that continuous applicati of FYM can stabilize the productivity of this system improving soil health in this region. Billore *et al.* (200 observed that incorporation of organic sources, irrespecti of mineral fertilizers, improved the productivity soybean-wheat system. Incorporation of soybean residue wi FYM and Zn has proved extremely superior in enhancing t yields. Billore *et al.* (2005) earlier also reported simil results. Impact of legume residue when combined wi mineral fertilizers and other organic manures has tremendo effect as earlier reported by Bahl *et al.* (1986), Sharma a Mishra, (1998) and Saxena and Chandel, (1997). Thus, the is no doubt that combined use of organic and inorgan fertilizers is necessary for balanced plant nutrition a protecting soil health against degradation. Jaipaul *et*

(2008) used yield target concept for balanced fertilization of soybean grown in rotation with wheat. Their results showed that prescription-based fertilizer recommendation in yield target concept can be used efficiently up to yield target of 3 t/ha for soybean and wheat in the wet temperate zone of Himachal Pradesh. They further reported that with addition of 3 t/ha of FYM to soybean, fertilizer doses to subsequent wheat crop can be reduced by 20, 13 and 30 kg/ha for N, P, and K, respectively.

Broiler litter has an economic value associated with the nitrogenous and other mineral nutrient contents (Suppadit *et al.*, 2002). Pelleted broiler litter can be conveniently handled. This process also eliminates foul smell and contains growth of harmful microbes. Suppadit *et al.* (2008) reported that substitution of up to 75% of chemical fertilizers with pelleted poultry manure was best for harnessing the potential productivity of soybean and performed better than chemical fertilizers. Thus, application of organic materials to the field crops not only meets nutrient requirement but also plays important role in improving the soil chemical, biological and physical properties. Fertilizer application through essential for increased productivity and production, but must be supplemented with organic manures and crop residues for sustaining high productivity. It also takes care of small requirement but highly essential micronutrient elements. Singh *et al.* (2008) investigated quality parameters of soybean and soil quality parameters as influenced by different organic materials. They observed that FYM or cattle dung manure gave the highest grain yield of soybean (1374 to 1420 kg/ha) as compared to control (1218 kg/ha). It increased the protein content of seed and also influenced positively the S-containing essential amino acids, methionine and cistein. Ramamurthy and Shivashankar (1995) also reported improvement in nutritional quality due to addition of organic materials in combination with P-fertilizer in soybean. Organic materials also improved the soil organic carbon content from 0.49% in control to 0.64% with treatment. Better microbial activity as a result of organic matter application can be judged from the reported increase in dehydrogenase level in soil at the end of the cycle. Dehydrogenase activity in soil is an indicator of its quality. Even the sequence of herbicide use, whether it is pre-emergence or post-emergence also matters in this regard. Singh *et al.* (2008) reported that pre-emergence application of herbicide alachlor significantly reduced dehydrogenase activity in soil, while application of post-emergence herbicide did not have such adverse effect on soil microbial activity as judged from dehydrogenase level in soil. With decrease in fertilizer dose, there was reduction in urease activity and there was significant decrease in grain yield of soybean with decrease in fertilizer level.

Tillage management is gaining momentum due to the need in reduction of production costs and protecting SOM from oxidation. About 25-30% of the total energy required for field preparation can be saved through tillage management. In soybean-based rainfed cropping system, hardly 10 days time is available between harvesting of soybean and timely sowing of wheat crop. Reduced tillage can play significant role in facilitating timely sowing to utilize residual moisture for proper germination and also reduce the production costs. Prakash *et al.* (2004) studied the influence of reduced tillage in soybean-wheat, soybean-lentil, and soybean-field pea production systems. On pooled basis, conventional tillage gave the highest yield of soybean equivalent (3432 kg/ha) being at par with zero-tillage (3306 kg/ha). They further observed that plots under zero-till recorded significantly higher value of available N and OC compared to conventional tillage. Soil water retention at field capacity (0.03 MPa) and water holding capacity were significantly higher under zero tillage (0, 32 m^3/m^3 and 42.13%) in 0-15 cm layer than conventional tillage.

Many farmers in this area are trying to venture in to organic farming. Organic sources used continuously for at least 3 years, have been found to be as good as chemical fertilizers and even better after 3 years of application (Ramesh *et al.*, 2008b). Poultry manure proved more beneficial and gave 17% higher yield than when compared with chemical fertilizers. At the end of 3 cropping sequences, SOC, available N, P, and K status and enzymatic activity was higher in plots constantly receiving organic manures as compared to chemical fertilizers. This shows that over time, use of organic materials improve soil health and biological activity in soil. Organic farming resulted in better economic returns due lower costs of production. However, soybean quality in terms of protein content and oil content in soybean remained unaffected with application of organic manures or chemical fertilizers.

RAPESEED-MUSTARD

Rapeseed and mustard are most important oilseed crops of arid and semiarid regions of the country. Indian mustard (*Brassica juncea*) accounts 21% of the total area under oilseed crops and 23% of total oilseed production in the country. It is next most important oilseed crop in the country with an area of more than 6 m. ha and production of 7.2 m.t with an average productivity of 1143 kg/ha as against world's average of 1800 kg/ha (2008-09). It is commonly grown in post-monsoon season under dryland conditions. Lower input of fertilizers and limited irrigation are the major constraints responsible for low productivity of this crop. Its productivity can be enhanced by wise management of limited inputs of fertilizers and irrigation. Understanding climatic and edaphic variables is necessary for efficient management of inputs in the limited moisture availability conditions. Apart from application of critical irrigation, optimum use of fertilizer N is important for this crop especially under rainfed conditions. Thus, imperfect and inadequate integration of essential plant nutrients limits productivity of these crops. Balanced nutrient management of rapeseed-mustard crops still remains the most critical input in its production (Pasricha and Rana, 1985; Pasricha *et al.*, 1994).

Nitrogen, phosphorus and sulphur requirements: These crops are highly sensitive to N availability in soil and respond remarkably to its application. Rana and Rana (2003) and Singh and Meena (2004) reported increased mustard seed yield with fertilizer-N application under dryland conditions of Rajasthan. Response to fertilizer N is closely linked to availability of moisture in the root zone. In order to assess the effect of irrigation and fertilizer N on the seed yield of mustard to identify superior combination, Nema *et al.* (2008) observed maximum yield response of 800 kg/ha with response ratio of 10 kg/kg of fertilizer N with an application of 4 cm water depth at 50% silique formation stage. A regression model of yield as a function of fertilizer N and irrigation gave a significantly good predictability of 0.96 and an expected yield in the range of 1263 kg/ha in control to 2757 kg/ha with 80 kg N/ha and two irrigations of 4 cm depth each, one at flowering and other at 50% silique stage.

Oilseed crops in general have high S requirement, but *Brassica* oilseed crops have exclusively more S needs than rest of the oilseed crops (Bahl, *et al.*, 1990a; Lekkineni and Abrol. 1992; 1994). For producing a yield of 1 t/ha, 16 kg S/ha is required (Mc Grath *et al.*, 1996). With increasing cropping intensity and use of S-free fertilizers, its deficiency in crops is appearing more frequently (Pasricha and Abrol, 2003). Thus, S is the other nutrient which is required in adequate amounts in soil both for productivity and quality. It is a constituent part of *Brassica* oils and impart it peculiar colour and pungency. Light-textured soils of north-western and acid soils of north-east India are generally low in available S supply. Acid soils though have high retention for S against leaching, but these soils are intrinsically low in extractable S. Whatever small amount of S is present in these soils, it is held by soil components so strongly that crop plants on these soil show deficiency of S. Abraham (2001) studied split application of S on yield of mustard. Application of 20 kg S/ha resulted in highest yield of 2.51 t/ha against 1.75 t/ha and 1.46 t/ha with single split and single time application. Single application may not be very effective, especially in light-textured soils with alkaline reaction where its retention in soil is very low. Sulphur is more likely to be lost through leaching in these soils especially with simultaneous application of P fertilizers. Phosphorus application dislodges adsorbed SO_4-S and accentuates its leaching.

The availability of S can be increased if organic amendments in combination with lime are applied to the acid soils. Integrated use of S and FYM improves the availability of S in these soils and plays an important role in increasing the yield of rapeseed mustard crops and also improves their quality. Pasricha *et al.* (1970) reported that besides affecting seed yield, application of S enhances the quality by increasing oil content and methionine (S-containing essential amino acid) content in *Brassica* oil crops. *Brassica* oilseed crops have been found to give tremendous response to N when combined with S, both in terms of yield and quality, while interaction effect of P and S is significant in improving its yield and quality (Aulakh and Pasricha, 1977; Pasricha and Aulakh, 1991; Aulakh *et al.*, 1995). *Brassica* oilseed crops have exceptionally high requirement for S and yield significantly very high when S is applied in combination with up to 100 or even 150 kg N/ha (Aulakh *et al.*, 1977; Aulakh *et al.*, 1980b;Pasricha and Aulakh, 1993). It is a known crop of the rainfed area, and its requirement of fertilizer nutrients depends on the availability of moisture in the root zone. Kumar *et al.* (2009) reported that application of N up to 80 kg/ha recorded increase in seed yield and yield attributes in Indian mustard. There occurred a similar increase in yield with S application up to 45 kg S/ha in combination with different N levels. The mean maximum (1.28 t/ha) and minimum (1.06 t/ha) seed yield was obtained with 80 kg N/ha + 45 kg S/ha, and N_0S_0 treatment combinations respectively. The economic dose of N and S for mustard under rainfed conditions ranged from 39.5 to 46 kg N/ha and 25 kg S/ha, respectively. Application of 80 kg N/ha significantly increased oil content and oil yield over lower rates of N application. Similarly, oil yield increased significantly up to 45 kg S/ha. Seed yield of mustard increased with increasing levels of N, S, and Zn up to 120, 60 and 5 kg/ha (Singh *et al.*, 2005). Nitrogen and S application increased the yield by 36% while Zn application gave a yield increase of 12%.

Improved genotypes of Indian mustard respond remarkably to S (Pasricha and Aulakh,1997; Gopa *et al.*, 1997) and this response is determined by the amount of water in the root zone or the adequacy of irrigation water supply and time of irrigation to the crop. Proper irrigation scheduling on the basis of IW:CPE ratio (Prihar *et al.*, 1981) can give high seed yields in *Brassica* oil crops but oil content may decrease in case of excessively more irrigation application to this crop. Therefore, proper irrigation schedule and S application plays a significant role in determining seed as well as oil yield when applied in combination with required level of fertilizer N. Significant increase in yield (1.6 t/ha) up to an IW:CPE ratio of 0.8 with two irrigations of 5 cm depth has been observed by Bharti and Prasad (2003). Crop responded to S up to 15 kg/ha. Drymatter yield/plant increased significantly when combined with 0.4 ratio of irrigation. Oil yield of 0.57 t/ha was significantly higher with 15 kg S/ha from the control yield of 0.49 t/ha.

Sharma *et al.* (2008) reported a significant response of this crop to application of P in combination with fertilizer N. The response was limited to 40 kg P_2O_5/ha as DAP. Ghosh and Bera (1986) and Sharma *et al.* (2002) ascribed poor yields of Indian mustard in Rajasthan to poor weed and fertilizer management. While adequate weed management increased the yield by 54-81%, progressive increase in fertilizer P application from 0 to 8.8, to 17.6 kg P/ha increased the seed yield from 1.43 to 1.64 to 2.1 t/ha, respectively in presence of adequate N (60 kg N/ha) and weed management (Sharma *et al.*, 2002). Application of 17.6 kg P/ha was found optimum which resulted in 41% increase in seed yield with increased net returns of ₹ 6,505/ha over control. Information of P x S interaction on seed yield and nutrient uptake in crops is conflicting, as both synergistic and antagonistic effects have been reported (Tandon, 1991). Mustard is common rainfed crop grown on Inceptisols of mid-hill region of Jammu. Sulphur and P when applied in combination, significantly increased the seed yield of mustard showing a synergistic effect (Sharma and Jalali, 2001). The increase in yield was up to 40 kg P/ha and 60 kg S/ha (1.47 t/ha). The additive effect of combined application of S and P is due to balanced nutrition of the crop. Application of P is known to mobilize more soil S, but such an increased mobility may increase its chances of leaching and loss from the root zone under high rainfall conditions. An application of S from outside as fertilizer may prove useful. Earlier, Jaggi and Sharma (1997) also observed similar results on mustard crop. An antagonistic effect can be noticed when applied doses of P and S are increased as observed by Aulakh *et al.* (1990a) in case of soybean. Increased removal of S and P due to increased uptake under balanced application has an added environmental advantage. Greater removal of P in the presence of adequate amount of S minimizes its chances to get lost to environment.

Integrated nutrient management for higher fertilizer use efficiency: There is a lot of thinking pouring in as how to maximize the use efficiency of chemical fertilizers in crop production. One tested way is to use these chemicals in balanced proportion, possibly in combination with adequate organic materials. Shukla *et al.* (2002) tried to relate various morphological and physiological determinants of seed yield of Indian mustard with nutrient elements. At 100% of fertilizer nutrient application, yield obtained was 1.2 t/ha with FYM, 1.27 t/ha with FYM + S, 1.35 t/ha with FYM + S + Zn, 1.43 t/ha with FYM + S + Zn + B and 1.53 t/ha with FYM + S + Zn + B + *Azotobacter* inoculums. The control yield with 100% recommended fertilizers (NPK) was 1.08 t/ha. In view of increasingly higher costs of chemical fertilizers and associated environmental concerns under constant use of these chemicals, there is a strong need to look for an alternative source of N for non-legumes having high N demands. Non-symbiotic bacteria like *A. chroococcum* and *Azospirillum* are potential bio-fertilizers and have capability of contributing N to a number of non-legumes. Integrated nutrient management holds great promise not only for achieving optimum yields but also protecting soil health against degradation. Singh and Sinsinwar (2006) tried to establish best combination of FYM, biofertilizers and different levels of fertilizer N to attain optimum productivity with improved quality in case of Indian mustard. Increase in N level from 0 to 40 kg/ha and 80 kg N/ha gave seed yields of 967, 1488 and 1563 kg/ha, respectively. An application of 5 t/ha of FYM along with *A. chroococcum* + *Azospirillum* gave highest yield of 1505 kg/ha seed yield as average of two-year data. In a long-term study on the effect of integrated nutritional management on the yield and quality of Indian mustard, Gauri Shankar *et al.* (2002) observed highest seed yield (1286 kg/ha) with 100% of the recommended NPK level along with 10 t/ha of FYM and *Azotobacter* inoculation. Long-term use of such a practice improved soil infiltration rate by decreasing bulk density and improved soil structure. From these data, it seems that long-term application of FYM may prove highly beneficial with considerable residual effect but direct application of 80-100 kg N/ha is very effective especially under irrigated conditions. Application of organic manures can supplement significantly the effect of fertilizer-N. Application of combination of 60 kg N/ha, 13 kg P/ha and 17 kg K/ha in conjunction with 10 t/ha of FYM gave maximum seed yield, and oil content. They also observed improvement in soil quality with continuous application of FYM in combination with inorganic fertilizers. Residual effect on the succeeding rice yield was also significant. Ramesh *et al.* (2009) reported that a combined application of 4 t/ha of cattle dung manure and 2 t/ha of poultry manure in an experiment conducted for 4 years from 2004-05 to 2007-08 recorded the highest yield (1.822 t/ha) and oil content (38.44%) in Indian mustard compared to recommended level of 60 kg N/ha and 17.5 kg P/ha fertilizers (1.775 t/ha) and absolute control (1.06 t/ha) (Table 4). Continuous application of organic manure resulted in improved soil organic carbon content, available soil N, P, and K levels and soil biological parameters (microbial bio-mass, dehydrogenase and phosphatase activity in soil). Agronomic N use efficiency (12.63 kg/kg nutrient applied) and field water use efficiency (8.28 kg grain/mm water) were highest in combination of organic manures of cattle dung manure + poultry manure. They reported highest gross returns (₹30,352), net returns (₹21,552) and benefit/cost ratio (3.44) in treatments receiving organic manure combination. Ramesh *et al.* (2008a) in an earlier study reported similar effects on seed yield of mustard grown in rotation with maize. Patel and Shelke (2000) reported highest oil content in mustard with continuous application of organic manures as compared to chemical fertilizers. This can also be attributed to improvement in the availability of some essential micronutrients that are supplied with organic manures besides its supplementing effect on the availability of other major nutrient elements.

Table 4. Effect of consistent application of organic manure and mineral fertilizers over four years (2004-05 to 2007-08) on the soil quality, yield and oil content of mustard (Ramesh *et al.*, 2009)

Organic manure*/Fertilizer applied	Soil organic carbon (%)	Microbial biomass (µg/g soil)	Seed yield (t/ha)	Oil yield (kg/ha)
CDM 4 t/ha +PM 2 t/ha	0.74	309	1.822	700.4
60kg N/ha+ 17.5 kg P/ha	0.56	246	1.775	666.3
Control	0.48	223	1.064	391.55
CD (P=0.05)	0.04	16.3	0.172	

*CDM=Cow dung manure; PM=Poultry manure

Dhillon *et al.* (1984) investigated the effect of green manuring, green leaf manuring, crop residue incorporation and inclusion of grain legumes in cropping sequences for economizing N and increasing the use efficiency of fertilizers and other inputs. They observed a highly significant effect of green-manuring and green leaf manuring on the yield of Indian mustard and *ghobi sarson* (*B. napus*). It greatly improved the harvest index of these crops. In *B. campestris*-wheat rotation, green manuring of *B. campestris* with cowpea grown for 45 days, increased the yield from 220 kg/ha in control to 830 kg/ha with green manuring without any fertilizer N (Pasricha *et al.*, 1991; Baddesha and Pasricha, 1991) which was equivalent to yield obtained with 60 N/ha. Green manuring further increased the yield to 1390 kg/ha when combined with 60 kg N/ha, demonstrating the increased crop potential with green manuring. Residual effect of green manuring was studied on the succeeding crop of late-sown wheat, after *B. campestris* (grown in *B. campestris*-wheat rotation); *B. napus*, after maize (grown in maize-*B. napus* rotation) and sunflower after *B. campestris* (grow in *B. campestris*-sunflower rotation) and it ranged from 220 to 460 kg/ha in wheat, 110 to 200 kg/ha in *B. napus* and 90 to 460 kg/ha in sunflower (Bahl *et al.*, 1986; Bahl and Pasricha, 2001). Rice has been shown to respond remarkably to green manuring, but because of shortage of time between harvest of winter season crop and transplanting of rice, it has not found favour with the farmers. Therefore it was thought why not to try green manuring to a winter season crop and see its residual effect on the succeeding rice crop. With this point in mind, Aulakh and Pasricha (1998) conducted field experiments for 4 years and found that in *B. napus*-rice rotation, green manuring gave 310 kg/ha additional yield in *B. napus* and as much as 910 kg/ha additional yield of rice due to residual effect of green manuring (Table 5). In the presence of 100 kg N/ha application as basal dose to both the crops, yield of *B. napus* without green manuring was 1.85 t/ha and with green manuring, it was 2.06 t/ha. Yield of following rice crop without residual green manuring was 6.36 t/ha and with residual green manuring, it increased to 7.28 t/ha (Table 5). Singh *et al.* (2009) reported effect of integrated nutrient management in brown sarson (*B. campestris*) and its residual effect on the succeeding aromatic rice (land race). These studies demonstrate a viable technology for enhancing the productivity of a production system through integrated use of green manuring especially in coarse-textured soils low in organic carbon by improving physico-chemical and biological conditions of the soil besides supplying N.

Table 5. Influence of incorporation of 45-60 day old cowpea as green manuring crop into the soil on the performance of *Brassica napus* and following rice crop at 100 kg N/ha level (Average of 4 years data) (Aulakh and Pasricha, 1998)

Yield (kg/ha)				Total increase in yield (t/ha)
Brassica napus		Rice		
Without GM	With GM	Without residual GM	With residual GM	
1853	2056	6360	7280	1123

Nutritional requirement in cropping system and intercropping: Another aspect that is receiving increasingly more attention these days is improved management through introduction of oilseed crops in cropping systems and intercropping with major crops. Such management practices are aimed at enhanced efficiency of plant nutrients. In dryland areas, quantum and distribution of rainfall plays an important role in deciding which crop will suit during the winter season. Choice of winter crop will depend upon the quantum of rainfall received in summer and amount of moisture in the root zone at the time of seeding of winter crop. Under optimum soil moisture conditions, winter crop like mustard respond markedly to fertilizer nutrient application. With the availability and success of short-duration rainy season crops such as pearlmillet (crop cultivar 67). there are chances for taking a successful crop of mustard on the conserved moisture after harvesting the fodder crop slightly before the final withdrawal of monsoons. This method is helpful in enhancing the production of oilseeds in the country. In the rainfed areas of north-east acid soils, conservation of moisture in the soil profile is a must for taking winter crop. Therefore, any soil management technology that helps in conserving moisture in these soils will be a welcome step for taking a successful winter crop on residual moisture sufficient to have proper germination of winter crop of mustard (*B. campestris*) after maize. *In situ* crop residue management with appropriate tillage options not only helps in conserving moisture in soil but also helps in improving soil quality when practised over time. Such practice often designated as conservation agricultural practices help in conserving, soil moisture and increasing soil organic matter content when these practices are used over years and improve soil health. Saha *et al.* (2009) in a field experiment during 2006-08 assessed the effect of *in situ* residue management and tillage on water use efficiency, evapotranspiration and yield mustard crop. Their results showed that irrespective of tillage and residue management, moisture extraction pattern was maximum (39-59%) up to 0-30 cm depth with maize stalk cover. All residue management practices recorded higher seed yield of mustard. The highest water use efficiency (14.6 kg/ha/mm) was observed due to maize stalk cover + poultry manure @ 5 t/ha irrespective of tillage practices. They observed that under conventional tillage practice, soil moisture profile was less due to greater evapotranspiration losses in the absence of mulching effect of maize stalk. Greater increase in the seed yield with maize stalk cover with corresponding lower evapotranspiration value evidently resulted in significantly higher water use efficiency. Hati *et al.* (2001) studied the effect of irrigation levels and combinations of NPK and FYM on moisture use, evapotranspiration, water use efficiency and yield of Indian mustard. Application of recommended dose of NPK (60, 13 and 17 kg/ha) + FYM @ 10 t/ha (FYM applied to previous rainy season crop) resulted in significantly high seed yield. It also improved the water use-efficiency. Maize-mustard cropping system occupies a significant area in the sub-tropical hill eco-system of north-eastern region of the country. Mustard is the preferred winter crop due to its wide adaptability and ability to sustain efficiently on residual moisture in the soil profile. However, due to imbalanced and under-use of nutrients, productivity of this system is relatively low in this region. Das *et al.* (2010) investigated the effect of integrated use of organic manures, chemical fertilizers and *Azolla* compost on the productivity of this system in mid-altitude sub-tropical region of Meghalya. They observed maximum yield of maize (3.21 t/ha) with integration of all sources of nutrients. Seed yield of following mustard crop was significantly affected by the residual fertility of the organic manures. Yield of mustard almost doubled when compared with residual control. When compared with the recommended levels of NPK. the yield was still higher by almost 37%. They reported highest production efficiency with combined application of *Azolla* compost (5 t/ha) to maize with residual effect on mustard. Application of organics improved soil health by increasing its soil organic carbon content and extractable major nutrient elements like N, P and K in soil.

Indian mustard and sunflower are grown during spring season in many parts of northern India. With the availability of short duration varieties and flexibility in the time of sowing, these crops fit well in the intensive cropping sequences especially under low-input supply, medium soil fertility and limited supply of irrigation water (Rana *et al.*, 2004). These crops, because of wide variations in their morphology and rooting system, have variable nutrient requirement and possess different capacities to make use of soil available nutrients from different soil layers. Rana *et al.* (2007) studied direct, residual and cumulative effect of P and S applied on this cropping sequence. Depending upon the level of their combined application, PxS interaction could be synergistic or antagonistic (Aulakh *et al.*, 1990a; Mariswami Gouda *et al.*, 2001). Recommended dose of 40 kg P_2O_5/ha and 30 kg S/ha alone and in combination caused significant increase in the seed yield of Indian mustard and sunflower over control. Residual effect of P alone or in combination on Indian mustard and sunflower became visible during the third year. Annual system productivity in terms of mustard seed equivalent recorded increasing trend due to P and S application across the years. On an average, P and S application alone or in combination either to Indian mustard or sunflower recorded a net returns of ₹31,880, ₹ 28,242 and ₹ 34,935/ha, respectively. Both P and S application improved the seed quality significantly by increasing the oil content in both the crops.

In a pearlmillet-mustard rotation, application of various combinations of N and P, not only increased the yield of pearlmillet but there was significant residual effect with increase in yield of mustard up to 12.4% with the application of $N_{60}P_{30}$ combination to previous pearlmillet crop. Direct application of combined N at 60 kg/ha and P at 30 kg P_2O_5/ha to mustard, however, gave 28.3% additional seed yield. Residual effect on mustard seed yield was equivalent to 2.96 t/ha with benefit/cost ratio of 2.2 where as direct application of this combination to mustard gave a yield equivalent of 2.99 t/ha with benefit/cost ratio of 2.26. Mahala *et al.* (2006) reported similar results for mustard in maize-mustard cropping system. Cotton-mustard is also common rotation followed by farmers in north-western India. However, cotton is harvested late and field can not be vacated before December. This delays the seeding of following mustard crop which decreases its yield considerably. To overcome this difficulty, Prasad and Prasad

(2004) studied the effect of residual fertility on performance of transplanted mustard crop. Twenty three day old seedlings planted immediately after the harvest of cotton on residual fertility gave a significantly higher yield of 1.69 t/ha. Transplanted mustard has been reported to have 100% establishment (Pasricha *et al.*, 1991).

Intercropping increases the total productivity per unit land area and per unit time. It allows reduced use of inputs in the management of soil fertility and also in the control of weeds. Monoculture and high inputs, on the other hand, are suited to high-production systems. Padhi and Panigrahi (2006) opined that intercropping of oilseeds and pulses is the other way to increase their production in the country because intercropping is more advantageous than sole cropping of either crop. Abraham *et al.* (2010) reported that the seed yield of mustard was significantly affected by irrigation and fertilizer application. On the basis of 2 years average yield data (2005-06 and 2006-07), sole mustard yield was almost 0.9 t/ha higher at 1.5 t/ha than when sown as intercrop with chickpea at 0.608 t/ha. Application of recommended levels of fertilizer combination of N, P, and S at 40, 60, and 20 kg/ha application, respectively, gave significantly higher yields of 1.14 t/ha. Net returns and B:C ratio was also higher in this case. Ridge and furrow sowing system recorded higher yields (1.21 t/ha) than the flat sowing (1.09 t/ha) in case of Indian mustard crop. Prihar *et al.* (2009) reported a marked positive residual effect of nutrients applied to previous crop of pearlmillet. The residual effect of integrated application of 30 kg N + 20 kg P_2O_5 + 6 t FYM/ha to preceding pearlmillet recorded significantly higher yield, total N and P uptake and net returns in the succeeding mustard crop. Basumatary and Talukdar (2007) looked into the effect of integrated use of S and FYM on rapeseed grown in rotation with rice. They observed that use of 30 kg S/ha along with 1.5 to 3.0 t FYM/ha resulted in the higher yields of seed and stover, uptake of N, P and K and protein content in seed of rapeseed than that of single super phosphate or FYM alone. Indian mustard grown in rotation with wheat-potato responded significantly to K fertilizers. Degree of response to applied K increased with increase in fineness of muriate of potash in all the three crops (Dwivedi *et al.*, 2001). Finer size (75% of MOP remaining on 0.25 mm sieve) gave the highest yield of 188 t/ha of mustard which was 0.45 t/ha higher than control with 50 kg K/ha applied to mustard.

Among the *Brassica* oilseed crops, *toria* (*B. rapa*) is the shortest duration crop which can fit well as inter-season crop. It has significant scope under intensive cropping and can add significantly to the total oil production in the country. A timely sown *toria* crop requires adequate mineral nutrients, especially N. Charak *et al.* (2006) investigated N requirement of *toria* in relation to its time of sowing and row-spacing in Rajasthan. They observed that a crop sown in the first week of September and row-spaced at 30 cm responded significantly to N application up to 60 kg/ha and gave a seed yield of 1.2 t/ha, which was 29% higher than the control treatment. Further increase in the level of applied N to 90 kg/ha had the little effect in further improving the yield. This shows that for such a short duration crop, 60 kg N/ha is optimum for optimum yield. *Toria* is grown as a catch crop between maize and wheat in the hilly region of Himachal Pradesh. Suri *et al.* (2002) summarized information obtained from the prescription-based general fertilizer recommendations for *toria* from field experiments done over a large area in Himachal Pradesh from 1995-2000. They found that for the production of a yield of 1 t/ha of *toria* seed, 45, 3, and 30 kg N, P, and K was required. Contribution of soil N and P for the production of this much yield has been calculated at 5, 13 and 66%, respectively. Based on this information, the yield of this crop can be easily increased to 1.51 t/ha as is evident from the results of the field experiments carried out at 11 different sites in the state.

GROUNDNUT

Groundnut is the third most important oilseed crop in the country covering an area of 6.16 m. ha. with annual production of around 7.16 m. t. (2008-09). There is great scope in improving its productivity from the present level of 1163 kg/ha. Being a leguminous crop, it can meet a major part of its N requirement through symbiotically fixed N. However, P and S are the major nutrient elements whose deficiency can limit its productivity both under irrigated as well as in rainfed conditions. It is relatively more efficient in making use of soil-derived, less soluble forms of P. When grown in rotation with wheat, it can subsist on residual P without any adverse effect on its yield (Pasricha *et al.*, 1980; Pasricha, 1985).

Phosphorus requirement in groundnut-based cropping systems: In a field experiment on the effect of P applied as direct, residual and cumulative application in groundnut-wheat rotation, it was observed that wheat remarkably responded to both direct and cumulative P application while magnitude of response was relatively small in case of groundnut. Based on three year data of this experiment, it was concluded that while the direct application of P is necessary in case of wheat, subsequent groundnut crop can do well on residual P and there is no response to direct application of P to groundnut if it follows wheat which has received recommended level of 60 kg P_2O_5/ha of fertilizer P (Pasricha *et al.*, 1980). Crop species vary greatly in their efficiency to make use of soil and fertilizer P (Pasricha *et al.*, 1991). In this regard soybean is least efficient (Aulakh *et al.*, 1990a) while groundnut is most efficient (Pasricha *et al.*, 1980). In their eight year field experiment, Aulakh and Pasricha (1991) and Aulakh *et al.* (1991) observed that groundnut did not respond to applied P even in soils, which tested low in Olsen's extractable P where as wheat grown in the same fields showed marked response to residual as well as direct application of P. Further more, total P removed by groundnut and wheat were comparable. On the same piece of land, in control plots, while groundnut removed 21 kg P/ha, wheat could remove only 9-10 kg P/ha, but when wheat was fertilized with P, the P removal was 21-22 kg/ha. This showed that groundnut could use less soluble forms of P present in soil. In comparison of different chemical extractants for evaluation of soil test for groundnut, Pasricha *et al.* (2002) found that Nelson's acid extractant (0.05 N HCl + 0.25 N H_2SO_4) gave the significant relationship with yield (r=0.89**). Other methods like Colwell (0.5 M $NaHCO_3$, pH 8.5, 16 h), Bray (0.03 N NH_4F + 0.025 N HCl) and Olsen (0.5 M $NaHCO_3$, pH 8.5, 0.5 h) failed to give any relationship. Most of reserve P in these alkaline soils is Ca-bound (Aulakh and Pasricha, 1991), which can perhaps be utilized by groundnut. On further fractionation of soil P into Ca-bound P, Al-bound P, Fe-bound and saloid-bound P, Pasricha *et al.* (2002) observed that Ca-bound P gave significant relationship (r=0.71**) with groundnut yield. Nelson's extractant being acidic can extract major portion of Ca-bound P, thus the reason why this extractant gave the relationship with groundnut yield.

A notable difference in soil fertility with respect to Olsen's extractable P were observed after eight years of applying phosphatic fertilizer in groundnut-wheat rotation (Aulakh *et al.*, 1991; Aulakh and Pasricha, 1991). Of the total fertilizer P applied in eight year periods, 33-67; 82-93 and 77-91% were present in soil of wheat applied, groundnut-applied and cumulative-P treatments, respectively, in groundnut-wheat rotation. Significantly lower amounts of P found in labile and semi-labile fractions for cumulative-P treatment, revealed that increased rates and frequency of applied P tend to enhance the conversion of residual P to more stable forms, which are less available to plants. It was thought that perhaps continuous application of P to groundnut was responsible for immobilization of Zn resulting in its non-availability to the plants. Therefore, Zn problem in groundnut soils was investigated from another angle by Pasricha *et al.* (1987). They studied the effect of application of low to very high levels of P (0-122 μg P/g soil). They reported that isotherm of Zn-(Ca+Mg) exchange for the soils at different P levels remained unchanged and were super impossible, which revealed that applying P to soil did not decrease the Zn intensity or in other words, its availability remained unaffected even with exceptionally heavy dressings of fertilizer P. Thus, it was concluded that seat of antagonistic reaction between Zn x P is not at least soil.

Das *et al.* (2009) reported that groundnut yield, grown in groundnut-rice rotation on red and lateritic soils was improved significantly under distillery effluent irrigation @ 3 cm at 7-10 days interval. In eastern India, red and lateritic soils cover a major area, where groundnut-rice rotation is one of the promising cropping systems, especially in Odisha. The soils are invariably acidic in reaction. Continuous use of such effluents can increase the soil pH and improve availability of nutrients, especially P to the crops. There are instances of soil health improvement through an increase in soil organic carbon content which increased by 38 to 73% (Das *et al.*, 2009). In eastern India, groundnut is grown in winter both under irrigated and un-irrigated conditions on residual moisture with or without fertilizers. Singh *et al.* (2005) investigated the nutrient-water interaction in winter season groundnut under shallow water table conditions in the coastal soils of eastern India. Profile moisture depletion, upward soil-water flux and its contribution towards evapotranspiration demand varied considerably with irrigation and level of applied nutrient elements. Influence of irrigation and nutrient levels on evapotranspiration, water-use efficiency, and pod yield was significant and their interaction positive. Combined application of N and P was more effective than application of either of two or no nutrients under shallow water table.

Sulphur requirements: Application of gypsum as a source of S to groundnut has been tried by Subbiah and Pasricha (1970). It also improves soil structure and facilitates smooth pegging in groundnut (Agasimani *et al.*, 1992). Combined application of Ca and S through gypsum, helps smooth development and pegging in the pod-zone of groundnut crop (Geetha Lakshmi and Lourduraj, 1998). Gypsum as a source of S to the groundnut crop is not only a cheaper source but is as effective as any other soluble S source (Subbiah and Pasricha, 1970; Aulakh *et al.*, 1980a). Crop varieties respond differently to gypsum. Excessively higher application of 200 kg and 400 kg/ha were tried by Adhikari *et al.* (2003). They found that groundnut variety ICG3-49 showed higher kernel weight (70.58), shelling percentage (67.6) and number of pods/plant (47) and oil content (47.2%). In a comparison of S containing phosphatic fertilizers, single super phosphate (SSP) with S-free phosphatic fertilizers like diammonium phosphate (DAP) and triple super phosphate (TSP). It was found that SSP as a source of P proved much better than DAP and TSP in groundnut and gave additional yield at both the applied levels of 30 and 60 kg P_2O_5/ha (Table 6) (Aulakh *et al.*, 1980a; Aulakh *et al.*, 1988; Pasricha *et al.*, 1980b; Pasricha *et al.*, 1990). Single super phosphate [$Ca(H_2PO_4)_2 \cdot CaSO_4 \cdot 2H_2O$] contains gypsum to the extent of about 50% by weight of the fertilizer, therefore, supplies S also to the crops. Mean yield increase with SSP over DAP and TSP was 31% at 30 kg P_2O_5/ha level and 29% at 60 kg P_2O_5/ha. These results also indicate that at the site-I, the crop virtually did not respond to P. TSP and DAP sources which do not contain any S did not show any increase in yield at the low levels of P application. On the other hand, SSP, which contains S showed a remarkable response (mean increase in the yield of 790 kg/ha of groundnut pod yield).

Results of other field experiments on source, dose and time of application to groundnut indicated that gypsum and pyrite applied @ 20 kg S/ha was equally effective in raising the yield of the crop (Bahl *et al.*, 1990b). These studies further revealed that the difference in yield response to the time of application of S to groundnut was not significant which means S (gypsum) can be top-dressed at later stages as well, if it has not been applied at the time of sowing. Many of the groundnut growing soils are sandy in texture and low in available Zn besides other nutrients. Groundnut responded remarkably to combined application of S and Zn on these soils (Bahl *et al.*, 1986). Maximum economic yield of 2.61 t/ha was obtained with combined application of 15 kg S and 10 kg Zn/ha that was 0.52 t/ha higher than in control plots.

Table 6. Effect of levels and sources of phosphorus on the yield of groundnut (*Arachis hypogaea*) (Pasricha *et al.*, 1990)

Source of P*	Yield (kg/ha)							
	Site-I				Site-II			
	P_0	P_{30}	P_{60}	Mean	P_0	P_{30}	P_{60}	Mean
SSP	-	3190	3040	3120	-	2940	3150	3040
TSP	-	2510	2200	2360	-	1920	2220	2070
DAP	-	2340	2520	2430	-	2320	2400	2360
Control	2330	-	-	2330	1990	-	-	1990

* SSP= Single super phosphate; TSP= Triple super phosphate; DAP= Diammonium phosphate

Nutrient requirement under intercropping: Farmers in Rajasthan take mono crop of groundnut or as a mixed crop on loamy sand soils. Oilseed-oilseed intercropping can be practised by taking an early maturing and short-stature cultivars (Singh and Jodha, 1989). Both castor and sesame are such rainy season oilseed crops, which are compatible with groundnut as they are having a large interval between the harvests (Bhondave *et al.*, 1994). Dayanand *et al.* (2002) tried non-legume oilseed intercrop and row ratio for groundnut-based intercropping system by fertilizing with S. They observed a higher oil content (45.1%) and a higher oil yield (133.78 kg/ha) of groundnut with sole groundnut crop. It was at par with intercropping groundnut with sesame in 4:1 row ratio. Application of 40 kg S/ha increased the oil yield to 485 kg/ha and N-uptake to 119.39 kg/ha. Total S uptake (12.6 kg/ha), protein content (23.6%) and oil content of groundnut kernels (45%) significantly increased up to 60 kg S/ha. Thus, S application has more effect on quality of the crop. Pigeonpea + groundnut intercropping system is widely followed in several parts of the country like Suarashtra, parts of Maharashtra, Andhra Pradesh and Uttar Pradesh. The wide row space between the rows of pigeonpea is profitably utilized by planting groundnut, which generates additional income without adversely affecting the pigeonpea yield. Jat and Ahlawat (2009) observed significant increase in the yield of groundnut intercropped in pigeonpea on application of adequate quantity of FYM. Application of S @ 35 kg S/ha increased the growth attributes and yield of groundnut. It improved the crop quality by increasing protein and oil content in groundnut. Total yield of pigeonpea and intercropped groundnut was higher than the individual crops grown as sole crops.

Integrated nutrient management: Groundnut is a recent introduction in the north-eastern mid-hill altitude of the country. This crop is gaining momentum for its high yield potential. However, declining soil fertility and productivity due to continuous use of chemical fertilizers alone have caused nutrient imbalance in soil. This has been recognized as the most important factor that limits the productivity of groundnut in this region. Groundnut removes ample amounts of nutrients other than N from soil (Kachot *et al.*, 2001). However, there is always a wide gap between crop removal and replenishment of nutrients through fertilizers. It is now considered that restricted use of chemical fertilizers and inclusion of organic materials in soil fertility management could be alternative to overuse of chemical fertilizers alone (Palaniappan and Annadurai, 1999). Hence the challenge is to use combined application of organic manures with chemical fertilizers to optimize nutrient availability for optimum plant growth, yield and quality of groundnut in this ecological region. Panwar and Munda (2007) observed that an application of 10 t/ha of FYM or pig manure gave a yield which was comparable to recommended dose of chemical fertilizers to groundnut crop. However, 5 t/ha of FYM applied in combination with 50% of recommended N, P and K levels gave the highest pod yield of 3.16 t/ha and economic returns of ₹ 16,278/ha. It also influenced positively the quality of the produce by significantly increasing kernel protein and oil content. In the north-eastern state of Mizoram, groundnut cultivation is gaining momentum. It is mostly grown in shifting cultivation in this area. Its productivity in Mizoram is, however, very low because of such constraints as steep sloppy land, undulating topography, highly uneven distribution of rain, severe soil erosion, and inadequate use of chemical fertilizers. Because of loss of soil organic matter due to erosion of surface soil, its content in the soil is very low. Thus, any management practice that involves the use of bulky organic materials in the integrated management of these soils will, thus, be a welcome step. Laxminarayana and Patiram (2005) investigated the effect of integrated use of inorganic, biological, and organic manures on the yield and nutrient uptake by groundnut on Typic Hapludult soils in Mizoram. Application of optimum level of N, P, and K at the rates of 40, 20, and 33 kg/ha, respectively in combination with 15 t FYM/ha, recorded the highest yield of 2.26 t/ha as the average of two-year data. Control yield was only 1.29 t/ha. They observed that conjunctive use of organic manures, along with chemical fertilizers not only results in higher and sustainable crop yield but also enhance input use efficiency of other external inputs such as improved seed, irrigation water, pesticides and labour. It also protects soil health against degradation.

SUNFLOWER

Sunflower is a highly promising oilseed crop as it is photo-insensitive and can fit in the crop rotation any time. It has short growth duration and has wide adaptability to different agro-climatic regions and soil types. It is mostly grown as a winter season crop, but it gives more robust growth when grown in spring season. It is very sensitive to nutrient deficiency in soils and responds remarkably to N. In case of limited supply of N, this crop can exhaust soil of its native N. Sunflower crop with an average seed yield of 1 t/ha removes as much as 200 kg N , 13 kg P and 250 kg K/ha.

Sadiq *et al.* (2000) gave its nutrient requirements at 80 kg N, 60 kg P, and 50 kg K/ha for optimum yields. Shekhawat *et al.* (2008) reported a seed yield increase of 788 kg/ha with application of recommended levels of N application. Prilled urea and calcium-ammonium nitrate (CAN) as a source of N did not differ so far the seed yield is concerned. Singh *et al.* (2000) observed that seed yield of summer sunflower significantly increased up to 120 kg N/ha. Yield at this level (1678 kg/ha) was almost double of what was observed without N (894 kg/ha). Magnitude of response to S application was much lower than N, but significantly higher yields were observed with combined application of 30 kg S/ha and 120 kg N/ha. Similar results have been earlier reported by Bindra and Kharwara (1992) and Singh *et al.* (1995). Application of 50 kg S/ha and 1.5 kg B/ha when applied in combination with recommended N level gave the highest yield of 2007 kg/ha.

Application of 60 kg N/ha in combination with 60 kg P_2O_5/ha increased the seed yield of hybrid sunflower (Aulakh and Pasricha, 1996). However, higher combinations of $N_{90}P_{90}$ proved deleterious and sharply decreased the yield (Fig. 1). It was found that sunflower is a natural scavenger of N and can utilize large amounts of soil-derived N (54 kg N /ha) where other crops fail. Effect of combination of $N_{60}P_{60}$ was also evaluated on the quality of crop (Bahl *et al.*, 1997). While P application increased oil content, N alone decreased the oil content. An increase in unsaturated fatty acid (Oleic acid) and decrease in saturated fatty acid (Palmitic acid) is indicative of improvement in the quality with combined application of N and P. Nitrogen application up to 120 kg/ha improved the physiological growth parameters, yield attributes and seed yield by over 20% over 60 kg N/ha in sunflower (Sarkar and Mallick, 2009). They observed a significant increase in growth parameters with 60 kg S/ha over 30 kg S/ha. Application of 60 kg S resulted in significantly high yield of 2.07 t/ha, which was 33% higher over no S. A combined application of 120 kg N/ha along with 60 kg S/ha and foliar application of 0.406% Ca $(NO_3)_2$ was found most effective in increasing sunflower yield in spring season.

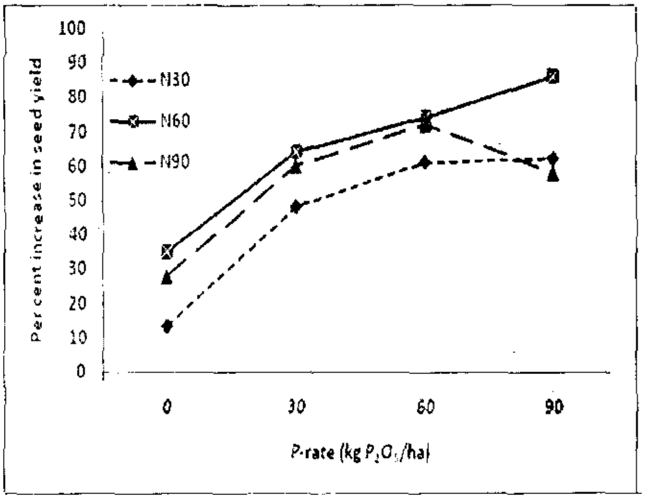

Fig. 1 Yield response of hybrid sunflower to phosphorus at different levels of Nitrogen (Av. of two year's data) (Aulakh and Pasricha, 1996)

CASTOR

Castor (*Ricinus communis* L.) is one of the major non-edible industrial oilseed crops grown in India on an area of 0.86 million ha with annual production of 0.446 m. t. of oil, which has an export potential of more than ₹2000 crores per annum. It has a unique distinction of earning large foreign exchange owing to its use in cosmetics, pharmaceuticals, lubricants, synthetic yarn, etc., principally competing with Brazil and China for international market. It is mostly grown under rainfed conditions on marginal soils by resource- poor farmers with low input. Its productivity varies with the total amount of rainfall and its distribution received through south-west monsoons. Soil fertility and fertilizer application influence the yield of castor as much as other crops (Velayutham *et al.*, 1976; Velayutham, 1979). Other factors which can be manipulated to improve its performance are management and crop genotypes. Riazuddin *et al.* (2001) worked out optimal soil test-based fertilizer requirements for achieving different yield targets of castor. For meeting this objective, information on the nutrient requirements, extent of soil nutrient availability/deficiency and fertilizer nutrient efficiency has to be taken into account (Ramamoorthy *et al.*, 1967). Mean castor seed yield was found to be 988.5 kg/ha in treated plots, which significantly correlated both with soil test value and fertilizer nutrient application. They reported that for each 100 kg of seed yield, an estimated 2.85 kg N, 0.94 kg P, and 2.9 kg K/ha, respectively are required. The amounts of nutrients applied can be increased to get a yield of castor seed up to 1.8 t/ha. These workers have given a ready reckoner for fertilizer application at varying soil test values for different yield targets up to 1.0 t/ha. They, however, reported that their control yields ranged from 0.31 to 1.1 t/ha.

It is grown in Gujarat under irrigated conditions and as rainfed crop in Andhra Pradesh under conditions of salinity and sodicity alkalinity that can be traced to the hydro-geochemical conditions and relief. Such a situation renders these soils unsuitable for raising a variety of other crops. These soils are unique in the sense that they cannot be easily reclaimed for want of good quality water and poor drainage conditions of this soil. It is grown on 3.45 m. ha. of land in Andhra Pradesh alone with annual production of 1.4 lakh tonnes (Damodaram and Hegde, 2007). Oilseed crops exhibit a differential response to alkalinity as they differ in their intrinsic ability to tolerate excessive salinity/alkalinity in soil (Raghavaiah *et al.*, 2003). Castor genotype 48-1 has been found to be more tolerant to excessive salts (Raghavaiah *et al.*, 2006a). There was an increase in plant Na/K ratio and decrease in plant Ca/Na ratio with the increased level of salinity of the soil medium (Raghavaiah *et al.*, 2006b). This genotype gave a higher seed yield of 22-32% with improved agronomic practices of applying 2 t/ha of FYM and seeding on the side of the ridge.

Raghavaiah *et al.* (2008) used targeted yield approach developed by Ramamoorthy *et al.* (1967) for working out balanced fertilizer combinations for this crop. Nitrogen, S and Zn have been reported to play a key role in improving its oil content as in so many other oilseed crops. They investigated its N, S and Zn requirement on the soil test basis in Alfisols of Andhra Pradesh. From their data, it is evident that there exists a wide variation in soil test values of the Alfisols. Castor yield responded remarkably to fertilizer application based on soil test values. Using the targeted yield equation derived from the basic data, they prepared a ready reckoner of soil test-based fertilizer doses of N, S and Zn for aiming a yield target of 800 to 1000 kg/ha. Their data clearly indicated that when soil test values are high, targeted yields can be achieved by application of lower quantity of fertilizers thereby, lowering the cost of production.

This crop is ideally suited for intercropping systems owing to its wider inter- and intra-row spacing. Risk due to drought is minimized by adopting suitable cropping system, which can utilize the available resources in a most efficient manner. Padmavathi and Raghavaiah (2004) reported that in years of less than normal rainfall (2001-02), the seed yield of intercropped castor crop (1523 kg/ha) was quite close to the yield of sole crop (1821 kg/ha). The castor equivalent yields increased when castor was intercropped with two rows of cluster bean (2187 kg/ha), cucumber (2356 kg/ha) and lablab (2255 kg/ha). Crop varieties are known to exhibit different level of tolerance to salinity level (Yadav, 1975). Castor can be grown under wide soil pH ranging from acid soils of pH 5.0 to alkaline soils of pH 8.5. In Andhra Pradesh alone salt-affected soils cover about 4.5 lakh ha in Telangana region. Raghavaiah *et al.* (2002) reported that identification of varieties and hybrids has an immense potential for enhancing and stabilizing castor production where salinity is a potential yield limiting factor. They evaluated 19 genotypes of castor across the gradient of salinity level up to 10 dS/m in terms of seed germination, shoot length and dry weight. The castor genotype exhibited different salinity sensitivity. Genotype TMV-5, DCH-151, DPC-9, DCH-32, and DCH-149 were found relatively more tolerant to increased salinity level as investigated under controlled laboratory conditions. For more reliability and large scale adoption, these tests must be verified under field conditions.

SESAME

Sesame is an important oilseed crop in the eastern India. It is commonly grown in the trans-Mahanadi belt of Chhattisgarh. When grown on marginal light-textured Inceptisols without fertilizers or fertilizers applied in a highly imbalanced manner, it yields very low. Farmers often apply N and P but rarely K to this crop. It is a component of rice crop. In these light textured soils, available level of K and S are often low and may not meet the requirement of the crop to its full yield. Tiwari *et al.* (2003) reported its K and S requirements to be 64 kg and 12 kg/ha, respectively. Thakur and Patel (2004) studied its K and S requirement on the Inceptisols under rainfed conditions. On an average, application of 25 kg K/ha resulted in 583 kg seed and 279 kg oil yield/ha. Similarly, application of 20 kg S/ha gave a seed yield of 577 kg and oil yield of 277 kg/ha. They observed a significant increase in the uptake of K with each successive application of K levels. Because of its tolerance to drought conditions, in the coastal districts of Odisha, it is grown in early summer on the residual moisture. Its productivity is low in Odisha, though summer sesame has higher yield potential than that of wet season crop (Kathiresan, 2002).

It is pertinent to have an idea as to how the irrigation is going to affect the available nutrient regime as a result of improved microbial activity. Such knowledge will help in formulating requisite strategy for integrated water and nutrient management for the following summer crop of sesame. Kundu and Singh (2006) examined the effect of supplying irrigation water on availability of N, P, and K in these acidic soils. Use efficiency of irrigation was highest when applied at flowering stage (40-47 kg seed/ha/cm). Irrigation increased the extractable N by 125%, but extractable P and K were not significantly affected in this acid soil where most of the soil P is present in iron and aluminum bound. Currently research efforts are more directed towards increased productivity per unit land area per unit time by growing crops in cropping sequence. Such a system also helps in making best use of irrigation water and nutrients supplied through fertilizers and organic manures. Mondal *et al.* (2008) observed maximum seed yield of sesame (670 kg/ha) after rice. Balanced application of chemical fertilizers along with organic manures improved agronomic efficiency, recovery percentage, and soil fertility status.

Sesame is grown both as sole crop as well as an intercrop. In sole crop, weed and N management determines its performance. The nitrogen requirements of this crop is quite high, and it reflects on its quality besides yield (Thakur *et al.*, 1998; Mehrotra *et al.*, 1978). While N application is essential, it can encourage weeds if not managed judiciously (Om Prakash *et al.*, 2001). An application of 60 kg N/ha resulted significantly higher yield of 0.807 t/ha, it also resulted in bolder seeds, a character attractive for table use.

LINSEED

Linseed is another industrially important oilseed crop. It finds its use in paints and varnishes. In linseed, a six year field study indicated that combined application of 60 kg N, 40 kg P_2O_5 and 30 kg S/ha increased the yield from 0.58 t/ha in control to 1.28 t/ha (Aulakh *et al.*, 1989a; Aulakh *et al.*, 1989b). In another study, the combined application of N, P and S, increased the per cent oil in the linseed and maximized the per hectare oil yield. Sowing of linseed in the mid October instead of mid November produced 540 to 750 kg/ha higher yield. This practice of advancement in sowing of the crop thus greatly increased the use efficiency of fertilizer N and other inputs (Pasricha *et al.*, 1986; Aulakh *et al.*, 1989b; Pasricha and Aulakh, 1993).

With the availability of high yielding hybrid/composite varieties of maize, maize-linseed cropping system has become more remunerative as linseed can be grown with limited irrigation after maize in the state of Madhya Pradesh. Ramesh *et al.* (2008a) reported highest yield of 1375 kg/ha of linseed with application of 2.6 t/ha of poultry manure directly and 5.3 t/ha to previous maize crop. On the other hand, chemical fertilizers provided only 1048 kg/ha of linseed yield. They also reported higher soil biological activity in the organically treated plots *vis-a-vis* chemical fertilizer treated plots. Dhillon and Kler (1981) reported that cross sowing (bi-directional) of linseed was better than traditional method owing to efficient utilization of soil moisture, nutrients and solar radiations. Badiyala and Sharma (2001) reported that bi-directional sowing resulted in high use efficiency of nutrients by increasing linseed yield from 1.3 t/ha to 1.55 t/ha with east-west sowing.

SAFFLOWER

Safflower is an important crop grown in Vertisols under receding moisture conditions of post rainy season. Vertisols are often deficient in Zn and P nutrients. Remarkable response of safflower on these soils to N, P and Zn has been earlier reported (AICRP, 2005; AICRP, 2006). In order to work out fertilizer recommendation, estimation of soil and plant nutrient content at critical stage provides an indication of the critical limit of Zn (Gupta and Vyas, 1999; Murthy and Padmavathi, 2008). Murthy and Padmavathi (2008) established critical P:Zn ratios. The critical Zn level and P:Zn ratio for safflower (genotype A-1) was 26 mg/kg and 80.2. For NARI-NH1 genotype, these levels were 27.0 and 81, respectively at flowering stage. Similarly, critical DTPA-Zn in black soils was found to be 0.63 mg/kg for A-1 and 0.72 mg/kg for NARI-NH1 genotype of safflower.

FUTURE LINE OF WORK

The challenges are to increase the total production of oilseed crops by increasing their productivity and by diverting more area to these crops. Investment in research for development of new technologies and improvement of existing production technologies on nutrient management for oilseed-based cropping and oilseeds intercropped with cereals offer considerable potential. Marginal areas, where most of the oilseeds in the country are grown, must be directly the subject of research if we want to address the increase in production of oilseed crops. In addition to improved crop management in cropping systems and in intercropping, for higher fertilizer use efficiency, it is essential to breed oilseed crops for improved water use and drought resistance to better use the limited amount of moisture available in the root-zone. Conservation tillage and no-till practices increase the proportion of rainfall infiltrating into soil. It also protects the moisture from surface evaporation due to mulching effect of the crop residue. Thus, conservation of residual moisture in the root-zone through adoption of conservation agricultural practices of tillage options and residue management afford a great scope for increasing the productivity of oilseed-based production systems. Such practices when used over time in combination with the integrated nutrient management increase biological productivity of the soil for sustaining high production. More than 70% of oilseed crops are grown in the country under rainfed conditions, mostly by resource-poor farmers. Marginal soils affected by excessive quantities of salt can be more profitably put under oilseed crops. Salt-affected soils still occupy more than 8 million ha area in the arid and semi-arid regions of the country pursuant to hydro-chemical conditions and relief in various agro-eco zones. Developments and adoption of salt-tolerant oilseed genotypes can form a major low cost-input for enhancing productivity on such soils. Cultivation of high oil corn crop offers a new and potential avenue for producing high quality edible oil in the country. Approximately 400,000 ha of high oil corn (HOC) with oil concentration >7% in harvested grain is annually produced in USA. Top cross maize production technology can be easily adopted and perfected for this purpose to suit Indian conditions.

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Evaluation of soybean (*Glycine max*) varieties for rainy season in northern Telangana region of Andhra Pradesh

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ABSTRACT

An experiment was conducted during rainy season of 2004 and 2005 at Regional Agricultural Research Station, Jagtial located in the northern Telangana agro-climatic zone of Andhra Pradesh. Among the 13 soybean [*Glycine max* (L.) Merr.] varieties tested, *JS-(SH) 93-37, JS-335 and PK-472 were identified as most suitable for cultivation in Vertisol during rainy season under rainfed condition with grain yields of 1814, 1556 and 1512 kg/ha, respectively.* Maximum yield in these varieties can be attributed to more number of pods/plant, number of seeds/pod and test weight. Though the rainfall was 503 mm during 2004 as compared to 941 mm during 2005, the mean grain yield was high during 2004 (1425 kg/ha) when compared with 2005 (1072 kg/ha) due to occurrence of two dry spells at pod formation and seed filling stages during 2005. Under moisture stress conditions, chlorophyll content (2.35 mg/g) and relative water content (81%) were higher in JS (SH) 93-37 over rest of the varieties.

Key words: Chlorophyll content, Rainfed condition, Relative water content, Seed yield, Soybean genotypes, Vertisol

Soybean [*Glycine max* (L.) Merr.] is one of the important oilseed crops of India and is fast expanding in Andhra Pradesh. Area under this crop is increasing year after year, particularly in northern Telangana agro-climatic zone, as there are sufficient processing industries, good support price and marketing facilities. It is replacing some traditional rainy season crops like groundnut, greengram and jowar in some districts. Being newly introduced crop, information on the suitable varieties is meager. Keeping this in view, an experiment was conducted with 13 varieties during rainy season of 2004 and 2005 at Regional Agricultural Research Station, Jagtial under rainfed situation.

MATERIALS AND METHODS

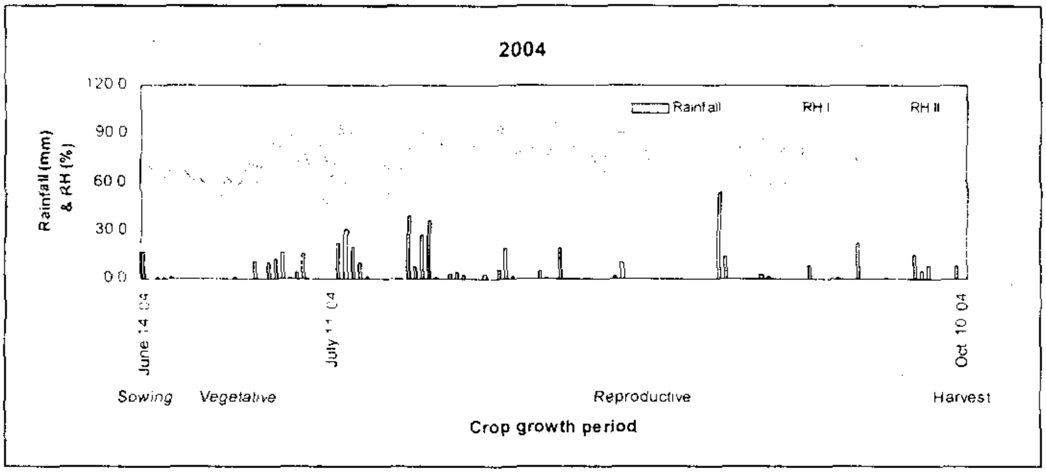
A field experiment was conducted during the rainy season of 2004 and 2005 in vertisols under rainfed situation at Regional Agricultural Research Station, Jagtial. Sowing of 13 soybean varieties (Table 1) was taken up on 14th June, 2004 and 24th June, 2005 and were harvested on 10th October, 2004 and 16th October, 2005. Experiments were laid out in randomized block design with three replications. Recommended dose of NPKS (*30:60:40:20 kg/ha*) was applied during last ploughing. Pre-emergence herbicide alachlor was sprayed @ 5 ml/l after sowing for effective weed control. Need based plant protection measures were undertaken. Five plants in each plot were tagged separately and were used to record data on plant height and yield contributing characters during crop growth and harvest. During moisture stress periods in both the years, total chlorophyll content in leaves was estimated by following Hiscox and Israelstam method (1979), and relative water contents were also measured.

The total rainfall received during 2004 and 2005 years was 503 and 941 mm, respectively. There were three dry spells of 11-15 days during early vegetative stage, pod formation and grain filling stage in 2004, where as two dry spells of 10 and 20 days occured in 2005 coinciding with grain filling stage. Data on rainfall and relative humidity, prevailed during crop growth period in two seasons were presented in fig. 1.

RESULTS AND DISCUSSION

Two years results revealed that among the 13 varieties tested, JS (SH)-93-37 has recorded highest grain yield of 1814 kg/ha followed by JS-335 and PK-472 with an yield of 1556 and 1512 kg/ha, respectively (Table 1). Similar results with June second fortnight sowings were also reported by Barik and Sahoo (1989) and Devaraju *et al.* (2005). Highest grain yield in these varieties was due to more plant height, more number of pods/plant, more number of seeds/pod and test weight (Table 1). These results are in conformity with *the results of Lavanya Veni and Murthy (2003) where higher* plant height, more number of branches and more leaf area have increased the grain yield.

Among the test varieties, LSb-1 was found to be early maturing (72 days) with a mean grain yield of 965 kg/ha. Low yield in this variety may be due to short stature of plant, less number of pods/plant and less grain filling period. LSb-3 was identified as late variety with duration of 116 days and 1141 kg/ha mean grain yield.



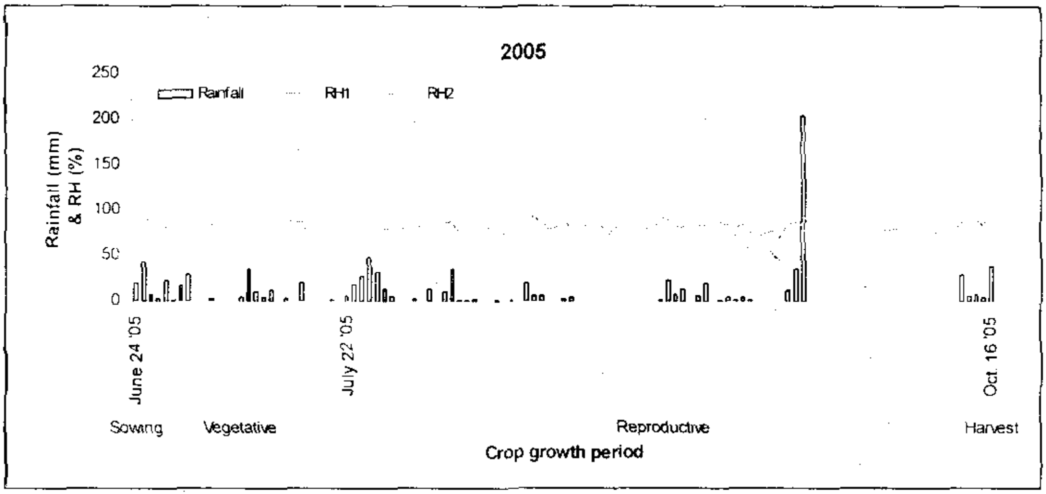


Fig. 1. Rainfall and relative humidity during the crop growth period of rainy season soybean

Table 1 Yield attributes, grain yield and harvest index of soybean varieties during rainy season (mean of 2004-05)

Variety	Plant height (cm)	Days to 50% flowering	Days to maturity	Grain filling period (days)	Number of pods/plant	Number of seeds/pod	1000 seed weight (g)
MACS-450	64	45	109	64	39	2.1	97
PK-472	38	46	110	64	48	2.0	114
PK-1029	35	40	114	74	42	2.0	95
NRC-12	43	34	104	70	33	1.9	101
NRC-37	63	46	105	60	28	1.9	90
NRC-51	56	48	108	60	40	2.0	95
JS-335	46	42	103	61	47	2.4	114
JS-93-05	39	37	90	53	36	2.0	87
JS (SH)-93-37	83	42	106	65	53	2.5	123
Lsb-1	31	28	72	45	34	2.2	122
Lsb-3	65	50	116	67	33	1.7	95
MAUS-47	35	40	96	57	34	1.8	89
Dsb-1	69	43	107	64	35	2.0	88
CD (P=0.05)	3.6	3.54	4.5	6.3	3.7	NS	6.1
CV (%)	8.8	10.5	5.4	12.5	12.1	22.9	7.5

Table 1 (contd...)

Variety	Total Drymatter (kg/ha)			Grain yield (kg/ha)			Harvest index (%)		
	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean
MACS-450	4233	3826	4030	1399	1228	1314	33.2	32.1	33
PK-472	4646	4097	4372	1581	1442	1512	34.1	35.2	35
PK-1029	4794	2545	3670	1722	771	1247	36.0	30.3	33
NRC-12	4405	1608	3007	1449	426	938	32.8	26.5	30
NRC-37	2553	1754	2154	719	593	656	28.6	33.8	31
NRC-51	5013	3840	4427	1677	1344	1511	33.5	35.0	34
JS-335	4748	4337	4543	1672	1440	1556	35.2	33.2	34
JS-93-05	4520	3783	4152	1332	1309	1321	29.5	34.6	32
JS (SH)-93-37	5014	5063	5039	1785	1843	1814	35.7	36.4	36
Lsb-1	4032	1540	2786	1406	523	965	34.9	34.1	35
Lsb-3	4215	3240	3728	1378	904	1141	32.6	27.9	30
MAUS-47	4193	4280	4237	1262	1361	1312	30.2	31.8	31
Dsb-1	3613	2653	3133	1140	756	948	31.7	28.5	30
CV (%)	13.8	7.2		12.3	24.2		7.6	10.2	
CD (P=0.05)	483.4	191.9		142.0	203.6		2.0	2.7	

Table 2 Chlorophyll (mg/kg) and relative water content (%) in different soybean varieties during 2004-05

Varieties	Chlorophyll content (mg/g)									
	2004					2005				
	August 23rd	September 1st	September 11th	September 21st	Mean	August 20th	September 4th	September 18th	October 3rd	Mean
MACS-450	2.74	2.15	1.90	1.17	1.99	2.85	2.10	1.82	1.21	2.00
PK-472	2.70	2.08	1.97	1.39	2.04	2.90	2.60	1.89	1.36	2.19
PK-1029	2.85	3.05	2.00	1.55	2.36	2.56	2.40	1.75	1.12	1.96
NRC-12	2.94	2.52	2.16	1.59	2.30	2.13	2.02	1.80	1.26	1.80
NRC-37	2.60	1.89	1.46	0.95	1.73	2.48	2.35	1.90	1.31	2.01
NRC-51	2.91	2.60	2.16	1.52	2.30	2.61	2.42	1.93	1.26	2.06
JS-335	2.69	2.41	2.06	1.50	2.17	2.91	2.46	1.88	1.49	2.19
JS-93-05	2.10	1.65	-	-	1.87	2.52	2.29	2.00	-	2.27
JS (SH)-93-37	2.92	2.65	2.23	1.69	2.37	2.96	2.64	2.06	1.68	2.34
Lsb-1	1.48	-	-	-	1.48	1.95	-	-	-	1.95
Lsb-3	3.08	2.74	2.11	1.52	2.36	2.68	2.35	1.86	1.40	2.07
MAUS-47	2.68	1.95	1.45	-	2.03	2.75	2.50	1.95	1.10	2.08
Dsb-1	2.73	2.88	2.18	1.51	2.33	2.86	2.53	1.87	1.26	2.13
	Relative water content (%)									
MACS-450	83	79	80	68	77	85	83	78	64	78
PK-472	85	82	80	70	79	84	82	80	69	79
PK-1029	84	80	81	72	79	85	81	79	67	77
NRC-12	83	81	79	69	78	83	80	75	65	76
NRC-37	81	79	78	66	76	82	79	74	60	74
NRC-51	84	81	82	71	76	80	78	72	61	73
JS-335	85	82	83	73	81	83	82	76	62	76
JS-93-05	76	70	-	-	73	78	75	67	-	73
JS (SH)-93-37	88	82	84	72	81	87	85	81	72	81
Lsb-1	73	-	-	-	73	72	-	-	-	72
Lsb-3	83	80	78	65	76	80	80	73	58	73
MAUS-47	82	80	71	-	77	81	78	69	-	76
Dsb-1	83	79	80	72	78	82	80	72	63	74

Year wise grain yield and rainfall data showed that, the mean grain yield was more during 2004 (1425 kg/ha) as compared to 2005 (1072 kg/ha). Interestingly, the rainfall was 503 mm during 2004 where as it was 941 mm during 2005. Main reason for reduction in grain yield during 2005 was occurrence of two dry spells of 10 and 20 days which coincided with the pod formation and grain filling stage, which in turn reduced the number of pods/plant, number of seeds/pod and test weight. This clearly indicates that soybean crop can be successfully cultivated in Telangana region even under moderate rainfall, provided the distribution is uniform with out significant dry spells.

Data in table 2 indicate that under moisture stress conditions the variety JS (SH) 93-37 possessed more mean chlorophyll content in leaves (2.35 mg/g) and relative water content (81%) in comparison with other genotypes. These two physiological factors could have helped the plants to withstand moisture stress, which enabled the plants to maintain sustained photosynthetic rates and finally resulting in better grain yields.

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Growth, productivity and quality of canola and non-canola cultivars of oilseed rape (*Brassica napus*) as influenced by time of application of nitrogen and sulphur

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ABSTRACT

The effect of time of application of nitrogen (N) and sulphur (S) on the productivity and quality of an oil and seed meal of oilseed rape (*Brassica napus* L.) cultivars was studied under field conditions on loamy sand soils of Punjab Agricultural University Ludhiana. The experiment was conducted in three replications using split plot design with two canola (GSC-5 and OCN-3) and one non canola (GSL-1) cultivars assigned to main plots and eight treatments of time of application of nitrogen and sulphur *viz.*, N_0S_0, N_0S_{40}, $N_{50+50}S_0$, $N_{50+50}S_{40}$, $N_{50+50}S_{20+20}$, $N_{50+25+25}S_{20+10+10}$, $N_{34+33+33}S_{14+13+13}$, $N_{25+50+25}S_{10+20+10}$, to sub plots. Nitrogen and sulphur as per treatments were applied either at sowing (single dose), sowing and vegetative stage (two splits) or sowing, vegetative and 50% flowering stages (three splits). Canola cultivars registered higher (31%) harvest index than non canola cultivar (25%). Seed yield of OCN-3 (1804 kg/ha) was 11.2% higher than GSC-5 and 14.9% higher than GSL-1 which attained tall stature and accumulated higher biomass. Late flowering concomitant with shorter reproductive phase during high temperature and low relative humidity conditions led to poor development of seeds in GSL-1 as compared to OCN-3 and GSC-5. Oil yield of OCN-3 was 4.8% higher than GSC-5 and 9.4% higher than GSL-1. Application of N alone or in combination with S resulted in conspicuously better growth of oilseed rape than application of S alone or without application of nutrients. Split application of N and S resulted in a significantly higher number of primary branches and siliqua/plant and seeds/siliqua. The highest seed yield (1891 kg/ha) was obtained with application of N and S as one-fourth at sowing + one half at vegetative stage + one fourth at 50% flowering. Application of S increased glucosinolate contents in seed meal, whereas its application in conjunction with N increased oil content in seed. Fatty acid composition of oil was only marginally influenced by combined application of N and S.

Key words: Application time, Nitrogen, Oilseed rape, Quality, Sulphur, Yield

Traditional cultivars of rapeseed-mustard (*Brassica* sp) contain high amounts of nutritionally undesirable long chain fatty acids, particularly erucic acid and low proportion of desirable oleic acid in oil and high amounts of glucosinolate in seed meal. High erucic acid content is known to cause cardiac complications while breakdown products of glucosinolate in seed meal lower palatability and lead to nutritional disorders in animals (Vermorel *et al.*, 1986). Oilseed rape (*Brassica napus* L.) has higher yield potential, oil content and better frost and white rust tolerance than Indian mustard (*Brassica juncea* L.) which make it a promising winter oilseed crop for north India. Development of canola cultivars of oilseed rape which are free from erucic acid and contain a higher proportion of oleic acid in the oil and low amount of glucosinolates in de-oiled seed meal is likely to increase its area under cultivation in the future.

Nitrogen (N) and sulphur (S) are the important nutrients that not only influence several metabolic processes involved in growth and productivity but also the content and quality of oil. Time of application of N and S may further influence the quality of an oil and seed meal. Since there is a strong positive interaction between these two nutrients for productivity gains and quality enhancement, simultaneous availability of an optimum amount of both at different growth stages is considered imperative. Split application of N and S at various growth stages may better fulfill the nutrient needs of the crop, by matching their availability, for producing optimum yields.

The present investigation was conducted to study the effect of time of application of N and S on the performance of canola and non-canola cultivars of oilseed rape (*Brassica napus* L.) in terms of growth, yield attributes, seed and oil yield, quality of an oil and seed meal.

MATERIALS AND METHODS

The field investigation was carried out at the Punjab Agricultural University Ludhiana (30°54', 75°48', 247 m

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above mean sea level) during the winter season of 2006. The loamy sand soil (0-15 and 15-30 cm) of the experimental field was slightly alkaline (pH 8.0), low in organic carbon (0.15%) and available nitrogen (124 kg/ha), medium in available phosphorus (12.5 kg/ha) and sulphur (18.4 kg/ha) and medium in available potassium (105 kg K_2O/ha). The experiment was replicated thrice and conducted in split plot design by assigning two canola (GSC-5 and OCN-3) and one non canola (GSL-1) cultivars to main plots and eight treatments of dose and time of application of N (100 kg/ha) and S (40 kg/ha) *viz.*, N_0S_0, N_0S_{40}, $N_{50+50}S_0$, $N_{50+50}S_{40}$, $N_{50+50}S_{20+20}$, $N_{50+25+25}S_{20+10+10}$, $N_{34+33+33}S_{14+13+13}$ and $N_{25+50+25}S_{10+20+10}$, to sub plots. The cultivars were sown on 28th October 2006 at row spacing of 45 cm in a gross plot of 5.0 m x 3.6 m. Three weeks after sowings, optimum plant population was maintained by keeping plant spacing of about 12 cm within rows. Nitrogen and sulphur were applied in the form of urea and gypsum respectively at sowing, sowing and vegetative stage or sowing, vegetative and 50% flowering stages as per treatments. In addition, di-ammonium phosphate was drilled at the time of sowing to supply 30 kg P_2O_5/ha and contribute part of the basal dose of N.

Chlorophyll content of leaves of intact plant was measured periodically with the help of Minolta-SPAD 502. For each observation, ten plants from each treatment were randomly selected and second or third fully opened leaf from apex avoiding midrib was used. Ancillary data was recorded from 5 randomly selected plants for the number of branches and silique/plant and 20 silique for a number of seeds/siliqua. Nitrogen content in the seed was determined (Hesse, 1971). The oil content in seed was determined with Nuclear Magnetic Resonance spectroscope Newport Analyzer Model MK IIIA (Alexander *et al.*, 1967). Fatty acids in oil were trans-esterified and analyzed by gas liquid chromatography using the standard method (Appleqvist, 1968). Glucosinolate content in the de-oiled seed meal was also determined (Thies, 1982).

RESULTS AND DISCUSSION

Cultivars

Cultivars OCN-3 and GSC-5 registered significantly higher SPAD values than GSL-1 at 110 days after sowing (DAS), whereas, at earlier growth stages (50 and 80 DAS). All cultivars registered similar SPAD values (Table 1). Cultivar GSL-1 took significantly more number of days for flowering initiation (39 and 45), 100% flowering (30 and 34) and maturity (6 and 13) than canola cultivars (OCN 3 and GSC-5). Canola cultivars took about three weeks from flowering initiation to 100% flowering compared to two weeks required for GSL-1 (Table 1) indicating a faster reproductive growth of GSL-1 compared to OCN-3 and GSC-5.

Cultivar GSL-1 attained significantly more plant height, accumulated markedly higher drymatter (Table 1) and produced significantly more number of primary and secondary branches and silique/plant at harvest than OCN-3 and GSC-5, which were at par with each other (Table 2). Canola cultivars, however, produced significantly higher 1000 seed weight than GSL-1 (Table 2). Seed yield of OCN-3 (1804 kg/ha) was 11.2% higher than GSC-5 and 14.9% higher than GSL-1 but stover yield of GSL-1 was significantly higher than OCN-3 and GSC-5 resulting in lower harvest index (25%) than canola cultivars (31%).

Tall stature, progressively higher biomass accumulation and greater PAR interception (data not reported) of GSL-1 contributed to the higher number of primary and secondary branches and siliquae/plant compared to GSC-5 and OCN-3. However, lower chlorophyll content, late flowering concomitant with shorter reproductive phase during high temperature and low relative humidity conditions led to poor development of seeds in GSL 1 as compared to OCN-3 and GSC-5. Mathur and Wattal (1996) observed that early flowering and enhanced length of the reproductive period were positively correlated with higher 1000 seed weight and seed yield. Harvest index represents the physiological capacity to mobilize photo assimilates to organs of economic value. A positive correlation between harvest index and seed yield has been reported in *Brassica* species (Ahmad *et al.*, 1998).

There was no difference among cultivars for seed protein content (Table 3). GSL-1 produced significantly higher oil content (44.2%) than both canola cultivars (42.0%). Oil yield of OCN-3 was 4.8% higher than GSC-5 and 9.4% higher than GSL-1 due to its higher seed yield (Table 2).

Canola cultivars were superior in quality because of high amounts of oleic acid and linoleic acid than GSL-1 whereas, eicosenoic and erucic acid content in GSL-1 was substantially higher than both the canola cultivars (Table 3). The highest linolenic acid content was observed in OCN-3. An inverse relationship between palmitic acid and stearic acid with erucic acid content has been reported earlier by Ahuja *et al.* (1990). High oleic acid content in oil is desirable as it provides thermo-stability and imparts long shelf life to oil. Canola cultivars generally contain low oil content because of their superior fatty acid composition in comparison to non canola cultivars (Siddiqui and Mohammad, 2004). Glucosinolate content of non canola cultivar, GSL-1 was significantly higher than both the canola cultivars (Table 3).

Nitrogen and sulphur application

Nitrogen applied alone or in combination with S resulted in significantly higher plant height and drymatter and SPAD values than application of S alone or without application of nutrients (Table 1). Combined application of N and S failed to alter the onset of different phenophases (Table 1). Different treatments of combined application of N and resulted in a higher number of branches, silique/plant and seeds/siliqua over application of N or S alone or without application of nutrients (Table 2). Split applications resulted in a significantly higher number of primary branches/plant over $N_{50+50}S_{40}$. Highest number of siliquae/plant was obtained with $N_{50+25+25}S_{20+10+10}$ whereas seeds/siliqua were highest with $N_{25+50+25}S_{10+20+10}$.

The highest seed yield (1891 kg/ha) obtained with N, and S applied as one fourth at sowing, one half at vegetative and one fourth at 50% flowering was 4.4% higher than application of N alone, 64.1% higher than application of S alone, and 83.4% than without application of nutrients (Table 2). Application of 40 kg S/ha at sowing significantly increased seed yield (1570 kg/ha) to the tune of 52.1% over control. *Application of 100 kg N/ha in two equal splits at* sowing and vegetative stages (1811 kg/ha) resulted in 75.6 and 15.3% higher seed yield over control and application of S @ 40 kg/ha, respectively. Different treatments of split application of N and S resulted in statistically similar seed, oil and stover yields. Thakur *et al.* (2005) also reported increase in seed yield of gobhi sarson (*Brassica napus*) with N application. Kachroo and Kumar (1997) reported significant increase in seed yield of mustard with S application up to 60 kg/ha. Inadequate and imbalanced application of N and S resulted in less number of siliquae/plant (Ahmad *et al.*, 2005).

Application of S along with N ($N_{50+50}S_{40}$) resulted in 5.3% higher oil yield than application of N alone (763 kg/ha). Application of 100 kg/ha of N along with 40 kg/ha of S in three equal splits at sowing, vegetative stage and 50% flowering (43.6%) or in two equal splits at sowing and vegetative stages (43.4%) resulted in significantly higher oil content than their application as half dose of each at sowing + one fourth at vegetative stage + one fourth at 50% flowering (41.8%) or one fourth dose of each at sowing + one half at vegetative stage + one fourth at 50% flowering (41.9%). Reduction in oil content with N application in oilseed rape (Sardana and Sidhu, 1994) and increase with S application (Singh *et al.*, 1988) have been reported. Combined application of N and S as $N_{50+50}S_{40}$ and $N_{50+50}S_{20+20}$ resulted in low palmitic acid content, whereas their application in three splits as $N_{50+25+25}S_{20+10+10}$ resulted in low stearic acid content than application of N and S alone (Table 3). *Combined application of N and S in different splits* resulted in low linolenic acid but higher erucic and eicosenoic acid content than that discerned with application of N alone or without application of N and S.

The highest glucosinolate content (57.4 mole/g defatted meal) was obtained with application of basal dose of 40 kg S/ha, whereas application of 100 kg N/ha in two equal splits at sowing and vegetative stages resulted in lowest glucosinolate content (46.3 mole/g defatted meal) and the differences between these two treatments were significant. Similar role of N in reducing glucosinolates was reported by Sardana and Atwal (2007). Increase in glucosinolates in both *canola and non canola oilseed rape and mustard with S* application is well established (Wang *et al.*, 1997).

Table 1 Influence of oilseed rape cultivars and doses and time of application of nitrogen and sulphur on chlorophyll content, plant height, drymatter and occurrence of phenophases

Treatments	SPAD			At maturity		Days taken to		
	50 DAS	80 DAS	110 DAS	Plant height (cm)	Drymatter (q/ha)	Flowering initiation	100% flowering	Maturity
Cultivars								
OCN-3	48.2	51.4	49.6	130.4	58.4	56.5	77.5	145.9
GSC-5	48.3	50.4	47.2	127.0	53.7	52.0	73.7	138.8
GSL-1	49.4	50.7	44.0	167.0	64.8	95.0	107.6	151.4
CD (P = 0.05)	NS	NS	1.3	7.3	5.1	1.7	0.7	1.6
Application of nutrients (kg/ha)								
N_0S_0	41.7	44.2	44.0	121.0	35.3	67.5	86.3	145.0
N_0S_{40}	43.0	46.7	45.4	126.0	37.3	68.5	86.0	144.7
$N_{50+50}S_0$	50.6	52.2	47.5	150.3	64.9	67.7	86.1	145.2
$N_{50+50}S_{40}$	51.7	53.1	48.7	148.7	66.2	67.7	86.5	145.2
$N_{50+50}S_{20+20}$	50.8	52.0	48.0	148.0	66.5	67.7	86.2	145.3
$N_{50+25+25}S_{20+10+10}$	50.2	53.0	47.3	149.2	67.0	68.0	86.4	145.9
$N_{34+33+33}S_{14+13+13}$	49.1	52.2	47.3	141.4	67.8	67.2	86.1	145.9
$N_{25+50+25}S_{10+20+10}$	52.3	53.4	47.6	147.3	66.8	68.3	86.4	145.8
CD (P = 0.05)	1.9	1.5	2.1	5.2	4.7	NS	NS	0.7

DAS = Days after sowing

Table 2 Influence of oilseed rape cultivars and doses and time of application of nitrogen and sulphur on yield attributes, seed, stover yields and harvest index

Treatments	Branches/plant		Siliquae/ plant	Seeds/ siliqua	1000 seed weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index
	Primary	Secondary						
Cultivars								
OCN-3	4.1	4.0	218.8	20.7	3.3	1804	4037	0.31
GSC-5	4.1	3.8	207.3	21.0	3.0	1623	3749	0.31
GSL-1	7.2	6.0	242.4	21.0	2.8	1570	4920	0.25
CD (P=0.05)	0.3	0.3	20.0	NS	0.1	134	456	0.03
Application of nutrients (kg/ha)								
N_0S_0	4.0	2.4	153.0	20.0	3.0	1032	2498	0.30
N_0S_{40}	4.2	3.0	174.2	20.1	3.0	1152	2583	0.31
$N_{50+50}S_0$	5.4	4.8	225.1	21.3	3.1	1811	4683	0.28
$N_{50+50}S_{40}$	5.0	5.1	243.0	21.6	3.2	1877	4749	0.29
$N_{50+50}S_{20+20}$	5.8	5.2	264.5	21.1	3.1	1853	4802	0.28
$N_{50+25+25}S_{20+10+10}$	5.6	5.1	240.0	20.3	3.0	1846	4856	0.28
$N_{34+33+33}S_{14+13+13}$	5.6	5.6	248.8	20.6	3.1	1864	4917	0.28
$N_{25+50+25}S_{10+20+10}$	5.2	5.0	234.8	22.3	3.1	1891	4792	0.29
CD (P=0.05)	0.4	1.0	21.8	1.5	NS	114	430	NS

Table 3 Seed protein content, oil content, fatty acid composition of oil and glucosinolate content of seed meal in oilseed rape as influenced by cultivars and dose and time of application of nitrogen and sulphur

Treatments	Seed protein content (%)	Oil content (%)	Oil yield (kg/ha)	Fatty acid (%)							Glucosinolate content (μ mole/g defatted meal)
				Palmitic 16:0	Stearic 18:0	Oleic 18:1	Linoleic 18:2	Linolenic 18:3	Eicosenoic 20:1	Erucic 22:1	
Cultivars											
OCN-3	20.0	42.0	760	4.6	1.8	59.9	18.8	8.2	5.1	1.6	26.3
GSC-5	21.2	42.0	680	4.5	2.3	62.4	17.7	8.0	3.7	1.5	27.7
GSL-1	20.0	44.2	695	3.6	1.0	20.3	15.1	8.0	10.3	41.7	102.3
CD (P=0.05)	NS	0.8	56	-	-	-	-	-	-	-	5.8
Application of nutrients (kg/ha)											
N_0S_0	18.7	42.6	440	4.2	1.5	48.5	17.5	9.2	5.5	13.5	49.3
N_0S_{40}	18.7	43.5	502	4.4	1.8	48.6	15.9	7.6	6.3	16.3	57.4
$N_{50+50}S_0$	20.6	42.2	763	4.3	1.7	47.4	17.6	8.3	6.3	14.4	46.3
$N_{50+50}S_{40}$	19.4	42.9	803	4.1	2.1	46.0	17.0	7.4	7.8	15.5	46.8
$N_{50+50}S_{20+20}$	21.9	43.4	805	4.1	1.7	47.6	17.9	7.2	6.5	15.0	54.8
$N_{50+25+25}S_{20+10+10}$	21.2	41.8	772	4.3	1.4	48.0	17.2	7.5	6.3	15.3	53.3
$N_{34+33+33}S_{14+13+13}$	20.6	43.6	813	4.3	1.6	46.8	17.9	8.4	6.0	14.5	54.4
$N_{25+50+25}S_{10+20+10}$	20.6	41.9	793	4.2	1.8	48.3	16.6	7.7	6.5	14.8	54.8
CD (P=0.05)	0.16	1.3	53	-	-	-	-	-	-		7.4

Split application of N and S at different growth stages resulted in significantly higher glucosinolate content than application of N alone (Table 3). The study shows that S applied at sowing along with N might have been utilized in vegetative growth and formation of the sink, whereas part of the S applied at later stages (pre flowering or 50% flowering) might have been translocated to seed resulting in its higher concentration. Where S was applied alone, greater part of it might have remained unutilized during vegetative phase owing to poor growth and was deposited in developing seed.

Cultivars x Nutrients

The highest seed yield of OCN-3 (2080 kg/ha) wa obtained with $N_{50+50}S_{40}$ whereas in case of GSC-5, $N_{50+50}S_{20+}$ resulted in highest seed yield (1833 kg/ha) followed b $N_{50+50}S_{40}$ and $N_{34+33+33}S_{14+13+13}$ (1821 kg/ha). Higher oil yiel in OCN-3 (876 kg/ha) and GSC-5 (775 kg/ha) wit treatments $N_{34+33+33}S_{14+13+13}$ and $N_{50+50}S_{20+20}$, respectively were recorded (Table 4). GSL-1 produced the highest seed (1833 kg/ha) and oil yield (809 kg/ha) with $N_{25+50+25}S_{10+20+10}$ indicating some advantage of split application of nutrients.

The study reveals higher productivity of canola cultivar OCN-3 compared GSL-1 owing to the prolonged period available for seed and oil development due to early flowering. The oil yield of GSL-1 was higher than GSC-5 due to higher oil content (Table 3). Application of N and S was beneficial in increasing seed and oil yields than their applications alone. Combined application of N and S marginally lowered palmitic, stearic and linolenic acid contents but increased erucic and eicosenoic acid contents compared to N alone or control (without N and S). Sulphur application, particularly at later growth stages increased glucosinolate contents.

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Stability analysis in sesame (*Sesamum indicum*) genotypes under rainfed situation of Bastar plateau zone of Chhattisgarh

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ABSTRACT

Stability parameters of six promising sesame (*Sesamum indicum* L.) genotypes (RG-54, TKG-22, RT-46, TKG-55, TKG-21 and Local) were worked out for plant height, number of primary branches/plant and seed yield along with per plant performance under three environmental conditions. Highly significant differences among genotypes were observed for all the characters. The significant genotype x environment interaction was recorded for number of primary branches and seed yield. Environment (linear) interaction component was significant for all the traits, while the linear component of environment interaction was significant only for plant height. The variance due to pooled deviation (non linear) was highly significant for seed yield only, which reflect considerable genetic diversity in seed yield. The genotype TKG-22 was stable for plant height. TKG-22, RT-46 and TKG-21 were stable for number of primary branches. RT-54, TKG-22, RT-46, TKG-55 and TKG-21 were stable for seed yield.

Key words: Sesame, Stability, Yield components

In any breeding programme, it is necessary to find out phenotypically stable genotypes for yield, which could perform more or less uniformly under different environmental conditions. Seed yield is a complex character and largely depends upon its component characters, with an interaction with the environment resulting into the ultimate product, i.e., seed yield. To breed a stable variety, it is necessary to get the information on the extent of genotype x environment interaction for yield and its component characters. In the present investigation, the approach suggested by Eberhart and Russell (1966) has been employed to assess the stability of the performance of different sesame (*Sesamum indicum* L.) genotypes. Gene x environment interaction in sesame was earlier studied by Solanki and Gupta (2000) and John *et al.* (2001).

Six elite sesame genotypes (Table 1) were evaluated at Badi (protected area near homestead, situated on the top of landscape close to homestead which has light and well drained soils, rich in organic matter) situation of farmers field village-Tahkapal, Block-Tokapal, Bastar (Chhattisgarh) *during the rainy season of 2006, 2007 and 2008 under* rainfed condition. The experimental materials were sown in randomized complete block design with 3 replications. Each entry was sown in 6 lines of 4 m length, spaced 30 cm row to row and 5 to10 cm, plant to plant. The recommended package of practices were followed to grow the crop. The observations were recorded on five randomly selected plants for plant height (cm) and no. of primary branches/plant. For seed yield observation was recorded/plot basis and reported as kg/ha). The mean data were subjected to stability analysis as per the model of Eberhart and Russel (1966).

The analysis of variance for individual as well as pooled environments showed that mean sum of squares due to genotypes were significant for all the characters. The analysis indicated that genotypes interacted strongly with the environment.

Environment (linear) interaction component was significant for all the traits, while the linear component of environment interaction was significant for only plant height. The variance due to pooled deviation was highly significant for seed yield (kg/ha.), which reflected considerable genetic diversity in seed yield. A variety may be considered to be stable over different environments, if it show unity or less than unity regression coefficient (bi) with lowest deviation (non significant) from linear regression (S^2di). The mean, regression coefficient (bi) and deviation from regression (S^2di) for seed yield (kg/ha.), plant height (cm) and no. of primary branches/plant are presented in table 1.

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

The genotype TKG-22 was stable for plant height. TKG-22, RT-46 and TKG-21 were stable for no. of primary branches/plant. RT-54, TKG-22, RT-46, TKG-55 and TKG-21 were stable for seed yield.

The genotype which are showing high mean value than over all mean but exhibiting above average stability with bi>1 comes under the second group, indicated that they were highly sensitive to environmental conditions. The genotype TKG-22 for plant height, RT-46 and TKG-21 for no. of primary branches/plant, RT-54, TKG-55 and TKG-21 for seed yield comes under second group. Therefore, recommended for favourable environments.

The third group consisting the genotype, which are showing high mean value than the population mean and exhibiting below average in stability with bi <1, indicating that these genotypes were least sensitive to environmental conditions. The genotype TKG-22 for no. of primary branches/plant and RT-46 for seed yield comes under third group. Hence, adapted for poor environmental conditions. The genotype TKG-22 was stable for plant height. TKG-22, RT-46 and TKG-21 were stable for no. of primary branches. RT- 54, TKG-22, RT-46, TKG-55 and TKG-21 were stable for seed yield.

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Table 1 Estimates of different stability parameters for plant height, branches/plant and seed yield in sesame

Genotype	Plant height (cm)			No. of primary branches/plant			Seed yield (kg/ha)		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
RT-54	69.63	0.274**	-15.56	3.64	1.417**	-0.15	579.2	1.099**	415.6
TKG-22	83.50	2.999*	0.18	4.18	0.928**	-0.15	540.8	0.984**	-63.0
RT-46	75.02	-0.660	-11.70	3.73	1.180**	-0.006	501.6	0.944*	942.3
TKG-55	86.63	0.806	23.04	4.50	0.974	0.30	532.2	1.133**	716.9
TKG-21	68.06	2.031**	-9.99	3.82	1.276**	-0.139	500.4	1.137**	59.9
Local	61.21	0.550	-12.51	2.41	0.225	-0.025	215.5	0.703	4395.3***
Mean	74.01	1.0		3.71	1.0		478.3	1.0	
SEm ±	2.36	0.59		0.25	0.22		26.8	0.3	

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

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Residue management and N dynamics in legume-rice (*Oryza sativa*)-groundnut (*Arachis hypogaea*) cropping system for sustainable crop production

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ABSTRACT

Field experiments were conducted in the wetland farm of S.V. Agricultural College, Acharya N.G. Ranga Agricultural University, Andhra Pradesh for two consecutive years 2002-03 and 2003-04 to investigate the cumulative residual effect of incorporated crop residues and different nitrogen management practices applied to preceding lowland rice (*Oryza sativa* L.) on the performance of succeeding groundnut (*Arachis hypogaea* L.) and results revealed that by raising a reasonably short duration leguminous crop (either a pulse crop or vegetable crop depending up on the farming situation) preceding to rice and incorporation of the crop residues after picking the economic yield and supply of 50% recommended dose of nitrogen each through fertilizer and farm yard manure (FYM) to rice followed by raising groundnut as residual crop, to utilize the residual fertility was found the best integrated nitrogen management package for rice-groundnut cropping system to achieve higher growth, productivity and economic returns of succeeding groundnut.

Key words: Crop residue incorporation, Groundnut, Nitrogen management practices, Rice

In recent years, the emphasis has been shifted from individual crop to cropping system as a whole since the response in component crop of the cropping system are influenced by the preceding crops and the inputs applied to them. Legume crop residues incorporation in to the field after harvesting seed can contribute considerably to nitrogen (N) to succeeding crops (Rekhi and Meelu, 1983). Conjunctive use of nutrients partly through organics and inorganics to preceding rice exhibited significant residual effect on succeeding groundnut (Thimmegowda and Devakumar, 1994). Rice-groundnut is one of the important cropping system in the southern agroclimatic region and maintenance of optimum soil fertility is an important consideration for obtaining higher and sustainable yield due to large turn over of nutrients in soil plant system. Since, the information on cumulative residual effect of crop residue incorporation and N management practices on succeeding groundnut grown after rice is lacking for southern agroclimatic zone of Andhra Pradesh, the present study was conducted to assess the effectiveness of cumulative residual effect of incorporation of crop residues, farm yard manure (FYM) and fertilizer on growth, pod yield, nutrient uptake of groundnut and post-harvest soil fertility status.

MATERIALS AND METHODS

Field investigations were conducted during 2002-03 and 2003-04 at wetland farm of S.V. Agricultural College, Tirupati (Andhra Pradesh). Soil physico-chemical analysis (0-30 cm soil depth, prior to the commencement of the experiment) showed that experimental field was sandy clay loam in texture, slightly alkaline in reaction, low in organic carbon and available nitrogen (160.8 kg/ha), medium in available phosphorus (25.6 kg/ha) and available potassium (175.4 kg/ha).

The experiment was laid out in a randomized block design with five replications comprising of crop residue incorporation of four legume crops *viz*., C_1: greengram var. LGG-407, C_2: clusterbean var. Pusa Navabahar, C_3: fieldbean var. HA-3 and C_4: cowpea var. CO-4. The crop residues thus obtained were chopped and incorporated in respective plots. Samples of all the crop residues were taken plot and replication wise, to estimate the nutrient content (Table 1) before incorporation. N, P and K contents of crop residues were analysed by standard procedures outlined by Jackson (1973).

Rice (var. NLR 33359) crop was grown during the winter season after harvest of preceding legume crops (grown during rainy season) in the same layout, by sub-dividing each of the rainy season treatments into four sub-plots, to which four N management practices were assigned. The experiment was taken up in a split plot design with the incorporation of crop residues of preceding crops as main plot treatments *viz*., C_1, C_2, C_3 and C_4 and four N management practices imposed on winter rice as sub-plot treatments *viz*., N_1: No N, N_2:100% recommended N through fertilizer, N_3: 50% recommended N through fertilizer + 50% recommended N

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through FYM and N_4: 100% recommended N through FYM. The recommended dose of nutrients was 120 kg N, 80 kg P_2O_5 and 40 kg K_2O/ha. The N, P and K contents of FYM used in the experiment was 0.5, 0.2 and 0.5%, respectively. The N content in FYM was taken into consideration, quantified for N_3 and N_4 treatments and incorporated in to the plots 10 days before transplanting of rice. For the treatments N_2 and N_3, fertilizer N in the form of urea was applied in three split doses of 50% as basal, 25% at active tillering and 25% at panicle initiation stages. A uniform dose of 80 kg P_2O_5 and 40 kg K_2O/ha was applied basally to all the treatments except to N_1, in the form of single super phosphate and muriate of potash, respectively, after duly taking into consideration of phosphorus and potassium content of FYM in the FYM involved treatments. Soil fertility status in terms of soil organic carbon, available N, phosphorus and potassium were estimated (Walkey and Black, 1934; Subbaiah and Asija, 1956; Olsen *et al.*, 1954 and Jackson, 1973) by collecting soil samples after rice and groundnut crop harvests.

RESULTS AND DISCUSSION

Performance of preceding leguminous crops

Among the four leguminous crops incorporated preceding to rice, fieldbean produced the highest quantity of biomass and crop residues, while greengram produced the lowest quantity (Table 2). The highest economic yield (in terms of greengram equivalent yield) was produced by clusterbean and it was lowest with greengram. Gross and net returns were highest with clusterbean and the lowest with greengram. The crop which produced the highest quantity of crop residues could not give the highest saleable yield and monetary returns and vice versa. In this study, clusterbean produced higher economic yield and net returns, while fieldbean produced higher quantity of crop residues and consequently larger quantity of nutrients supplied to succeeding rice crop. Therefore, the choice of crop for the purpose of crop residues should be of short duration in nature, with capability to produce as large quantity of crop residues as possible along with the production of sizeable economic yield, to ensure reasonable monetary returns. However, crops like clusterbean, though appear more remunerative, should not be recommended for larger areas, since the cost and marketing of green pods for vegetable purpose is a possible constraint, besides huge labour cost involved for multiple picking of pods.

Drymatter and grain yield of rice

Incorporation of fieldbean crop residues resulted in higher dry matter production and grain yield of rice (Table 3). This beneficial effect of incorporation of fieldbean crop residues may be ascribed to higher quantity of nutrient addition. Availability of adequate quantity of nutrients in the soil, obviously promote the performance of rice crop. Comfortable level of absorbed and assimilated N in the plants has manifested elevated level of growth and yield structure, resulting in superior performance of rice crop. Adequate decomposition of green parts of fieldbean, which might have enabled the rice plant to get an ensured and continuous N supply distributed over the entire period of crop growth. Crop residues undergo decomposition at a slower rate under submerged conditions, releasing ammonical N in reasonable quantities over a long period of time. Thus, the rhizo-ecosystem of low land gets enriched with less leachable form of available N. Superior performance of rice crop with incorporation of fieldbean crop residues as observed in the present study corroborates the findings of John *et al.* (1992). The performance of rice crop was sub-optimal with the incorporation of greengram crop residues. This might be due to lesser quantity of readily available N in soil solution due to the lower quantity of residues incorporated.

Table 1 Nutrient content (%) of crop residues (fresh weight basis) incorporated before planting of rice (mean of 2 years)

Source	Per cent		
	N	P_2O_5	K_2O
Greengram residue	0.82	0.21	0.63
Clusterbean residue	0.53	0.13	0.5
Fieldbean residue	0.65	0.15	0.44
Cowpea residue	0.61	0.15	0.49

Supply of 100% N through fertilizer to rice was found to be superior to any other N management practices, with regard to drymatter production and grain yield of rice. This superiority with the supply of 100% N through fertilizer, might be attributed due to ready availability of comfortable level of instantly usable N by rice crop, which would have created favourable environment of N nutrition in the rhizo-ecosystem of low land rice. Fertilizer N was applied with 50% as basal and the remaining 50% in two equal splits at active tillering and panicle initiation stages of rice crop. Such situation of comfortable level of instantly usable N favours optimum N uptake by rice crop at different growth stages. Ready availability of N in soil solution may be delayed with higher proportion of organic sources due to the process of slow mineralization under anaerobic low land conditions. Superior performance of rice crop with supply of 100% N through fertilizer compared to substitution of 50 and 100% recommended dose of N through FYM as exhibited in the present study corroborates the findings of Jana and Ghosh (1996). Organic manures under go decomposition at a slower rate under submerged conditions, releasing N in regulated quantities over a long period of time. But many a time, it may be insufficient to meet the N requirement of rice crop at appropriate time during crop growing period. The performance of rice crop was sub-optimal with the supply of 100% N through FYM and it was only superior to no N. This might be due to disproportionate availability of N in soil solution due to the process of slow mineralization of FYM under low land conditions.

Post harvest soil fertility status (after rice harvest)

Post-harvest soil fertility status (after rice harvest) with regard to organic carbon, available N and potassium was superior with the incorporation of fieldbean crop residues followed by cowpea, clusterbean and greengram crop residues. The available phosphorus status did not vary to a statistically discernable extent due to crop residues incorporation. Incorporation of fieldbean crop residues left over substantial quantity of soil nutrients after the harvest of rice and increased the soil organic carbon content. Slowly mineralizing organic fractions under anaerobic lowland conditions would leave behind enriched status of soil fertility, even after sufficient uptake of nutrients by rice crop. Post harvest soil fertility status with regard to organic carbon, was superior by applying 100% N through FYM, which was significantly higher than applying 50% N each through FYM and fertilizer and both of them were significantly superior to supply of 100% N through fertilizer and no N. The highest status of residual soil available N and available potassium was recorded with the supply of 100% N through FYM, followed by supply of 50% N each through fertilizer and FYM, supply of 100% N through fertilizer and no N application, with significant disparity between any two. The lowest status of the above mentioned soil fertility parameters were recorded with non-supply of N followed by 100% fertilizer N. The available phosphorus status did not vary statistically due to N management practices. The above trend clearly indicates the role of organic manures in maintaining or building soil fertility. Post harvest fertility status of soil was at relatively lesser level with supply as 100% N through fertilizer, which might be due to higher level of nutrient uptake. Higher growth and yield associated with this treatment obviously removes larger quantity of nutrients from soil than the other N management practices. The above trend showed that application of recommended N either through exclusive organic source or the combination of organics and fertilizer to supply 50% N through each, would leave substantial quantity of soil nutrients after the harvest of rice or increase the soil organic carbon content. The advantage noticed in the present study with the integration of organic manures and fertilizer has been earlier reported by Vasantha Kumar (1996) also. Slowly mineralizing organic fractions under anaerobic lowland conditions would have left behind enriched status of soil fertility, even after sufficient uptake of nutrients by rice crop.

Growth of groundnut

Significant differences in plant height, LAI and drymatter production of groundnut were observed with the incorporation of crop residues of fieldbean to preceding rice followed by cowpea, clusterbean and greengram residues (Table 4). This might be due to substantial amount of residual nutrients left by fieldbean crop residues to extend the favourable carry over effect on succeeding groundnut crop. The tallest plants, highest LAI and drymatter production of groundnut were produced with the supply of 100% N through FYM to preceding rice, which were at par with 50% N each through fertilizer and FYM, but significantly superior to 100% N through fertilizer and no N application (Table 4).

Yield attributes and yield of groundnut

The highest number of pods/plant,100 pod weight,100 kernel weight, pod and haulm yield were produced with the incorporation of crop residues of fieldbean to rice followed by cowpea, clusterbean and greengram, with significant disparity between any two of them and the lowest number of pods/plant,100 pod weight, 100 kernel weight, pod and haulm yield was noticed with the incorporation of crop residues of greengram to preceding rice, during both the years of study (Table 4). This might be due to residual and cumulative effect with the incorporation of fieldbean crop residues, which was comparatively higher than that of the other crop residue incorporation, with in the crop residues incorporation, differential residual response with different crop residues added can be attributed to their pattern of mineralization and decomposition. Supply of 100% N through FYM to preceding rice resulted in the production of highest number of pods/plant, 100 pod weight, 100 kernel weight as well as pod and haulm yield, which was comparable with 50% N each through fertilizer and FYM, but significantly superior to 100% N through fertilizer and no N, which were comparable between them and the lowest number of pods/plant, hundred pod weight, hundred kernel weight, pod and haulm yield were noticed with non-supply of N to preceding rice, during both the years of study (Table 4). This might be due to the residual effect of FYM either alone or in combination with fertilizer N, which was comparatively higher than that of the exclusive inorganic source of N applied to preceding rice crop. Shelling percentage of groundnut did not show any significant variation due to residual and cumulative effect of either incorporation of different crop residues or N management practices tried on preceding rice. Harvest index of groundnut was not altered to a statistically noticeable extent either by incorporation of different crop residues or N management practices to preceding rice. However, the highest value of harvest index was recorded with incorporation of fieldbean crop residues in combination with the supply of 100% N through FYM to preceding rice, while it was the lowest with incorporation of greengram crop residues without any N supply.

In the present study, the residual effect of organic source at higher proportion was evident from higher drymatter accrual, number of pods/plant, 100 pod weight, 100 kernel weight, pod and haulm yield. This clearly shows, organic source at higher proportion can sustain the nutrient status of soil to produce reasonable residual effect. Organic source of N, besides supplying nutrients to the current crop, quite often leave substantial residual effect on succeeding crops in the cropping system. Significant carry over effect due to substitution of N with higher proportions of organic sources to rice crop on the succeeding crops was also reported by Paulraj and Velayudham (1995).

Nutrient uptake of groundnut

Higher uptake of N by groundnut crop with the incorporation of fieldbean crop residues and with the application of 100% N through FYM to preceding rice crop might be due to higher availability of N in the soil and enhanced drymatter production (Table 5). The higher uptake of phosphorus and potassium with the same treatments might be due to better foraging of soil, due to vigorous root growth, thus accumulating more phosphorus and potassium in plant in addition to enhanced drymatter accumulation under the influence of higher amount of residual N (Table 5).

Economics of groundnut

The highest gross returns and net returns as well as benefit-cost ratio of groundnut recorded with the incorporation of crop residues of fieldbean to preceding to rice, were due to higher pod and haulm yield realized by this treatment than to any other crop residues incorporation. The highest gross returns, net returns and benefit-cost ratio realized with the supply 100% nitrogen through FYM to preceding rice, were due to higher pod yield realized by this treatment thar to any other nitrogen management practices applied to preceding rice and also since groundnut crop was raised as residual crop, the cost of cultivation did not differ among the treatments.

Post-harvest soil fertility status (after groundnut)

The highest post harvest (available nutrient status in soil after groundnut harvest) organic carbon, available N and potassium content of soil were noticed with the incorporation of fieldbean crop residues to preceding rice, which were significantly superior to any other crop residues incorporation (Table 5). The available phosphorus content did not show any significant variation with different crop residues incorporation treatments, eventhough it was highest with incorporation of field been crop residues, while the lowest post-harvest organic carbon, available N and potassium content of soil was associated with the incorporation of greengram crop residues. The highest post harvest organic carbon content of soil was recorded with the supply of 100% N through FYM to preceding rice, which was however, comparable with the supply of 50% N each through fertilizer and FYM but significantly superior to supply of 100% N through fertilizer and non-supply of N to preceding rice, which were comparable with each other (Table 5). Post-harvest soil available N and potassium were the highest with supply of 100% N through FYM to preceding rice, which were followed by supply of 50% N each through fertilizer and FYM, 100% N through fertilizer and no N application, with significant disparity with each other. The available phosphorus did not show any significant variation with different N management practices, even through it was highest with supply of 100% N through FYM, while the lowest was recorded with supply of 100% N through fertilizer. Slow decomposition and mineralisation of crop residues and farmyard manure added in large quantities to preceding rice crop would have enriched the organic carbon, available N, phosphorus and potassium status of soil after the harvest of groundnut. These results are in agreement with those of Buresh and De Datta (1991).

Table 2 Biomass, crop residues, greengram seed equivalent yield and economics of preceding crops to rice (mean of 2 years data)

Preceding crops to rice	*Total biomass production* (kg/ha)*	*Crop residues** (kg/ha)*	*Absolute economic yield*** (kg/ha)*	Greengram seed equivalent yield (kg/ha)	Gross returns**** (₹/ha)	Net returns**** (₹/ha)
C_1 – Greengram@	2528	7100	1031	1031	16496	12292
C_2 – Clusterbean#	4406	13460	13687	3169	34217	27128
C_3 – Field bean#	6461	17050	862	1354	5172	2008
C_4 – Cowpea#	5392	15320	1388	1551	8328	5039
SEm ±	225.7	486.5	---	58.6	494.2	394.1
CD (P=0.05)	720	1552	---	187	1576	1257

* On dry weight basis; ** Incorporated on fresh weight basis in to the field immediately after picking the economic yield; #Green pods for vegetables; *** Data were not statistically analysed due to difference in nature of economic yield @ seed; **** Based on the monetary value of only economic yield of crops.

Table 3 Residual effect of crop residue incorporation and nitrogen management practices on grain yield of rice and soil fertility status after rice harvest (mean of 2 years data)

Treatments	Drymatter production (kg/ha)	Grain yield (kg/ha)	Available nutrient status in soil (kg/ha) after rice harvest			
			Organic carbon (%)	Nitrogen	Phosphorus	Potassium
Incorporation of crop residues						
C_1: Greengram	9134	3755	0.31	173	29.1	209
C_2: Clusterbean	9827	4249	0.33	182	31.6	217
C_3: Fieldbean	11237	5334	0.38	199	33.9	233
C_4: Cowpea	10528	4859	0.36	191	33.0	225
SEm ±	221	127	0.005	2.7	0.02	2.84
CD (P=0.05)	541	284	0.01	7.2	NS	6.2
Nitrogen management practices						
N_1: No N	8373	3292	0.29	155	28.7	193
N_2:100% recommended N through fertilizer	11483	5351	0.29	182	30.1	204
N_3: 50% recommended N through fertilizer + 50% recommended N through FYM	10782	4971	0.38	199	34.0	234
N_4: 100% recommended N through FYM	10088	4581	0.40	209	34.8	252
SEm ±	294	142	0.001	4.1	0.02	3.26
CD (P=0.05)	588	309	0.02	9.1	NS	8.4

Table 4 Growth of groundnut as influenced by cumulative residual effect of crop residue incorporation and nitrogen management practices to preceding rice (mean of 2 years data)

Treatments	LAI	DMP (kg/ha)	No. of pods/ plant	100 pod weight (g)	100 kernel weight (g)	Pod yield (kg/ha)	Haulm yield (kg/ha)	Shelling %	Harvest index*	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit-cost ratio
Incorporation of crop residues												
C_1	2.30	5134	9.5	73.5	29.5	1820	3499	73.0	34.0	24019	13369	2.25
C_2	2.56	5554	10.3	76.1	31.3	2000	3859	73.1	33.9	26396	15746	2.48
C_3	3.04	6370	11.8	81.0	34.1	2360	4638	73.5	33.6	31154	20505	2.92
C_4	2.80	5998	11.0	78.7	34.1	2180	4286	73.3	33.5	28778	18128	2.70
SEm ±	0.07	156	0.23	0.64	0.52	81.1	127	0.71	--	912	736	0.07
CD (P=0.05)	0.21	327	0.4	1.5	1.4	192	272	NS	--	2194	1781	0.21
Nitrogen management practices												
N_1	2.23	5111	9.3	73.4	29.0	1664	3645	72.4	31.3	22009	11359	2.07
N_2	2.48	5464	9.7	75.1	30.2	1854	3821	72.8	38.8	24497	13847	2.30
N_3	2.91	6069	11.6	79.6	34.2	2311	4285	73.5	35.1	30478	19828	2.86
N_4	3.07	6415	12.1	81.3	35.6	2531	4530	74.3	35.8	33362	22712	3.13
SEm ±	0.09	127	0.31	1.14	0.61	76.3	134	0.67	--	1174	1529	0.14
CD (P=0.05)	0.23	284	0.5	2.1	1.6	184	241	NS	--	2482	2712	0.22

C_1: Greengram; C_2: Clusterbean; C_3: Fieldbean; C_4: Cowpea; N_1: No N; N_2:100% recommended N through fertilizer; N_3: 50% recommended N through fertilizer + 50% recommended N through FYM; N_4: 100% recommended N through FYM

Table 5 Nutrient uptake of groundnut and soil fertility after groundnut harvest as influenced by cumulative residual effect of crop residue incorporation and N management practices preceding rice *(mean of 2 years data)*

Treatments	Nitrogen uptake (kg/ha)				Phosphorus uptake (kg/ha)				Potassium uptake (kg/ha)				Soil fertility status after groundnut harvest (kg/ha)			
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest	Organic carbon (%)	*Available* nitrogen	*Available* phosphorus	Available potassium
Incorporation of crop residues																
C_1	24.3	65.8	72.1	80.1	2.1	6.1	7.7	10.6	13.9	37.0	62.0	70.6	0.33	183	24.4	218
C_2	26.4	69.7	79.2	87.1	6.5	6.5	7.9	11.0	15.7	41.9	65.8	74.5	0.35	191	26.8	226
C_3	29.7	77.1	91.0	98.9	7.4	7.4	8.5	11.9	19.3	48.8	73.5	82.2	0.40	209	28.7	241
C_4	28.1	73.5	84.6	92.7	6.9	1.9	8.2	11.5	17.5	45.3	69.8	78.5	0.38	201	28.3	234
SEm ±	0.72	1.47	1.41	1.52	0.04	0.08	0.24	0.06	0.66	1.47	1.71	1.57	0.04	3.5	0.02	2.64
CD (P=0.05)	1.2	2.1	3.4	3.1	0.2	0.2	0.4	0.2	1.4	3.1	5.9	3.4	0.01	8.2	NS	5.7
Nitrogen management practices																
N_1	22.4	61.4	72.3	79.1	6.3	6.3	6.3	10.8	12.5	36.8	59.5	68.2	0.30	166	25.4	208
N_2	23.4	65.3	75.6	82.1	6.5	6.5	6.5	11.0	14.4	39.7	63.7	72.4	0.32	191	26.4	219
N_3	27.3	73.4	85.4	93.4	7.0	7.0	7.0	11.4	18.9	47.7	72.4	81.0	0.40	208	26.2	237
N_4	29.7	76.7	87.8	96.7	7.2	7.2	7.2	11.7	20.7	50.5	75.5	84.2	0.41	219	27.4	254
SEm ±	0.72	1.47	1.47	1.51	0.22	0.07	0.07	0.21	0.78	1.31	2.07	1.87	0.06	4.2	0.01	4.1
CD (P=0.05)	1.4	2.9	3.1	2.8	0.4	0.3	0.3	0.3	1.5	3.4	3.7	3.8	002	8.9	NS	8.4

DAS = Days after sowing; C_1: Greengram; C_2: Clusterbean; C_3: Fieldbean; C_4: Cowpea; N_1: No N; N_2:100% recommended N through fertilizer; N_3: 50% recommended N through fertilizer + 50% recommended N through FYM; N_4: 100% recommended N through FYM

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Effect of rate and frequency of zinc application on hybrid rice (*Oryza sativa*)-soybean (*Glycine max*) cropping system in Andhra Pradesh

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ABSTRACT

Field experiment was carried out for two consecutive years (2004-2006) in student's farm, ANGRAU, Hyderabad on a zinc (Zn) deficient Alfisol to evaluate the efficacy of different rates and frequency of Zn application on yield and depletion of available Zn by the crops involved in hybrid rice (*Oryza sativa* L.)-soybean (*Glycine max* L.) system. Zinc application (as Zinc sulphte) up to 50 kg/ha had significantly increased the yield of direct crop of hybrid rice and first residual crop i.e., soybean in the system. Application of Zn at highest dose i.e., 100 kg / ha resulted in the residual effects up to fourth crop of soybean. If an additional dose of 25 kg is applied to the third crop of hybrid rice to the initially applied 50 kg/ha to hybrid rice, significant response in fourth crop (soybean) was observed. There was a built up in the available Zn status up to 20.5 % at 0-15 cm depth. Application of Zn significantly increased the available Zn in soil. Available Zn was reduced in the control plots to an extent of 12.1 and 22.4% after direct and fourth crops in the system.

Key words: Alfisol, Available zinc, Direct and residual effects, Hybrid rice-soybean system

Zinc (Zn) is one of the most essential plant micronutrient and its importance for crop productivity is similar to that of major nutrients. Intensive agriculture coupled with the continuous application of straight fertilizers has led to the changes in the micronutrient availability in soil, especially Zn. If a crop falls short of micronutrients, higher yields cannot be expected with out supply of these. Ample reduction in crop growth and yield can be seen due to Zn deficiency sometimes even with out any occurrence of visual symptoms. Crops utilize only a small portion of applied Zn leaving the residual amount for further utilization by the subsequent crops (Yadav *et al.*, 1998). Hybrid rice (*Oryza sativa* L.) is highly responsive to fertilizers compared to conventional varieties because of it's higher yields. Hybrid rice-soybean (*Glycine max* L.) system is practiced in some parts of Andhra Pradesh and is grown on Alfisols, which are shallow in depth, poor in nutrient status, water holding capacity and organic matter content. Hence, the present study was planned for evaluating the efficacy of different rates and frequency of Zn application on hybrid rice-soybean system grown on Alfisols of southern Telangana zone of Andhra Pradesh.

MATERIALS AND METHODS

Field experiment was carried out for two consecutive years (2004-06) in student's farm, Rajendranagar, Hyderabad on a Zn deficient (0.58 mg/kg) sandy loam soil with an alkaline pH (8.23), low in soluble salt content (0.21 dS/m), organic carbon content (0.45%). The treatments adopted during first year were control (No $ZnSO_4$), 25 , 50, 75 and 100 kg $ZnSO_4$/ha. Hybrid rice cv. APHR-2 was planted during rainy season of first year of experimentation for knowing the direct effect of applied Zn. After the harvest of the rainy season hybrid rice, Soybean cv. GLS-11 was sown during winter season in the same plot to know the residual effects of Zn. After the harvest of soybean crop, the experimental plots were divided in to two. One plot was kept as it is for knowing the residual effect and in the other plot an additional application of 25 kg $ZnSO_4$/ha was applied uniformly to know the cumulative effects of added Zn. Hybrid rice was transplanted in these plots during rainy season of second year of experimentation for knowing the 2nd residual (which was applied during 1st season of first year) and cumulative effect of Zn (applied during 3rd season) on the hybrid rice. Fourth crop of soybean was sown after the harvest of rainy season rice to know the 4th residual and cumulative residual effects of applied Zn.

Index leaf samples were collected at 35th day of the crop for all the four crops. Yields were recorded at harvest of each crop. Plant samples (above ground parts) and post harvest soil samples were collected at harvest of each crop. The soil and plant samples collected were analysed for Zn content by following the standard procedures.

RESULTS AND DISCUSSION

Direct effect of applied Zn on hybrid rice

Application of Zn increased grain and straw yields of rice significantly at all the levels over control. Significant effect of applied Zn was noticed only up to Zn_{50} level on the direct crop of hybrid rice. However, the yields obtained at higher level of Zn (Zn_{75} and Zn_{100}) were on par with the yield obtained at Zn_{50} level. Grain and straw yields of rice increased significantly from 59.1 to 70.7 and 85.4 to 104.8 q/ha with a response range of 10 to 26 and 11.0 to 22.6 due to increased doses of $ZnSO_4$ application.

Bhupal Raj *et al.* (2001) reported that response of rice hybrids to zinc application was up to 24% compared to conventional varieties 18% when grown on '*chalka*' soils of Andhra Pradesh. Datta and Dhiman (2001) also confirmed these results.

Residual effect of applied Zn

The maximum seed and stalk yield of 23.2 and 25.7 q/ha was recorded in soybean in the Zn_{100} plots which was on par with Zn_{75} (22.9 and 25.5 q/ha) and Zn_{50} (21.8 and 25.2 q/ha) level, though it was significantly more than the seed yield obtained with the other treatments *viz*., Zn_{25} and Zn_0. Sakal (1985) reported that residual effects of zinc lasted only for two crops in rice-wheat rotation.

Maximum grain and straw yield of hybrid rice (2nd residual crop) was recorded in plots fertilized with Zn_{100} level, which was significantly higher than control, Zn_{25} and Zn_{50} level. No significant difference was observed between 75 and 100 kg $ZnSO_4$/ha levels (Table 1 and 2). The mean reduction in grain and straw yields were 0.4 and 3.3 q/ha, respectively when compared to the direct crop of hybrid rice. The stalk and seed yields of soybean increased significantly up to Zn_{100} level showing the residual effect of applied zinc on the fourth crop of soybean. The seed and stalk yields decreased from 21.2 to 18.8 and 23.6 to 21.1 q/ha in the 3rd residual crop of soybean. Patnaik and Bhupal Raj (2001) noticed the significant effect of zinc on grain and straw yields of rice even up to 3rd and 4th crops in Alfisols of Andhra Pradesh.

Cumulative and cumulative residual effect

The grain and straw yields of hybrid rice increased due to the cumulative effect of additional application of 25 kg $ZnSO_4$/ha up to 50 $ZnSO_4$/ha level. Further increase up to 100 kg $ZnSO_4$/ha showed that the yields were on par with Zn_{50} level. The grain and straw yields of hybrid rice showed variation from 61.3 to 69.4 and 87.8 to 98.5 q/ha, respectively with the increase in levels of applied Zn. The grain and straw yields increased by 8.2 and 3.4 q/ha, respectively over the 2nd residual crop of hybrid rice.

Seed and stalk yield of soybean was significantly influenced by the Zn levels. Seed and stalk yields were increased by 3.9 and 3.3q/ha, respectively at Zn_{125} over Zn_{25} level. Cumulative effect of added Zn on the stalk and seed yield of soybean was significantly increased up to Zn_{100+25} levels (23.3 and 24.5q/ha) and the mean increase was up to 16.2 and 11.4 %, respectively over the residual plots.

Zinc content and uptake

Zinc content showed an increase both in the grain and straw with increasing levels of applied Zn. The increase was found significant among different levels of Zn. The Zn concentration in grain and straw of direct crop of hybrid rice increased from 14.1 to 25.1 mg/kg and 22.0 to 35.6 mg/kg, respectively. The mean Zn concentration recorded in seed and stalks of first residual crop of soybean are 30.5 and 24.5 mg/kg, respectively. There was a significant effect of residual Zn on concentration in the second residual crop of hybrid rice. Grain Zn concentration ranged from 13.7 to 23.3 mg/kg while the Zn concentration in straw varied form 15.3 to 27.3 mg/kg. Concentration of Zn in the third residual crop of soybean seed varied from 22.4 to 30.6 mg/kg with a mean of 26.5 mg/kg while the concentration in stalk ranged from 15.9 to 23.5 mg/kg with a mean of 20.4 mg/kg (Table 3 and 4). Thus, a reduction in the Zn concentration was observed at harvest in the 3rd residual crop of this sequence. Zinc concentration increased both in the cumulative and cumulative residual crops compared to the corresponding second and third residual crops.

Different levels of applied Zn also significantly influenced the Zn uptake. The mean Zn uptake values observed in grain and straw of direct crop of hybrid rice were 137.3 and 295.0 g/ha at maturity; the total removal being 432.3 g/ha. The shoots removed on an average 58.5 g/ha of Zn, while the seed removed 65.3 g/ha of Zn due to different treatments in the first residual crop of soybean. The uptake of Zn by grain and straw of 2nd residual crop of hybrid rice increased significantly with increasing residual Zn levels. There was a reduction in the uptake by the rice crop at maturity to the extent of 18.7% in grain and 29.2% in straw in the 2nd residual crop compared to direct crop of hybrid rice. Uptake of 49.7 and 43.5 g/ha was observed in seed and stalk, respectively with a reduction in total removal by 30.6 g/ha in the 3rd residual compared to 1st residual (Table 3 and 4). Singh *et al.* (1998) also reported similar findings in rice- wheat sequence where significant influence of Zn was seen on Zn uptake even up to 4th crop. The Zn removal by the cumulative Zn applied hybrid rice showed an increase by 37.4 g/ha in grain and 38.2 g/ha by the straw over the hybrid rice grown on residual Zn only. The results are in conformity with the earlier findings of Patnaik and Bhupal Raj (2001) in rice- rice system both for yield and uptake.

Available Zn status

There was a significant build up in the available Zn level in the surface (0-15 cm) and subsurface (15-30 cm) soils due to the application of Zn at different levels. The built up of available Zn status was up to 20.5% at surface and 16.2 % at sub surface soil wherein rice was grown as direct crop. However, due to cumulative application of Zn, the built up was to an extent of 10.4 and 18.1%, respectively at both the depths.

The results presented in table 5 showed that available Zn content decreased with the number of crops grown and it is clearly seen as the content decreased from 0.51 to 0.45 mg/kg in the control plots and 0.69 to 0.51 mg/kg in the maximum Zn applied plots. The mean available Zn content decreased from 0.61 in the direct crop of hybrid rice to 0.53 mg/kg after the harvest of 3rd residual crop. Available Zn content in the soil increased significantly by the Zn application. The available Zn status increased from 0.51 to 0.69 mg/kg in the direct sown rice, and the residual effect of Zn was seen in the 3rd residual crop also i.e., 0.45 to 0.51 mg/kg. In the subsoil also, increased levels of Zn increased the available Zn status from 0.47 to 0.65 mg/kg in the direct crop of hybrid rice and from 0.41 to 0.55 mg/kg in the 3rd residual crop by the residual effect of Zn. (Table 5). Depletion of available Zn status with the crop growth was also reported by Reddy and Reddy (1998) for maize-soybean system, Patnaik and Bhupal Raj (2001) for rice-rice system and Poonam *et al.* (2008) for hybrid rice-wheat system.

Table 1 Effect of Zn on grain and seed yields (q/ha) of hybrid rice and soybean in hybrid rice-soybean cropping system

Treatments ZnSO$_4$ (kg/ha)	Direct crop Hybrid rice	Residual crops Soybean (1st)	Hybrid rice (2nd)	Soybean (3rd)	Cumulative Hybrid rice	Cumulative residual Soybean
0	59.1^{a}	17.8^{a}	51.7^{a}	16.1^{a}	61.3^{a}	19.6^{a}
25	65.1^{b}	20.3^{b}	55.8^{b}	17.6^{b}	63.7^{b}	20.8^{b}
50	69.4^{c}	21.8^{c}	58.8^{c}	18.8^{c}	68.4^{c}	22.2^{c}
75	69. 9^{c}	22.9^{c}	61.6^{d}	19.9^{d}	68.9^{c}	23.3^{d}
100	70.7^{c}	23.2^{c}	62.9^{d}	21.8^{e}	69.4^{c}	23.5^{d}
Mean	66.8	21.2	58.2	18.8	66.4	21.9

Figures with the same letter are not significantly different at 5 % level by DMRT.

Table 2 Effect of Zn on straw and stalk yields (q/ha) of hybrid rice and soybean in hybrid rice-soybean cropping system

Treatments Zn SO$_4$ (kg/ha)	Direct crop Hybrid rice	Residual crops Soybean (1st)	Hybrid rice (2nd)	Soybean (3rd)	Cumulative Hybrid rice	Cumulative residual Soybean
0	85.4^{a}	19.6^{a}	80.2^{a}	17.5^{a}	87.8^{a}	21.7^{a}
25	94.9^{b}	22.6^{b}	86.4^{b}	19.9^{b}	92.3^{b}	22.7^{b}
50	102.5^{c}	25.2^{c}	91.7^{c}	21.6^{c}	97.8^{c}	23.6^{c}
75	103.8^{c}	25.5^{c}	98.9^{d}	22.8^{d}	98.3^{c}	24.5^{d}
100	104.8^{c}	25.7^{c}	100.4^{d}	23.6^{e}	98.5^{c}	25.0^{d}
Mean	98.3	23.6	91.5	21.1	94.9	23.5

Figures with the same letter are not significantly different at 5 % level by DMRT.

Table 3 Effect of Zn on Zn uptake (g/ha) and Zn concentration (mg/kg) by grain and seed of hybrid rice and soybean in hybrid rice-soybean cropping system

Treatments ZnSO$_4$ (kg/ha)	Direct crop Hybrid rice	Soybean (1st)	Residual crops Hybrid rice (2nd)	Soybean (3rd)	Cumulative Hybrid rice	Cumulative residual Soybean
0	83.6^{a} (14.1^{a})	45.0^{a} (25.2^{a})	70.7^{a} (13.7^{a})	35.9^{a} (22.4^{a})	110.6^{a} (18.1^{a})	55.5^{a} (28.4^{a})
25	117.4^{b} (18.1^{b})	59.8^{b} (29.4^{b})	95.8^{b} (17.2^{b})	42.3^{b} (24.1^{b})	129.6^{b} (20.3^{b})	61.9^{b} (29.9^{b})
50	145.5^{c} (21.0^{c})	69.4^{c} (31.7^{c})	112.3^{c} (19.1^{c})	49.9^{c} (26.6^{c})	155.8^{c} (22.8^{c})	68.6^{c} (30.9^{c})
75	162.1^{d} (23.2)	75.0^{d} (32.8^{d})	132.8^{d} (21.6^{d})	56.8^{d} (28.6^{d})	167.5^{d} (24.3^{d})	76.9^{d} (33.1^{d})
100	177.7^{e} (25.1^{e})	77.2^{e} (33.5^{e})	146.3^{e} (23.3^{e})	63.5^{e} (30.6^{e})	181.2^{e} (26.1^{e})	81.3^{e} (34.6^{e})
Mean	137.3 (20.3)	65.3 (30.5)	111.6 (19.0)	49.7 (26.5)	148.9 (22.3)	68.8 (31.4)

Figures with the same letter are not significantly different at 5 % level by DMRT. Figures in the parenthesis are Zn concentration in mg/kg

Table 4 Effect of Zn on Zn uptake (g/ha) and Zn concentration (mg/kg) in straw and stalk by hybrid rice and soybean in hybrid rice-soybean cropping system

Treatments $ZnSO_4$ (kg/ ha)	Direct crop		Residual crops		Cumulative	Cumulative residual
	Hybrid rice	Soybean (1st)	Hybrid rice (2nd)	Soybean (3rd)	Hybrid rice	Soybean
0	187.5 a	37.4 a	122.9 a	27.7a	179.6a	47.2 a
	(22.0 a)	(19.1 a)	(15.3 a)	(15.9 a)	(20.5 a)	(21.8 a)
25	256.1 b	50.5 b	190.9 b	36.4 b	215.0 b	54.8b
	(27.0 b)	(22.6 b)	(21.8 b)	(18.5 b)	(23.3 b)	(24.2 b)
50	314.8 c	63.2 c	221.1 c	45.7 c	256.6 c	60.7 c
	(30.8c)	(25.2 c)	(24.1 c)	(21.2 c)	(26.2 c)	(25.7 c)
75	344.0 d	67.7 d	225.6 d	51.9 d	280.7 d	66.0 d
	(33.2d)	(26.9 d)	(25.8 d)	(22.8 d)	(28.6 d)	(26.9 d)
100	372.7 e	73.9 e	284.3 e	55.5 e	303.8 e	67.6 e
	(35.6e)	(28.7 e)	(27.3 e)	(23.5 e)	(30.9 e)	(27.1 e)
Mean	295.0	58.5	208.9	43.5	247.2	59.2
	(29.7)	(24.5)	(22.9)	(20.4)	(25.9)	(25.1)

Figures with the same letter are not significantly different at 5 % level by DMRT; Figures in the parenthesis are Zn concentration in mg/kg

Table 5 Direct and residual effects of applied Zn on available Zn status in soil under rice-soybean cropping system

Treatments $ZnSO_4$ (kg/ha)	Direct	Residual			Direct	Residual		
	rice	Soybean	Rice	Soybean	rice	Soybean	Rice	Soybean
	Surface (0-15 cm) soil				Sub-surface (15-30 cm) soil			
0	0.51	0.50	0.47	0.45	0.47	0.45	0.43	0.41
25	0.55	0.53	0.50	0.49	0.50	0.48	0.45	0.42
50	0.61	0.60	0.56	0.54	0.55	0.52	0.49	0.45
75	0.68	0.64	0.60	0.58	0.63	0.59	0.55	0.51
100	0.69	0.65	0.62	0.51	0.65	0.62	0.59	0.55
Mean	0.61	0.58	0.55	0.53	0.56	0.53	0.50	0.47
CD (P=0.05)	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02

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Effect of multi-micronutrients mixture on yield and uptake of micronutrients by mustard (*Brassica juncea*) in sandy loam soils of north Gujarat

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ABSTRACT

Field experiments were conducted on sandy loam soils at Sardarkrushinagar of north Gujarat to study the efficacy of multi-micronutrients mixture in improving the yield of mustard (*Brassica juncea* L.) (cv. Gujarat mustard-2). The significantly higher mustard seed yield as well as *yield attributes and uptake of micronutrients viz.*, iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) were recorded with the soil application of 15 kg $FeSO_4$ + 8 kg $ZnSO_4$/ha as per the soil test value (STV). The soil application of micronutrients mixture having content of Fe-2.0%, Mn-0.5%, Zn-5.0%, Cu-0.2% and B-0.5% grade V (General) also proved equally efficient with STV treatment. The yield increase due to soil application treatments were by 16.2 and 11.3% over control, respectively.

Key words: Multi-micronutrients mixture, Mustard and Yield

Mustard (Brassica juncea L.) is an important oilseed crop in north Gujarat region. Continuous use of high analysis fertilizers under intensive cropping and inadequate application of organic manures causes deficiencies of micronutrients. Widespread deficiencies of iron (Fe) and zinc *(Zn) in light textured soils (Singh, 2006)* of north Gujarat have been reported (Patel *et al.*, 1998). The prevalent Zn and Fe deficiency warrants the need for research on Zn and Fe especially on their usage individually and in combinations as foliar/soil application. Hence, the present field experiments were undertaken to study the effect of different multi-micronutrients mixture on yield and uptake of micronutrients by mustard.

MATERIALS AND METHODS

Field experiments were conducted at main castor-mustard research station, SDAU, Sardarkrushinagar, Gujarat during 2001-04 to study the efficacy of multi-micronutrient mixtures in improving the yield of mustard (*Brassica juncea* L.) (cv. Gujarat mustard-2). The treatments comprised of multi-micronutrient mixtures *viz.*, T_1-Control (water spray); Foliar spray treatments: T_2-Local formulation (LF) mixture grade-I (general); T_3-LF mixture grade-II (for Zn deficiency); T_4-LF mixture grade-III (for Fe deficiency); T_5-LF mixture grade-IV (for Zn and Fe deficiency). Soil application treatment: T_6-LF mixture grade-V (general); T_7-Soil application of micronutrients as per soil test value (STV) and T_8-Absolute control. The multi-micronutrients mixture grades having composition shown as under were prepared for supplementation of the micronutrients on the basis of average removal by crops (grades I and V) on the basis of wide occurrence of Zn or Fe or both Zn and Fe deficiencies in soils of Gujarat (grade II, III and IV). The rate of application of T_2, T_3, T_4 *and* T_5 *as foliar spray was kept @ 1%* and soil application T_6-@ 20 kg/ha and T_7(STV)-$ZnSO_4$ @ 8 kg/*ha*+$FeSO_4$ *@ 15 kg/ha. Foliar application was made at 30,* 40 and 50 days after sowing (DAS).

Multimicronutrients mixture grades	Content (%)				
	Fe	Mn	Zn	Cu	B
For foliar spray					
Grade I (general) : LF-I	2.0	0.5	4.0	0.3	0.5
Grade II (for Zn deficiency): LF-II	2.0	0.5	8.0	0.5	0.5
Grade III (for Fe deficiency): LF-III	6.0	1.0	4.0	0.3	0.5
Grade IV (for Zn and Fe deficiency) : LF-IV	4.0	1.0	6.0	0.5	0.5
For Soil application					
Grade V (Soil application) : LF-V	2.0	0.5	5.0	0.2	0.5

The treatments were replicated four times in randomized block design. The soil of the experimental field was sandy loam in texture and had pH-7.80, EC 2.5-0.16 dS/m, organic carbon-2.3 g/kg, available N-190 kg/ha, available P_2O_5-41.2 kg/ha, available K_2O-308 kg/ha, Fe-4.32 mg/kg, Mn-13.7 mg/kg, Zn-0.37 mg/kg and Cu-0.68 mg/kg. The plant samples were *collected for determination of total contents of* micronutrients. The oven dried plant samples were finely ground and *were digested with di-acid mixture of* HNO_3 : $HClO_4$ (4:1) (Jackson, 1973). Soil samples drawn from the experimental field after harvest were analyzed for available micronutrients by extracting with 0.005 M DTPA (Lindsay and Norvell, 1978) and the contents were determined with atomic absorption spectrometer.

RESULTS AND DISCUSSION

Yield attributing characters

The yield attributing characters like plant height, number of silique/plant, number of seeds/silique and 1000 seed weight were recorded and presented in table 2. The results indicated that soil application of $FeSO_4$+$ZnSO_4$ as per STV (T_7) significantly increased the number of silique/plant and oil content over control. Among the foliar treatments, application of grade-IV (T_5) significantly improved the number of silique/plant which was one of the reasons for increasing the mustard yield.

Mustard yield

The data presented in table 1 indicated that seed yield of mustard significantly increased due to soil application of 15 kg $FeSO_4$/ha and 8 kg $ZnSO_4$/ha as per STV over control. The different treatments of foliar application of multi-micronutrients mixtures also improved mustard yield in all the years and in pooled.

During the year 2001, soil application of deficient micronutrients i.e., Fe and Zn through 15 kg $FeSO_4$ and 8 kg $ZnSO_4$/ha, respectively as per STV recorded maximum mustard seed yield (2757 kg/ha) followed by foliar spray of 1% mixture grade - III for Fe deficiency (2634 kg/ha). These treatments were at par and found significantly superior over rest of the treatments. During the year 2001-02 among the different treatments, the soil application of micronutrients as per STV (T_7) also increased significantly higher yield (1868 kg/ha) over rest of the treatments, and it remained at par with foliar treatments *viz*., mixture grade-IV (T_4), mixture grade-III (T_3) and soil application of mixture grade-V (T_6).

During 2002-03 and 2003-04 treatment of micronutrient application as per soil test value (T_7) gave significantly higher seed yield (1647 kg/ha) and remained at par with T_6 (soil application of mixture grade-V @ 20 kg micronutrients mixture) in general. The pooled data given in table 1 also revealed that mustard seed yield due to soil application of micronutrients as per STV gave significantly higher yiel (1982 kg/ha) than other treatments and remained at par wi soil application treatment of mixture grade-V (T_6). The yiel increase due to treatments T_7 and T_6 were by 16.2 an 11.3%, respectively over control. The supplementation c micronutrients help in providing balanced nutrition whic increases crop growth and thereby yield. The benefici effect of micronutrients have also been reported in differe crops (Kotur, 1998; Nazim *et al.*, 2005).

Micronutrients uptake

The data presented in table 3 revealed that the uptake micronutrients *viz*., Fe and Mn by mustard seed improve over control due to different treatments. Among th treatments, the application of micronutrients as per STV (T increased Fe uptake significantly by mustard seed over re of the treatments in all the years as well as in pooled basi The data on Mn uptake by mustard seed showed that th treatment T_7 significantly increased uptake of Mn over oth treatment being at par with T_5 in 2000-01 and 2002-03, an T_4 and T_5 in 2001-02 and 2003-04. In general, the treatme T_7 showed its superiority over other treatments. The lowe uptake of Mn by seed was noted in control treatment (T_8).

In case of Zn uptake by mustard seed, the application c micronutrients as per STV (T_7) significantly increased Z uptake by seed over other treatments during all the years a well as in pooled (Table 3). However, treatment T_7 wa found at par with T_6 during 2002-03 and 2003-04. Th significantly lowest Zn uptake by seed was noted in contr treatment (T_8). The uptake of Cu by seed was significantl influenced due to application of micronutrients mixture. Th foliar application of grade-IV (T_5) having 0.5% Cu registere significantly maximum Cu uptake by seed being at par wit T_7. In general, the maximum uptake of differe micronutrients by mustard seed was observed due to Fe an Zn application as per STV followed by foliar application c multi-micronutrients mixture grade-IV (T_5).

Table 1 Effect of multi-micronutrients mixture on yield attributes of mustard (pooled mean of 2000-2004)

Treatment	Yield attributes				Oil conte
	Plant height (cm)	No. of silique/plant	No. of seeds/silique	Wt. of 1000 seeds	(%)
T_1 - Control (water spray)	159	290	12.4	6.01	38.3
T_2 - LF Grade-I (foliar)	160	311	13.0	5.94	38.3
T_3 - LF Grade-II (foliar)	157	305	12.4	5.82	38.3
T_4 - LF Grade-III (foliar)	159	311	12.6	5.97	38.4
T_5 - LF Grade-IV (foliar)	158	324	12.5	5.86	38.3
T_6 - LF Grade-V (soil)	160	316	13.1	5.95	38.4
T_7 - STV (soil)	159	336	12.8	6.05	38.7
T_8 - Absolute control	166	302	12.1	5.88	38.6
SEm±	4.1	10.3	0.3	0.07	0.12
CD (P=0.05)	NS	29	NS	NS	0.3
CV (%)	11.0	12.5	5.7	5.0	1.3

Table 2 Effect of multi-micronutrients mixture on the seed yield of mustard

Treatments	Mustard seed yield (kg/ha)					% Response over control
	2000-01	2001-02	2002-03	2003-04	Pooled	
T_1 - Control (water spray)	2467	1803	1592	1380	1811	--
T_2 - LF Mixture grade-I (general)	2492	1759	1532	1505	1822	6.8
T_3 - LF Mixture grade-II (for Zn deficiency)	2470	1836	1480	1480	1816	6.4
T_4 - LF Mixture grade-III (for Fe deficiency)	2634	1846	1640	1460	1895	10.3
T_5 - LF Mixture grade-IV (for Zn and Fe deficiency)	2512	1599	1522	1473	1777	4.2
T_6 - LF Mixture grade-V (general)	2533	1825	1631	1605	1898	11.2
T_7 - Micronutrient application as per STV	2757	1868	1647	1657	1982	16.2
T_8 - Absolute control	2505	1501	1425	1395	1706	--
CD (P=0.05)	124	231	139	153	92	--
CV (%)	5.3	8.9	6.1	7.0	7.2	--

Table 3 Effect of multi-micronutrients mixture on Fe and Mn uptake by mustard seed

Treatment	Fe uptake (g/ha)					Mn uptake (g/ha)				
	2000-01	2001-02	2002-03	2003-04	Pooled	2000-01	2001-02	2002-03	2003-04	Pooled
T_1- Control (water spray)	114	91	79	72	89.0	29.7	21.6	18.6	19.6	22.4
T_2 - LF Grade--I (foliar)	120	91	78	81	92.5	36.0	27.2	20.5	24.3	27.0
T_3- LF Grade-II (foliar)	124	100	79	84	96.7	38.5	28.7	20.3	24.4	28.0
T_4- LF Grade-III (foliar)	147	113	98	92	112.5	46.8	36.0	33.0	33.2	37.3
T_5- LF Grade-IV (foliar)	135	93	87	88	100.7	47.8	31.9	31.3	34.0	36.3
T_6 - LF Grade-V (soil)	139	108	95	98	110.0	35.1	29.0	22.5	26.2	28.2
T_7 - STV (soil)	157	127	108	113	126.2	52.1	38.4	32.8	37.3	40.2
T_8 - Absolute control	117	74	69	71	82.7	29.6	17.0	15.3	18.5	20.1
SEm±	3.0	5.0	3.0	3.0	2.0	1.6	1.5	1.0	1.4	0.8
CD (P=0.05)	8	15	8	9	5.0	4.8	4.6	3.3	4.2	2.3
CV (%)	4.0	10.0	6.0	7.0	8.2	8.3	10.5	8.5	10.6	9.5

Table 4 Effect of multi-micronutrients mixture on Zn and Cu uptake by mustard seed

Treatment	Zn uptake (g/ha)					Cu uptake (g/ha)				
	2000-01	2001-02	2002-03	2003-04	Pooled	2000-01	2001-02	2002-03	2003-04	Pooled
T_1- Control (water spray)	50.2	39.0	31.5	32.3	38.2	6.3	4.0	2.8	5.1	4.5
T_2 - LF Grade--I (foliar)	61.9	46.7	35.8	41.9	46.6	6.9	3.9	3.3	6.2	5.1
T_3 - LF Grade-II (foliar)	71.3	54.9	42.5	47.6	54.1	9.3	6.8	5.7	8.7	7.6
T_4 - LF Grade-III (foliar)	72.1	52.4	44.7	43.4	53.1	8.4	5.0	4.1	6.7	6.0
T_5 - LF Grade-IV (foliar)	68.3	47.2	42.6	44.2	50.5	10.5	6.4	6.9	9.6	8.3
T_6 - LF Grade-V (soil)	76.3	58.7	52.4	52.6	60.0	5.7	3.9	3.4	6.6	4.9
T_7 - STV (soil)	90.7	61.9	54.6	55.0	65.6	10.5	6.4	6.2	9.6	8.2
T_8 - Absolute control	49.1	30.3	27.4	30.4	34.3	5.7	2.8	2.9	5.7	4.3
SEm±	2.0	3.0	2.4	2.2	1.3	0.5	0.4	0.3	0.4	0.2
CD (P=0.05)	5.9	8.9	7.3	6.4	3.6	1.3	1.2	0.9	1.0	0.6
CV (%)	6.0	12.3	11.8	10.0	9.7	11.5	10.7	13.3	9.7	12.4

The results of the study indicated that use of the multi-micronutrients like Fe and Zn proved to be beneficial in improving mustard seed yield. However, other micronutrients need to be supplied in small quantities to provide balanced nutrition to the crop and prevent any kind of accumulation of the nutrients over years, so that soil quality is not adversely affected.

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Effect of spacing, drip irrigation and nitrogen levels on oil content, N content and uptake of late rainy season castor (*Ricinus communis*)

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ABSTRACT

A field experiment was conducted during the late rainy season of 2006-07 and 2007-08 at Anand Agricultural University, Thasra, Gujarat with two spacings (Pair row planting (180-60-180 cm) × 60 cm and 120 × 60 cm), three levels of drip irrigation (0.4, 0.6 and 0.8 ADFPE (Alternate day fraction pan evaporation)) and three levels of nitrogen [100% recommended dose of nitrogen (RDN)] through spot application, 50% and 100% RDN through fertigation). The results revealed that the spacing failed to exert any significant influence on oil content and N uptake in seed and stalk, whereas, spacing treatment 120 cm × 60 cm registered higher N content in seed. While, oil content in castor (*Ricinus communis* L.) seed was registered higher under drip irrigation treatment of 0.8 ADFPE, likewise N uptake in seed and stalk was also higher under drip irrigation treatment of 0.8 ADFPE. On contrary, N content was higher under drip irrigation treatment 0.4 ADFPE. Application of 100% RDN through spot application recorded significantly higher N content and oil content in seed, whereas, N-uptake in seed and stalk was recorded higher in 100% RDN through fertigation.

Key words: Castor, Drip irrigation, Nitrogen and Spacing

Castor (*Ricinus communis* L.) is an important non-edible and industrial oilseed crop grown in India. Research work on relative performance of castor crop under varying levels of spacing, drip irrigation and nitrogen has been rather limited. Hence, a field experiment has conducted to study the effect of spacing, drip irrigation and nitrogen levels on N content, N uptake and oil content of late rainy season castor.

MATERIALS AND METHODS

A field experiment was conducted at the Agricultural Research Station for Irrigated Crops, Anand Agricultural University, Thasra, Dist. Kheda (Gujarat) during two consecutive late rainy seasons of 2006-07 and 2007-08. The experimental soil was sandy clayloam in texture, having good drainage capacity. It was low in organic carbon (0.38%) and nitrogen (0.032%), medium in available phosphorus (33 kg/ha) and high in available potash (267 kg/ha). The soil had 65.0% sand, 10.2% silt and 24.1% clay with 21% F.C. and 6.5% PWP. The treatment comprised of two spacings [Pair row planting (180-60-180 cm) × 60 cm (S_1) and 120 × 60 cm (S_2), three levels of irrigation (drip irrigation at 0.4 (I_1), 0.6 (I_2) and 0.8 (I_3) Alternate day fraction pan evaporation (ADFPE) and three levels of nitrogen [100% recommended dose of nitrogen (RDN)] through spot application (N_1), 50% (N_2) and 100% RDN through fertigation (N_3) was laid out in split plot design with four replications. Combination of spacings and irrigations were assigned to the main plots and levels of nitrogen were assigned to the sub plots.

Phosphorus @ 50 kg/ha was applied as basal dose to all the plots in the form of single super phosphate. In fertigation 30% nitrogen as a basal dose and remaining nitrogen was applied in a four equal splits, each at one month interval, while in spot application treatment 50% as a basal dose and remaining nitrogen in two split at two months interval. Recommended dose of fertilizer 75 kg N + 50 kg P_2O_5/ha were applied as per treatment.

Drip system was laid out in such a way that the main pipe was connected with head unit. The line was divided into three sub mains having separate controlling valves for I_1, I_2 and I_3 drip irrigation levels. Lateral lines connected with sub main were laid out at a distance of 120 cm in normal planting and 240 cm in pair row planting. The drippers were placed on lateral lines at a distance of 120 cm in normal planting and 60 cm in pair row planting. The crop was sown in second fort night of September in both the year. The drip irrigation schedule was started after one month of monsoon cessation. The drip irrigation treatments were given at an alternate days based on fraction of pan evaporation of two days. Daily pan evaporation measured with the help of USDA Class-A pan evaporimeter installed at station in meteorological observatory.

Oil content in the seed for each treatment was estimated by nuclear magnetic resonance analysis (Tiwari *et al.*, 1974). Nitrogen uptake by seed and stalk was also calculated.

RESULTS AND DISCUSSION

Effect of spacing

Seed yield was significantly affected due to levels of spacing. Pair row planting (S_1) registered significantly higher seed yield (2734 kg/ha) as compared to S_2 (2573 kg/ha). The per cent increase in seed yield under treatment S_1 was to the extent of 5.9. It might be due to optimum space available per plant, higher availability of nutrients, moisture, light, better growth and development of plant which has resulted in increased seed yield. These results are substantiated with those of Rana *et al.* (2006) and Porwal *et al.* (2006). Spacing treatment S_2 registered higher N content in seed during both the years. Spacing treatments failed to exert any significant influence on oil content and N uptake in seed and stalk (Table 1) indicating that the crop under different spacing has no influence on these parameters.

Effect of drip irrigation

Seed yield of castor progressively and significantly increased with increase in levels of drip irrigation from treatment I_1 to treatment I_3. Significantly the highest seed yield of castor (2841 kg/ha) was obtained with drip irrigation treatment I_3. The increase in seed yield might be due to the effect of timely and frequent irrigation under drip irrigation treatment I_3 provided constant wet root zone, increased the nutrients availability enhanced the growth, yield attributes and ultimately higher seed yield. These results are collaborated with that of Firake *et al.* (1998) and Reddy *et al.* (2006). The effect due to different irrigation treatments on N content in seed was found significant. Treatment I_1 recorded significantly the highest N content in seed (1.57%) as compared to treatment I_2 and I_3, respectively. Significant differences was observed in N uptake in seed and stalk due to drip irrigation levels. Treatment I_3 recorded significantly highest N uptake in seed and stalk. Treatments I_2 and I_1 was also significantly differed with each other. Oil content in castor seed progressively and significantly increased with increase in levels of drip irrigation from treatment I_1 to treatment I_3. Significantly highest oil content in castor seed (48.8%) was recorded under drip irrigation treatment I_3 but, it was remained at par with treatment I_2.

Effect of nitrogen

Various doses of N fertilizer showed highly significant differences in oil content in castor seed. Treatment N_1 ranked first through recording significantly the highest value of oil content (49.1%). Treatment N_2 and N_3 were also significantly differed with each other. These might be due to higher test weight and uptake of nitrogen by seed. High levels of nitrogen may be responsible for lower oil content. Moreover, there is a competition for photosynthates between different metabolic sinks in oilseed crops, hence increasing the level of N nutrition might enhanced the crude protein content, but lowered the oil content.

Table 1 Effect of spacing, drip irrigation and nitrogen levels on oil content (%), N content (%) and uptake (kg/ha) in seed and stalk of castor (pooled)

Treatments	Oil content (%)	N content in seed (%)	N uptake (kg/ha) in Seed	N uptake (kg/ha) in Stalk	Test weight (g)	Seed yield (kg/ha)
Spacing						
S_1- Pair row planting (180-60-180 cm) × 60 cm	48.6	1.49	40.6	65.6	30.4	2734
S_2- 120 × 60 cm	48.4	1.58	40.9	65.9	30.0	2573
SEm±	0.1	0.019	0.1	0.1	0.2	28
CD (P=0.05)	NS	0.050	NS	NS	NS	83
Drip irrigation						
I_1- 0.4 ADFPE	47.9	1.57	39.2	64.2	29.4	2496
I_2- 0.6 ADFPE	48.7	1.55	40.6	65.6	30.1	2623
I_3- 0.8 ADFPE	48.8	1.49	42.5	67.5	31.1	2841
SEm±	0.1	0.027	0.2	0.2	0.3	50
CD (P=0.05)	0.4	0.080	0.6	0.6	0.9	144
CV (%)	1.5	10.27	2.4	1.5	4.9	9.23
Nitrogen						
N_1 - 100 % RD of nitrogen through spot application	49.1	1.62	38.8	63.8	28.0	2393
N_2 - 50 % RD of nitrogen through fertigation	48.4	1.58	40.1	65.1	30.6	2531
N_3 - 100 % RD of nitrogen through fertigation	47.8	1.42	43.3	68.3	32.0	3037
SEm±	0.1	0.019	0.1	0.1	0.2	31
CD (P=0.05)	0.3	0.050	0.3	0.3	0.5	86
CV (%)	1.4	8.35	1.5	0.9	4.9	7.99

Table 2 Interaction effects of spacing, drip irrigation and nitrogen on N uptake in seed and stalk

Treatment	Nitrogen (N) uptake					
	Seed			Stalk		
	N_1	N_2	N_3	N_1	N_2	N_3
Spacing (S)						
S_1	39.03	40.07	43.85	64.03	65.07	68.85
S_2	38.56	40.20	42.81	63.56	65.20	67.81
SEm ±		0.13			0.13	
CD (P= 0.05)		0.35			0.35	
CV (%)		1.50			0.93	
Drip irrigation (I)						
I_1	37.40	38.29	41.91	62.40	63.29	66.91
I_2	38.47	40.28	43.08	63.47	65.28	68.08
I_3	40.50	41.84	45.01	65.50	66.84	70.01
SEm ±		0.15			0.15	
CD (P= 0.05)		0.43			0.43	
CV (%)		1.50			0.93	

Nitrogen treatments had significant influence on N content in seed. Significantly the highest N content in seed (1.62%) was obtained in N_1 treatment. Significantly the highest N uptake in seed (43.3 kg/ha) and stalk (68.3 kg/ha) was obtained in treatment N_3. The increase in N uptake in seed and stalk under treatment N_3 level might have produced and converted more photosynthates needed for seed development. In addition to these, N fertilization increases the cation exchange capacity of plant root and thus, makes them more efficient in absorbing nutrient ions. Nitrogen application N_3 produced significantly highest seed yield as compared to rest of the treatments. This is due to better utilization of N owing to good development of roots system, better utilization of water and nutrients enhanced castor seed yield under treatment N_3. These results corroborates with those reported by Lakshmi and Reddy (2006) and Patel *et al.* (2006) in castor crop.

Interaction effect

Pooled analysis of data showed that interaction effects of spacing, drip irrigation and nitrogen were non-significant with respect to oil and N content in seed. Whereas with N uptake in seed, interaction effect was found to be significant.

N uptake in seed

Pooled analysis data on S × N interaction (Table 2) indicated that significantly highest N uptake in seed (43.9 kg/ha) was recorded under treatment combination S_1N_3 and significantly lowest (38.6 kg/ha) in treatment combination S_2N_1. Whereas, I x N interaction indicated (Table 2) that the highest N uptake in seed (45.0 kg/ha) was recorded under treatment combination I_3N_3.

N uptake in stalk

Results on S × N interaction (Table 2) indicated that significantly highest N uptake in stalk of 68.7 kg/ha was recorded under treatment combination S_1N_3. Treatment combination S_2N_1 recorded the significantly the lowest (63.6 kg/ha) N uptake in stalk. Data on I × N interaction (Table 2), results revealed that significantly the highest N uptake in stalk of 70.0 kg/ha was observed under treatment combination I_3N_3.

Thus, the castor crop sown at (180 - 60 - 180 cm) × 60 cm apart and irrigated through drip at 0.8 ADFPE in conjunction with nitrogen fertilizer @ 100% recommended dose in the form of urea (30% basal and 70% in four equal split at one month interval) has potential production and good oil content in the seed, N content and uptake in seed and stalk.

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Epidemiology of groundnut (*Arachis hypogaea*) rust in northern Karnataka

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ABSTRACT

The studies indicated that more uredospore counts of *Puccinia arachidis* were observed during August and September which coincided with the critical stages of infection to the pathogen. Further, 31 standard week was highly favourable for appearance and development of rust of groundnut (*Arachis hypogaea* L.). Spore load and per cent disease index of rust indicated positive correlation with rainfall and negative correlation with temperature and relative humidity. The final multiple linear regression equations arrived for spore load and disease incidence were $Y=170.48-2.04X_1-0.46X_3-1.14X_4+0.25X_5$ and $Y=747.05-11.12X_1-1.06X_3-5.15X_4+0.82X_5$, respectively.

Key words: Correlation, Disease, Groundnut, Regression, Rust

Groundnut rust (*Puccinia arachidis* Speg.) is an important disease of groundnut (*Arachis hypogaea* L.) and occurs in epidemic form in some parts of northern Karnataka. The disease incidence mainly depends upon seasonal conditions. Epidemiological studies of the disease help in developing appropriate forecasting models to take up suitable precautionary measures for the management of disease. In northern Karnataka, the disease appeared in moderate form year after year causing losses in the yield till 1999. But, in recent years, the disease is appearing in severe form and has become one of the major constraints for groundnut cultivation in parts of northern Karnataka (Pande and Narayan Rao, 2000 and Anonymous, 2002). To forecast the disease severity and loss, the information on effect of environmental factors like temperature, relative humidity and rainfall in rust disease management is very important in groundnut (Benagi, 1995). Keeping this in view, studies on effect of weather factors on development of spore load of *P. arachidis* and per cent disease index of rust were carried out.

MATERIALS AND METHODS

The popular but highly susceptible variety KRG-1 was sown in 0.4 ha with a spacing of 30 cm x 10 cm at Regional Agricultural Research Station, Raichur, Karnataka, India during the rainy seasons of 2002 and 2003. All the recommended package of practices for tillage, manuring and irrigation etc. were followed. To trap the uredospores of *P. arachidis*, aeroscope for exposure of stationary slides was mounted at a height of 1.5 m during the cropping seasons in the field. The slides were smeared with a thin layer of vaseline and used for trapping the uredospores. The slides were removed every day at 8.30 h. Average number of uredospores per microscopic field were recorded under low power objective (10x) by taking count of ten microscopic fields in each slide. Observations were made daily to record the first appearance of the disease. Further, disease intensity was recorded at an interval of seven days starting from first appearance of disease till harvest of the crop on 50 randomly selected plants using 1-9 scale and per cent disease index (PDI) was calculated as per the standard procedures. The weather data *viz*., maximum and minimum temperature, morning and evening relative humidity and rainfall received during the period of aerobiological studies were also recorded. The data were subjected correlation and regression analysis. The weather parameters were correlated to weekly spore load and weekly PDI by calculating the Karl Pearson's correlation coefficient ®. Further, the data was subjected to step down multiple linear regression analysis to find out the linearity of the independent variables for prediction. The step down procedure was adopted to include most significant weather parameters in the multiple regression analysis.

RESULTS AND DISCUSSION

Effect of weather factors on development of spore load of P. arachidis and correlation analysis

The results indicated that, first catch of spore was recorded at 40 and 37 days after sowing (DAS) (Table 2) during 2002 and 2003, respectively, where in weather conditions during the previous week were maximum temperature range of 35.1-36.9°C and minimum of 23.0-24.2°C and RH-I of 73.4-84.9% followed by rainfall of 1.2 to 4.4 mm were recorded. However, this needs to be confirmed with further studies on epidemiology of groundnut rust taking into consideration the spatial relation with nearby places. The present investigation also showed that, uredospores were present in atmosphere well in advance (6 to 8 days) of actual appearance of rust on the host. Similar observations were made in wheat rust (Nargund, 1989) and in groundnut rust (Benagi, 1991). Further, it was observed that, more number of uredospores were trapped during August and September which coincided with the critical stages of infection to *P. arachidis*. Earlier, Mayee and Ekbote (1983) also recorded high spore counts of *P. arachidis* in September at Parbhani in Maharashtra.

The data (Table 3 and 4) on correlation and multiple linear regression analysis between spore load of *P. arachidis* and weather parameters indicated a high negative correlation between RH-I and RH-II during 2002. While, during 2003 the correlation coefficient between spore load and weather was non significant but the rainfall indicated positive relation where as the temperature and relative humidity were negatively related. Galgunde and Kurundkar (2002) reported that, humidity and temperature were negatively correlated, whereas rainfall was positively correlated with the incidence and intensity of rust of groundnut.

The multiple linear regression equation was fitted to the data (Table 4) and the equation arrived for all the weather parameters is, $Y=224.30-2.21X_1-1.73X_2-0.76X_3-0.84X_4+0.21X_5$. With the step down procedure, only one variable i.e., minimum temperature (X_2) was eliminated and final equation fitted to the data is $Y = 170.48-2.04X_1-0.46X_3-1.14X_4+0.25X_5$. Hence, it is evident from the data that all weather factors influence the spore load of *P. arachidis* to the extent of 66%, while significant weather factors influence spore load to the extent of 63%. When there is increase of one unit of maximum and minimum temperature, RH-I, RH-II and rainfall, the spore load is lowered by 2.21, 1.73, 0.76, 0.84 and increased by 0.21 units, respectively. When the significant weather factors were analyzed with every increase of one unit of minimum temperature, relative humidity and rainfall, the PDI is lowered by 2.04, 0.46, 1.14 and increased by 0.25 units, respectively.

Table 1 Initiation and development of groundnut rust during rainy season of 2002 and 2003 at RARS, Raichur, Karnataka. India

Standard week	Date	Per cent disease index (PDI)	Date	Per cent disease index (PDI)
31	12-8-2002 (Initiation)	12.1	8-8-2003 (Initiation)	13.3
32	19-8-2002	15.2	19-8-2003	17.6
33	26-8-2002	28.8	26-8-2003	30.4
34	2-9-2002	40.3	2-9-2003	44.5
35	9-9-2002	52.4	9-9-2003	60.0
36	16-9-2002	61.9	16-9-2003	69.5
37	23-9-2002	72.2	23-9-2003	76.8
38	30-9-2002	76.6	30-9-2003	79.5
39	7-10-2002	88.2	7-10-2003	80.1

Effect of weather parameters on development and spread of disease

Rust symptoms were first observed at 31 standard week when the crop was at 46 and 37 DAS, during 2002 and 2003, respectively. The favourable weather conditions were noticed during the period (Table 1) and also the first appearance of disease. The weather factors played an important role in the initiation and further spread of disease. It gives information to design supervisory control measures of disease in order to get expected pod and fodder yield. Krishna Prasad *et al.* (1979) reported that, intermittent rains with mean relative humidity above 87% favoured disease initiation. Rust development was proportionately better with every increment of the time of free water availability (Munde and Mayee, 1980). Patel and Vaishnav (1989) reported that severe rust infection was associated with relative humidity 74-89% and 10-13 mm rainfall during the preceding week. Lokhande *et al.* (1998) reported that, rain fall of 200 mm were congenial for rust disease development.

The relationship between rust PDI and weather factors during 2002 indicated a higher negative correlation between morning and evening relative humidity (Table 3). During 2003 the correlation coefficient between PDI and weather was non significant but the rainfall indicated positive relation where as the temperature and relative humidity were negatively related. These results are in agreement with Srikanta Das *et al.* (2000).

Further, multiple linear regression equation was fitted to the data (Table 4) and the equation arrived for all the weather parameters is : $Y=851.45-11.44X_1-3.37X_2-1.62X_3-4.56X_4+0.73X_5$. With the step down procedure, only one variable i.e., minimum temperature (X_2) was eliminated and final equation fitted to the data is $Y=747.05-11.12X_1-1.06X_3-5.15X_4+0.82X_5$. When there is an increase of one unit of maximum and minimum temperature, morning and evening relative humidity and rainfall, the PDI was lowered by 11.4, 3.4, 1.6, 4.6 and increased by 0.7 units respectively. The weather factors influence the disease incidence in KRG-1 to the extent of 80%. When the significant weather factors were analysed with every increase of one unit of minimum temperature, morning and evening relative humidity and rainfall, the PDI was lowered by 11.1, 1.1, 5.2 and increased by 0.3 units, respectively. The weather factors influence the disease incidence in KRG-1 to the extent of 80% and significant weather factors to the extent of 79%.

Table 2 Development of weekly spore load, disease index and meteorological parameters associated during 2002 and 2003 at RARS, Raichur

Standard week	Stage of crop	Weekly spore load	Weekly rust PDI	Temperature (° C)		Relative Humidity (%)		Rainfall (mm)
				Max.	Min.	RH-I	RH-II	
				2002				
28	19-25	0	0	33.8	22.6	84.3	59.5	12.2
29	26-31	0	0	34	22.7	85.3	60.4	28
30	32-38	0	0	35.1	23	84.9	49.7	1.2
31	39-45	2.20	12.1	33.8	23.9	87.3	64.1	20
32	46-52	4.42	15.2	29.1	21.8	89.9	75.9	79.8
33	53-59	6.57	28.8	32.6	22.9	79.7	52.1	0
34	60-66	15.43	40.3	33.2	22.5	78.7	45.3	4
35	67-73	12.43	52.4	34.3	24	73	49.4	3.4
36	74-81	19.86	61.9	34.3	22.6	78.6	43.6	28.2
37	82-88	17	72.2	34.6	23.4	72.6	45.4	0
38	89-95	23.14	76.6	33.6	22.4	82	48.1	81
39	96-102	35.2	88.2	35.2	23.6	75.9	36.3	0
				2003				
28	17-23	0	0	34.1	22.8	85.5	55.1	14.4
29	24-30	0	0	36.9	24.2	73.4	49.6	4.4
30	31-37	1.03	0	33.1	23.6	84.6	55	1.6
31	38-44	1.61	13.3	34.4	22.9	79.6	55	10.8
32	45-51	3.14	17.6	31.7	23	82.6	60	30.2
33	52-58	15.28	30.4	34.8	23.5	75.8	43	4.4
34	59-65	14.86	44.5	30.5	22.2	87.1	66	73.2
35	66-72	22.71	60.0	33	22.8	78	53	15.2
36	73-79	18.2	69.5	33.4	22.2	77	46	0
37	80-86	12.6	76.8	34.3	21.9	72.9	44	12.4
38	87-93	12	79.5	34.2	23.8	71.6	41	0
39	94-100	21.14	80.1	31.3	22.6	89.6	60	66.6

Table 3 Correlation between weekly spore load of *P. arachidis* and per cent disease index of rust and weather parameters

Weather parameter	Correlation coefficient ®			
	Spore load		% disease index	
	2002	2003	2002	2003
Maximum temperature (°C)	0.14	-0.41	0.18	-0.33
Minimum temperature (°C)	0.29	-0.45	0.28	-0.49
Relative humidity (%) morning	-0.76*	-0.03	-0.74*	-0.19
Relative humidity (%) evening	-0.66*	-0.12	-0.76*	-0.28
Rainfall (mm)	0.03	0.34	0.01	0.25

* Significant at 1% probability level

Table 4 Multiple linear regression of spore load of *P. arachidis* and per cent disease index of rust in relation to weather parameters

Year	Constant (A)	X_1	X_2	X_3	X_4	X_5	R_2
Spore load							
All weather factors	224.30	-2.21	-1.73	-0.76	-0.84	0.21	0.66
Significant weather factors	170.48	-2.04	--	-0.46	-1.14	0.25	0.63
Per cent disease index of rust							
All weather factors	851.45	-11.44	-3.37	-1.62	-4.56	0.73	0.80
Significant weather factors	747.05	-11.12	--	-1.06	-5.15	0.82	0.79

X_1= Maximum temperature (°C); X_2= Minimum temperature (°C); X_3 = Relative humidity (%) RH-I; X_4 = Relative humidity (%) RH-II; X_5 =Rainfall (mm)

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Performance of castor (*Ricinus communis*) hybrids under irrigated conditions during winter season in Andhra Pradesh

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ABSTRACT

Castor (*Ricinus communis* L.) cultivation in Andhra Pradesh is mostly confined to rainy season. However, its cultivation is decelerating due to several biotic and abiotic stresses. The Directorate of Oilseeds Research (DOR) identified key agro-ecological regions wherein castor could be taken up during winter season based on the principle of comparative advantage and motivated innovative farmers to take up the same with technical back up from the Directorate. The demonstrations were conducted in Mahabubnagar district of Andhra Pradesh (AP).The results indicate that the performance of DOR hybrids in winter season gave 3247 kg as against 2689 kg/ha with local practice and the increase in yield was 21%. The additional net returns accrued was ₹ 7111/ha with BCR of 2.47. In case of DCH-519, the yield obtained was 3138 kg in contrast to 2533 kg/ha with local. The incidence of insect pests particularly sucking pests were more on DCH-177 as compared to DCH-519. The farmers suggested the need to evolve resistant cultivars for sucking insect pests. The results further indicated the scope for higher productivity potentials of castor under irrigated conditions during winter season.

Key words: Irrigation, Productivity potential, Profitability, Winter castor

Castor (*Ricinus communis* L.) is an important oilseed crop known for its numerous industrial applications. It is grown in the cropping systems of dryland agriculture in semi-arid regions of the country, because of its deep root system, drought hardiness and fast growth. In India, it is mostly confined to Gujarat, Andhra Pradesh, Rajasthan, Tamil Nadu, Karnataka and Orissa (Vaghasia and Kavani, 2009). The crop is cultivated in an area of 7.9 lakh ha in the country, with a production of 10.5 lakh t. and productivity of 1339 kg/ha (Damodaram and Hegde, 2007). Unlike in Gujarat, castor in Andhra Pradesh is confined to rainfed conditions during rainy season in the districts of Mahabubnagar, Nalgonda and Ranga Reddy. Its cultivation is also gradually spreading to other districts like Prakasam, Kadapa, Kurnool, Anantpur and Warangal. However, the status of the crop in this area has been marked by low yield levels with poor management practices and heavy damage due to pest and diseases during rainy season. Keeping the milieu in view, demonstrations were conducted to show the productivity potentials of castor hybrids that were released from the Directorate of Oilseeds Research (DOR), Hyderabad under irrigated conditions during winter season in Mahabubnagar and the problems and suggestions as perceived by the farmers under such situations have been explained in this paper.

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MATERIALS AND METHODS

The castor farmers in Andhra Pradesh prefer its cultivation during rainy season under rainfed conditions due to the principle of comparative advantage. However, of late, due to the abnormal weather conditions and other major biotic and abiotic stresses, there has been a stagnation and/or deceleration in the productivity levels. Under this situation a group discussion at DOR involving farmers of various villages in Mahabubnagar district was held and a few areas have been identified for conducting demonstrations under irrigation during winter. Hence, to prove the productivity potentials of irrigated castor under real farm conditions, demonstrations were conducted in various villages viz., Cherkur and Peddapur of Veldanda Mandal, Jangireddypalli of Amrabad Mandal and Ramapur of Waddepalli Mandal in Mahabubnagar district of Andhra Pradesh during 2006-07 to 2008-09. The crop was allowed to grow 5 to 7 months on the fields and during grand growth period field days were conducted at the field sites in some of the villages, to create an opportunity for the fellow farmers from the neighbouring villages to get convinced about the productivity potentials of irrigated castor. The yield, economics and farmers' problems and suggestions were collected and analysed using suitable statistical tools like average, percentage and others.

RESULTS AND DISCUSSION

From table 1, it could be observed that the yield obtained across years and villages ranged from 1750 to 4200 kg/ha for

DCH-177 as against 2200 to 3600 kg/ha with farmers' practice. Similarly, the mean yield recorded across demonstrations of DCH-177 was 3247 kg/ha in contrast to 2689 kg/ha with farmers' practice. The percentage of yield increase obtained in improved technology ranged from 6 to 55%. Similarly, the yield of DCH-519 ranged from 1725 to 3450 kg/ha as against 2200 to 2800 kg/ha with farmers' practice. The increase in yield ranged from 19 to 70% over farmers' practice. The mean yield of DCH-519 was 3138 kg/ha as against 2592 kg/ha with farmers' practice, while the mean percentage yield increase was 24% over farmers' practice.

Table 1 Productivity potentials of castor hybrids under irrigation in winter season

Year	Hybrid	Area (ha)	Yield (kg/ha)		% increase in yield
			IT	FP*	
2006-07	Cherkur	0.8	3500	2800	25
	Shettipally	0.4	4200	3600	16
	Ramapuram	0.8	3800	3600	6
2007-08	Jangireddypally	0.8	3200	2400	33
	Peddapur	2.0	3300	2800	18
2008-09	Ramapuram	0.4	3500	2200	59
		0.4	2875	2200	31
		0.4	1750	2200	-20
		0.4	3000	2200	45
		0.4	2750	2200	25
		0.4	2875	2200	31
Mean		7.2	3247	2689	21
2007-08	Peddapur	2.0	3450	2800	23
		0.4	3750	2200	70
2008-09	Ramapuram	0.4	2625	2200	19
		0.4	1725	2200	-22
		0.4	3250	2200	48
Mean		3.6	3138	2533	24

IT = Improved technology; FP = Farmers practice

Table 2 Economics of castor hybrids under irrigation

Year	Hybrid	Area (ha)	Cost of cultivation (₹/ha)*		Gross returns (₹/ha)*		Addl. net returns (₹/ha)	BC ratio	
			IT	FP	IT	FP		IT	FP
				DCH-177					
2006-07	Cherkur	0.8	23,550	21,750	63,000	50,400	10,800	2.68	2.32
	Shettipally	0.4	21,625	18,650	63,000	54,000	6,025	2.91	2.89
2007-08	Ramapuram	0.8	28,650	27,250	68,400	64,800	2,200	2.39	2.38
	Jangireddypally	0.8	26,500	24,500	57,600	53,200	2,400	2.17	2.17
	Peddapur	2.0	27,550	25,250	77,000	61,600	13,100	2.79	2.44
		0.4	32,675	23,550	72,100	51,700	11,275	2.21	2.19
		0.4	28,675	23,550	56,063	51,700	762	1.96	2.19
2008-09	Ramapuram	0.4	22,050	23,550	35,000	51,700	-15,200	1.59	2.19
		0.4	27,265	23,550	61,800	51,700	6,385	2.27	2.19
		0.4	26,900	23,550	64,625	51,700	9,575	2.40	2.19
		0.4	24,658	23,550	67,563	51,700	9,903	2.74	2.19
Mean		7.2	26,631	24,066	65,731	56,055	7,111	2.47	2.33
				DCH-519					
2007-08	Peddapur	2.0	27,550	25,250	79,200	61,600	15,300	2.87	2.44
		0.4	25,500	23,550	77,250	51,700	23,600	3.03	2.19
2008-09	Ramapuram	0.4	22,450	23,550	51,188	51,700	588	2.28	2.19
		0.4	26,265	23,550	36,050	51,700	-18,365	1.37	2.19
		0.4	31,550	23,550	66,950	51,700	7,250	2.12	2.19
Mean		3.6	27,057	23,550	64,028	57,200	4,265	2.37	2.33

IT = Improved technology; FP = Farmers' practice; * = then existing price

It could be inferred that there exists considerable potential to enhance the yield levels of winter season castor in the study area as evidenced by the existing yield increase over the local practice using the hybrids of DOR under irrigated conditions. The economics of the castor hybrids (Table 2) reveals that the cost of cultivation for DCH-177 varied from ₹ 21,625 to 32,675/ha as against ₹ 18,650 to 27,250/ha with farmers' practice. The gross returns for DCH-177 ranged from ₹ 35,000 to 77,000/ha in contrast to ₹ 50,400 to 64,800/ha with farmers' practice. The additional net returns ranged between ₹ 762 and 13,100/ha. Similarly for DCH-519, the cost of cultivation varied from ₹ 22,450 to 31,550/ha as against ₹ 23,550 to 25,250/ha with farmers' practice. The gross returns for DCH-519 was ranged from ₹ 51,188 to 61,600/ha as against ₹ 51,700 to 61,600/ha with farmers' practice. The additional net returns accrued ranged from ₹ 588 to 23,600/ha. The mean data revealed that ₹ 4,265/ha was the additional net returns accrued from castor hybrids under irrigated conditions during winter season.

Problems as perceived by the farmers:

- More incidence of sucking pests on DCH-177 as compared to DCH-519.
- Less spacing between rows induce lanky growth of plants with less branches
- Nonavailability of timely labour and high cost of labour
- Fluctuation in market prices
- Nonavailability of quality seeds
- Lack of information on irrigated castor production technology
- Nonavailability of fertilizers locally

The following are the suggestions offered by the farmers:

- Need for high yielding and pest resistant cultivars suitable for irrigated situation
- Short ideotype plant with more branching
- Availability of quality seed and inputs like pesticides and fertilizers locally
- Organizing more number of demonstrations
- More number of field demonstrations and field days for fast spread of technology
- Announcement of castor procurement price like other edible oilseed crops

The present study indicates that the productivity potentials and profitability of castor hybrids were higher when compared to the farmers' practices during winter season under irrigated conditions. It indicates that there exists considerable scope for increasing the castor production in Andhra Pradesh, by creating awareness among the castor growers about the potential and prospects of the winter season castor under irrigation. The seed producing agencies should play a greater role in producing the hybrids like DCH-177 and DCH-519, thus paving a way for enhancing castor productivity. The state Department of Agriculture should play a major role in identifying suitable areas for winter season castor for enhancing the productivity of castor in AP.

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Short communication

Genetic variability, correlation and path analysis for yield, its components and late leaf spot resistance in groundnut (*Arachis hypogaea*)

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ABSTRACT

The present investigation was carried out to study the variability parameters, correlations and path coefficients for 13 metric traits in 33 advanced breeding lines and genotypes of groundnut (*Arachis hypogaea* L.). Significant genotypic differences were observed for all the traits studied indicating the considerable amount of variation among genotypes for each character. The highest genotypic and phenotypic coefficient of variation was observed for late leaf spot (LLS) score at 80 DAS followed by LLS score at 90 DAS, kernel yield/plant, plant height, pod yield/plant and test weight. Similarly, high heritability coupled with high genetic advance was observed for these traits indicating the scope for their improvement through selection. Kernel yield/plant was positively and significantly correlated with pod yield/plant, shelling per cent, plant height, sound mature kernel per cent and harvest index. The path analysis suggested that pod yield/plant and shelling per cent were the main contributors towards kernel yield/plant. Hence, main emphasis should be given on these traits in breeding programme.

Key words: Component traits, Correlations, Groundnut, Late leaf spot resistance, Path analysis, Variability parameters

Groundnut (*Arachis hypogaea* L.) is one of the most important economic and edible oilseed crops of India. Selection of elite genotypes from the available genetic variation forms an important component of genetic improvement of any crop. The basic rationale in any crop improvement is the increase in yield potential of the crop. The yield has got a complex gene action and is dependent on several components, which contribute directly or indirectly. Further, disease resistance traits have to be considered in conjunction with yield and its components to formulate a selection criterion to isolate the elite genotypes of groundnut. Hence, the present investigation was undertaken to establish variability parameters, correlation and path analysis for yield, its components and late leaf spot resistance traits in groundnut.

The present investigation was carried out during late rainy season of 2006 at wetland farm of S.V.Agricultural College, Tirupati. The experimental material consisted of 33 advanced breeding lines and genotypes of groundnut procured from AICRP on groundnut scheme, Junagarh, Gujarat, India. The experiment was laid out in a randomized block design replicated thrice. Each genotype was sown in each replication in two rows of 3 m length with a spacing of 30 cm between the rows and 10 cm between the plants within the row. The genotype JL-24 was employed as a late leaf spot (LLS) susceptible check and sown after every three genotypes in the treatment plots and in borders to provide congenial conditions of natural disease development in the plots. Recommended package of practices were followed to grow the crop. Five randomly selected plants from each plot per replication were scored for recoding observations on 13 metric traits *viz.*, days to 50% flowering, days to maturity, plant height (cm), sound mature kernel per cent, number of primary branches/plant, shelling per cent, test weight (g), pod yield/plant (g), harvest index (%), late leaf spot (LLS) disease score at 70 days after sowing (DAS), 80 and 90 DAS and kernel yield/plant (g), different genetic parameters like mean, range, phenotypic and genotypic coefficients of variation (GCV), heritability and genetic advance were calculated as suggested by Burton and Devane (1953) and Johnson *et al.* (1955). The computation of phenotypic and genotypic correlation coefficients was done (Al-Jibouri *et al.*, 1958). Path coefficient analysis was also done (Dewey and Lu, 1959).

The mean, range, GCV and phenotypic coefficient of variation (PCV), heritability (broad sense) and expected genetic advance as percent of mean was been presented in table 1. Significant genotypic differences were observed for all the traits indicating that there was significant genetic variation among the genotypes for all the traits. Highest range was observed for sound mature kernel per cent followed by shelling per cent, plant height and harvest index. As expected, the value of PCV was higher than that of GCV for all the traits. The highest GCV and PCV values were observed for LLS score at 70 DAS followed by the sound mature kernel per cent, LLS score at 80 DAS and kernel yield/plant. Thus, appreciable amount of variability was present among the genotypes for all these traits and selection could be effective for further improvement of these characters. Similar findings were also reported by Gowda *et al.* (1996) for the LLS disease score. On the contrary, moderate estimates of GCV and PCV were recorded for harvest index, number of primary branches/plant and shelling percentage. This indicates little improvement could be expected under selection for these characters. However, low estimates of variability were recorded for days to 50% flowering and days to maturity indicating the limited scope of selection for these traits. The smaller difference between PCV and GCV values indicated greater role of genetic component and less influence by environment, which also supports the findings of Gowda *et al.* (1996).

The estimates of heritability were very high for all the characters except days to 50% flowering . However, high estimates of heritability for days to maturity, harvest index, shelling per cent and number of primary branches/plant was not associated with the high values of genetic advance. This might be due to the lower values of phenotypic standard deviation observed for these characters. High heritability coupled with high genetic advance as percent of mean was recorded for all the remaining characters *viz*., LLS scores at 70, 90 and 80 DAS, kernel yield/plant, pod yield/plant, plant height, test weight and sound mature kernel per cent indicating that these characters can be improved through direct selection since the additive gene action is being involved in the inheritance of these characters. These findings are in agreement with the results of John *et al.* (2006) for LLS resistance, pod yield/plant and kernel yield/plant and Karikari *et al.* (2003) for test weight and sound mature kernel per cent.

In the present study, the genotypic correlations were higher than phenotypic correlations for almost all the characters indicated that genetic factors played a major role in determining these correlations (Table 2). Pod yield/plant followed by shelling per cent, test weight, plant height and sound mature kernel per cent showed a significant positive correlation with kernel yield/plant. Significant positive associations were also observed between plant height with test weight, pod yield/plant, harvest index and shelling per cent, between test weight and pod yield/plant. Similar kind of significant and positive correlations of test weight and harvest index were observed with all the three intervals of LLS scores i.e., at 70, 80 and 90 DAS. Further, it is interesting to note that the *inter se* correlations among three LLS scores were found to be highly significantly positive among them. On the contrary, all the three LLS scores were significantly and negatively correlated with days to maturity indicating the linear reduction in the leaf spot infection with the decrease in maturity duration. Similarly, the association of the number of primary branches/plant with test weight and pod yield/plant were found to be significantly negative as well as with all the remaining yield components indicating that mere increase in a number of primary branches would not lead to proportionate increase in kernel yield and its components. These results are in agreement with the earlier findings of John *et al.* (2006) for late leaf spot resistance scores with kernel yield and its components.

It is evident from table 3 that pod yield/plant had the highest direct and positive effect on kernel yield/plant followed by shelling per cent, LLS score at 80 DAS and sound mature kernel per cent there by indicating that the genetic correlation between pod yield/plant and kernel yield/plant explains the true relationship between these two characters since pod yield/plant not only showed the highest correlation with kernel yield but also had the maximum direct effect on this dependent character. Similar results were also observed for shelling percent. On the contrary, three characters *viz*., plant height, sound mature kernel per cent and shelling per cent were significantly correlated with kernel yield/plant but had a low direct effect on the dependent character. However, test weight showed a significant positive correlation with kernel yield/plant though it had the negative direct effect on this dependent character partly because of its high and positive indirect effects were exerted via shelling per cent and sound mature kernel per cent. Similarly, LLS scores at 70 and 90 DAS exerted a low negative direct effect on kernel yield but correlated positively with kernel yield due to their positive indirect effects displayed via pod yield/plant. Further, the characters sound mature kernel per cent and harvest index showed the highest positive indirect effects on kernel yield through pod yield/plant. Though, the characters test weight, LLS score at 70 and 90 DAS exerted a negative direct effect on kernel yield, their association with kernel yield was found to be positive. This is because indirect effects of these characters through days to the maturity and primary number of branches/plant were found to be positive though negligible. The path coefficient analysis revealed that pod yield/plant contributed the maximum direct effect followed by shelling percentage, LLS score at 80 DAS, days to maturity, days to 50% flowering and harvest index on kernel yield/plant. These results were in agreement with the earlier findings for harvest index, Suneetha *et al.* (2004) for test weight, John *et al.* (2006) for days to maturity and for a number of primary branches/plant. Hence, selection based on these characters would be effective in increasing the kernel yield in groundnut genotypes.

The pod yield/plant and shelling per cent which showed high positive direct effects also contributed indirectly via harvest index and test weight, respectively, again indicated the influence of these two traits on kernel yield. The value of residual effect of undefined factors (Table 3) was low (0.3910). This residual effect of path analysis indicated that major portion of variability (61%) for kernel yield could be attributed to variation in 12 independent characters *considered in this study and 39% variation in yield was* attributable to some undefined factors. Thus, pod yield/plant, *shelling per cent, test weight, harvest index and LLS score at 70 DAS were the most important component* traits of kernel yield and need emphasis while selecting high yielding LLS *resistant genotypes in groundnut.*

Table 1 Estimates of variability, heritability and genetic advance for yield and its component traits in groundnut

Characters	Mean	Range	Coefficient of variation (%)		Heritability (%)	Genetic advance as % of mean
			Genotypic	Phenotypic		
Days to 50% flowering	32.91±0.98	31.26 -35. 00	1.71	4.14	17.42	1.45
Days to maturity	119.5±1.22	115.70-122.94	1.33	1.83	52.97	1.99
Plant height (cm)	30.13±0.98	22.83-48.03	17.58	20.08	76.64	39.99
Sound mature kernel (%)	52.5±5.86	20.88-70.74	23.81	27.47	75.18	42.53
No. of primary branches/plant	4.66±0.37	3.50-6.37	11.94	15.47	59.15	18.66
Shelling (%)	53.57±3.87	36.15-63.50	10.39	13.66	57.93	16.29
Test weight (g)	31.02±0.76	21.99-43.55	16.84	17.11	96.91	34.13
Pod yield/plant (g)	10.54±0.70	8.22-13.71	15.29	17.82	77.78	28.55
Harvest index (%)	49.96±3.36	40.88-58.40	9.26	12.40	55.80	14.25
LLS score at 70 DAS	5.22±0.19	1.80-7.87	30.65	31.00	97.45	62.06
LLS score at 80 DAS	6.33±0.27	2.84-8.34	23.00	23.59	94.84	45.97
LLS score at 90 DAS	7.2±0.18	3.60-8.75	18.42	18.68	97.06	37.22
Kernel yield/plant (g)	5.56±0.31	3.73-8.22	20.66	21.80	89.64	40.1

DAS = Days after sowing

Table 2 Phenotypic (r_p) and genotypic (r_g) correlation coefficients among the studied characters in groundnut

Characters		Days to maturity	*Plant height* (cm)	Sound mature kernel (%)	No. of *primary* branches/ plant	*Shelling* (%)	*Test* weight (g)	Pod yield/ plant (g)	*Harvest* index (%)	LLS score at 70 DAS	LLS score at 80 DAS	LLS score at 90 DAS	Kernel yield/plant (g)
Days to 50% flowering	rp	-0.0683	-0.1145	0.1447	0.1146	0.1434	0.0332	-0.0915	-0.1048	-0.0060	-0.0031	-0.0278	0.0415
	rg	-0.1173	-0.3144	0.1432	0.447	0.5382	0.0699	-0.0899	-0.3897	-0.0951	-0.0196	-0.1038	0.2585
Days to maturity	rp		0.0645	-0.3084**	0.0793	0.0176	-0.0461	0.0233	-0.1734	-0.5410**	-0.5072**	-0.5320**	-0.0016
	rg		0.1160	-0.4127	0.2250	-0.1103	-0.0579	0.0582	-0.3223	-0.7683	-0.7168	-0.7359	-0.0366
Plant height (cm)	rp			0.0718	0.0653	0.2090*	0.3673**	0.3478**	0.2264*	0.1633	0.0982	0.0979	0.4156**
	rg			0.0642	0.0281	0.3109	0.4271	0.4400	0.2995	0.1849	0.1576	0.1184	0.5036
Sound mature kernel (%)	rp				-0.3209	0.3095	0.5647	0.0959	0.1222	0.4511	0.4171	0.4462	0.3273**
	rg				-0.4610	0.4530	0.6711	0.1722	0.1493	0.5334	0.5153	0.5343	0.3976
Number of primary branches/plant	rp					-0.0017	-0.2051*	-0.2046*	-0.0282	-0.1021	-0.0690	-0.0627	-0.1597
	rg					-0.0549	-0.3100	-0.2281	-0.0028	-0.1252	-0.0628	-0.1161	-0.2129
Shelling (%)	rp						0.2540*	-0.1148	0.0220	-0.0174	0.0010	0.0156	0.5041**
	rg						0.3293	0.0206	0.0754	-0.0110	0.0053	0.0170	0.6403
Test weight (g)	rp							0.3296**	0.1022	0.3697**	0.3414**	0.3496**	0.4184**
	rg							0.3852	0.1240	0.3775	0.3615	0.3619	0.4545
Pod yield/plant (g)	rp								0.2374	0.1134	0.1639	0.1516	0.7002**
	rg								0.3154	0.1313	0.1737	0.1804	0.7782
Harvest index (%)	rp									0.3038**	0.2696**	0.2617**	0.2065*
	rg									0.4123	0.3643	0.3867	0.2934
LLS score at 70 DAS	rp										0.8945**	0.8926**	0.1015
	rg										0.9311	0.9196	0.1083
LLS score at 80 DAS	rp											0.9635**	0.1646
	rg											0.9899	0.1754
LLS score at 90 DAS	rp												0.1608
	rg												0.1709

DAS = Days after sowing; *,** significant at P=0.05 and P=0.01 levels, respectively

Table 3 Phenotypic (P) and genotypic (G) path coefficients among the studied characters in groundnut

Characters	Day to 50% flowering	Days to maturity	Plant height (cm)	Sound mature kernel(%)	No. of primary branches/plant	Shelling (%)	Test weight (g)	Pod yield/plant (g)	Harvest index (%)	LLS score at			Kernel yield/plant (g)
										70 DAS	80 DAS	90 DAS	
Days to 50% flowering	0.0199	-0.0014	-0.0023	0.0029	0.0023	0.0029	0.0007	-0.0018	-0.0021	-0.0001	-0.0001	-0.0006	0.0415
Days to maturity	0.0006	-0.0083	-0.0005	0.0026	-0.0007	-0.0001	0.0004	-0.0002	0.0014	0.0045	0.0042	0.0044	-0.0016
Plant height (cm)	-0.0067	0.0038	0.0587	0.0042	0.0038	0.0123	0.0216	0.0204	0.0133	0.0096	0.0058	0.0057	0.4156**
Sound mature kernel (%)	0.0166	-0.0353	0.0082	0.1146	-0.0368	0.0355	0.0647	0.0110	0.0140	0.0517	0.0478	0.0511	0.3273**
Number of primary branches/plant	0.0014	0.0010	0.0008	-0.0039	0.0122	0.0000	-0.0025	-0.0025	-0.0003	-0.0012	-0.0008	-0.0008	-0.1597
Shelling (%)	0.0787	0.0097	0.1148	0.1700	-0.0009	0.5493	0.1395	-0.0631	0.0121	-0.0096	0.0006	0.0086	0.5041**
Test weight (g)	-0.0015	0.0021	-0.0165	-0.0254	0.0092	-0.0114	-0.0449	-0.0148	-0.0046	-0.0166	-0.0153	-0.0157	0.4184**
Pod yield/plant (g)	-0.0684	0.0166	0.2599	0.0716	-0.1529	-0.0858	0.2463	0.7472	0.1774	0.0847	0.1225	0.1133	0.7002**
Harvest index (%)	-0.0002	-0.0003	0.0005	0.0002	-0.0001	0.0000	0.0002	0.0005	0.0020	0.0006	0.0005	0.0005	0.2065*
LLS score at 70 DAS	0.0006	0.0560	-0.0169	-0.0467	0.0106	0.0018	-0.0382	-0.0117	-0.0314	-0.1034	-0.0925	-0.0923	0.1015
LLS score at 80 DAS	-0.0004	-0.0613	0.0119	0.0504	-0.0083	0.0001	0.0413	0.0198	0.0326	0.1081	0.1209	0.1165	0.1646
LLS score at 90 DAS	0.0008	0.0160	-0.0029	-0.0134	0.0019	-0.0005	-0.0105	-0.0045	-0.0078	-0.0268	-0.0289	-0.0300	0.1608

DAS = Days after sowing; Phenotypic residual effect = 0.3910; Genotypic residual effect = 0.0149; Bold - Direct effects; Normal - Indirect effect

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Genetic divergence studies in groundnut (*Arachis hypogaea*)

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ABSTRACT

Genetic divergence among 33 genotypes of groundnut (*Arachis hypogaea* L.) belonging to different eco-geographical regions were studied by using Mahalanobis D^2 statistics. The analysis of variance revealed significant differences among the genotypes for all the traits. The 33 genotypes were grouped into six clusters, where a cluster I was the largest containing 18 genotypes followed by cluster II with 10 genotypes. The inter cluster distance was maximum between cluster IV and V followed by cluster III and V. Based on inter cluster distance and *per se* performance of genotypes. ISK-04-26, ISK-05-20 (cluster IV), ISK-04-11 (cluster V) and ISK-04-15 (cluster III) could be suggested for inclusion in the hybridization programme to evolve high yielding and late leaf spot resistant genotypes.

Key words: *Arachis hypogaea,* D^2 statistics and Genetic divergence

Groundnut (*Arachis hypogaea* L.) is one of the potential oilseed legumes which plays major role in Indian economy. The importance of genetic diversity of parents in a hybridization programme has been emphasized as the crosses involving genetically diverse parents are likely to produce not only high heterotic effect but also desirable transgressive segregants in the later segregating generations. In groundnut, several advanced breeding lines have been recently developed from different source materials. These advanced lines differ for yield and its components as well as for resistance traits. The present investigation was carried out to know the magnitude of diversity present in these advanced breeding lines and to select diverse parents to obtain the heterotic crosses and wide array of recombinants for selection of late leaf spot resistant high yielding genotypes.

The present investigation was carried out during late rainy season of 2006 at Wetland Farm of Sri Venkateswara Agricultural College, Tirupati. The experimental material consisted of 33 advanced breeding lines and genotypes of groundnut received from AICRP scheme on groundnut, Junagarh, Gujarat, India. The experiment was laid out in a randomized block design. Each genotype was sown in two rows of 3 m length with a spacing of 30 cm between the rows and 10 cm between the plants within the row and replicated thrice. The genotype JL-24 was employed as susceptible check and sown after every three genotypes in the treatmental plots and in borders in each plot to provide congenial conditions of natural disease development in the plots. The crop was fertilized @ 30 kg N, 40 kg P_2O_5 and 50 kg K_2O/ha in the form of urea, superphosphate and muriate of potash. In each entry, five plants were randomly tagged and utilized to collect data on yield and its component characters *viz.*, days to 50% flowering, days to maturity, number of primary branches/plant, plant height (cm), kernel yield/plant (g), shelling (%), harvest index (%), test weight (g), pod yield/plant (g), late leaf spot (LLS) disease score at 70, 80 and 90 days after sowing (DAS). The data were subjected to statistical analysis using Mahalanobis D^2 statistic (Mahalanobis, 1936) and Tocher's method as described by Rao *et al.* (2000) was applied for determining the group constellation. Average intra and inter cluster distances were also estimated (Singh and Chaudhary, 1977).

The analysis of variance revealed highly significant differences among the genotypes for all the traits under study. Based on D^2 analysis, the 33 genotypes were grouped into six clusters with a variable number of entries revealing the presence of a considerable amount of genetic diversity in the material (Table 1). The cluster I comprised of a maximum number of 18 genotypes, followed by cluster II with 10 genotypes and cluster IV with two genotypes. The remaining three clusters *viz.*, clusters III, V and VI had one genotype each. The pattern of distribution of genotypes into various clusters was at random suggesting that the genetic diversity was not related to geographic diversity. This might be attributed due to the forces other than geographical separation, which was responsible for diversity such as natural and artificial selection, exchange of breeding material, genetic drift and environmental variation. Similar results were reported by Vijayasekhar (2002) and Garjapa *et al.* (2005) in the genetic divergence studies on groundnut.

Average intra and inter cluster D^2 values among the 33 genotypes revealed that cluster III, V and VI showed minimum intra cluster value (0.00) since they are mono genotypic clusters (Table 2) while, cluster II showed maximum intra cluster D^2 value (56.6) followed by cluster I (41.5) and cluster IV (19.0) revealing the existence of diverse genotypes in these clusters. The inter cluster D^2 value ranged from 70.1 to 471.8. Minimum inter cluster D^2 value was observed between cluster V and VI indicating the close relationship among the genotypes included in these clusters. Maximum inter cluster value was observed between cluster IV and V (471.8) followed by cluster I and IV (332.3), cluster III and V (282.9) and cluster IV and VI (282.2) which indicated that the genotypes included in these clusters may give heterotic response and thus better segregants. The lines derived from the same source of parentage were grouped into different clusters demonstrating the impact of selection pressure in increasing genetic diversity.

The cluster means and contribution of each trait towards divergence are presented in table 3. The data revealed considerable differences among the clusters for most of the characters studied. The cluster VI (GPBD-4) recorded the highest kernel yield/plant, harvest index, pod yield/plant, shelling per cent, sound mature kernel per cent and comparatively least LLS disease score at 70 and 80 DAS. Apart from these, relatively it was found to be latest in flowering and maturity. However, cluster III (ISK-04-15) recorded early flowering and maturity as well as the least LLS disease score at 90 DAS. Further, cluster IV (ISK-04-26 and ISK-05-20) recorded the higher number of primary branches/plant, test weight and least LLS disease scores both at 70 and 80 DAS. Similarly, the cluster V (ISK-04-11) recorded the highest plant height and harvest index. The knowledge on characters influencing divergence is an important aspect to a breeder which can be estimated by D^2 analysis. The character LLS score at 70 DAS (35.5%) contributed maximum towards divergence followed by test weight (34.9%), LLS score at 90 DAS (11.8%), LLS scored at 80 DAS (7.1%) and kernel yield/plant (5.5%) indicating the divergence of genotypes is due to these three traits (Table 3). Vijayasekhar (2002) reported the maximum contribution of test weight towards genetic divergence in groundnut, which is in consonance with the findings of the present study.

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 one or more characters were seemed to be desirable. On this basis, ISK-04-26, ISK-04-11, ISK-05-20, ISK-04-15 and GPBD-4 were selected. Inter crossing of divergent groups would lead to greater opportunity for crossing over, which releases hidden potential variability by disrupting the undesirable linkages (Thoday, 1960). The progenies derived from such diverse crosses are expected to have wide spectrum of genetic variability, providing a greater scope for isolating transgressive segregants in the advanced generations, particularly in a segmental allotetraploid crop like groundnut. Hence, these genotypes could be utilized in a multiple crossing programme to recover desirable transgressive segregants.

Table 1 Distribution of 33 groundnut genotypes in 6 clusters based on D^2 values

Clusters	Number of genotypes	Genotypes
I	18	ISK-04-17, JL-24, ISK-2-04-5, ISK-04-13, ISK-05-15, ISK-04-18, ISK-05-21, ISK-1-05-2, ISK-04-12, ISK-04-16, ISK-2-04-26, Narayani, ISK-05-30, ISK-05-16, ISK-04-25, ISK-1-05-3, ISK-04-5, ISK-3-03-4
II	10	ISK-04-2, ISK-04-3, ISK-05-17, ISK-04-4, ISK-3-03-6, ISK-04-6, ISK-3-03-5, ISK-04-7, ISK-04-9, ISK-1-05-6
III	1	ISK-04-15
IV	2	ISK-04-26, ISK-05-20
V	1	ISK-04-11
VI	1	GPBD-04

Table 2 Average intra and inter cluster distances (D^2 values) of 33 groundnut genotypes

Cluster	I	II	III	IV	V	VI
I	41.5 (6.4)	129.3 (11.4)	90.1 (9.5)	332.3 (18.2)	93.5 (9.7)	123.2 (11.1)
II		56.6 (7.5)	98.4 (9.9)	112.6 (10.6)	256.6 (16.0)	179.8 (13.4)
III			0.0 (0.0)	280.2 (16.7)	259.9 (16.1)	282.9 (16.8)
IV				19.0 (4.4)	471.8 (21.7)	282.2 (16.8)
V					0.0 (0.0)	70.1 (8.4)
VI						0.0 (0.0)

Table 3 Cluster means and per cent contribution of characters towards divergence in groundnut

Cluster number	Days to 50% flowering	Days to maturity	Plant height (cm)	Sound mature kernel (%)	Primary branches/ plant	Shelling (%)	Test weight (g)	Pod yield/ plant (g)	Harvest Index (%)	LLS score at			Kernel yield/ plant (g)
										70 DAS	80 DAS	90 DAS	
I	32.9	118.7	29.3	59.6	4.5	54.2	32.5	10.4	50.4	7.2	8.0	5.58	6.2
II	32.8	120.5	29.9	45.4	4.8	52.7	27	10.8	49.0	5.2	6.2	5.62	3.8
III	32.3	117.1	25.2	20.8	4.9	43.8	22.7	9.8	51.6	6.8	8.1	4.21	5.7
IV	33.2	120.2	27.1	48.3	5.0	49.5	34.3	10.1	52.6	4.3	5.0	4.98	4.4
V	32.8	120.9	48.0	57.4	4.5	59.6	42.7	10.1	55.4	6.3	7.7	8.31	5.9
VI	35.0	121.3	27.2	59.6	4.5	63.5	31.2	12.8	56.7	3.9	5.8	6.80	8.0
Per cent contribution	0.0	0.1	1.2	0.3	0.5	0.3	34.9	1.4	1.0	35.4	7.13	11.7	5.5

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Genetic divergence in some exotic genotypes of groundnut (*Arachis hypogaea*)

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ABSTRACT

Genetic divergence among 30 groundnut (*Arachis hypogaea* L.) genotypes was worked out using Mahalanobis D^2 statistics. Based on genetic distance, these genotypes were grouped into six different clusters. Maximum intra cluster distance was observed in cluster V comprising two groundnut genotypes *viz.*, RCM-556 and MS-48-1. Inter cluster distance was found to be maximum between cluster II and cluster V followed by cluster I and cluster V, cluster V and VI, cluster III and cluster VI, cluster II and cluster VI, cluster II and cluster V and cluster I and cluster VI and were identified genetically diverse clusters could be used for hybridization programme in crop improvement in groundnut.

Key words: Genetic divergence, D^2 statistics, Inter cluster, Intra cluster

The D^2 statistics is one of the tool to evaluate large number of germplasm lines for their genetic diversity and helps in the identification of genetically divergent parent for their exploitation in hybridization programme as hybrids between lines of diverse origin display a greater heterosis than those between closely related strains. Mahalanobis D^2 statistics (1936) is powerful tool to know the clustering pattern to establish the relationship between genetic and geographic divergence and to determine the role of different quantitative characters towards the maximum divergence. Using this method in the present study, an attempt has been made to classify the 30 genotypes of groundnut (*Arachis hypogaea* L.) to quantify the magnitude of genetic divergence for their further use in recombination breeding with expectation of getting potential transgressive segregants.

The field experiment was conducted at Research Farm, Department of Agricultural Botany, College of Agriculture, Dapoli, Dist. Ratnagiri, Maharashtra state during the rainy season of 2005. Dapoli is situated in the sub-tropical region on the 17°45' North latitude and 73°12' East longitude having elevation of 250 m above the mean sea level. Soil experimental plot was lateritic. The climate was tropical which is characterised by warm and humid. The total rainfall received during the period of field trial was 3733 mm in 94 days. The relative humidity during the crop period was in the range of 83 to 98%. The minimum temperature varied from 13°C to 25.1°C, while the maximum temperature was in the range of 26.8°C to 33.2°C.

The seed material used for the present investigation comprised of 30 genotypes of groundnut collected from National Research Centre for Groundnut, Junagadh, Gujarat. The experiment was laid out in randomised block design with 3 replications. The distance between rows to plants was 45 and 10 cm, respectively. Seed of genetic material were sown on 2nd June, 2005. The seed were sown by hand-dibbling method at a depth of 4 cm approximately. Recommended cultural practices were followed to raise the crop. The mean data of 5 plants selected randomly from middle rows of each plot and average for each genotype per replication was calculated.

The data were subjected to the Mahalanobis D^2 statistics (1936) to measure the genetic divergence. Genotypes were further grouped into different clusters by Tochers method.

Analysis of variance revealed significant differences among the genotypes for all the 15 characters suggesting adequate variability among the genotypes. Based on the relative magnitude of D^2 values 30 genotypes were grouped into six clusters (Table 1). The cluster I was largest cluster which comprised nineteen genotypes followed by cluster II and III, which had three genotypes each. Cluster IV and V had two genotypes each, while cluster VI included only one genotype and remained solitary. The above grouping indicates existence of wide genetic divergence among constitute genotypes. Katule *et al.* (1992) and Golakiya and Makne (1991) also reported the genetic divergence among groundnut genotypes.

The maximum intra cluster distance was observed in cluster V followed by cluster IV, cluster II, cluster III and cluster I, thereby indicate highest degree of variability within cluster V. The solitary cluster indicating their independent identity and importance due to the unique characters possessed by that strains. These genotypes may serve as potential parent for breeding programme.

The maximum inter-cluster distance was recorded between cluster II and cluster V followed by cluster I and V, cluster V and VI, cluster III and VI, cluster II and VI, cluster

III and V and cluster I and VI, while it was minimum between cluster I and II. The rest of the clusters maintained moderate distance among themselves as well as others. The genotypes which included in genetically diversed clusters could be used for hybridization programme in crop improvement in groundnut (Golakiya and Makne, 1991). The average cluster wise mean values for different clusters presented in table 3 showed that the genotypes included in cluster V *viz.*, RCM-556 and MS-48-1 had better average than the population mean for the clusters plant height, pods/plant, pod length, pod width, number of kernels/plant, kernel yield/plant, kernel length, kernel width, 100 kernel weight, 100 pod weight, shelling percentage and pod yield/plant. The genotypes NAS-209, GA-167 and HI-678 in cluster II had maximum values for plant height, days to flowering, number of primary branches/plant, pods/plant, number of kernels/plant, shelling percentage and days to maturity than population mean. The genotypes RCM-585, TAINAN # 1 and RCM-449-4 included in cluster III showed better mean values for days to flowering, number of primary branches/plant, pod width, kernel yield/plant, kernel length, kernel width, 100 kernel weight, 100 pod weight, shelling percentage, days to maturity and pod yield/plant than population mean. The cluster IV, comprised of 2 genotypes *viz.*, 680/73 and AMM 836, the performance of these genotypes for plant height, pod length, pod width, kernel length, kernel width, 100 pod weight and shelling percentage were superior than their respective population means. The genotypes U-2-1-35 in cluster VI which was solitary had better average for plant height, days to flowering, number of primary branches/plant, pod length, pod width, kernel length, 100 kernel weight and days to maturity. Thus, these genotypes hold great promise as parents to obtain promising elite lines through hybridization and to create further variability for these characters.

Table 1 Grouping of groundnut genotypes into different clusters by Tocher method

Cluster	Genotypes included in cluster	Name of genotypes included in cluster
I	19	STARR (3), LIU YUEH TSAO (16), NCAC-339 (8), RCM 449-2 (29), K-491 (19), RCM 455-3 (2), EC-24411 (28), IN-38 (9), MS-24 (22), SAM COL-207 (1), B-353 (14), 57-453 (10), NCAC-422 (15), MAROHHO TYPE (5), WCG-123 (20), U 4-4-6 (27), AH-7082 (4), GA 207-2 (21), CPI-10490 (13)
II	3	NAN-209 (17), GA-167 (26), HL-678 (25)
III	3	RCM-585 (30), TAINAN # 1 (11), RCM-449-4 (6)
IV	2	680/73 (23), AMM-836 (18)
V	2	RCM-556 (7), MS 48-1 (12)
VI	1	U 2-1-35 (24)

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

Cluster	I	II	III	IV	V	VI
I	**10.15**	12.23	13.27	15.86	24.71	20.64
II		**11.08**	16.01	19.28	28.87	21.71
III			**10.80**	15.67	20.69	22.32
IV				**13.10**	18.03	17.26
V					**20.66**	24.23
VI						0.00

Table 3 Cluster means for characters in 30 genotypes of groundnut

Character	Cluster						Population mean
	I	II	III	IV	V	VI	
Plant height	53.13	58.82	51.95	60.98	67.80	60.04	55.31
Days to flowering	28.59	32.77	32.22	28.66	26.83	31.00	29.34
Number of primary branches/plant	5.24	5.55	6.13	5.33	5.83	6.66	5.45
Pods/plant	12.64	14.19	12.33	8.83	12.63	8.8	12.38
Pod length	23.30	21.86	23.77	31.89	33.49	40.8	25.04
Pod width	10.68	10.79	11.99	11.39	12.8	11.13	11.03
Number of kernels/plant	22.06	24.73	20.39	19.53	32.29	19.93	22.66
Kernel yield/plant	7.78	7.98	8.7	7.07	13.13	7.21	8.19
Kernel length	12.73	13.46	14.97	15.86	18.69	13.93	13.68
Kernel width	7.30	6.97	7.8	8.03	8.4	7.00	7.43
100 kernel weight	39.05	33.46	43.82	35.46	51.22	40.66	39.60
100 pod weight	87.68	66.90	112.38	113.56	132.82	83.04	92.66
Shelling percentage	69.94	74.84	72.07	74.41	76.58	69.08	71.36
Days to maturity	117.55	119.44	120.21	117.83	116.00	120.33	118.02
Pod yield/plant	11.09	10.47	12.99	9.74	21.22	10.13	11.77

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Genetic architecture for seed yield and its components in Indian mustard (*Brassica juncea*)

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ABSTRACT

Six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2 of two Indian mustard [*Brassica juncea* (L.) Czern and Coss] crosses namely PRQ-9701-46 × Kranti (C_1) PRQ-9701-46 × Pusa Bold (C_2) were evaluated in compact family block design with 3 replications under two set of environments *viz.*, timely sown condition (TS) and late sown condition (LS). Observations were recorded on 14 important quantitative traits namely, days to flower initiation, days to 50% flowering, days to maturity, plant height, length of main shoot, number of siliquae on main shoot, number of primary branches, number of secondary branches, siliqua length, number of seeds/siliqua, seed yield/plant, 1000 seed weight, oil content and harvest-index. Additive effects were found to be more important in the inheritance of days to flower initiation. Additive × additive effect was relatively more important for all characters except days to flower initiation, days to 50% flowering, number of primary branches and number of secondary branches, dominance effect for plant height, length of main shoot, number of siliquae on main shoot, number of seeds/siliqua, seed yield/plant, 1000 seed weight, oil content and harvest index, dominance × dominance for days to flower initiation, number of primary branches, additive × dominance for number of secondary branches and plant height.

Key words: Epistasis, Gene action, Generation means, Mustard and Yield components

In recent years, though there has been an increase in the area and production of Indian mustard [*Brassica juncea* (L.) Czern and Coss], the average productivity in India is quite low compared to some of the developed countries. In India, however production of edible oils is about 50% of the requirements. Consequently, large quantities are being imported to make the shortfall, which in turn, is a heavy drain on foreign exchange resources. Vigorous efforts, therefore, are needed to increase the seed yield levels and to achieve self-sufficiency. Yield is one of the most important economic characters and is the product of multiplicative interaction of contributing characters. Hence, in the present investigation, an effort has been made to find out the inheritance of yield and its attributes for their further utilization in the mustard breeding programme.

Six generations namely, P_1, P_2, F_1, F_2, BC_1 and BC_2 of each of these two crosses *viz.*, PRQ 9701-46 × Kranti (C_1), PRQ 9701-46 × Pusa Bold were evaluated in a compact family block design with three replications in 5m long rows spaced 30 cm, apart with plant to plant distance of 10 cm during winter season of 2003. The distance of 10 cm between plants was maintained by thinning. One border row on either side of main plots was sown with a variety of mustard (Vardan) and was treated as non-experiment. The whole experiment was planted at two sowing dates *viz.*, 22nd October, 2003 for timely sown condition (TS) and 13th November, 2003 for late sown condition (LS). The number of rows was different for different progenies. Each plot thus consisted of different number of rows i.e., single row for parents (P_1 and P_2) and F_1s three rows for backcrosses (BC_1 and BC_2) and seven rows for F_2 generations. Ten randomly selected plants each of P_1, P_2 and F_1, 40 plants of F_2 and 20 plants each of BC_1 and BC_2 generations were utilized for recording observations on various characters. Observations were recorded on important quantitative traits namely, days to flower initiation, days to 50% flowering, days to maturity, plant height, length of main shoot, siliquae on main shoot, number of primary branches, number of secondary branches, siliqua length, number of seeds/siliqua, seed yield/plant, 1000 seed weight, oil content and harvest index. Recommended package of practices were followed to grow the crop. The data were subjected to scaling test (Mather, 1949) to detect the presence of epistasis and genetic parameters m, d, h, I, j, and l were estimated. In case of significance of scaling tests, data were then subjected to the estimation of various genetic components as per Jinks and Jones (1958). More precise estimates of these parameters were then obtained by using joint scaling tests (Cavalli, 1952). Adequacy of two models i.e., additive-dominance (3

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parameters) and digenic interactions (5 parameters) model was tested by joint scaling tests. In case, where additive-dominance (3 parameters) and digenic interaction (5 parameters) models were inadequate, parameters of complex model, digenic interactions (6 parameters) model have been described.

The scaling test A,B,C and D revealed significance deviation from zero in all the crosses for all the characters except C_1 (LS) for days to flower initiation; C_1 (LS) and C_2 (TS) for days to 50% flowering; C_2 (TS and LS) for days to maturity; C_1 (LS) for length of main shoot; C_1 (LS) for siliquae on main shoot; C_2 (LS) for siliqua length; C_2 (TS) for seed yield/plant; C_1 (TS and LS), C_2 (LS) for 1000 seed weight and C_1 (TS) for oil content. The significance of any one of four scales is taken to indicate the presence of non-allelic interaction and hence adequacy of an epistatic or non-epistatic model. Non-significant estimates of all the 4 scaling tests showed the adequacy of non-epistatic model. Though the estimates of simple scaling tests indicated that an epistatic model was required for detecting and estimating the epistatic effect for, days to 50% flowering in C_2 (LS), number of secondary branches in C_1 (LS), siliqua length in C_2 (TS), harvest index in C_2 (TS), no epistatic effect was found significant under digenic interaction model (Table 1). The non-significance of joint scaling test for, plant height in C_1 (LS) length of main shoot in C_2 (LS), siliquae on main shoot in C_2 (TS), number of seeds/siliqua in C_1 (LS), seed yield/plant in C_1 (LS) clearly showed a good fit of additive-dominance model for the respective characters, but at the same time significance of A,B,C and D scales showed the presence of digenic or still higher order interaction and or linkage in the inheritance of these traits (Table 1). The discrepancy between the results of individual scaling tests and parameters of digenic interaction model may be attributed to dispersion of interaction genes or the internal cancellation of gene effects. Mather and Jinks (1971) also showed that such a balancing action is frequently introduced by positive and negative increments made by different loci involved and ultimately in contribution in generation means.

The estimates of gene effects and interactions for the best fit model with different traits in two crosses of Indian mustard are given in table 2. Partitioning of the genetic components of variance indicated that mean (m) values were highly significant for all the characters in all the crosses. The inheritance pattern varied with cross, character and sowing condition. Importance of epistatic variation in the inheritance of various quantitative traits was revealed from significant estimates of gene effects for different crosses under two environments. Additive (d) component was more important in the inheritance of days to flower initiation, revealed that selection in early segregations generation would be effective for obtaining genetic gain of this character. Dominance gene effect (h) is having important role in governing the inheritance of plant height, length of main shoot, number of siliquae on main shoot, siliqua length, seed yield/plant, 1000 seed weight, oil content and harvest index. Both additive and dominance gene effects were involved in the expression of days to 50% flowering, days to maturity, number of secondary branches and number of seeds/siliqua.

The fixable component, additive × additive (I) was found to be most important interaction component being significant and in desirable direction for days to maturity, plant height, length of main shoot, siliqua on main shoot, siliqua length, number of seeds/siliqua, seed yield/plant, 1000 seed weight, oil content and harvest index. Among the interaction, dominance × dominance (l) was relatively more important component by virtue of its higher magnitude and desirable direction for days to flower initiation, days to 50% flowering and number of primary branches, whereas, additive × dominance (j) gene effect governed the expression of number of secondary branches.

Opposite sign of 'h' and 'l' components indicated the operation of duplicate epistasis in almost all the crosses for various quantitative characters under both environments indicated hindrance in selection improvement. In this situation, reciprocal recurrent selection is likely to be useful for the effective utilization of both types of additive and non-additive gene action simultaneously, while complementary epistasis was observed for number of primary branches in cross 2 under late sown condition showed considerable amount of heterosis in negative direction.

Additive effect (d) was highly significant for the inheritance of days to flower initiation. Among the interaction effects dominance × dominance (l) was relatively more important component having higher magnitude and desirable (negative) direction. Negative sign of significant effects indicated that the genes for earliness were dominant over the genes for lateness. Inadequacy of additive-dominance model in C_1 (LS) indicated that, either gene interaction or linkage or both are playing an important role in expression of this character. For days to flower initiation duplicate epistasis and dominance × dominance (l) interaction contributed significantly along with additive gene effects. Therefore, the improvement in this trait may not be feasible with simple breeding methods. So recurrent selection method may be applied. These results akin to the results obtained by Kant and Gulati (2001) and Sridhar and Raut (2003).

Additive (d) as well as dominance (h) effect was more pronounced and in desirable direction for the inheritance of days to 50% flowering. Epistatic effect were absent in both the crosses. Absence of epistasis in these crosses is due to inter cancellation of positive and negative epistatic effect of parents. Present findings are in agreement with the results obtained by Sridhar and Raut (2003).

For days to maturity additive and dominance effects were significant. Among the interactions, additive × additive (I) were significant in C_1 while epistatic effect were absent in C_2 under both condition. There were negative dominance gene effects for days to maturity in C_1 (TS and LS), C_2 (TS) which showed that crop duration could be decreased by exploiting these to develop early maturing mustard cultivars. Kant and Gulati (2001) and Sridhar and Raut (2003) obtained the same results.

Inheritance of plant height was controlled by dominance effect (l). The fixable component, additive × additive (l) was found to be most important interaction component being significant and in desirable direction. This suggested that selection for plant height would be more fruitful if selection is delayed till dominance component is reduced due to selfing. Similar results were obtained by Varsha *et al.* (1999).

Considering the magnitude and direction, dominance component (h), dominance × dominance (negative significant), additive × additive (positively non-significant) were important in the inheritance length of main shoot. Negative sign of 'l' parameter for length of main shoot indicated reducing effect in the expression of this character.

An estimate of gene effect revealed that dominance and additive × additive gene effects governed the expression of siliquae on main shoot. Verma *et al.* (1992) reported presence of additive 'd', dominance 'h' and 'I' 'j' and 'l' epistasis for this traits. Dominance (h), additive × additive (I), dominance × dominance (l) gene effect was important for the expression of number of primary branches. Negative sign of additive × additive effects showed the presence of dissociated gene pairs for this trait. Additive component had a negative sign coupled with duplicate epistasis indicating the possibility of direct exploitation of heterosis. Further recurrent selection may yield fruitful results. Verma *et al.* (1992) and Rishipal and Kumar (1993) obtained similar results.

Dominance effects were important for the inheritance of number of secondary branches in both crosses under TS condition, dominance being more in magnitude. Among the interactions, additive × dominance (j) effect was important. Similar finding obtained by Verma *et al.* (1992) and Singh and Srivastava (1999). Inheritance of siliqua length was controlled by dominance and additive × additive gene effects. The role of G×E interaction was indicated as 3 parameter model best fitted under late sown condition but not under timely sown condition for this trait. Existence of appreciable additive × additive gene effects in two crosses in timely sown condition for this trait reflects the possibility of making effective improvement by selection. Present findings are in agreement with Singh and Srivastava (1999).

Additive and dominance effects were responsible for the inheritance of number of seeds/siliqua. Additive × additive type of epistasis was also present, indicating that this trait might be improved by selection in later generations in C_1 (TS). Epistatic effects were absent in C_1 (LS). Non-allelic effects were absent in C_1 (LS) and C_2 (TS and LS) because of adequacy of additive-dominance model for this trait. Present findings are supported by Rishipal and Kumar (1993) and Singh and Srivastava (1999).

Dominance effect (h) contributed significantly in the inheritance of seed yield/plant. Among the interaction effects additive × additive (I) was significant. Role of G×E interaction was also observed for this trait. Verma *et al.* (1992), Singh and Srivastava (1999), Kant and Gulati (2001) reported similar resulted for this traits.

For 1000 seed weight, dominance effect and additive × additive (I) dominance × dominance (l) effects were important in C_2 (TS). Additive-dominance model was found adequate for C_1, indicating the absence of epistatic effects. The role of G×E interaction was recorded as 3 parameter model was adequate under LS condition but not under TS condition in C_2. Singh and Srivastava (1999), Kant and Gulati (2001) also reported similar results.

Dominance effect (h) and additive × additive (I) gene effects governed the expression of oil content and harvest index. Present finding were in accordance with Yadava *et al.* (1990). Two crosses had significant positive dominance effect and their magnitude was also higher than that of additive effect (d) suggesting greater importance of dominance effect (h). The presence of duplicate epistatis for two crosses further confirmed the prevalence of dominance effect. Significant additive × additive action fraction of intra allelic interaction however indicated the possibility of manipulating these traits by selection in subsequent generations.

Considering overall results it was apparent that most of the characters in either of the crosses were found to be under the control of additive and non-additive gene effects coupled with duplicate type of epistasis indicating that heterosis breeding and recurrent selection would be more fruitful for the improvement of most of the characters. The duplicate epistasis for most of the characters showed their complex nature of inheritance. Therefore, breeding strategies should be designed accordingly to get desired results. Use of reciprocal recurrent selection has been suggested to improve the characters when both additive and non-additive genes are involved in expression of traits.

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Table 1 Scaling tests and joint scaling test in respect of seed yield and yield attributing traits in two environments

Crosses	Environment	A	B	C	D	Joint scaling test (x^2 at 3 d.f.)	Best fit model (parameter)
Days to flower imitation							
C_1	TS	0.00	2.93**	2.24*	3.88**	16.82*	5
	LS	0.47	1.62	0.89	1.45	5.37(ns)	3
C_2	TS	0.81	2.75**	6.73**	3.53**	47.97*	6
	LS	0.42	2.31*	4.43**	0.06	21.97**	5
Days to 50% flowering							
C_1	TS	1.76	0.50	2.23	1.74	0.75(ns)	3
	LS	0.32	0.48	0.91	1.06	1.55(ns)	3
C_2	TS	1.11	1.17	0.21	0.24	4.20(ns)	3
	LS	1.33	2.31*	0.61	0.55	7.58*	6
Days to maturity							
C_1	TS	4.24**	4.21**	0.08	3.40**	35.64*	5
	LS	2.01*	1.60	3.39**	3.13**	23.09	6
C_2	TS	0.19	1.34	0.24	0.85	2.21(ns)	3
	LS	0.98	0.40	1.00	0.46	1.28(ns)	3
Plant height							
C_1	TS	15.93**	17.34**	5.81**	15.19**	492.57*	6
	LS	0.22	0.24	1.96*	1.93	7.71(ns)	3
C_2	TS	0.98	5.71**	6.27**	4.35**	64.37*	6
	LS	3.59**	2.18	0.99	2.05	17.98*	5
Length of main shoot							
C_1	TS	11.50**	23.76**	2.43*	3.87**	632.39*	5
	LS	0.55	1.45	0.49	0.74	2.17(ns)	3
C_2	TS	2.18*	3.56**	0.06	2.44*	16.88*	5
	LS	3.96**	2.08*	2.98**	0.01	18.65*	3
Siliqua on main shoot							
C_1	TS	12.50**	9.75**	2.88**	4.46**	185.90*	5
	LS	0.98	1.78	0.66	0.75	3.55(ns)	3
C_2	TS	0.52	0.94	2.37*	1.58	6.14(ns)	3
	LS	4.05**	3.00**	1.88	5.98**	40.02	5
Number of primary branches							
C_1	TS	4.66**	5.13**	5.83**	2.74**	54.04*	6
	LS	1.27	0.04	3.36**	2.72**	19.32*	5
C_2	TS	2.56*	3.16**	11.53**	4.69**	135.90*	5
	LS	4.14**	1.11	8.04**	3.47**	67.49*	5
Number of secondary branches							
C_1	TS	15.51**	21.46**	6.65**	13.70**	656.31*	6
	LS	0.23	0.67	4.40**	2.44*	21.85*	5
C_2	TS	21.46**	16.08**	12.98**	1.22	600.84*	6
	LS	2.67**	0.70	13.30**	3.47**	206.37*	5
Siliqua length							
C_1	TS	2.18*	0.40	3.93**	2.77*	17.38*	5
	LS	2.56*	0.96	1.89	1.01	7.41(ns)	3
C_2	TS	2.81**	2.74**	3.53**	1.47*	23.03	5
	LS	0.29	0.17	1.73	1.63	3.80(ns)	3
Number of seed/siliqua							
C_1	TS	0.25	3.24**	2.50**	4.34*	36.26	6
	LS	0.12	0.15	2.25*	2.36	6.38(ns)	3
C_2	TS	0.39	2.57**	0.00	1.53	6.99(ns)	3
	LS	1.21	1.57	1.20	1.08	4.88(ns)	3
Seed yield/plant							
C_1	TS	2.78**	2.46*	2.46*	2.17*	15.04*	5
	LS	0.02	1.04	2.61**	0.07	7.53(ns)	3
C_2	TS	2.32*	1.13	1.41	0.99	6.00(ns)	3
	LS	6.41**	3.50**	5.32**	1.75	56.39*	5
1000 seed weight							
C_1	TS	1.20	0.57	1.31	1.78	4.49(ns)	3
	LS	0.06	0.21	0.44	0.22	0.24(ns)	3
C_2	TS	4.21**	3.09**	0.64	3.41**	27.47*	5
	LS	1.31	0.38	0.10	0.36	1.73(ns)	3
Oil content							
C_1	TS	1.38	1.52	0.10	1.29	4.12(ns)	3
	LS	2.14*	1.05	0.68	2.76**	8.63*	5
C_2	TS	1.88	1.67	0.76	2.51*	7.78(ns)	5
	LS	3.06**	0.78	0.32	2.00*	28.09*	5
Harvest index							
C_1	TS	2.78**	1.96*	0.75	1.86	11.52*	5
	LS	0.08	0.39	2.70**	3.19**	10.92*	5
C_2	TS	1.62	2.39*	0.86	1.08	10.71*	6
	LS	4.90**	5.29**	2.06*	2.62*	48.13*	5

C_1 = PRQ-9701-46 x Kranti; C_2 =PRQ-9701 x Pusa Bold; TS=Timely sown condition; LS=Late sown condition, ns=Non significant

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

Table 2 Estimates of gene effects and interactions along with standard error and type of epistasis for various quantitative traits in two environments

Crosses	Condition	m	d	h	i	j	l	χ2	Type of epistasis
Days to flower initiation									
C_1	TS	37.50**±1.91	-1.83*±0.33	15.16*±4.92	7.33*±1.88	-3.66±1.49	-10.99*±3.12	-	Duplicate
	LS	56.42**±1.05	-0.23±1.05	-6.44*±1.91	-	-	-	5.37(ns)	-
C_2	TS	40.49**±1.91	-2.83**±0.33	3.49±4.92	6.67*±1.89	3.00±1.49	-2.33±3.12	-	-
	LS	59.37**±6.22	-3.97*±0.61	-22.77±17.94	-2.06±6.10	-	16.07±11.80	0.11 (ns)	-
Days to 50 % flowering									
C_1	TS	50.89**±0.34	-3.13**±0.33	-3.96**±0.52	-	-	-	7.52 (ns)	-
	LS	64.68**±0.43	-1.40*±0.39	-5.43**±1.16	-	-	-	1.55 (ns)	-
C_2	TS	50.22**±0.37	-1.42**±0.35	-4.61**±0.85	-	-	-	4.20 (ns)	-
	LS	69.83**±7.21	-3.50**±0.74	-14.16±19.03	-4.00±7.18	13.66±5.69	5.00±12.03	-	-
Days to maturity									
C_1	TS	155.37**±4.09	-2.99**±0.47	-41.12**±9.40	-13.47*±9.40	-	27.40**±5.48	0.50 (ns)	Duplicate
	LS	145.16**±3.85	-2.49*±0.47	-25.16*±8.49	-11.99±3.82	5.00*±1.76	10.99±4.85	-	-
C_2	TS	141.52**±0.40	-1.70**±0.39	-3.38**±0.86	-	-	-	2.21 (ns)	-
	LS	132.98**±0.70	-1.26±0.68	0.44±1.09	-	-	-	1.28 (ns)	-
Plant height									
C_1	TS	118.33**±2.90	-6.93**±0.61	154.45**±7.12	43.06**±2.83	4.66±2.05	-107.85**±4.97	-	Duplicate
	LS	160.56**±2.59	-3.19±2.57	16.47*±5.44	-	-		7.71(ns)	-
C_2	TS	154.41**±3.72	-5.63**±0.80	24.20*±8.82	15.89*±3.64	10.20**±2.52	-9.82±5.23	-	-
	LS	31.73**±13.68	-0.51±2.42	100.29*±31.95	26.69±13.13	-	-67.92**±18.86	0.89 (ns)	Duplicate
Length of main shoot									
C_1	TS	22.46±6.01	-2.40**±0.43	91.27*±12.21	23.27±6.00	-	-61.44**±6.29	0.126(ns)	Duplicate
	LS	38.22**±1.44	-0.56±1.31	8.99*±3.01	-	-	-	2.17 (ns)	-
C_2	TS	41.29**±3.35	-1.57**±0.34	29.34*±7.74	8.70±3.31	-	-17.60**±4.66	0.00 (ns)	Duplicate
	LS	37.28**±5.73	1.33±0.99	19.44±13.29	-1.77±5.38	-	-18.43±8.27	2.25 (ns)	-
Siliqua on main shoot									
C_1	TS	16.66*±3.73	-1.08**±0.28	63.81**±8.00	16.91*±3.72	-	-45.34**±4.60	1.34 (ns)	Duplicate
	LS	29.51**±1.72	-1.55±1.33	3.67±3.35	-	-	-	3.55 (ns)	-
C_2	TS	36.44**±0.59	-0.38±0.59	1.30±0.93	-	-	-	6.14 (ns)	-
	LS	11.67**±2.33	0.06±0.78	43.83**±6.91	10.54**±1.80	-	-28.50**±5.07	1.42 (ns)	Duplicate
Number of primary branches									
C_1	TS	3.78**±0.34	-0.28**±0.03	4.61*±0.98	0.93±0.33	-1.16±0.31	-3.03*±0.65	-	Duplicate
	LS	9.21**±1.03	-0.23±0.14	-7.07*±2.67	-3.68*±1.01	-	3.02±1.90	1.59 (ns)	-
C_2	TS	6.14**±0.38	0.11*±0.03	-2.13±1.02	-1.79**±0.38	-	0.48±0.66	0.01 (ns)	-
	LS	6.54**±0.68	-0.12±0.12	-1.39±1.84	-2.28*±0.67	-	-0.58±1.24	1.29 (ns)	Complementary
Number of secondary branches									
C_1	TS	-2.26*±0.56	-0.033±0.13	29.43**±1.35	7.53**±0.54	-1.33*±0.40	-18.99**±0.83	-	Duplicate
	LS	16.46*±4.52	-1.18±0.95	-15.61±12.98	-11.09±4.39	-	8.18±8.62	0.13 (ns)	-
C_2	TS	4.90**±0.49	0.46**±0.04	6.06**±1.05	-0.59±0.48	0.46*±0.18	-5.33**±0.60	-	Duplicate
	LS	16.45**±1.88	0.05±0.42	-19.88*±5.48	-12.01**±1.80	-	7.97±3.63	3.58 (ns)	-
Siliqua length									
C_1	TS	3.85**±0.33	0.56±0.07	1.16±0.85	0.79*±0.30	-	-0.15±0.55	1.61 (ns)	-
	LS	4.45**±0.11	0.07±0.11	0.16±0.21	-	-	-	7.41 (ns)	-
C_2	TS	4.38**±0.63	-0.01±0.07	0.55±1.41	0.93±0.63	-	0.30±0.79	0.01 (ns)	-
	LS	4.66**±0.07	0.09±0.06	0.48*±0.14	-	-	-	3.80 (ns)	-
Number of seeds/siliqua									
C_1	TS	9.78**±0.63	0.21±0.07	7.78*±1.81	2.73**±0.62	-1.16±0.59	-4.16*±1.25	-	Duplicate
	LS	13.16**±0.16	-0.01±0.18	0.51±0.45	-	-	-	6.38 (ns)	-
C_2	TS	12.89**±0.10	0.43**±0.10	0.38±0.16	-	-	-	6.99 (ns)	-
	LS	12.66**±0.14	0.30±0.14	0.66±0.30	-	-	-	4.88 (ns)	-
Seed yield/plant									
C_1	TS	-8.76±6.17	0.18±0.89	52.47*±17.61	12.58±6.07	-	-34.55*±11.67	0.61 (ns)	Duplicate
	LS	5.28**±0.37	-1.08±0.56	2.32*±0.67	-	-	-	7.53 (ns)	-
C_2	TS	7.88**±0.80	1.77*±0.71	2.14±1.76	-	-	-	6.00 (ns)	-
	LS	-0.47±1.53	0.37±0.34	17.35**±4.01	3.47*±1.42	-	-13.67**±2.54	2.39 (ns)	Duplicate
1000 seed weight									
C_1	TS	3.04**±0.09	0.07±0.09	0.003±0.09	-	-	-	4.49 (ns)	-
	LS	2.86**±0.10	0.004±0.09	-0.02±0.16	-	-	-	0.24 (ns)	-
C_2	TS	1.71*±0.44	-0.21*±0.03	4.36*±0.98	1.58*±0.44	-	-2.82**±0.57	0.67 (ns)	Duplicate
	LS	3.08**±0.06	-0.10±0.05	-0.84±0.12	-	-	-	1.73 (ns)	-
Oil content									
C_1	TS	39.20**±0.50	1.09±0.47	1.94±1.00	-	-	-	4.12 (ns)	-
	LS	28.53**±2.43	-0.84±0.50	21.25*±6.71	6.83*±2.39	-	-12.44**±4.44	0.23 (ns)	Duplicate
C_2	TS	36.88**±1.30	-0.96±0.45	10.43*±3.84	3.06*±1.25	-	-718*±2.76	0.68 (ns)	Duplicate
	LS	28.25**±1.58	-0.79±0.41	23.40**±4.45	7.27**±1.40	-	-15.24**±3.49	0.46 (ns)	Duplicate
Harvest index									
C_1	TS	1.40±6.74	0.72±1.33	50.76*±15.91	12.35±6.30	-	-30.28*±9.70	0.24 (ns)	Duplicate
	LS	5.61±3.21	-0.29±0.51	23.26*±7.31	9.77*±3.02	-	-9.04±4.32	0.09 (ns)	-
C_2	TS	13.15±6.78	-0.75±0.88	17.52±14.36	7.32±6.72	6.82±2.59	-8.72±7.81	-	-
	LS	0.42±4.65	-0.85±0.70	46.59**±10.45	11.96±4.50	-	-33.66**±6.08	0.26 (ns)	Duplicate

C_1 = PRQ-9701-46 x Kranti; C_2=PRQ-9701 x Pusa Bold; TS=Timely sown condition; LS=Late sown condition; ns=Non-significant
*=Significant at 5% level; **=Significant at 1% level

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Short communication

Genetic variability for yield and yield components in Indian mustard (*Brassica juncea*)

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ABSTRACT

A study on genetic variability was made with 36 genotypes (8 diverse parents + 28 F_1s) for eight quantitative characters in Indian mustard [*Brassica juncea* (L.) Czern & Coss.]. Analysis of variance revealed significant differences among the genotypes (parent vs. crosses) for all the characters except number of seeds/siliqua. The magnitude of PCV was higher than GCV for all the characters, suggesting the role of environmental variance. High heritability was observed for number of siliquae/plant and 1000 seed weight. The estimate of high heritability accompanied with high expected genetic advance for siliquae/plant and 1000 seed weight indicating the presence of additive gene action in the expression of these traits.

Key words: Genetic advance, Heritability and Variability

Rapeseed- mustard [*Brassica juncea* (L.) Czern & Coss.] is an important group of oilseed crops in the world. Mustard oil is widely used as cooking oil in the whole world as well as in India. Indian mustard is an important oilseed crop covering about 80% of the rapeseed-mustard cropped area in the country. But the productivity of this crop is low in India as compared to other countries. The area, production and productivity of rapeseed-mustard has been estimated to increase 6.18 m.ha, 7.36 m. t. and 1190 kg/ha, respectively during 2008-09. The knowledge of nature and magnitude of genetic variability is of immense value for planning efficient breeding programme to improve the yield potential of genotypes. Heritability and genetic advance of seed yield and its component help to assess the genetic gain that can be obtained by selection hence, present study was undertaken to gather information on variability, heritability and genetic advance in genotypes (parent vs. crosses) for eight characters.

The present investigation was carried out using 36 genotypes (8 parents + 28 F_1s) of Indian mustard. The material was grown at research farm of Birsa Agriculture University, Ranchi in randomized complete block design with three replication in single row of 5m length having an inter and intra row spacing of 30 cm and 10 cm respectively during winter season 2006. Observations were recorded for 5 randomly taken plants from parents and F_1s in each replication for days to 50% flowering, days to maturity, plant height (cm), number of siliquae/plant, number of seeds/siliquae, seed yield/plant (g), 1000 seed weight (g) and oil content (%). Genotypic and phenotypic co-efficient of variance (GCV and PCV) were estimated based on formulae given by Burton (1952) and heritability and genetic advance (GA) were calculated according to Lush (1949).

The analysis of variance revealed highly significant difference among the genotypes for all the characters studied, except, number of seeds/siliquae. This observation indicated the preference of substantial amount of genetic variability in the genotypes for most of the characters under study. Parent's vs. crosses were also highly significant for all the characters, except, number of seeds/siliqua and 1000 seed weight (Singh *et al.*, 2009). The magnitude of PCV was higher than GCV for all the characters, indicating the effect of environment on the expression of the traits. High GCV was found for number of siliquae/plant, seed/siliquae indicating that selection with these characters may be a good approach for enhancing seed yield of the genotypes (Table 1). Similar results were also reported by Singh *et al.* (2002). Genetic co-efficient of variation help to measure the range of genetic variability present in the particular character. However, it is not possible to determine the amount of heritable variation with the help of GCV alone. Burton (1952) suggested that genetic co-efficient of variation alone with heritability estimate would be more useful than the heritability value alone. Panse (1956) suggested that if the heritability is mainly due to non-additive genetic effect, the genetic gain would be low. On the other hand where heritability is chiefly due to additive effect of gene, a high genetic advance (GA) may be expected. In the present study, the estimate of heritability was high in number of siliquae/plant, 1000 seed weight, days to 50% flowering and days to maturity. The GA as per cent of mean was high for number of siliquae/plant, seed yield/plant and 1000 seed weight. The estimate of high heritability accompanied with high GA for siliquae/plant and 1000 seed weight indicating the predominance of these additive gene action in the expression of these characters. Phenotypic selection on the basis of these characters may be effective for yield improvement. High heritability associated with lower GA for day to 50% flowering and days to maturing may be due to lack of genetic variability. A low heritability with low GA was observed for plant height, number of seeds/siliqua and oil content, suggesting that environment has a major role in its expression. Its is concluded that improvement of seed yield could be achieved by selection for number of siliquae/plant and 1000 seed weight.

Table 1 Phenotypic and genotypic variability in Indian mustard

Characters		Range	Mean ± SE	GCV	PCV	Heritability (%)	GA (%)
Days to 50% flowering	P	55.0-64.0	59.2 ± 0.54	4.8	4.9	92.6	9.4
	C	51.0-65.0	56.9 ± 0.43	5.9	6.0	95.0	12.2
Days to maturity	P	114.0 -119.7	117.3 ± 0.49	1.6	1.7	83.8	3.0
	C	110.3 -119.0	116.8 ± 0.45	1.7	1.8	84.5	3.1
Plant height (cm)	P	127.9 -140.5	133.9 ± 6.35	2.6	7.0	13.8	2.0
	C	126.3 -168.6	138.8 ± 5.79	4.7	8.9	27.9	4.9
Siliquae/plant	P	218.3 -312.9	255.9 ± 6.67	11.5	12.5	85.0	21.8
	C	239.3- 497.1	341.3 ± 7.03	24.4	24.9	96.3	37.0
Seed/siliquae	P	12.3 -14.1	13.2 ± 0.55	2.9	7.7	14.3	2.3
	C	12.3 -14.6	13.5 ± 0.52	1.7	7.2	5.6	8.4
Seed yield/plant (g)	P	8.9 -15.7	11.8 ± 0.44	17.9	20.4	77.3	32.4
	C	10.9 -21.5	15.2 ± 0.71	22.5	24.5	84.3	33.1
1000 seed weigh (g)	P	3.5 - 4.7	4.3 ±0.17	9.3	11.7	63.5	15.2
	C	3.3 - 5.3	4.2 ± 0.18	36.2	36.9	96.2	73.2
Oil content (%)	P	38.4 - 41.9	39.7 ± 0.55	2.6	4.0	41.8	3.5
	C	38.4 - 42.0	40.3 ± 0.69	1.6	3.5	22.0	1.6

P : Parent; C : Cross

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GM 3 : Early maturing, high yielding and bold seeded variety of mustard (*Brassica juncea*) for Gujarat

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ABSTRACT

Breeding efforts were made to develop bold seeded early maturing varieties suitable for short winter period of Gujarat area. Because of these efforts, the line SKM 9927 (GM3) was isolated and evaluated for its yield potentiality along with national and zonal check varieties (Varuna, GM 1 and GM 2) at different locations of Gujarat under state and AICRP trials. Compared to check varieties, SKM 9927 variety matured earlier (108 days) and recorded a higher mean seed yield of 2175 kg/ha. The seed size was also bold (6.02g/1000 seed weight) with a high oil content of 40.06%.

Key words: Bold seed, Early maturing, Mustard

Rapeseed-Mustard is an important oilseed crop in India after groundnut. The crop accounts for 22.7% of the total oilseeds production and 19.2% of the total cropped area in the country. Winter season in Gujarat is short but crop is well suited and cultivated in 3.48 lakh ha area with production of 4.76 lakh t. and productivity 1369 kg/ha. The productivity is higher than national productivity (1056 kg/ha) (Anonymous, 2006). In Gujarat mustard is well suitable as winter crop, which is more remunerable than wheat, fetching higher price requiring less irrigations. Earlier, the GM 1 and GM 2 varieties were developed by the University, GM 1 is early maturing, high yielding variety, with a medium seed size. The variety GM 2 matures one week late as compared to GM 1. However, it was felt essential to develop bold seeded early maturing varieties for short winter period of Gujarat.

With a view to develop bold seeded early maturing varieties suitable for short winter period for area of Gujarat, the breeding efforts were initiated at Main Castor-Mustard Research Station, Sadarkrushinagar. The crosses were attempted between RSK 78 and Varuna in year 1992-93 and segregating material were handled through pedigree method. As a result, the line SKM 9927 (GM 3) was isolated and evaluated for its yield potentiality at different locations of Gujarat under State and AICRP trials during 1999 to 2003 along with checks (Anonymous, 2004). It was tested at 16 locations in LSVT, in SSVT at 4 locations as well as a location in PYT. In AICRP trials it was tested at 16 locations in different mustard growing zones of country. The seed yield data recorded for this newly developed variety along with three checks *viz*., Varuna, GM 1 and GM 2 of all the locations of Gujarat. The SKM 9927 recorded the mean seed yield (average of 19 trials) of 2175 kg/ha against 1859 kg/ha of Varuna. 1953 kg/ha of GM 1 and 1922 kg/ha of GM 2 with an yield improvement of 17.4, 10.2 and 13.2% over the checks, Varuna (NC), GM 1 (SC) and GM 2 (SC), respectively (Table 1).

The yield performance of this variety in AICRP trials is presented in table 2 which indicated that this variety has given mean seed yield of 1757 kg/ha (16 locations) which was 22.5, 16.2 and 21.9% higher over the checks Varuna (NC), Kranti (NC) and RL 1359 (ZC), respectively.

GM 3 was tested under rainfed conditions in AICRP trials at five locations (Baval, Shriganganagar of Zone II and Shillongani, Kanke Dholi of Zone V) recorded 1055 kg/ha yield under rainfed condition which was 11.9 and 42.2% higher over Varuna and Pusa bold, respectively.

The performance of SKM 9927 in FLD during 2002-04 indicated 27.5, 15.8 and 13.7% higher yield over the checks Varuna, GM 1 and GM 2, respectively. SKM 9927 (GM 3) was screened for powdery mildew and aphid of mustard during 2000-04 under natural conditions with Varuna (NC) and two state checks GM 1 and GM 2 indicated its performance at par with released variety (Anonymous, 2004). The variety was tested for major pest Allete aphid under natural condition with national and state checks indicate its tolerant to this prevalent pest.

The performance of this variety under different fertility levels were tested which indicated that it has given maximum yield over all the varieties tested and recorded yield when it was fertilized with 125 recommended dose of fertilizer i.e., 75-50-30 NPK kg/ha.

Morphological features of SKM 9927 (GM 3) and two check varieties are presented (Table 3). A perusal of this table indicated that this variety mature at the earliest (108 days) over the all checks, which is a desirable feature for mustard cultivation in Gujarat, because winter being a shorter period in Gujarat. The number of seeds per siliquae are higher than the checks. The seed size is bolder (6.02 g/1000 seed weight) than all the checks, The bold seeded varieties are preferred and purchased by oil exaction industries. In addition to performance for bold seed, variety GM 3 (40.06%) is also preferred for its higher oil content as compared to Varuna (38.36%), GM 1 (40.53%) and GM 2 (40.10%). Due to its consistent superior performance under irrigated conditions in different trials and under rainfed conditions, early maturing habit (108 days) with bold seeded high oil content, responsiveness to fertilizer, the variety, SKM-9927 has been released and notified by Central Variety Release Committee for mustard growing area of whole Gujarat in the year 2007.

Table 1 Mean performance of mustard genotype SKM 9927 (GM 3) at different location in Gujarat (1999-2000 to 2003-04)

Location	Trials	Year	Mean yield (kg/ha)				% increase over		
			GM 3	Varuna	GM 1	GM 2	Varuna	GM 1	GM 2
North Gujarat (S.K.Nagar, Vijapur, Ladol)	8	1999-04	2768 (8)	2339 (8)	2532 (8)	2400 (4)	18.3	9.3	15.3
Middle Gujarat (Anand)	4	2000-04	2290 (4)	2094 (4)	2178 (4)	2184 (4)	9.4	5.1	4.9
South Gujarat (Navasari, Waghi)	3	2000-03	1423 (3)	1164 (3)	1140 (3)	1305 (3)	22.3	24.8	9.0
Saurashtra Kutch	4	2001-03	1436 (4)	1155 (4)	1277 (4)	1167 (4)	24.3	12.5	23.1
Grand Mean			2175 (19)	1853 (19)	1973 (19)	1922 (19)	17.4	10.2	13.2

Table 2 Performance of SKM 9927 (GM 3) under AICRP trials (2002-03)

Zone/Center	Trials	Seed yield (kg/ha)				% Increase over		
		SKM 9927	Varuna	Kranti	RL 1359	Varuna	Kranti	RL 1359
Zone II	4	1940 (4)	1364 (4)	1558 (4)	1449 (4)	42.2	24.5	23.9
Zone III	7	1673 (7)	1526 (7)	1468 (7)	1436 (7)	9.6	14.0	16.5
Zone IV	2	2317 (2)	1768 (2)	2084 (2)	-	28.9	11.2	-
Zone V	3	1333 (3)	1074 (3)	1176 (3)	-	24.1	13.4	-
Grand Mean		1757 (16)	1434 (16)	1512 (16)	1441 (16)	22.5	16.2	21.9

Table 3 Morphological description of SKM 9927 (GM 3) and checks

Descriptor	Genotypes			
	GM 3	Varuna	GM 1	GM 2
Plant type	Compact	Compact	Compact	Compact
Days to maturity	108	113	108	114
Plant height (cm)	159.3	156.1	142.8	159.9
Number of branches/plant	17.5	17.3	18.4	18.2
Number of silique/plant	317	325	327	328
Length of *siliqua* (cm)	4.10	3.98	4.01	4.18
No. of seeds/siliqua	14.3	12.4	12.3	13.4
1000 seed weight (g)	6.02	5.16	5.01	5.59
Oil Content	40.06	38.36	40.53	40.10

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Correlation studies in F_3 generation of crosses involving mono/shy branch and branched genotypes in sesame (*Sesamum indicum*)

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ABSTRACT

Correlation analysis was carried out in direct and reciprocal direction of 18 crosses involving mono and branched genotypes of sesame (*Sesamum indicum* L.). The study revealed that seed yield was positively correlated with number of capsules/plant in all parents and crosses. The crosses and parents had differential association between plant height and number of branches. Number of seeds/capsule and 100 seed weight showed non-significant correlation with yield in most of parents and crosses. The differential association in the crosses irrespective of the parents involved may be due to contrast plant types of shy and more branched types involved in the crosses. Hence. specific selection indices are necessary for each cross for effective selection programme. Crosses with no association between number of branches and seed yield can be profitably exploited to evolve high yielding mono/shy branching types.

Key words: Correlation, Seed yield and Sesame

Yield is a complex quantitative trait and greatly influenced by environment. Hence it is necessary to assess the association of component character with seed yield in various cross combinations to formulate selection indices. In the present study, correlation analysis as carried out in direct and reciprocal direction of ten crosses involving mono/shy branch and branched genotypes of sesame (*Sesamum indicum* L.).

The sesame genotypes were classified based on branching pattern namely mono/shy branch (<2 branches) and branched types (>2 branches). Crosses were made between three branched genotypes (TMV 4, TMV5 and Paiyur 1) and five mono/shy branching genotypes (Cordeborga, KS99037, KS99812, KS99813, and KS9953). Population in F_3 generation of 18 crosses (both direct and reciprocal) and their parents were utilized for the present study. The basic crosses are *viz.*, Paiyur 1 x Cordeborga, TMV 4 x KS 99037, TMV 4 x KS 99812, TMV 4 x KS 99813, TMV 5 x KS 99153, TMV 5 x KS 99037, TMV 5 x KS 99812, TMV 5 x KS 99813, TMV 5 x KS99153 in F_3 generation. The experiment was carried out at the oil seed farm, centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore during rainy season of 2004. All the recommended practices and need based plant protection measures were followed under irrigated conditions. Observation were recorded on plant height, number of branches/plant, number of capsules/plant, number of seeds/capsule, 100 seed weight, seed yield/plant. Correlation coefficients for the yield and its components were worked out as per the standard method.

All the parents studied had significant and positive association between number of capsules/plant and seed yield (Table 1). Significant and positive association between number of capsules and a seed yield was already reported by Manivannan (1998), Kathiresan and Gnanamurthy (2000) and Sumathi (2004). Except TMV 4 and KS 99813, all parents had significant association between number of branches and seed yield/plant. The parent TMV 4 and TMV 5 alone had significant and positive association between plant height and seed yield. Positive association of plant height and number of branches with seed yield was reported by Sumathi (2004).

All the crosses tested recorded positive and significant association between number of capsules and seed yield. Both direct and reciprocal crosses of TMV 4 x KS 99812, TMV 4 x KS 99813, TMV 5 x KS 99037 and TMV 5 x KS 99813 had significant and positive association between number of branches and seed yield. In crosses TMV 4 x KS 99037, TMV 4 x KS 99153 and TMV 5 x KS 99153 recorded differential association between number of branches and seed yield in direct and reciprocal crosses. Though the parents TMV 4 and KS 99813 has no association between number of branches and seed yield, the crosses involved showed significant association.

In case of plant height, the association exists in TMV 4 and TMV 5, while in crosses the association between plant height and seed yield was also exhibited in TMV 4 x KS 99812, TMV 4 x KS 99813, TMV 4 x 99153 and TMV 5 x KS 99037 where the TMV 4 is used as female parent. However, in other crosses this trend was not observed.

In case of inter correlation, among yield components plant height had significant and positive association with number of branches and number of capsules in most of the crosses (Table 2). The character number of branches had positive association with number of capsule. Association between Plant height and number of branches was reported by Deepa Sankar and Ananda Kumar (2003). Sumathi (2004) reported association between plant height and number of capsules/plant while Pawar *et al.* (2002), Ramireddy Kumar and Sundaram (2002) and Sumathi (2004) reported association between number of branches and number of capsules/plant.

However, in parents similar association was not observed. Hence, to formulate the selection index, the character, number of capsules/plant alone may be considered. The differential association in the crosses irrespective of the parents involved may be due to contrast plant type of shy and more branching types involved in the crosses. Hence, formulation of specific selection indices is necessary for each cross for effective selection programme. Crosses with no association between number of branches and seed yield can be profitably exploited to evolve high yielding mono/shy branching types.

Table 1 Correlation between seed yield and component characters in crosses and parents of sesame

Crosses		Plant height (cm)	No. of branches	No. of capsules	No. of seeds/capsules	100 seed weight (g)
Paiyur 1 x Cordeborga	Direct	0.15*	0.13	0.71*	0.12	-0.02
	Reci.	0.30*	0.14	0.60*	0.08	0.14
TMV4 x KS 99037	Direct	0.03	0.11	0.76*	0.13	0.16
	Reci.	0.36*	0.51*	0.78*	0.08	0.21*
TMV4 x KS 99812	Direct	0.17*	0.29*	0.62*	0.10	0.01
	Reci.	0.21	0.33*	0.70*	0.06	0.02
TMV4 x KS 99813	Direct	0.28*	0.34*	0.76*	0.04	0.21
	Reci.	0.25	0.29*	0.68*	0.17	0.04
TMV4 x KS 99153	Direct	0.52*	0.67*	0.82*	0.08	-0.08
	Reci.	0.35	0.32	0.91*	-0.05	-0.07
TMV5 x KS 99037	Direct	0.36*	0.44*	0.65*	-0.06	-0.15
	Reci.	0.19	0.37*	0.73*	0.03	-0.004
TMV5 x KS 99812	Direct	0.10	0.31	0.89*	-0.09	0.20
	Reci.	0.27	0.56	0.47*	-0.25	-0.15
TMV5 x KS 99813	Direct	0.32*	0.33*	0.76*	0.03	0.19*
	Reci.	0.29*	0.50*	0.85*	0.004	0.01
TMV5 x KS 99153	Direct	0.05	0.24*	0.60*	-0.004	0.08
	Reci.	-0.07	-0.07	0.52*	0.02	0.20
Paiyur 1		-0.14	0.72*	0.67*	0.45	0.50
TMV 4		0.38*	0.20	0.70*	-0.034	-0.019
TMV 5		0.71*	0.43*	0.92*	0.20	0.11
Cordeborga		0.44	0.68*	0.85*	0.30	0.06
KS99037		0.01	0.50*	0.72*	-0.19	0.41
KS99812		0.35	0.56*	0.65*	0.22	-0.41
KS99813		0.19	0.32	0.98*	-0.02	-0.38
KS99153		0.48	0.85*	0.52*	-0.25	-0.46

Significant at 5%

Table 2 Correlation among yield component characters in crosses and parents in sesame

Crosses		Plant height (cm)				No. of branches			No. of capsules with		No. of seeds/capsule
		No. of branches	No. of capsule	No. of seeds/capsule	100 seed weight (g)	No. of capsule	No. of seeds/ capsule	100 seed weight (g)	100 seed weight (g)	No. of seeds/ capsule	100 seed weight (g)
Paiyur 1 x Cordeborga	Direct	0.33*	0.36*	0.17*	-0.02	0.38*	0.40*	-0.05	0.35*	-0.05	-0.05
	Reci.	0.23	0.50*	0.03	0.10	0.41	0.13	0.16	0.43*	-0.25*	-0.24
TMV4 x KS 99037	Direct	0.60*	0.38	0.05	0.02	0.36*	-0.19	-0.37*	0.29*	-0.23	-0.19
	Reci.	0.49*	0.47*	0.03	0.12*	0.61*	0.02	0.01	0.17*	-0.09	0.05
TMV4 x KS 99812	Direct	0.36*	0.32*	-0.04	-0.10	0.56*	0.03	-0.02	0.36*	-0.17*	-0.17
	Reci.	0.53*	0.43*	0.05	-0.05	0.54*	-0.06	-0.012	0.38*	-0.15	-0.25
TMV4 x KS 99813	Direct	0.53*	0.35*	-0.03	0.10	0.47*	-0.03	-0.04	0.32*	-0.29*	-0.08
	Reci.	0.70*	0.48*	0.20	0.08	0.53*	0.19	0.07	0.20	-0.14	-0.03
TMV4 x KS 99153	Direct	0.15	0.48*	0.12	-0.17	0.42	-0.05	-0.19	0.53*	-0.03	-0.23
	Reci.	0.27	0.50*	-0.14	-0.03	0.47*	0.01	0.18	0.20	-0.16	-0.25
TMV5 x KS 99037	Direct	0.63*	0.48*	0.01	0.10*	0.68	0.01	0.11	0.28*	-0.06	0.25*
	Reci.	0.38*	0.33*	0.05	-0.07	0.61	0.21	0.18	0.23*	-0.16	-0.01
TMV5 x KS 99812	Direct	0.52*	0.23*	-0.05	0.12	0.43*	0.35	-0.13	-0.16	-0.04	0.23
	Reci.	0.67*	0.75*	-0.22	-0.22	0.62*	-0.06	-0.13	0.10	-0.24	-0.25
TMV5 x KS 99813	Direct	0.36*	0.47*	0.13	0.11	0.53*	0.24	0.03	-0.08	0.03	-0.08
	Reci.	0.47*	0.27*	-0.09	-0.08	0.86*	0.15	0.10	0.24	-0.05	-0.01
TMV5 x KS 99153	Direct	0.30*	0.23*	0.10	0.06	0.53*	0.23*	-0.01	0.16	0.05	0.01
	Reci.	0.34	-0.13	-0.09	-0.01	0.20	0.16	0.02	0.13	-0.33	-0.16
Paiyur 1		0.07	0.15	0.29	0.03	0.69*	0.35	-0.41	0.17	0.44	0.18
TMV 4		0.32	0.41*	-0.13	-0.05	0.56*	-0.08	-0.04	0.12	0.06	-0.15
TMV 5		0.60*	0.69*	-0.05	0.12	0.55*	0.05	0.20	0.09	-0.25	-0.05
Cordeborga		0.48	0.45	0.41	0.003	0.80	0.01	0.44	0.29	0.19	0.25
KS99037		0.25	0.34	-0.12	0.24	0.60*	0.01	0.31	0.53*	0.09	0.28
KS99812		0.25	-0.03	0.09	-0.12	0.86*	0.22	0.55*	0.24	-0.05	-0.01
KS99813		0.62*	0.24	-0.07	-0.32	0.40	-0.35	-0.20	0.30	-0.46	-0.09
KS99153		0.42	0.56*	-0.08	-0.03	0.1	-0.34	-0.11	0.37	-0.19	-0.51

Significant at 5%

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Inheritance of pollen and stigma colour in sunflower (*Helianthus annuus*)

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ABSTRACT

Inheritance of pollen and stigma colour in sunflower (*Helianthus annuus* L.) was studied using two distinct colour morphs: yellow and white pollen, yellow and purple stigma. Yellow pollen and yellow stigma are the most common phenomorphs, while white pollen and purple stigma are rare in cultivated sunflower types. The two parents used in the study i.e., 33B and IB-55 had purple stigma+ yellow pollen and yellow stigma+ white pollen colour respectively. The F_1 plants had purple stigma and yellow pollen colour uniformly in all the plants which revealed that purple stigma and yellow pollen are dominant over yellow stigma and white pollen colour. In F_2, out of the 114 plants scored 83 plants had purple stigma and 31 plants had yellow stigma. The variation for pollen colour revealed 76 plants having yellow pollen and 38 plants had white pollen. The data showed good fit into 3:1 ratio for both the characters, indicating monogenic inheritance with dominance of purple stigma and yellow pollen colour. Joint coring of stigma colour and pollen colour, statistically fit into 9:3:3:1 ratio for purple stigma + yellow pollen, yellow stigma + yellow pollen, purple stigma + white pollen and yellow stigma + white pollen. These segregation ratios indicate that pollen colour and stigma colour in sunflower are controlled by two different genes inherited independent of each other.

Key words: Digenic, Monogenic, Pollen colour, Stigma colour, Sunflower

Flower colour polymorphism, the co-occurrence of two or more distinct flower colour phenotypes within the same population is a conspicuous feature of many crop plants. Variations of floral colour and morphology in sunflower (*Helianthus annuus* L.) and inheritance of pollen colour, branching, anthocyanin pigment have been reported by many workers earlier (Duka, 1986; Fick, 1976; Luczkiewiez, 1975 and Khulbe *et al*., 2007). Most of the available literature on the inheritance of floral and morphological variation in sunflower reviewed recently indicates that differences in pigmentation or morphology are qualitative characters controlled by one or two major genes. The single dominant gene control for the presence of anthocyanin pigment in disc flower has been one of the most useful observations because it allows verifications of hybridization in breeding and genetics studies. Both pollen and stigma colour in sunflower can be used as genetic markers in hybridization studies. In view of this, the efforts were made to investigate the inheritance patterns of these two traits together.

The parents used in crosses were true breeding lines and had contrasting phenotypes with respect to stigma and pollen colour. One parent i.e., 33 B (P_1) had purple stigma and yellow pollen while other parent IB-55 had yellow stigma and white pollen colour. Gibberellic acid (100 mg/l) was used for inducing male sterility in both the lines for attempting reciprocal crosses during offseason 2007. The F_1 plants were grown in spring season 2008 and self pollinated to get F_2 seed. The F_2 generation was grown in offseason 2008 and observations were recorded on pollen colour and stigma colour. Goodness of fit of observed to the expected number of plants in the segregating population for these two characters was tested by the Chi square method.

All the five F_1 plants of the cross between 33 B (P1) x IB-55(P2) exhibited purple stigma and yellow pollen colour. The presence of purple stigma and yellow pollen only in all the F_1 plants of the cross 33B x IB-55 as well as IB-55x 33B indicated that purple stigma and yellow pollen colour are dominant over yellow stigma and white pollen respectively. Similar observations for stigma colour have been reported earlier by Khulbe *et al.* (2007), Luczkiewicz (1975), Fick (1976), Duka (1986) and Joshi *et al.* (1994). Studies by Fambrin *et al.* (2009) indicated orange pollen colour to be dominant over yellow and white and it was revealed in their study that the different pollen colour morphs differed with respect to the carotenoid content. In white pollen morphs the carotenoid content was extremely reduced.

In F_2 generation, of the 114 plants scored for stigma colour, 83 plants were observed to have purple stigma and 31 plants had yellow stigma (Table 1). The observed data showed good fit into 3:1 ratio for purple and yellow stigma indicating monogenic inheritance with dominance of purple stigma colour. The dominant state (PsPs or Psps) conditions purple stigma colour while yellow colour is conditioned by homozygous recessive state of the two alleles (psps). Purple stigma colour in sunflower is due to the presence of anthocyanin pigment and is associated with the production of purple colour in the hull of the seed. For oil extraction the purple seed is not desirable because it imparts colouration to the oil, however this problem can be overcome by refinery process. In this study it was confirmed that purple colour in stigma is dominant in expression, therefore the female parent to be used in the hybridization programme should not have the purple stigma colour. With respect to pollen colour, 76 plants had yellow pollen while 38 plants had white pollen (Table 1). For this character also the observed ratio was statistically consistent with the expected ratio of 3:1. Monogenic inheritance of pollen colour in sunflower has also earlier been reported by Fambrin *et al.* (2009) and Sharypina *et al.* (2008) and in hazelnut by Mehlenbacher and Smith (2002).

In joint scoring for stigma and pollen colour, 55 plants were observed to have purple stigma+ yellow pollen colour, 21 plants had yellow stigma and yellow pollen, 28 plants had purple stigma and white pollen while 10 plants had yellow stigma and white pollen. Assuming a digenic model, the results were found to statistically fit into 9:3:3:1 ratio for purple stigma and yellow pollen, yellow stigma and yellow pollen, purple stigma and white pollen and yellow stigma and white pollen. Aggregate of results suggests the possible genotypes of the inbred lines used with respect to these two traits considering two allele system as: Female parent 33B : PsPs YpYp and Male parent IB-55 : psps ypyp.

Table 1 Segregation pattern for stigma and pollen colour in the cross 33 B(P_1) x IB-55(P_2)

Parent/Cross	Observed ratio				Expected ratio		Chi square	
	Stigma colour		Pollen colour		Stigma colour	Pollen colour	Stigma colour	Pollen colour
	Purple	Yellow	Yellow	White				
33B (P_1)	All	-	All	-	Purple	Yellow	-	-
IB-55 (P_2)	-	All	-	All	Yellow	White	-	-
33Bx IB-55 (F_1)	5	-	5	-	Purple	Yellow	-	-
33B x IB-55 (F_2)	83	31	76	38	3:1	3:1	0.009	0.62

Table 2 Combined segregation pattern for stigma and pollen colour in cross 33B x IB-55

Parent/Cross	Observed segregation				Expected ratio	Chi square
	Purple stigma + yellow pollen	Yellow stigma + yellow pollen	Purple stigma + white pollen	Yellow stigma + white pollen		
33B (P_1)	All	-	-	-	Purple stigma + yellow pollen	
IB-55 (P_2)	-	-	-	All	Yellow stigma + white pollen	
33B x IB-55 (P_1)	5	-	-	-	Purple stigma + yellow pollen	
33B x IB-55 (F_2)	55	21	28	10	9:3:3:1	**3.8**

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Short communication

Effect of pollination methods on seed yield and yield components in sunflower (*Helianthus annuus*) hybrid NDSH-1

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ABSTRACT

Studies were conducted at Seed Research and Technology Center, Rajendranagar, Hyderabad during winter season of 2006-07. Open pollination supplemented with hand pollination on alternate days resulted in the highest yield of sunflower (*Helianthus annuus* L.) hybrid, NDSH-1 which was significantly on par with daily pollination. Similarly seed setting percentage was high with open pollination coupled with hand pollination on alternate days followed by daily hand and bee pollination with 8 frames. Hundred seed weight was found to be the highest with net pollination followed by spray of sugar solution (5%) on heads at 25, 50 and 75% flowering.

Key words: Honey bee (*Apis mellifera*), Hybrid seed production, Pollination methods and Sunflower

Sunflower (*Helianthus annuus* L.) is an important oilseed crop cultivated extensively in India. The demand for quality hybrid seed is increasing day by day due to its day neutrality, short duration, wide adaptability, high yielding potential and remunerative price. In hybrid seed production plots, daily hand pollination is being practiced by engaging labour during flowering period, which becomes a costly affair. Therefore, a study was conducted to find out the effect of different pollination methods on seed setting and seed quality of sunflower.

The experiment was conducted at Seed Research and Technology Center, Rajendranagar, Hyderabad during winter season of 2006-07. The parental lines of sunflower hybrid, NDSH-1 *viz.*, CMS-234 A (A-line) and RHA-859 (R-line) was sown in block method in 9:3 ratio. The experiment was sown in a randomized block design with three replications. The plot size of each treatment was 36 m^2 with a spacing of 60 cm x 30 cm. Seven treatments were imposed in hybrid seed production plot of NDSH-1 (Table 1). The observations were recorded on ten randomly selected plants and their average values were computed.

The data presented in table 1 showed significant differences among the seven treatments. Of the seven treatments imposed, open pollination supplemented with daily hand pollination on alternate days resulted in highest yield, which was significantly on par with daily hand pollination. Thus, in the present study, open pollination coupled with hand pollination on alternate days resulted in highest seed yield compared to open pollination coupled with daily hand pollination. Hand pollination on every alternate day or 3 days recorded on par yield levels. Treatments involving bee population also resulted in less yield compared to hand pollination. Daily hand pollination resulted in less yields compared to hand pollination on every alternate day. To overcome this injury, additional plant nutrients were required for the repair of the damage and this might have led to poor seed development. All these disturbances might affect pollen viability or stigma may be no more receptive. Consequently leading to poor seed set and seed yield as compared to hand pollination on every alternate day (Singh *et al.*, 2001). Similarly, Choulwar *et al.* (1988), Abrol (1996), Rajagopal *et al.* (1999) and Sinha and Atwal (2000) reported increased seed yield and seed number when pollination was made on every alternate day.

Seed setting percentage was high with open pollination coupled with hand pollination on alternate days followed by daily hand and bee pollination with 8 frames. The high seed setting percentage was due to less injury to stigmatic surface compared to daily hand pollination. Low yields in bee pollination (8 frames) plot are due to mortality of bee population and pollen carrying bees are not visiting the female line. Test weight was found to be highest with net pollination followed by spray of sugar solution on heads at 25, 50 and 75% flowering. Open pollination coupled with hand pollination on every alternate day resulted in less seed weight. The high seed set percentage resulted in low test weight as the available photosynthates are to be distributed among more number of seeds/capitulum. Ganapathi *et al.* (1997) also reported decrease in test weight with increase in the frequency of hand pollination.

Thus, it can be concluded that open pollination coupled with hand pollination on every alternate day resulted in significantly higher yield. Since production of hybrid seed is labour intensive, by resorting to supplementary pollination on alternate days, farmers can reduce investment on daily hand pollination with simultaneous increase in hybrid seed yields.

Table 1 Effect of pollination methods on seed yield and seed of sunflower hybrid, NDSH-1

Treatment	Seed setting (%)	Seed yield (kg/ha)	100 seed weight (g)
Open pollination	22.8	403	4.6
Open pollination + hand pollination on alternate days	87.2	1533	3.6
Bee pollination (4 frames)	19.5	334	4.7
Bee pollination (8 frames)	51.6	864	4.2
Daily hand pollination	76.5	1408	3.9
Sugar spray (5%) on heads at 25, 50 and 75 % flowering	16.9	301	5.0
Pollination in net covered plots (wind)	11.5	206	5.3
CD (P=0.05)	4.9	71	0.59
CV (%)	6.2	5.59	3.92

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Response of winter season groundnut (*Arachis hypogaea*) to iron and zinc application

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ABSTRACT

A field trial was conducted during winter season of 2005 at Department of Agronomy, College of Agriculture farm, Latur to study the response of groundnut (*Arachis hypogaea* L.) crop to application of iron and zinc. The study revealed that application of 25 kg of $ZnSO_4$/ha along with recommended dose of fertilizer 25 : 50 kg N and P/ha has given significantly higher dry pod yield (kg/ha), kernel yield (kg/ha), haulm yield (kg/ha) and maximum oil yield (666.3kg/ha).

Key words: Groundnut, Iron sulphate and Zinc sulphate

Groundnut (*Arachis hypogaea* L.) is the second important oilseed crop in India. Groundnut contributes to atmospheric nitrogen fixation to improve soil fertility, minimizing soil erosion and suppressing weed growth through nearly closed canopy, thereby soil degradation. The causes for low yields of groundnut in Maharashtra state is due to the cultivation of crop on marginal and sub marginal lands under rainfed conditions, frequent drought, poor agronomic practices, use of low yielding and late maturing cultivars, lack of plant protection measures. Other probable reason for declining yield is inadequate and imbalanced nutrition and moisture stress at critical stages of the crop growth. Among these factors, mineral nutrition plays an important role, particularly the secondary and micronutrients. Hence, an experiment was conducted to find out the iron and zinc required for winter groundnut and to assess their effect on yield and quality of groundnut.

Field experiment was conducted at Department of Agronomy farm, College of Agriculture, Latur, Marathwada Agricultural University, Parbhani during winter season of 2005. The experiment was laid out in randomized block design with three replications and seven treatments (Table1). Variety TAG-24 was sown by dibbling method at 5 cm depth, and at 30 cm x 15 cm spacing. The soil of the experimental site was clayey in texture having pH of 8.1, organic carbon 4.5 g/kg, EC 0.32, available nitrogen (181 kg/ha), phosphorus (17 kg/ha) and potassium (658 kg/ha). The sowing of groundnut was undertaken on 30th September, 2005. Before sowing, the kernels were treated with Bavistin @ 5g/kg of seed and rhizobium culture at 250 g/kg of seed. The recommended doses of fertilizer 25:50 kg N and P/ha were applied fully at the time of sowing. Ferrous sulphate ($FeSO_4$) and zinc sulphate ($ZnSO_4$) fertilizers were applied treatment wise at the time of sowing. Four irrigations were given at different growth stages. Two hand weedings were given at 20 and 45 days after sowing. The harvesting of crop was done on 17th February, 2006.

The results revealed that total number of developed pods/plant was significantly highest in treatment T_6 (RDF +12.5 kg $ZnSO_4$/ha) followed by treatment T_3 (RDF +12.5 kg $FeSO_4$/ha). Effects of various levels of $FeSO_4$ and $ZnSO_4$ on test weight was found non significant. Mean shelling per cent was significantly higher in treatment T_6, but it was at par with treatment T_3, T_4 and T_7. Dry pod yield was found to be highest with treatment T_6 than treatment T_3. Mujumdar *et al.* (2001) reported that pod and straw yield, number of pods/plant, shelling percentage, and P content of kernel, protein and oil content significantly increased with increasing P and Zn rates. Similar trend was observed by Janakiraman *et al.* (2004). Saini *et al.* (1975) reported that groundnut pod yield and shelling percentage increased due to micro nutrient application. Reddy *et al.* (1984) reveled that application of 25 kg $ZnSO_4$ ha increased the pod yield of groundnut by 8% over control. They further noticed that when zinc is applied along with 40 kg P_2O_5/ha, the increase in pod yield was 20.2% over control. Similar trend was observed by Subrahmaniyan *et al.* (2001). Haulm yield as influenced by various treatments of iron and zinc sulphate showed significant effect and treatment T_6 gave highest haulm yield followed by treatment T_3. Harvest index as influenced by the various levels of $FeSO_4$ and zinc $ZnSO_4$ (Table 1) showed no significant influence. Oil yield (kg/ha) and protein content was highest at treatment T_6 than that of the treatment T_3, T_4 and T_7. Jagadeeswaran *et al.* (2001) reported that application of Ferro gypsum in amounts equivalent gypsum/ha significantly increased the pod and haulm yield, quality (shelling per cent, oil content, protein content and nitrogen content) and nutrient uptake (N, P, K, Ca, Mg, S, Fe, Zn and Cu) in groundnut. The beneficial effect was similar to those, obtained with the application of gypsum + $FeSO_4$. Oil percentage of groundnut was not significantly influenced by application of various levels of $FeSO_4$ and $ZnSO_4$. Raut *et al.* (1999) reported that seed yield and protein percentage increased with increasing Fe application. Similar trend was observed by Krishnappa *et al.* (1992).

Table 1 Effect of iron and zinc application on the yield and quality of groundnut

Treatments	No. of pods/plant	100 kernal weight (g)	Shelling (%)	Dry pod yield (kg/ha)	Kernal yield (kg/ha)	Haulm yield (kg/ha)	Harvest index (%)	Oil yield (kg/ha)	Protein content (%)	Oil content (%)
T_1: RDF	27	39.8	62.5	1531	959.5	3687.6	29.3	449.2	22.5	46.3
T_2: RDF+12.5 kg $FeSO_4$	29	40.7	64.9	1774.9	1154.3	4109.5	30.2	553.8	24.9	47.7
T_3: RDF+ 25 kg $FeSO_4$	31.6	42.1	69.9	1910.6	1347.6	4596.4	29.5	645.6	26.5	47.9
T_4: RDF + 37.5 kg $FeSO_4$	29.7	41.4	66.9	1834.3	1228.4	4188.3	30.5	601.4	25.4	48.8
T_5: RDF+ 12.5 kg $ZnSO_4$	29.2	40.9	65.7	1767.9	1163.5	4112.2	30.1	541.1	25.1	46.4
T_6: RDF+ 25 kg $ZnSO_4$	31.8	45.7	71.1	1992	1418.3	4765	29.5	666.3	27.3	46.9
T_7: RDF+ 37.5 kg $ZnSO_4$	30	41.6	67.4	1863.9	1255.6	4237.1	30.6	595.5	25.6	47.4
SEm ±	0.72	1.25	1.55	57.7	38.3	201.8	1.187	23.83	0.84	1.54
CD (P=0.05)	2.2	NS	4.76	177.5	217.8	620.9	N.S.	73.32	2.59	N.S.
CV (%)	6.2	5.2	5.1	9.5	8.5	8.2	7.9	9.1	5.7	4.6

RDF = 25 kg N : 50kg P/ha

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Short communication

Effect of sulphur and calcium on yield and quality of mustard (*Brassica juncea*)

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ABSTRACT

A field experiment was conducted with three levels of sulphur (0, 20 and 40 kg/ha) and calcium (0, 10 and 20 kg/ha) to study the yield and quality of mustard [*Brassica juncea* (L.) Czern & Coss.] cv. Varuna as test crop. Results revealed that application of sulphur (S) and calcium (Ca) alone and in combination significantly affected the siliqua, yield, oil content and quality of oil. In each case, the application of S at 40 kg/ha + Ca at 10 kg/ha was found superior over other treatments. However, the application of Ca at 20 kg/ha with S adversely affected the siliqua number, yield, oil content and quality of oil.

Key words: Calcium, Mustard and Sulphur

Among oilseed crops grown in the India, *Brassica* rank second in acreage occupying about 6.5 m ha. India stands second in mustard production, but the average yield is low (694 kg/ ha) compared to European countries (2007 kg/ ha). Sulphur (S) deficiency in *Brassica* crops is increasing worldwide due to the use of high grade, S-free fertilizers, the breeding of high yielding crop varieties, the declining use of elemental S for plant protection purpose and the efficient reduction of atmospheric S depositions in industrial countries. *Brassica* crops such as oilseed rape and mustard show a high S demand because of high protein content in their seeds and also the characteristic's presence of S-containing glucosinolate. Calcium (Ca) is very essential in the formation of plant's cell membrane and being a part of cell membrane makes straw and stalk hard. Calcium enhances the uptake of nitrate nitrogen and therefore, is interrelated with nitrogen metabolism. Calcium nutrition is often considered as yield limiting factor for oilseed crops. Addition of Ca and S may increase the production of oil. Since mustard is an important oilseed crop, the present study was initiated to study the effect of Ca and S.

A field experiment was conducted during 2006 in randomized block design consisting of six treatments and four replications at the research plot of Department of Agricultural Chemistry and Soil Science, Udai Pratap Autonomous College, Varanasi. Mustard variety, Varuna was the test crop. Experimental soil (Inceptisol) had pH 7.5, EC 0.54 dS/m, organic carbon 0.66%. Available NPK and S were 184, 12, 220, and 11 kg/ha, respectively. Treatments comprising T_1: Control, T_2 : 40 kg S/ha, T_3:20 kg Ca/ha, T_4:40 kg S/ha +10 kg Ca/ha, T_5:40 kg S/ha +20 kg Ca/ha and T_6:20 kg S/ha + 20 kg Ca/ha. Recommended doses of N, P and K (90, 60 and 40 kg/ha) were applied in all the treatments. Half of the N and full doses of P and K were applied as basal at the time of sowing. Rest half of N was top dressed after 30 days of sowing. Sulphur and Ca were applied through elemental sulphur and calcium nitrate, respectively at the time of sowing. Number of siliqua was counted at 55 and 70 days after sowing. The crop was harvested and seed and stover yields were recorded. Oil content in seed and fatty acids in oil were determined by the method of AOAC (1970) and GLC (Luddy *et al.*, 1968), respectively.

Highest number of siliqua was recorded with 40 kg S/ha +10 kg Ca/ha at both the stages of plant growth (55 and 70 DAS) compared to other treatments. Tripathi and Sharma (1995) also reported the increase in growth attributes due to application of Ca and S. Application of Ca at 20 kg/ha decreased the number of siliqua as compared to 40 kg S/ha +10 kg Ca/ha. Results revealed that application of Ca at 20 kg/ha with S at 40 kg/ha decreased the growth attributes when compared with the dose of Ca at 10 kg/ha + S at 40 kg/ha. This is an indication of antagonistic effect of Ca at the higher doses on S. Higher dose Ca might have suppressed the adequate absorption of S and other nutrients and consequently, decreased the growth of mustard.

Application of S and Ca alone in combination significantly increased the seed and stover yield as compared to control (Table 1). The highest seed (1697 kg/ha) and stover (4386 kg/ha) yields of mustard were recorded with the application of S at 40 kg/ha + Ca at 10 kg /ha which were 158.2 and 123.7% higher in comparison to control. Increase in seed and stover yields on addition of S and Ca might be due to their deficiency in experimental soil. The improved nutritional environment as a result of addition of S and Ca have favourably influenced the carbohydrate metabolism led to increased translocation of photosynthesis towards seeds resulting in formation of healthy seeds. Better availability of native and applied plant nutrients (S and Ca) at active growth stages increases cell division and cell elongation, which probably led to more plant stature combined with the better spread of plants. Therefore, increase in vegetative growth of plants was ultimately responsible for an increase in stover yield of mustard. Beneficial effects of S and Ca on yield attributes are also documented by Ramchandrappa and Kulkarni (1992).

Oil content increased significantly with the application of S and Ca be lowest at control (35.2%) and highest (42.8%) at 40 kg S/ha + 10 kg Ca/ha (Table 1). The increase in oil content by an addition of S was probably due to the increase in glucosides and thio glucosides. Mishra *et al.* (2002) have also documented the favourable effect of S on yield and quality of mustard. Singh and Singh (1996) observed marked effect of gypsum application in increasing the oil content of groundnut in limed soil compared to without lime application. This is an indication of beneficial effect of Ca in an increasing the oil content. The fatty acid composition of oil was influenced significantly by the application of S and Ca. The oleic and linoleic acid contents increased with the application of S and Ca. The increase in oleic acid, linoleic acid and decrease in erucic acid contents on addition of S and Ca improve the quality of mustard oil. Higher dose of Ca at 20 kg/ha recorded lower amount of oil as compared to lower dose.

Table 1 Effect of different treatments on yield, oil content and quality of mustard

Treatment	No. of siliqua/ plant		Grain yield (kg/ha)	Stover yield (kg/ha)	Oil content (%)	Oleic acid (%)	Linoleic acid (%)	Erucic acid (%)
	55 DAS	70 DAS						
T_1 Control	8	46	675	1960	35.2	15.15	11.98	47.57
T_2 40 kg S/ha	10	108	1450	3866	38.3	15.76	12.76	47.13
T_3 20 kg Ca/ha	9	106	1300	3166	37.5	16.98	14.35	46.21
T_4 40 kg S/ha+10 kg Ca/ha	11	116	1697	4386	42.8	18.16	16.28	44.16
T_5 40 kg S/ha +20 kg Ca/ha	9	100	766	2618	40.9	17.63	15.73	44.46
T_6 20 kg S/ha + 20 kg Ca/ha	9	56	700	2360	39.8	17.95	14.89	45.39
CD (P=0.05)	NS	6.1	300	424	0.23	0.81	0.95	NS

DAS = Days after sowing; NS=Non-significant

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Response of rainfed soybean (*Glycine max*) to sulphur and zinc application

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ABSTRACT

A field experiment was conducted at Agriculture College Farm, Latur during 2004 to study the response of rainfed soybean (*Glycine max* L.) to application of sulphur and zinc. The data revealed that the application of 30 kg/ha elemental sulphur along with recommended dose (30:60:30 kg/ha NPK) of fertilizer (RDF) recorded the higher seed yield (19.9 kg/ha) followed by 20 kg/ha elemental sulphur + RDF but the differences was at par. Same trend of seed yield was observed in protein content and harvest index. The lowest seed yield (15.1 kg/ha) was obtained when only RDF was applied.

Key words: Elemental sulphur, Soybean and Zinc sulphate

Soybean (*Glycine max* L.) is basically a pulse crop, but is gaining importance as an oilseed crop too. Soybean serve as a good rotational crop and help in enrichment of soil fertility. It is a good source of protein and contains ample amino acids, which is essential for human nutrition. It is a good source of vegetable oil having 20% oil content. Soybean fixes atmospheric nitrogen in soil through the nodules and therefore requires less nitrogen. Sulphur (S) and zinc (Zn) are essential nutrients required for crop growth and development. Sulphur is essential for protein and oil synthesis and Zn is required for plant metabolism. In view of the above, the present experiment was conducted to assess the effect of S and Zn on growth, yield and quality of soybean.

A field experiment was conducted at Agriculture College Farm, Latur, Marathwada Agricultural University, during rainy season of 2004. The experimental soil was clay loam in texture with pH 8.1, EC 0.35 dS/m, organic carbon 4.7 (g/kg), low in available nitrogen (184 kg/ha), medium in phosphorus (19 kg/ha) and high in available potassium (663 kg/ha). The experiment was laid out in randomized block design with four replications. The treatments consisting of three levels of sulphur (10, 20 and 30 kg/ha) and two levels of zinc sulphate (10 and 20 kg/ha) were tested against control. The gross and net plot size were 4.5 m x 3.6 m and 4.0 m x 2.7 m, respectively. Sowing of soybean cultivar JS-335 crop was undertaken on 4th July, 2004 by dibbling method with two seeds per hill at a distance of 45 cm x 5 cm at 3-4 cm depth. Two hand weedings, first in third week of July and second in fourth week of August and one hand hoeing one month after sowing was preferred. The recommended dose of fertilizer 30:60:30 kg NPK/ha was applied at the time of sowing as basal. Harvesting of crop was done on 8th October 2004. Well distributed rainfall was received during growth season except a dry spell in 35th and 42nd meteorological week. Total precipitation was 748.1 mm spread over 30 rainy days.

It was found that growth attributing characters such as plant height, branching, number of functional leaves/plant, leaf area/plant, dry matter accumulation and leaf area index increased with application of 30 kg elemental S/ha than lower levels. The growth characters were also increased with application of 20 kg Zn/ha. Khandwe and Sharma (2002) also observed increased height with increase in S level of soybean. Dwivedi *et al.* (1999) reported increase in leaf area of soybean due to application of S. Similar results were obtained by Singh and Singh (1995). Yield attributes like number of pods/plant, grain weight/plant (g) and test weight (g) increased significantly with the application of 30 kg S/ha and 20 kg Zn/ha. Agrawal *et al.* (1996) and Majumdar *et al.* (2001) reported that the number of pods/plant, number of seeds/pod and seed weight/plant increased with increase in Zn content. The seed yield and harvest index increased with application of 30 kg S/ha and 20 kg Zn/ha. The beneficial effect of application of S upto 30 kg/ha on seed yield of soybean was also reported by Ramamoorthy *et al.* (1996) and Teotia *et al.* (2000). Quality parameters like oil content (%) and protein (%) increased significantly with the application of 30 kg S/ha and 20 kg Zn/ha. Sonune *et al.* (2001) reported that application of 40 kg S/ha through gypsum gave highest protein and oil content in soybean. Sharma and Dixit (1987) also observed that application of 25 kg $ZnSO_4$/ha gave higher protein content in soybean. Thus the soybean crop responded upto 30 kg S/ha and 20 kg Zn/ha in the Marathwada region of Maharashtra.

Table 1 Growth, yield and quality of soybean as influenced by different levels of sulphur and zinc

Treatments/ha	Plant height (cm)	No. of branches/ plant	Drymatter/ plant (g)	No. of pods/ plant	Weight of grain/ plant (g)	100 seed weight (g)	Seed yield (q/ha)	Harvest index	Oil content (%)	Protein content (%)
RDF	39.9	2.4	8.1	20.0	3.6	11.1	15.1	38.5	18.2	39.7
RDF+10kg $ZnSO_4$	40.5	2.6	9.0	22.2	3.9	11.2	17.0	38.9	18.5	40.2
RDF+ 20 kg $ZnSO_4$	43.1	2.3	10.0	26.3	4.4	11.1	18.2	40.1	19.3	41.7
RDF + 10kg elemental S/ha	47.7	2.8	9.6	23.0	4.2	10.9	17.4	39.2	19.0	40.8
RDF+ 20 kg elemental S/ha	44.9	3.3	10.6	29.2	4.5	11.0	18.7	40.3	19.5	42.3
RDF + 30 kg elemental S/ha	45.2	3.4	11.7	33.5	4.7	11.7	19.9	40.6	20.4	42.6
SEm ±	0.91	0.13	0.2	1.3	0.17	0.3	0.7	0.13	0.13	0.21
CD (P=0.05)	2.7	0.39	0.62	3.8	0.53	NS	2.1	0.39	0.39	0.64
CV (%)	3.7	7.8	9.8	4.2	7.0	4.4	6.7	0.6	1.2	0.9

RDF = 30 kg N : 60 kg P and 30 kg K/ha

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Short communication

Effect of biofertilizers on yield, nutrient content and quality of soybean (*Glycine max*) under rainfed condition

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ABSTRACT

An experiment with biofertilizers *viz.*, Rhizobium and phosphorous solubilizing bacteria (PSB) application on soybean (*Glycine max* L. Merr.) was conducted at research farm, Cotton Research Station, College of Agriculture, MAU, Parbhani (M.S) during rainy season of 2005. The protein and oil content in soybean was varied form 33.3 to 38.9% and 16.7 to 19.5%, respectively. The dual inoculation of Rhizobium + PSB was found beneficial for oil production in soybean with and without chemical fertilizers. The result from the experiment revealed that the soybean under rainfed condition gave highest seed yield in treatment T_1S_3(100% RDF + Rhizobium + PSB) as well as highest N and P contain in seed also recorded in T_1S_3 treatment.

Key words: Biofertilizers, Nutrient content, Quality, Soybean, Yield

Introduction of soybean (*Glycine max* L. Merr.) and sunflower (*Helianthus annuus* L.) played a key role in the yellow revolution. Soybean is a newly introduced and commercially exploited crop in India. The crop has been playing an important role in national economy by earning an average of ₹ 20,000 million/annum through export of soy meal and contribution about 10% to the edible oil production. Madhya Pradesh, Maharashtra, Rajasthan, Karnataka and Andhra Pradesh are the main soybean producing states in India. Maharashtra occupies 2nd position in the production. Rhizobium inoculation is recommended for inoculation of seeds of various pulses and legume crops for meeting about 80% of the nitrogen requirement. The range of nitrogen (N) fixed by soybean is 60-80 kg/ha/year. Phosphorous (P) is one of the most limiting nutrients governing the yield of soybean. It has attained grater significance than other plant nutrients for higher tonnage of oilseed production particularly in a crop like soybean.

An experiment with biofertilizers *viz.*, Rhizobium and phosphorous solubilizing bacteria (PSB) application on soybean (*Glycine max* L. Merr.) was conducted at research farm, Cotton Research Station, College of Agriculture, MAU, Parbhani (M.S) during rainy season of 2005. The soil of the experimental site was clayey and slightly alkaline in reaction . The soil analysis showed that pH 8.3, EC 0.27 dS/m, organic carbon 40.6 g/kg. Available phosphorous 15.9 kg/ha and available potassium 588 kg/ha. The area falls under semi-arid agro-climate zone with annual mean precipitation of 786 mm. The field experiment was undertaken with soybean cultivar JS-335 (Jawahar). The 12 treatments consisting of different combination of 3 main and 4 sub treatments. The three main treatments were T_1:100% recommended dose of fertilizer (RDF) (30:60:30 kg NPK/ha), T_2:75% RDF (22.5:45:22.5 kg NPK/ha) and T_3:No RDF combined with four sub treatments S_1: only Rhizobium inoculation, S_2: only PSB inoculation, S_3 : Rhizobium + PSB inoculation and S_4 : No biofertilizers. The treatments were laid out in a factorial randomized block design with four replications (Table 1). Rhizobium and PSB inoculation were used @ 250 g/10kg seed.

It was observed form the table 1 that amongst the different treatments combination of the dual inoculation of Rhizobium +PSB with 100% RDF gave highest grain yield than only chemical fertilizer or only biofertilizers application. The data further revealed that the dual inoculation of Rhizobium+PSB with 100% RDF (T_1S_3 treatment) recorded maximum grain yield of 15.5 q/ha which was 51.4% more over control. In case of biofertilizer treatment, S_3 treatment showed highest grain yield of 13.5q/ha which was 37.3% more over the control. Namdeo and Gupta (1999) reported the highest pigeonpea yield with co-inoculation of Rhizobium +PSB among with 100% RDF. Similar findings were reported by Shrivastav and Rajput (2000).

Highest N and P content in grain was observed due to inoculation of Rhizobium+ PSB with 100% RDF (6.2 and 2.7%, respectively) than single inoculation (Table 1). Similar

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result were reported by Singh and Pareek (2003). Rhizobium *inoculation might have increased the root nodulation* through better root development and more nutrient availability, resulting in better absorption and utilization of all plant nutrients, thus resulted into more N and P content in seed. The combined treatments showed statistically significant variation in N content but non significant P content in soybean grain. The treatment T_1S_3 showed highest P content, which was followed by T_1S_2 treatment.

In general, protein and oil content in soybean were higher with the application of 100% RDF + Rhizobum + PSB (39.0% and19.5% respectively). However, the results revealed that the oil content in soybean indicated non significant variation due to different treatments but the oil yield showed significant result and highest oil yield was recorded in T_1S_3 *treatment (300.9 kg/ha),* T_2S_3 *treatment* (269.8 kg/ha) and T_3S_3 treatment (192.0 kg/ha) in 100%, 75% RDF with biofertilizer and only in biofertilizer treatment, respectively, over single inoculation and only chemical fertilizer application (Table 1). Singh and Rai (2004) reported highest oil content with NPK+FYM+*biofertilizer treatments.* Similar results ware reported by Jain and Trivedi (2005). Highest B:C ratio was recorded in treatment T_3S_1, while lowest in T_2S_4 treatments. Exclusive use of biofertilizers showed *highest B:C ratio* over rest of the treatments (Table 1). Hence poor farmers can easily opt for use of biofertilizers with minimum cost. Though the maximum extra income to ₹ 8,734/- was recorded in T_1S_3 treatment but highest B:C ratio of ₹ 5.16 was harvested with T_2S_3 treatment. Farmers also getting maximum extra income by using 75% RDF +Rhizobium +PSB. Gautam *et al.* (2003) noticed highest net returns with dual inoculation and rock phosphate.

Table 1 Effect of biofertilizers on grain yield, nutrient content, quality parameters and economics of soybean production

Treatment	Grain yield (q/ha)	Nutrient content (%)		Quality parameters			Extra income over control (₹)	B:C ratio
		Nitrogen	Phosphorus	Protein content (%)	Oil content (%)	Oil yield (kg/ha)		
Chemical fertilizers								
T_1: 100% RDF	12.72	6.02	2.59	37.6	18.8	240.9		
T_2: 75% RDF	11.54	5.83	2.54	36.6	18.2	211.3		
T_3: No RDF	9.26	5.59	2.46	34.9	17.4	166.0		
SEm±	0.145	0.042	0.014	0.26	0.132	2.98		
CD (P=0.05)	0.402	0.11	0.039	0.734	0.367	8.26		
Biofertilizers								
S_1: Only Rhizobium inoculation	11.5	5.91	2.50	36.7	18.4	214.1		
S_2: Only PSB inoculation	11.1	5.82	2.57	36.3	18.1	205.5		
S_3: Rhizobium +PSB	13.5	6.01	2.60	37.5	18.7	254.2		
S_4: No biofertilizer	8.4	5.52	2.44	34.5	17.2	146.6		
SEm±	0.2	0.049	0.016	0.306	0.153	3.44		
CD (P=0.05)	0.5	0.13	0.046	0.848	0.424	9.54		
Interaction effect								
T_1S_1	13.1	6.15	2.53	38.4	19.2	252.7	6138	3.17
T_1S_2	12.9	6.06	2.66	37.8	18.9	243.6	5872	3.03
T_1S_3	15.5	6.23	2.68	38.9	19.4	300.9	8734	4.47
T_1S_4	9.5	5.64	2.50	35.2	17.6	166.5	2134	1.11
T_2S_1	12.0	5.90	2.53	36.8	18.4	121.0	4950	3.40
T_2S_2	11.6	5.76	2.56	36.0	18.0	208.7	4488	3.08
T_2S_3	14.2	6.07	2.60	37.9	18.9	269.8	7590	5.16
T_2S_4	8.3	5.60	2.47	34.9	17.4	145.8	891	0.61
T_3S_1	9.5	5.70	2.45	35.6	17.8	168.7	2145	143.0
T_3S_2	9.3	5.63	2.51	35.1	17.5	164.2	1991	132.73
T_3S_3	10.7	5.73	2.53	35.8	17.9	191.9	3520	177.33
T_3S_4	7.5	5.33	2.36	33.3	16.6	127.3	-	-
SEm±	0.3	0.084	0.028	0.53	0.265	5.97	-	-
CD (P=0.05)	0.1	0.23	NS	1.46	NS	16.53	-	-

RDF : Recommended dose of fertilizer

The quality parameter of soybean i.e., crude protein and oil content were improved by biofertilizers with 100% RDF. For profitable soybean production dual inoculation of Rhizobium and PSB (seed treatment) along with 75% RDF is recommended which brings 25% saving on expenditure of chemical fertilizers. The dual inoculation of Rhizobium and PSB is found economical at all the levels of fertilizers application. Hence it is applicable to all poor and rich farmers to opt biofertilizer technology for soybean production.

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Short communication

Effect of sowing dates on growth and productivity of castor (*Ricinus communis*) genotypes in central agro-climatic zone of Uttar Pradesh

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ABSTRACT

A field experiment was conducted at Kalyanpur during the rainy season of 2007 to find out appropriate time of sowing castor (*Ricinus communis* L.) for maximum yield and returns. Early seeding of crop on 30th June and 15th July recorded significant increase in plant height, number of spikes/plant, spike length and number of capsules/spike as compared to delayed sowings. Similarly seed yield was also increased significantly with early sowings on 30th June and 15th July over delayed sowings on 30th July, 15th August and 30th August in both the years. With each delayed sowing after 15th July, there was significant reduction in seed yield and lowest yield was obtained when sowing was done on 30th August during both the years. Gross returns, net returns and B:C ratio were higher with sowing of 30th June and 15th July and delayed sowing on 30th August recorded negative net returns in both the years.

Key words: Castor, Delayed sowings, Economic returns, Seeding time

Castor (*Ricinus communis* L.) is an industrially and medicinally important non-edible oilseed crop of India. Castor fetches a sizeable amount of foreign exchange to India. Sowing time of the crop is fore most and non-monetary input determining the plant productivity to a greater extent. To boost the castor productivity, sowing at right time is an important consideration. Hence to utilize available growing period effectively in non-traditional areas of castor, proper sowing time needs to be identified.

A field experiment was conducted at Oilseeds Research Farm, Kalyanpur, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur during the rainy season of 2007 with 5 sowing dates (30th June, 15th July, 30th July, 15th August and 30th August). The treatments were replicated four times in randomized block design. The soil of the experimental plot was sandy loam in texture with pH 7.8, low in organic carbon (0.43%) and available phosphorus (11.7 kg/ha) and medium in available potash (150 kg/ha). Recommended dose of fertilizers i.e., 50kg N, 25kg P_2O_5 and 15kg K_2O/ha in the form of diammonium phosphat (DAP), urea and muriate of potash, respectively were applied equally to all the treatments. Half of the recommended dose of nitrogen along with entire dose of phosphorus and potassium was applied at the time of sowing in furrows as basal. Remaining half of the nitrogen was applied in two-equal splits at 30 and 45 days after sowing. Seeds were treated with carbendazim @ 1g/kg of seeds to protect from seed borne diseases. Castor crop was sown as per sowing dates using variety 'Chandraprabha' in 2006 and hybrid GCH-4 in 2007. The seeds were dibbled @ 2 seeds/hill at a depth of 4-5 cm in the rows spaced 90 cm apart with 60 cm plant to plant distance. Recommended cultural practices and need base suitable plant protection measures were adopted. Both the year, the crop was harvested in three pickings manually based on physiological maturity of the capsules.

Sowing dates significantly influenced growth and yield attributing characters of castor genotypes (Table 1). Sowing the crop on 30th June produced tallest plants which were comparable with 15th July sowing during 2006. Delay in each successive sowing after 15th July, there was significant reduction in plant height. Similar trend in plant height was also reported by Reddy *et al.* (2007).

Early sowing on 30th June as well as 15th July significantly increased the number of spikes/plant over other sowing dates. While delayed sowings on 30th July, 15th August and 30th August reduced the number of spikes/plant significantly. Reddy *et al.* (2007) reported that delayed sowing on 2nd fortnight of August reduced the number of spikes/plant significantly.

Sowing the crop on 30th June and 15th July produced significantly longer spike over remaining sowing dates. In case of delayed sowing beyond 15th July length of spike was reduced significantly and 30th August sowing resulted in significantly lowest spike length. Goverdhan and Chand Pooran (2002) also reported that delayed sowing on 18th August resulted in significantly lowest spike length.

Number of capsules/spike were also differed significantly with planting time. Early planting on 30th June and 15th July produced maximum capsules/spike while the crop sown after 15th July showed significant reduction in number of capsules/spike comparatively with each previous sowing date. Last sowing date (30th August) recorded significantly lowest number of capsules/spike in castor genotypes. Significantly higher number of capsules/spike with early sowing over delayed sowing was also reported by Sardana *et al.* (2008).

Sowing dates had significant effect on total seed yield of castor genotypes during the years of experimentation (Table 2). Early seeding of crop either on 30th June or on 15th July being comparable with each other, recorded significantly higher seed yield than delayed sowings on 30th July, 15th August and 30th August irrespective of variety or hybrid. With every fortnight delay in sowing beyond 15th July, there was significant decline in seed yield. Beyond 30th July, there was drop in seed yield and the lowest yield was obtained in 30th August sowing. The increase in seed yield with 15th July sowing was in tune of 40.9%, 77.1% and 138.5% in the year 2006 and 31.5%, 118.6% and 379.4% in the year 20078 over 30th July, 15th August and 30th August sowing, respectively. Similarly Sardana *et al.* (2008) also recorded maximum seed yield in early sowing at Ludhiana (Punjab). The yield reduction in castor with delayed sowings was also observed by Patel *et al.* (1991).

Economics of seeding dates *viz.*, gross returns, net returns and B:C ratio were higher with 30th June and 15th July seedings. With each successive delay in sowing beyond 15th July, caused severe reduction in gross returns, net returns and B:C ratio and 30th August sowing showed negative net returns in both the years.

Table 1 Effect of sowing dates on growth and yield attributing characters of castor genotypes

Sowing dates	Plant height (cm)		No. of spikes/plant		Spike length (cm)		Capsules /spike	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
30th June	128.8	165.5	5.2	7.4	37.4	73.3	55.7	83.3
15th July	127.5	154.4	5.6	7.3	37.8	73.2	57.8	83.1
30th July	100.5	139.7	4.0	6.5	30.8	60.2	40.9	72.2
15th Aug.	93.6	131.7	3.2	5.6	25.7	46.8	35.9	61.0
30th Aug.	72.8	80.3	2.4	4.1	20.7	36.3	24.5	35.2
SEm±	0.7	1.6	0.2	0.1	0.7	1.4	0.9	1.5
CD (P=0.05)	2.1	5.0	0.5	0.4	2.0	4.3	2.7	4.6

Table 2 Influence of sowing dates on seed yield (kg/ha) and economics of castor genotypes

Sowing dates	Total seed yield (kg/ha)		Cost of cultivation (₹/ha)		Gross returns (₹/ha)		Net returns (₹/ha)		B:C ratio	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
30th June	1664	3400	12507	19703	25706	68000	13199	48297	2.06	3.45
15th July	1794	3356	11984	19703	27869	67120	15885	47417	2.33	3.41
30th July	1273	2552	11984	19703	19507	51040	7523	31337	1.63	2.59
15th Aug.	1013	1535	12507	20148	16132	30700	3625	10552	1.29	1.52
30th Aug.	752	700	11984	20148	11831	14000	-153	-6148	0.99	0.69
SEm±	64	72	-	-	-	-	-	-	-	-
CD (P=0.05)	198	222	-	-	-	-	-	-	-	-

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Short communication

Influence of mycorrhizal association on water extractability of sunflower (*Helianthus annuus*) plants under stress

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ABSTRACT

A pot culture experiment was conducted in sunflower (*Helianthus annuus* L.) to study the influence of mycorrhizal association on water extractability by the plant under receding soil moisture conditions. The soil water content was assessed at different stress cycles. Observations recorded during the crop growth period showed that, mycorrhizal (M) plants showed high leaf area, biomass and significantly high water use efficiency compared to non-mycorrhizal (NM) plants even under stress. Mycorrhizal plants extracted and transpired more water from the soil. In five cycles of stress, although the wilting symptoms appeared simultaneously in NM and M plants, the soil water content at wilting was always low in M plants, suggesting that, the plants with mycorrhizal association are capable of extracting more water from the soil due to the presence of extra metrical hyphae.

Key words: Cumulative water uptake, Sunflower, Vesicular arbuscular mycorrhiza, Water extraction, Water use efficiency

Sunflower (*Helianthus annuus* L.) is predominantly grown as a rainfed crop. Drought and high temperature are the two important abiotic constraints, which affect vegetative, reproductive growth and seed yield adversely. Among the abiotic stresses, water is the major limitation for growth and yield. Crops depend heavily on stored soil moisture for their water requirements (Sangamesh and Martin, 2002). Mycorrhizal symbiosis can protect host plants against detrimental effects caused by drought stress (Ruiz-Lozano *et al.*, 1999; Sanchez-Diaz and Honrubia, 1994). Vescicular arbuscular mycorrhizal hyphae were reported to enhance water uptake in sunflower and cowpea (Faber *et al.*, 1991) under moisture stress. Hence, a pot culture experiment was conducted with sunflower to study the water extraction capacity of plant roots in association with mycorrhiza and the extent to which mycorrhizal association helps in water absorption from the soil.

The sunflower hybrid KBSH-1 seeds were sown in pots of medium size which can hold 20 kg of sterilized soil provided with drain holes at the bottom. Recommended dose of fertilizers and all micronutrients in a nutrient solution were added to the sterilized soil. Mycorrhizal inoculum (*Glomus fasciculatum*) was applied (20g) for 25 number of plants 2 cm below the seeds (M plants) and another 25 plants were without mycorrhizal inoculation (NM plants). Three sunflower seeds were sown in one seedling spot and the plants were watered daily. Fifteen days after sowing (DAS) one seedling was maintained per pot. Plants were sampled 25 DAS for initial leaf area and initial drymatter. The soil surface in all the pots was covered with battery pieces to check evaporation loss. Evaporation controls were maintained without plants but covered with battery pieces to know the amount of evaporation loss. Thirty DAS, 15 pots showing similar leaf area were selected for imposing stress. Five plants were taken as replicates to record the observations. The data was analyzed by using completely randomized design.

Up to 40th day all the pots were irrigated equally and then all the pots were saturated with water and left for 3 hrs to bring them back to a moisture content of 15%. The drainage holes of the pots were closed by plugging them with cement. The weight of individual pot with soil, pot pieces and plant was recorded with the help of mobile electronic load cell balance of 50 kg capacity with a resolution of 50 g. The pots were weighed daily for 3 times to record the amount of water lost through transpiration. All the plants were watered and plants were left without watering till they showed wilting symptoms. Again the weight was taken. After they wilted, early in the morning plants were watered to attain field capacity. This process was repeated for 19 days and in total 5 cycles were obtained.

Observations were recorded on daily water uptake, leaf area, total drymatter and cumulative water use. Rate of water loss, biomass accumulated, water use efficiency, functional leaf area and soil moisture content at the time of wilting of the plant were computed.

The initial leaf area was about 421 cm^2. During the experimental period of 21 days, leaf area increased markedly. The final leaf area/plant was 2451 cm^2 in non-mycorrhizal and 2989 cm^2 in mycorrhizal plants. Thus the mycorrhizal plants produced 22% more leaf area. Leaf area duration also showed similar trend (Table 1). Biomass at the end of the experiment was also significantly high in M plants. During the cycles of moisture stress, M plants accumulated about 68 g of biomass while in NM plants it was 32 g. The amount of biomass produced per unit functional leaf area is also significantly high in M plants indicating that photosynthetic rate was maintained relatively high in plants with mycorrhizal association.

Mycorrhizal plants always extracted and transpired more water from the soil. The influence of mycorrhizal plants on water extraction from the soil and transpiration measured at 4 hrs interval for 32 hrs (Fig 1) clearly indicated that, the water taken up was high in M plants by 22 to 33% over NM plants. Once the plants started showing wilting symptoms, plants were irrigated and again water loss from the pots was determined as a measure of uptake and transpiration by the plants. During the cycles of stress, M plants always showed high water extraction compared to NM plants.

Observation recorded on the total amount of water used during the experimental period suggests that the M plants used nearly 20% more water compared to NM plants. Although the rate of water loss was less in M plants, the difference is not statistically significant. Water use efficiency was significantly high in M plants.

Table 1 Physiological parameters in non-mycorrhizal and mycorrhizal sunflower hybrid (KBSH-1) plants

Treatments	Initial leaf area (cm^2/plant)	Final leaf area (cm^2/plant)	Leaf area duration (dm^2/day)	Initial drymatter (g/plant)	Final drymatter (g/plant)	ADM	ADM/LAD	CWU/plant (ml)	Rate of water loss (ml/dm^2/day)	WUE (g/ml)
NM plants	421	2451	431	9.7	41.36	31.68	7.50	83	193	3.15
M plants	421	2989	524	9.7	77.72	68.04	12.86	100	190	6.56
CD (P=0.05)	-	113	139	-	7.76	9.50	3.52	14.58	NS	1.80

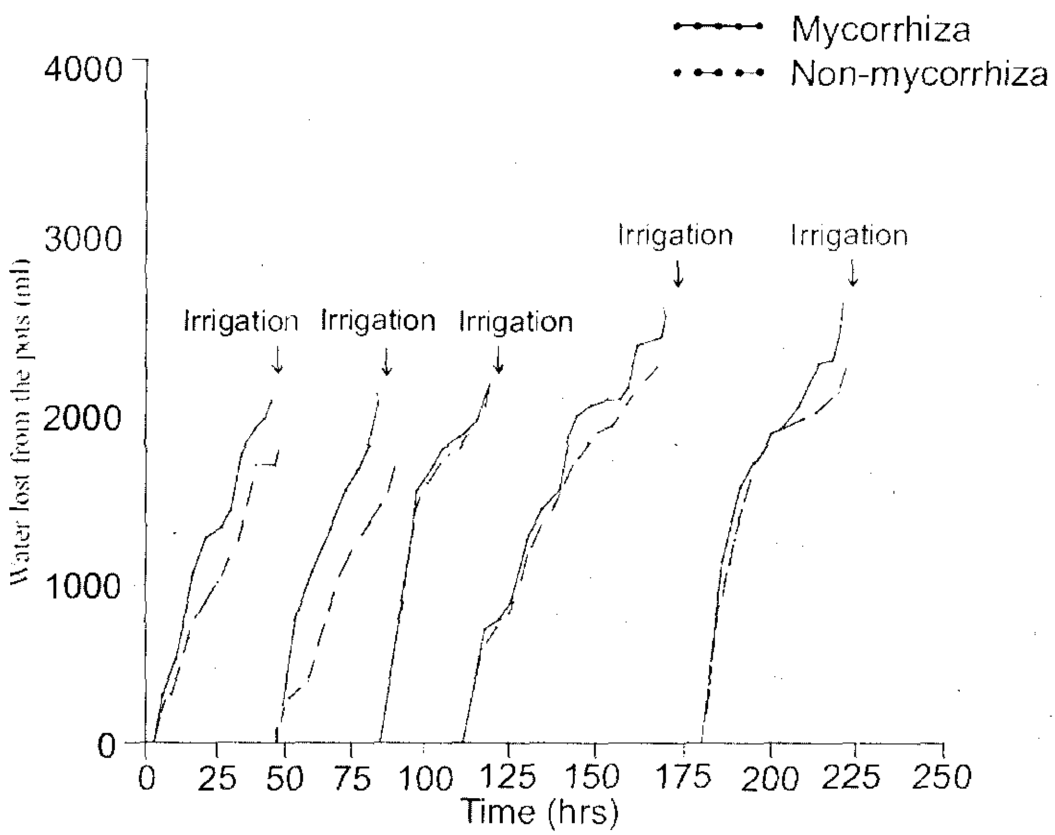

Fig. 1. Water extraction pattern of non-mycorrhizal and mycorrhizal plants during five cycles of moisture stress

The soil moisture content when the plants showed wilting symptoms was determined at the end of first 3 cycles of stress. Although wilting appeared in more than 50% of the plants in both M and NM plants, the moisture content of the soil at the time of wilting was less in plants with mycorrhizal association. Mycorrhizal association is capable of extracting relatively high amount of water in the soil (Table 2).

Table 2 Soil moisture content in pots at the time of wilting in non-mycorrhizal and mycorrhizal plants

End of stress cycle	Soil moisture content (%)	
	NM plants	M plants
1	8.66 ± 0.51	7.13 ± 0.41
2	9.66 ± 0.61	7.48 ± 0.45
3	7.42 ± 0.43	7.20 ± 0.44

Although wilting symptoms appeared simultaneously in mycorrhizal and NM plants, the water content in the soil at the time of appearance of wilting symptoms of leaves was always less in mycorrhizal plants at the end of each cycle of stress. Thus, the mycorrhizal association was beneficial in extracting water from deeper layers of soil which is not available for roots. Many researchers (Allen *et al.*, 1981; Hardie and Leyton, 1981) have already shown that the low resistance by water movement in the water transport pathway might be helping in extraction of more water from soil.

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Biochemical changes in resistant and susceptible varieties of peanut (*Arachis hypogaea*) in relation to early and late leaf spot disease

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ABSTRACT

Studies on the biochemical changes (total chlorophyll, phenol and soluble sugar contents) in tikka disease pathogens, *Cercospora arachidicola* Hori. *Phaeoisariopsis personata* (Berk.and Curt.)V.Arx. was carried out at the field level for two susceptible cultivars (GG-2 and GG-7) and two resistant cultivars (ICGV-86590 and ICGV-86564) of groundnut (*Arachis hypogaea* L.) were measured at 35 and 90 days after sowing. The maximum chlorophyll content was observed in resistant varieties compared to susceptible varieties. The high total phenol content was observed in resistant varieties than in susceptible varieties and also total soluble sugar content was observed maximum in resistant varieties than susceptible varieties. The total chlorophyll, phenol and soluble sugar contents at different stages of infection showed that chlorophyll, phenol and sugar contents increased with the progress of infection in resistant and susceptible entries also. There was a significant difference in total chlorophyll, phenol and soluble sugar contents between resistant and susceptible groundnut cultivars.

Key words: Chlorophyll, Early and late leaf spot disease, Peanut, Phenols, Sugars

Groundnut (*Arachis hypogaea* L.) is one of the principal oilseed crops of the world. India occupies 30% of global area (7.6 m. ha) and 22% (7.8 m.t) of total groundnut production (Anonymous, 2005). Eighty per cent of the total groundnut is confined to five states *viz*., Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra, accounts for 84% of the total production.

The major biotic factors affecting groundnut yield and quality in India are foliar fungal diseases, stem rot, collar rot, root rot and seedling rots etc. Early (*Cercospora arachidicola* Hori.) and late leaf spots [*Phaeoisariopsis personata* (Berk. and Curt.) Von Arx.] are the most widely distributed and economically important foliar diseases of groundnut causing severe damage to the crop (Kokalis-Burelle *et al*., 1997).

In Saurashtra region of Gujarat State, leaf spots are a major problem. So looking to the importance and severity of disease resulting in heavy yield losses, attempt was made to study the biochemical changes during disease development due to early and late leaf spots.

The studies were conducted during the rainy season of 2005 at Department of Plant Pathological Research Farm, Main Oilseed Research Station of the Junagadh Agricultural University, Junagadh Campus, Junagadh and summer 2006 farmer field at Govindpara village (Veraval taluka, Junagadh district).

The biochemical changes (total phenol, soluble sugars and chlorophyll content) of two susceptible cultivars (GG-2 and GG-7) and two resistant cultivars (ICGV-86590 and ICGV-86564) of groundnut were measured at 35 and 90 days after sowing (DAS). Total Phenol (Bray and Thorpe, 1954), total soluble sugar (Dubois *et al*., 1951) and total chlorophyll (Hiscox and Israelstam, 1979) contents were estimated.

One hundred milligrams (0.1g) of leaf tissue in fractions was placed in vial containing 10 ml DMSO (Dimethyl sulphoxide) and chlorophyll was extracted into the fluid without grinding. DMSO containing test tube kept for overnight, a 3.0 ml sample of chlorophyll extract was transferred to cuvette, and the OD values at 645 and 663 nm were read in a Spectrophotometer against a DMSO blank. Chlorophyll content was calculated following the equation and the results were expressed as mg/g of fresh weight.

$$\text{Chlorophyll a} = 12.7\,(A_{663}) - 2.69\,(A_{645}) \times V/\,1000 \times W$$
$$\text{Chlorophyll b} = 22.9\,(A_{645}) - 4.68\,(A_{663}) \times V/\,1000 \times W$$
$$\text{Total Chlorophyll} = 20.2\,(A_{645}) + 8.02\,(A_{663}) \times V/\,1000 \times W$$

Where, A = Absorbance at specific wave lengths
V = Final volume of chlorophyll extract
OD = Optical density
W = Fresh weight of tissue extracted

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The perusal of data presented indicated that the maximum chlorophyll content was observed in resistant variety of ICGV-86590 at 35 and 90 DAS followed by ICGV-86564 (Table 1). The chlorophyll content in susceptible varieties such as GG-2 and GG-7 was low. The total chlorophyll content with infection at different stages showed that chlorophyll content decreased with the progress of infection in resistant entries and susceptible entries also. There was a significant difference in chlorophyll content between resistant and susceptible groundnut cultivars.

The results at 35 and 90 DAS revealed that the maximum total phenol content was observed in resistant variety of ICGV-86590 followed by ICGV-86564. The total phenol content in susceptible varieties such as GG-2 and GG-7 was low (Table 1). The results showed that disease resistance entries possessed more total phenol content than susceptible ones. There was a significant difference in total phenol content between resistant and susceptible groundnut cultivars.

The results at 35 and 90 DAS revealed that the maximum total soluble sugar content was observed in resistant variety of ICGV-86590 followed by ICGV-86564 (Table 1). The total soluble sugar in susceptible varieties such as GG-2 and GG-7 was low. The total soluble sugar content at different stages of infection showed that sugar content increased with the progress of infection in resistant and susceptible entries also. The results indicated that disease resistance entries possessed more total soluble sugar content than susceptible entries ones. There was a significant difference in total soluble sugar content between resistant and susceptible groundnut cultivars.

These studies are in conformity with Sindhan and Parashar (1996) and Bera *et al.* (1999).

Table 1 Changes in total chlorophyll, phenol and soluble sugar contents (mg/g fresh weight) in groundnut released varieties during early and late leaf spot disease development stages

Varieties	Total chlorophyll content (mg/g fresh weight)			Total phenol content (mg/g fresh weight)			Total soluble sugar content (mg/g fresh weight)		
	35 DAS* (ELS)	90 DAS* (LLS)	% decrease	35 DAS* (ELS)	90 DAS* (LLS)	% decrease	35 DAS* (ELS)	90 DAS* (LLS)	% decrease
ICGV-86590**	2.458	2.205	10.32	6.510	7.965	22.35	0.180	0.234	30.0
ICGV-86564**	2.138	1.865	12.76	5.300	6.810	28.49	0.125	0.214	71.2
GG-2***	1.603	1.338	16.53	4.805	6.148	27.95	0.109	0.195	78.8
GG-7***	1.345	1.123	16.56	4.160	5.753	38.29	0.103	0.178	72.8
SEm±	0.035	0.029		0.088	0.122		0.003	0.004	
CD (P=0.05)	0.109	0.088		0.271	0.376		0.010	0.013	

* Mean of four replications; ELS = Early leaf spot; LLS = Late leaf spot; ** Resistant check; *** Susceptible check

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Short communication

Analysis of trypsin inhibitor activity in soyflour and soyproducts of soybean (*Glycine max*) genotypes

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ABSTRACT

The present study was undertaken at Parbhani during 2006-07 to analyse the trypsin inhibitor activity of soybean [*Glycine max* (L.) Merr.] genotypes and processed soy products. Nine genotypes of soybean and six soy products were investigated for trypsin inhibitor activity (TIA). The genotypes *viz*., JS-335, JS-9305, Kalitur, MAUS-32 and MAUS-81 were showed lower TIA as compared to other genotypes under study. The trypsin inhibitors reduces the digestibility of protein. The TIA of soybean genotypes, MAUS-2, MAUS-47, MAUS-71 and MAUS-61 was found higher. The soy flour made from these genotypes needs to be processed for more time to prepare different snacks. Trypsin inhibitor activity of soaked soybean and soy husk was found higher than soyane, sev, soy dal and roasted soybean. The roasted soybean and soy dal exhibited lowest TIA due to proper processing of these products. The soybean genotype JS-335 was found better in TIA.

Key words: Soybean, Trypsin inhibitor activity

Soybean [*Glycine max* (L.) Merr.] is generally referred as golden as well as wonder bean because of its protein and energy source. The protein of soybean is comparable to those of animal protein except for methionine content. The use of soybean has been studied in the preparation of several traditional foods to solve the problems of protein-energy malnutrition in India. Soybean also considered as power house of phytochemicals such as soy lecithin, vitamin E, oligosaccharides, isoflavones, phytosterols, phytates and trypsin inhibitors, which act as anti-carcinogenic and hypocholesterolemic compound.

The presence of enzyme inhibitors were reported in legumes such as soybean, kidney bean and navy bean. Trypsin inhibitor is one of the toxic constituents occurring naturally in the legumes, especially in soybean (Read and Haas, 1938).Two types of trypsin inhibitors are present in soybean *viz*., Kunitiz inhibitor and Bowman Brik inhibitor (BBI). They are proteins, which can bind to the digestive enzyme trypsin. The trypsin inhibitor reduces the digestibility of protein by inhibiting tryptic activity. Trypsin inhibitor activity (TIA) was also inactivated to a greater extent by germination of soybean, heating of soymilk before fermentation and blending of tomato sauce with soy flour (Tripathi and Nirankarnath, 2002). The present study was therefore undertaken to analyse the TIA of soybean genotypes and processed soy products.

Nine different genotypes of soybean (as soy flour) and six soy products were investigated for the pattern of accumulation of TIA. The genotypes *viz*., MAUS-2, MAUS-32, MAUS-47, MAUS-61, MAUS-71, MAUS-81, JS-335, JS-9305 and Kalitur were collected from Soybean Research Centre, Marathwada Agricultural University, Parbhani. Soy products like soyane, sev, soyadal, soaked soybean, roasted soybean and soy husk were prepared from the soybean genotypes under study.

The TIA was measured indirectly by inhibiting the activity of trypsin. A synthetic substrate (BAPNA) is subjected to hydrolysis by trypsin to produce yellow coloured p-nitroanilide. The degree of inhibition by the extract of the yellow colour production is measured at 410 nm.

In each test tube 20 µl of extract and 40 µl of trypsin solution was added, 200 µl volume was made by adding Tris HCl buffer (pH 7.8). From the above prepared reaction mixture 50 µl of solution was used in duplicate sets of test tube. In each test tube 400 µl of tris HCl buffer (pH 7.8) and 400 µl of substrate (BAPNA solution) were added. Samples were incubated for 30 min at room temperature. Later the reaction was terminated by adding 200 µl of 30% acetic acid. Then the absorbance was recorded at 410 nm against the reagent blank by using spectrophotometer. The TIA was calculated and expressed as per cent.

Trypsin inhibitor activity of soy flour

Trypsin inhibitor activity of soy flour of different genotypes was given in table 1 and the differences among the genotypes were found significant. The results indicated that, the TIA of soy flour obtained from different soybean genotypes ranged between 16 to 35%. Trypsin inhibiting proteolytic activity of MAUS-2 was 35%, which was significantly higher than JS-335, JS-9305, Kalitur, MAUS-32 and MAUS-81.

The genotype *viz*., JS-335, JS-9305, Kalitur, MAUS-32 and MAUS-81 were inhibiting the low protein content of digestive enzyme due to lowest proteolytic activity as compared to other genotypes under study. The soybean genotype JS-335 was found better in inhibiting the lower protein activity (16%). Therefore, the genotype, JS-335 was identified best for alternative uses followed by JS-9305, Kalitur, MAUS-32 and MAUS-81.

The trypsin inhibiting proteolytic activity of soybean genotypes, MAUS-2, MAUS-47, MAUS-71 and MAUS-61 was highest as compared to other genotypes. The soy flour made from these genotypes needs to be processed for more time while using in preparation of different snacks. Kakade and Evans (1966) reported that soaking of beans decreases TIA. They also reported the use of heat for destruction of trypsin inhibitor in soybean samples.

Trypsin inhibitor activity of soy products

Trypsin inhibitor activity of different soy products was given in table 2. Significant differences were observed in TIA of different soy products. Trypsin inhibitor activity of different products of soybean ranged form 9-22%. Trypsin inhibitor activity of soaked soybean and soy husk was found 22 and 21%, respectively, which was significantly highest than other soy products. This indicated that the soaked soybean and soy husk highly inhibits the protein activity among all other soy products .

The roasted soybean and soy dal exhibited significantly lowest TIA than other soy products. These two soy products indicated 9% TIA. Among the six soy products under study, the roasted soybean and soy dal can serve better in protein content because they have lower TIA.

Trypsin inhibitory activity in soaked soybean and soy husk were found highest among all other products *viz*., soyane, sev, soyadal and roasted soybean. The roasted soybean and soy dal exhibited lowest TIA due to proper processing of these products. Sharma and Subramanian (1991), Subba Rao and Prasannappa (1989) also reported that trypsin inhibitors were destroyed in processed soybean.

Table 1 Trypsin inhibitor activity of soy flour

Genotypes	Trypsin inhibitor activity (%)
MAUS-2	35
MAUS-32	24
MAUS-47	34
MAUS-61	32
MAUS-71	32
MAUS-81	25
JS-335	16
JS-9305	22
Kalitur	22
SEm+	1.2
CD (P=0.05)	3.9

Table 2 Trypsin inhibitor activity of soy products

Soy products	Trypsin inhibitor activity (%)
Soyane	15
Sev	14
Soy dal	9
Soaked soybean	22
Roasted soybean	9
Soy husk	21
SEm±	0.9
CD (P=0.05)	3.1

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Short communication

Techniques for pathogenicity testing and screening of safflower cultivars against *Macrophomina phaseolina*

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ABSTRACT

Pathogenicity of 24 isolates of *M. phaseolina* on safflower was proved by germination towel technique and soil cup method. *M. phaseolina* isolate Mp-4 which was highly pathogenic in both the methods of pathogenicity testing was used for screening 18 cultivars of safflower for disease reaction. All cultivars showed similar kind of reaction to the pathogen in germination towel technique and soil cup method. The study indicates suitability of germination towel technique and infested soil cup method for screening the safflower genotypes against *M. phaseolina*.

Key words: Germination towel technique, *Macrophomina phaseolina*, Pathogenicity, Safflower, Soil cup method

Macrophomina phaseolina (Stasis) Goid is one of the most destructive plant pathogens in the tropics and subtropics causing diseases in a wide range of hosts (Dhingra and Sinclair, 1977). The pathogen is soil borne and causes root rot in safflower. Safflower yield and seed quality are affected when disease symptoms are severe. Progress in developing resistant genotypes against *M. phaseolina* has been hampered because of a lack of reliable and efficient method for screening. Many researchers used direct soil inoculation for testing pathogenicity of *M. phaseolina* (Mayek-Perez *et al.*, 2001) or root and crown inoculation techniques (Prett *et al.*, 1998). Our attempt of root inoculation of *M. phaseolina* isolates failed to cause root rot indicating non suitability of the method in safflower. Thiyagu *et al.* (2007) have reported rapidness and ease of the germination towel technique for pathogenicity testing of *M. phaseolina* in sesame. The present study has been undertaken to demonstrate the adoptability of germination towel and infested soil cup techniques for pathogenicity testing and screening safflower cultivars against *M. phaseolina*.

Pathogenicity of twenty-four isolates of *M. phaseolina* was tested by germination towel and infested soil cup techniques based on root rot induced on susceptible safflower cultivars A-1 and NARI-6. In germination towel test, seeds were surface disinfected with 2% sodium hypochlorite solution, followed by serial washings with sterile water. Surface disinfected seeds were inoculated with *M. phaseolina* isolates inoculum separately (approx. $2x10^3$ cfu/seed). Untreated seeds served as check. For each treatment, 50 seeds were taken into account with 4 replications. The seeds were placed on the moist germination towels (germination towels were sterilized by dipping in mancozeb 0.2% solution) and incubated at 25°C. On 7[th] day, the germination towels were opened without disturbing the roots, culture suspension of *M. phaseolina* was inoculated @$2x10^3$cfu/ml by smearing on to the roots using sterile cotton swab and incubated for 3 days at 25°C. Root rot incidence was recorded and confirmed for microsclerotia formation in the infected roots by microscopy. In the soil cup method, sterile soil infested with the 24 isolates of *M. phaseolina* separately grown in potato dextrose broth (approx. $2x10^4$ cfu/gm of soil) was placed in plastic cups of 5cm diameter with 10cm depth. Three seeds susceptible safflower cultivars A-1 and NARI-6 were sown in infested soil cup separately and 10 replications were maintained for each treatment. Seeds sown in cups with untreated soil served as check. Observations on seed germination, root rot incidence by each isolate were recorded 14 days after sowing.

Eighteen cultivars of safflower were screened for their reaction to *M. phaseolina* by following the two techniques described above. Observations on germination, root rot incidence in each cultivar was recorded 14 days after sowing by following standard techniques and confirmed for microsclerotia formation in the infected root.

All the 18 isolates of *M. phaseolina* have induced root rot on susceptible cultivars A-1 and NARI-6 when pathogenicity tests conducted by germination towel and infested soil cup methods and one isolate designated as Mp 4 was found to be highly pathogenic inducing more than 80% disease incidence in two susceptible cultivars. Hence, the *M. phaseolina* isolate Mp 4s was used for screening safflower cultivars for their

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reaction. Germination towel technique and infested soil cup method were tried for screening safflower cultivars and out of 18 varieties screened, 7 varieties *viz.*, NARI-NH-1, PBNS-12, NARI-6, Sharada, A-2, PBNS-40 and SSF- 658 were resistant to *M. phaseolina* 4 were as remaining all 11 varieties (Nira, JSI-7, JSF-1, Bhima, NARI-38, Phule kusuma, AKS-207, NARI-NH-15, Manjira and A-1) and the hybrid DSH-129 were pathogen susceptible in both the methods of screening. These results indicate germination towel technique and infested soil cup method are reliable and rapid to screen the safflower genotypes for their reaction to *M. phaseolina*. In conclusion, germination towel technique and infested soil cup method can be employed for testing pathogenicity of *M. phaseolina* isolates in safflower and for screening safflower cultivars for their reaction to the pathogen.

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Short communication

Adoption behaviour of soybean (*Glycine max*) growers

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ABSTRACT

A study was carried out during 2009-10 in Indore district of Madhya Pradesh focused on the factors influencing adoption of soybean [*Glycine max* (L.)] production technologies by soybean growers. The data were collected through interview schedule from 120 randomly selected growers and the findings revealed that majority of the growers had complete adoption in case of recommended land preparation, varieties, spacing and weeds management. The study further revealed that majority of the growers belonged to medium level of adoption. The adoption behaviour of soybean growers was positively influenced by education, annual income, cosmopoliteness, economic motivation and knowledge of soybean growers and negatively by their age. The lack of knowledge and non availability of input were the important constraints perceived by the soybean growers in adoption of the recommended technology.

Key words: Adoption behaviour, Recommended technology and Soybean growers

Soybean [*Glycine max* (L.)] is an important oilseed crop which ranks third in oilseeds after groundnut and rapeseed-mustard. Madhya Pradesh is the main soybean producing state in India. In 2006-07, total production was nearly 49.8 lakh t in India, while during 2007-08, production was 57.8 lakh t. During the 2007, soybean has been grown in Madhya Pradesh in an area of about 4.9 m. ha with an average productivity of 10.2 q/ha (Anonymous, 2007) which is low as compared to average productivity of other countries. The major constraints in production include non-availability of adequate amount of quality seeds of improved varieties, poor adoption of improved production technology and the risks of crop cultivation in rainfed conditions. In order to overcome the problem of low yield, application of modern technology in soybean cultivation can play a crucial role. Hence, the present study has been designed to know the adoption behaviour of soybean growers and constraints in adoption of modern technologies of soybean production.

The study was conducted in Indore district of Madhya Pradesh. Indore district comprises of four blocks namely Indore, Mhow, Depalpur and Sanwer. Out of these four blocks, two blocks namely Indore and Depalpur were selected randomly. From each selected block, a list of villages was prepared and ten villages (five villages from each block) were selected randomly. A list of all the soybean growers from each of the selected village was prepared. From this list, 12 respondents (4 small, 4 medium and 4 large) were randomly selected from each village. Thus, a total sample size of 120 respondents was covered from the operational area.

Sixteen independent variables were selected based on judges rating and these variables were quantified with the help of available measurement procedures. The data were collected through personal interview by using well structured interview schedule.

Measurement of dependent variable

The adoption behaviour intended the degree to which a farmer had actually adopted the recommended soybean production technologies. After perusal of relevant literature and based on discussion with scientists, ten practices (preparation of land, use of recommended varieties, seed treatment with fungicide, time of sowing, use of recommended spacing, sowing depth, seed rate, weed management, insect management and disease management) were identified in soybean cultivation. Each respondent was asked to tell the practices followed by him.

In order to ascertain adoption of improved soybean production technologies, the responses of the respondents were collected on ten practices. Practice-wise responses were categorized into three level of adoption i.e., no adoption, partial adoption and complete adoption.

The responses of the respondents were evaluated on the basis of correct and incorrect answers. The score of "2" was assigned to those respondents who adopted the particular practice completely. The partial adoption of practices was given "1"score while "0" score was given to those respondents who did not adopt the particular practice.

The total score which was obtained from the respondents on all the items of soybean cultivation was adoption behaviour score. The raw score which was obtained from the respondents were converted in to adoption index score (AIS). The range of adoption index score was divided into three groups *viz.*, low, medium and high on the basis of mean ± SD.

Practice-wise adoption of soybean production technology by growers

Vast majority (99%) of the respondents had complete adoption in case of recommended land preparation practices followed by use of recommended varieties (73.3%), spacing (70.8%), time of sowing (66.7%), and weed management (65%).

It was further noted that about half (54.2%) of the respondents had partial adoption in case of insect management and sowing depth (52.5%). About 32% respondents had partial adoption in case of time of sowing followed by seed rate (29.2%), use of recommended varieties (25%), spacing (22.5%), weed management (21.7%) and disease management (19.2%) (Table 1).

Thus, the findings of the study revealed that out of ten recommended practices, five practices *viz.*, land preparation, use of recommended varieties, spacing, time of sowing, and weed management were completely adopted by majority of the soybean growers, while two practices *viz.*, insect pest management and sowing depth were partially adopted by majority of the soybean growers. The rest two practices *viz.*, disease management and seed treatment were not adopted by majority of the soybean growers.

Level of adoption behaviour of soybean growers

More than half of respondents (61.7%) had medium level of adoption, while about 22% had high and 15% had low level of adoption. It can be stated that most of the respondents had medium level of adoption. The finding of the study is in agreement with the results obtained by Shrivastav *et al.* (2002), Patel *et al.* (2003), Dhillon and Kumar (2004), Jadav and Munshi (2004), Thyagarajan (2004), Talukar and Sontanki (2005), Sharma *et al.* (2005) and Johnson and Manoharan (2007).

Relationship between socio-personal, socio-economic, communication and psychological factors and adoption behaviour

The correlation coefficient in respect of age was found to have negative correlation with adoption scores, which indicated that young farmers had better adoption in comparison to old farmers, because younger persons are generally more energetic, change prone, progressive and innovative than older ones (Table 2). The finding is in conformity with the findings of Subhashini and Thyagarajan (2002) Motamed and Singh (2003), Talukar and Sontanki (2005).

Other factors like annual income, mass media exposure, cosmopoliteness, economic motivation and knowledge were found to be positively correlated with adoption behaviour. Capital is very important to run any enterprise. Therefore farmers who had higher financial status had higher adoption level. In case of mass media exposure, it is well known that exposure to mass media had direct effect on perception in the minds of the people. Subhashini and Thyagarajan (2002) reported similar finding. Similarly, cosmopoliteness also plays an important role in decision making of an individual. The cosmopolite farmer is likely to be unique individual in that he is motivated to look beyond his environment (Patel *et al.*, 2003 and Talukar and Sontanki, 2005).

Economic motivation is also considered as a main driving force working behind the progressive farmers and has been supported by many researchers (Motamed and Singh, 2003). Knowledge is one of the important components of human behaviour. It plays a major role in covert and overt behaviour of human beings. Knowledge about farm technology has a direct relationship with adoption behaviour. Similar results were reported by Patel *et al.* (2003) Singh *et al.* (2003).

Multiple regression analysis for identifying the factors influencing adoption behaviour

Multiple regression analysis indicated that all the 16 variables taken together explained 77.9% of the variation (R^2=0.779) for adoption behaviour of soybean growers. The result implied that all the variables accounted for significant amount of variation for adoption behaviour.

Optimum model of multiple regression analysis of adoption behaviour with selected variables

For the purpose of arriving at an optimum model of multiple regression analysis of selected variables with adoption behaviour only those factors which contributed to R^2 with values equal to or more than 1% were included in the optimum model.

The partial regression coefficients of all the factors were found to be significant (Table 3). Among these factors education, cosmopoliteness, and knowledge were significant at 0.05 level of probability and annual income and economic motivation were found significant at 0.01 level of probability. The R^2 value (0.764) obtained with five factors on adoption behaviour was observed at 0.01 level of probability (F 61.05) with 5 and 114 degree of freedom. This indicated that 76.4% variation in adoption behaviour was explained by five variables accounted for significant amount of variation for adoption behaviour.

Constraints in adoption of recommended soybean production technology

Only 1.7% respondents were not found to adopt improved varieties of soybean due to lack of knowledge (Table 4). In case of seed treatment, majority (93.3%) of the respondents were not found to adopt seed treatment practice due to lack of knowledge (50%), non availability of fungicides (25%) and high cost of fungicides (18.3%).

The data further revealed that only eight (6.7%) respondents did not adopt recommended spacing due to lack of knowledge (4.2%) and lack of good quality of seed (2.5%). Similarly, 7.4% respondents did not adopt sowing depth due to lack of knowledge (4.2%) non availability of proper sowing device (1.6%) and lack of adequate moisture at the sowing time (1.6%). Nearly 27% respondents did not adopt recommended seed rate due to lack of knowledge. The data also indicated that 13.3% of respondents were not using weedicides due to lack of knowledge (4.2%), high cost of weedicides (6.6%) and non-availability of weedicides (2.5%). About 7% of the respondents did not adopt insect management practices due to lack of knowledge (4.2%), high cost of insecticides (1.6%) and non availability of insecticides (1.6%).

The data further revealed that about 40% did not adopt disease management due to lack of knowledge (24.2%), high cost of fungicides (8.3%) and non availability of fungicides (8.3%).The results obtained were in conformity with the findings of Shrivastava *et al.* (2002).

Intensive extension efforts are needed to improve the adoption level of respondents towards insect-pest management, disease management, seed treatment and depth of sowing. Farmers with fairly better level of education, cosmopoliteness, annual income, economic motivation and knowledge towards improved soybean production technologies may be selected as "contact farmers" to influence the adoption behaviour of soybean growers.

Table 1 Practice-wise adoption of the soybean production technology by soybean growers (n=120)

Recommended technology	Complete adoption	Partial adoption	No adoption	Score	Rank
Preparation of land	119 (99.2)*	1 (0.8)	0 (0)	239	I
Use of recommended varieties	88 (73.3)	30 (25)	2 (1.7)	206	II
Time of sowing	80 (66.7)	39 (32.5)	1 (0.8)	199	III
Spacing	85 (70.8)	27 (22.5)	8 (6.7)	197	IV
Weed management	78 (65)	26 (21.7)	16 (13.3)	182	V
Sowing depth	48 (40)	63 (52.5)	9 (7.5)	159	VI
Insect management	46 (38.3)	65 (54.2)	9 (7.5)	157	VII
Seed rate	53 (44.2)	35 (29.2)	32 (26.7)	141	VIII
Disease management	8 (6.7)	23 (19.2)	89 (74.2)	39	IX
Seed treatment	3 (2.5)	5 (4.2)	112 (93.3)	11	X

*The figures in parentheses are percentage of the total

Table 2 Correlation and regression analysis of selected characteristics of soybean growers with their adoption behaviour

Factor	Correlation coefficient "r"	Standard partial regression coefficient	Percentile contribution	Regression coefficient "b"
Age	- 0.215*	0.001	-0.034	0.001
Education	0.211	0.124	3.378	1.391*
Family type	0.067	-0.095	0.817	-2.172
Family size	0.046	0.074	0.446	0.231
Social participation	- 0.103	0.049	-0.648	0.389
Annual income	0.772**	0.376	37.234	0.161**
Land holding	0.06	-0.024	-0.197	-0.126
Material possession	0.061	0.078	0.615	0.123
Information seeking	0.012	-0.009	-0.015	-0.090
Mass media exposure	0.215*	-0.093	-2.566	-0.577
Cosmopoliteness	0.245*	0.136	4.296	0.280*
Extension participation	0.120	-0.020	0.064	0.125
Economic motivation	0.7853**	0.476	47.917	2.655**
Knowledge	0.427**	0.161	8.817	0.670**
Management orientation	0.037	-0.026	-0.124	-0.063
Scientific orientation	0.003	-0.115	0.003	-0.703

R^2= 0.780 Multiple R= 0.883** F-value=22.8** with 16 and 103 degrees of freedom; *, **Significant at 5% and 1% level, respectively

Table 3 Step-down regression analysis of selected characteristics of soybean growers with their adoption behaviour

Factor	Standard partial regression coefficient	Percentile contribution	Regression coefficient "b"
Education	0.106	2.944	1.188*
Annual income	0.375	37.911	0.884**
Cosmopoliteness	0.108	3.466	0.281*
Economic motivation	0.470	48.254	0.898**
Knowledge	0.133	7.425	0.489*

R^2 = 0.764, Multiple R = 0.874** F-value 61.1 with 5 and 114 degrees of freedom; *, ** Significant at 5% and 1% level respectively

Table 4 Constraints in adoption of recommended soybean production technology

Recommended practices	No. of non-adopters	Constraints	Frequency	Per cent
Use of recommended varieties	2 (1.7%)	Lack of knowledge	2	1.7
Seed treatment	112 (93.3%)	Lack of knowledge	60	50.0
		Non availability of fungicide	30	25.0
		High cost of fungicide	22	18.3
Time of sowing	01(0.8%)	Lack of knowledge	01	0.8
Spacing	8 (6.7%)	Lack of knowledge	5	4.2
		Lack of good quality seed	3	2.5
Sowing depth	9 (7.4%)	Lack of knowledge	5	4.2
		Non availability of proper sowing device	2	1.6
		Lack of adequate moisture at sowing time	2	1.6
Seed rate	32 (26.7%)	Lack of knowledge	32	26.7
		Lack of knowledge	5	4.2
		High cost of weedicide	8	6.6
		Non availability of weedicide	3	2.5
Insect management	9 (7.4%)	Lack of knowledge	5	4.2
		High cost of insecticide	2	1.6
		Non availability of insecticide	2	1.6
Disease management	49 (40.8 %)	Lack of knowledge	29	24.2
		High cost of fungicide	10	8.3
		Non availability of fungicide	10	8.3

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