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Genetic architecture for yield and its components in castor

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Abstract

The genetic architecture of seed yield and related traits was investigated through generation mean analysis for three crosses in six generations. Additive and non-additive gene effects for seed yield and majority of the traits were significant. However, magnitude of dominance and epistatis components were higher than additive components. None of traits was under the control of the epistatis types of interaction effects. Duplicate type of epistatis was observed in almost all the cases. Higher magnitude of dominance and dominance x dominance gene effects were observed for seed yield per plant. Thus heterosis breeding, synthetic variety and population improvement adopting *inter se* mating among promising divergent genotypes and effecting simultaneous selection for seed yield, oil content and other components of yield is an ideal breeding approach for castor improvement.

Key words : Genetic architecture, yield components, gene action

Introduction

Yield is the ultimate product of action and interaction of number of yield components, which are governed by a large number of genes having small effects and are greatly influenced by environment. Effect of small individual gene cannot be selected, collective effect of the genes can be estimated any of the attributes. The information on the nature of gene action could be helpful in predicting the effectiveness of selection in a population. A distinct knowledge on type of gene effect, its magnitude and composition of genetic variance are essential. The efficient partitioning of genetic variance into additive, dominance and epistatis help in formulating an effective and sound-breeding programme.

The castor crop has great commercial value but the information on gene effects and other genetic parameters are limited. The present study was undertaken to study the nature and magnitude of gene action governing the yield and its components.

Materials and methods

The material comprised three hybrids *viz.*, VP-1 x 48-1 (C_1), Geeta x SH-72 (C_2) and Geeta x 2-73-11 (C_3) involving five diverse parents. The experiment with six generations (P_1, P_2, F_1, F_2, B_1 and B_2) generated in previous two seasons, was conducted in RBD with three replications at the Oilseeds Research Station, Gujarat Agricultural University, Junagadh during *kharif 1996-97*. Each replication was divided into three randomly allotted compact blocks each consisting of six generations. Each block consisted of two rows of P_1, P_2, and F_1 four rows of B_1 and B_2 and six rows of F_2 generations. There were 12 plants in a row. The recommended inter and intra row spacing of 90 and 60 cm respectively was adopted. Ten plants from each plot of parents and F_1's, twenty plants from each plot of B_1 and B_2 and thirty plants from each plot of F_2 were selected randomly and tagged. From each replication data was recorded for 11 quantitative characters (Table 1). Data collected on the individual plants were subjected to weighted least square analysis (Join scaling test), Cavalli (1952). Chi-square test was used for testing the adequacy of additive-dominance and digenic interaction model, Fisher(1941).

Results and discussion

The estimates of gene effects for the best-fit model with respect of 11 different traits in three crosses of castor are given in Table 1. Days to flowering of primary raceme was under the control of additive (d), dominance (h), additive x dominance (j) and dominance x dominance (l) effects in cross 1 and 3. Negative sign of (h) and (l) parameters indicated duplicate type of epistasis for this character. In cross 2, additive (d), dominance (h), additive x additive (i) and additive x dominance (j) type of interaction controlled this character, the value of dominance effect being high in all three crosses. Thakkar (1987) and Patel (1991).

Table 1 Estimates of gene effects for different characters in three crosses of castor

Cross	f^2 at		Genetic components						Types of epistasis
	3 d.f.	6 d.f.	M	D	h	i	j	l	
			Days to flowering of primary raceme						
C_1	120.60**	0.34	56.93**	-6.10**	2.51**	-	7.60**	-24.17**	Duplicate
C_2	78.64**	3.30	75.51**	3.20**	-17.18**	-14.60**	6.59**	-	-
C_3	39.47**	3.59	68.30**	-5.27**	7.54**	-	-6.76**	-11.37**	Duplicate
			Number of nodes up to primary raceme						
C_1	23.51**	2.71	18.66**	-0.52**	-2.99**	-2.41**	-	-	-
C_2	4.47	-	17.88**	3.05**	-1.46**	-	-	-	-
C_3	19.21**	4.64	21.22**	-1.41**	-5.59**	-	-	3.91**	Duplicate
			Plant height						
C_1	39.05**	1.18	52.13**	-22.03**	-15.05**	-	12.77*	27.42**	Duplicate
C_2	-	-	-	-	-	-	-	-	-
C_3	85.20**	0.49	72.08**	14.25**	-52.74**	-	-12.34*	54.32**	Duplicate
			Total length of primary raceme						
C_1	21.74**	1.18	34.12**	4.38**	-19.45**	-	-9.96*	16.83**	Duplicate
C_2	-	-	-	-	-	-	-	-	-
C_3	-	-	-	-	-	-	-	-	-
			Effective length of primary raceme						
C_1	37.26**	2.41	32.73**	5.77**	-32.31**	-	-9.53*	23.97**	Duplicate
C_2	57.24**	1.39	12.77**	0.61	17.37**	19.98**	-	-	-
C_3	22.60**	0.80	26.18**	7.82**	-13.18**	-	-11.90**	12.43**	Duplicate
			Days to maturity of primary raceme						
C_1	29.17**	3.83	124.86**	-3.82**	12.28**	-	-	-12.94**	Duplicate
C_2	26.37**	1.50	135.81**	2.21**	-14.93**	-7.83**	10.33**	-	-
C_3	15.73**	3.47	134.33**	-3.01**	0.74	-	-	-7.94**	Duplicate
			Number of capsules per primary raceme						
C_1	35.40**	2.89	25.29**	3.54*	28.57**	24.89**	-	-	-
C_2	105.39**	1.11	32.36**	5.71**	-9.54	28.36**	-	32.35*	Duplicate
C_3	49.74**	1.27	25.90**	12.49**	23.65**	27.87**	-18.14**	-	-
			Number of raceme per plant						
C_1	5.24	-	4.02**	-0.45**	0.57*	-	-	-	-
C_2	21.35**	0.58	2.76**	0.36**	2.47**	1.91**	-	-	-
C_3	-	-	-	-	-	-	-	-	-
			100 seed weight						
C_1	21.66**	1.17	24.28**	-2.25**	3.49**	3.69**	-	-	-
C_2	-	-	-	-	-	-	-	-	-
C_3	1.72	-	27.04**	1.12**	3.69**	-	-	-	-
			Seed yield per plant						
C_1	56.37**	3.47	74.82**	-8.05**	-58.46**	-	29.78**	86.87**	Duplicate
C_2	100.91**	0.81	77.76**	7.10*	112.81**	81.72**	-39.74**	-	-
C_3	137.08**	5.35	79.97**	9.70**	-103.67**	-	-	123.40**	Duplicate
			Oil content						
C_1	15.61**	3.12	49.89**	-0.62**	1.17*	3.72**	1.49**	-	-
C_2	18.21**	1.24	49.23**	0.19**	-1.11**	-	-	1.55**	Duplicate
C_3	258.30**	0.74	42.63**	-0.12	13.27**	6.96**	-	-5.07**	Duplicate

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

Additive dominance model was found to be adequate to explain the genetic variation for number of nodes up to primary raceme in cross 1. Additive, dominance and additive x additive gene effects were found significant in cross 1 whereas, in cross 3 (d), (h) and (l) genetic parameters were found significant among them, dominance effect pre-dominance. The negative sign of (h) and (l) in cross 3 indicated the presence of duplicate epistasis. Present findings are in agreement with the results obtained by Thakkar (1987) and Patel (1991).

An estimate of gene effects revealed that additive, dominance, additive x dominance and dominance x dominance gene effects governed the expression of plant height in cross 1 and 3. However, in cross 3, dominance and dominance x dominance gene effects were predominant, a duplicate dominant epistasis in nature. The present findings are in close agreement with the results obtained by Thakkar (1987) and Patel (1991).

The genetic components of variation revealed that all the gene effects except additive x additive were involved in the expression of trait total length of primary raceme. The magnitude of dominance and dominance x dominance gene effect was higher and duplicate in nature for total length of primary raceme in cross 1. In cross 2 and 3 scaling testa and genetic components were not carried out as there were non-significant results in analysis of variance. The results akin to the results obtained by Pathak *et al.* (1988) and Patel *et al.* (1993).

Effective length of primary raceme was influenced by additive, dominance, additive x dominance and dominance x dominance gene effects in cross 1 and cross 3. However, dominance and dominance x dominance gene effects were predominant with duplicate type of epistasis and the possibility of releasing transgressive segregants. While dominance and additive x additive gene effects were involved in cross 2. Thakkar (1987) also reported additive and non-additive gene effects to be involved in the inheritance of this trait.

Additive, dominance and dominance x dominance gene effects for days to maturity of primary raceme were significant in cross 1. In cross 2 all the gene effects except dominance x dominance were significant whereas, additive and dominance x dominance gene effects were prevailing in cross 3. However, in all three crosses values of additive gene effects were small indicating that non-additive types of gene effects were important for this trait. Thakkar (1987) obtained the same results.

The genetic components of variation revealed that additive, dominance and additive x additive gene effects were involved in the expression of number of capsules per primary raceme in cross 1. The additive, additive x additive and dominance x dominance gene effects were involved in cross 2 whereas, all the gene effects except dominance x dominance were significant in cross 3. In all the three crosses magnitude of additive component was lower than the other gene effects, indicated that heterosis breeding may give good result for this trait. Thakkar (1987) and Dobaria *et al.* (1992) obtained the same results.

For cross 1 simple additive dominance model was adequate. Both the main effects were involved in the expression of number of raceme per plant in cross 1 while additive, dominance and additive x additive gene effects were significant in cross 2. Additive x additive type of epistasis in cross 2 indicated the possibility of obtaining segregants with more number of racemes per plant in later generations. The findings are akin to the results obtained by Patel (1991) and Dobaria *et al.* (1992).

Both additive and dominance gene effects were involved in the expression of 100-seed weight in cross 1 and cross 3. In cross 1 additive x additive type of epistasis was also present indicating that this trait might be improved by selection in later generations. Patel *et al.* (1993) has reported preponderance of additive gene effects while, Patel (1991) has reported both additive and non-additive gene actions.

Except additive x additive, all gene effects were involved in the expression of seed yield per plant in cross 1. In cross 2, except dominance x dominance all gene effects were involved. Additive, dominance and dominance x dominance gene effects were significant in cross 3. The dominance and dominance x dominance gene effects were in opposite direction indicating the involvement of duplicate epistasis in the expression of this trait in crosses 1 and 3. Additive as well as non-additive gene effects governed the inheritance of this trait. Hence, to obtain good segregants, recurrent selection would be more useful. However, dominant effect was predominant over the additive gene effects in the presence of epistatic gene effect in all the crosses. Duplicate epistatis was also present in two crosses. Therefore, resorting to heterosis breeding for exploitation of yield would also give fruitful results. Several workers like Thakkar (1987), Pathak *et al.* (1988), Patel (1991) and Dobaria *et al.* (1992) reported that both additive as well as non-additive gene effects play important role in the expression of seed yield per plant.

All the gene effects, except dominance x dominance for oil content were involved in cross 1. Additive, dominance and dominance x dominance gene effects in cross 2 while dominance, additive x additive and dominance x dominance gene effects in cross 3 were involved in the expression of this trait. The opposite signs of (h) and (l) in cross 2 and cross 3 indicated the presence of duplicate epistatic effects found significant while additive component

had a negative sign, indicating the possibility of direct exploitation of heterosis. Further recurrent selection will yield fruitful results. These results were in agreement with the results obtained by Dobaria *et al.* (1989) and Patel (1991).

Most of the characters in either of the crosses were found to be under the control of additive and non-additive gene effects and duplicate type of epistatis indicating that heterosis breeding and recurrent selection would be more fruitful for the improvement of most of the characters.

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Mutagenic frequency, effectiveness and efficiency of EMS, NG, gamma rays and their combinations in sesame (*Sesamum indicum*)

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Abstract

Seed treatments with Ethyl methane sulphonate (EMS), Nitroso-guanidine (NG), gamma rays, gamma rays + NG in sesame var. B 67 reduced gemination, seedling survival and seed set in M_1 , 700 Gy gamma rays + 0.02% NG produced highest Mutagenic frequency in M_2 . Combination treatments produced higher frequency of chlorophyll and morphological mutations. Most effective and efficient mutagens were 0.01% NG and 0.02% NG, respectively. Effectiveness of combined treatments were lower than corresponding single treatments of *EMS* and *NG*. Combined treatments showed higher efficiency than respective single treatments of EMS, NG and gamma rays, except 0.02% NG. No association was observed between mutagenic effectiveness and efficiency.

Key words : Mutagen; macro-mutation; effectiveness; efficiency; sesame.

Introduction

Induced mutagenesis has become an important tool for amending and rectifying specific defects in adopted varieties or creating sufficient genetic variability in order to utilise economic mutants in crop improvement programme. The basic information regarding Mutagenic sensitivity, frequency, effectiveness, efficiency, treatment methods and effective methods to handle the treated population essential for success in mutation breeding programme. The effectiveness and efficiency of various physical and chemical mutagens in sesame has been reported earlier. However, published works on simultaneous treatment of both physical and chemical mutagens in sesame are scanty. So, the present study was undertaken to assess the mutagenic effectiveness and efficiency of ethyl methane sulphonate (EMS), nitrosoguanidine (NG), gamma rays and combination treatments of gamma rays with EMS and NG in sesame.

Materials and methods

The materials for the present comparative study of effectiveness and efficiency of EMS, NG, gamma rays and their combination treatments (gamma rays + EMS, gamma rays + NG) were comprised of 400 dry, uniform and well-filled seeds of sesame var. B 67 (Tilottama) for each treatment, out of which 300 treated seeds were used for experimental trials and rest 100 seeds were used for viability test. Along with a separate stock of 100 seeds / treatment for viability test, the seeds used for gamma ray and combination treatments were irradiated with three doses of gamma rays 500 Gy, 700 Gy and 900 Gy in Co^{60} gamma cell at the Division of Genetics, IARI, New Delhi. For chemical mutagenesis, the seeds were pre-soaked in distilled water for 12 hours followed by treatment with three different concentrations of EMS (0.25%, 0.50%, 0.75%) and NG (0.01%, 0.02%, 0.04%) aqueous solutions for eight hours. For combined treatments, 700 Gy gamma ray irradiated seeds were presoaked in distilled water for 12 hours and then treated with above mentioned three concentrations of EMS and NG for eight hours. All the chemical treatments were carried out at room temperature (22 ± 1° C) with intermittent shaking. The seeds treated with chemical mutagens were thoroughly washed under tap water for 30 minutes to leach out the residual chemicals adsorbed to the treated seeds and then the seeds were dried on blotting paper.

One hundred treated seeds from each treatment including control were sown in Petri-dishes for germination in the laboratory. Percentage of germination (viability) was recorded after 7 days. The remaining 300 seeds of each treatment along with control seeds (soaked only in distilled water) were sown with spacing of 30 x 10 cm^2 at Central Research Station, OUAT Bhubaneswar to raise M_1 generation. The observation on survival percentage (plants survived upto harvest) and seed set was estimated from 30 random plants in each treatment and control by counting the number of seeds per capsule. Thus the biological

effects of different treatments in M_1 generation evaluated with respect to viability, lethality and sterility and expressed as percentage of control. Selfed seeds from M_1 generation were harvested and grown to raise M_2 generation. The mutation frequency was calculated following Gaul (1960). The mutagenic effectiveness and efficiency was worked out by modifying the formula of Konzak *et al.*, (1965), where instead of only chlorophyll mutations, total macro-mutations of M_2 were taken into consideration, as Prasad *et al.*, (1967) suggested that chlorophyll mutation frequency alone can not be fair enough to judge the effectiveness and efficiency of mutagens.

Results and discussion

M_1 Generation: All the mutagenic treatments resulted in reduction of M_1 parameters as compared to the control (Table 1). Maximum reduction in viability (<40% of control) and seed set (<48% of control) was observed for 900 Gy and 700 Gy of gamma ray irradiation, respectively. The seedling survival was less (<50% of control) for 700 Gy gamma ray + 0.04% NG treatment. In general, a dose dependent reduction for M_1 parameters was observed in all the mutagenic treatments.

Table 1 Effect of EMS, NG, gamma rays and their combinations on seed viability, lethality and sterility in M_1 generation

Treatment	Treatment symbol	Viability (%)	Lethality (%)	Sterility (%)
Control	C	100.00	0.00	0.00
EMS				
0.25%	E_1	88.59	15.87	5.30
0.50%	E_2	82.46	22.59	4.84
0.75%	E_3	67.99	40.86	4.36
NG				
0.01%	N_1	87.28	15.87	3.86
0.02%	N_2	74.57	37.50	0.59
0.04%	N_3	66.67	44.71	5.73
Gamma rays				
500 Gy	G_1	82.89	19.70	3.01
700 Gy	G_2	74.12	32.68	47.53
900 Gy	G_3	60.53	48.55	3.70
Combined treatment				
700 Gy + 0.25% EMS	$G_2 E_1$	75.88	25.00	7.33
700 Gy + 0.50% EMS	$G_2 E_2$	70.17	26.91	8.87
700 Gy + 0.75% EMS	$G_3 E_3$	64.47	36.54	8.44
700 Gy + 0.01% NG	$G_2 N_1$	81.58	11.15	5.83
700 Gy + 0.02% NG	$G_2 N_2$	71.49	33.17	9.81
700 Gy + 0.04% NG	$G_2 N_3$	62.28	49.42	11.26
Pooled over treatments				
EMS	E	79.68	16.44	4.83
NG	N	76.17	32.69	3.40
Gamma rays	G	72.51	33.65	18.08
Gamma rays + EMS	GE	74.56	29.48	8.21
Gamma rays + NG	GN	71.78	34.61	8.97

Viability = % germination (% control); Lethality = % not survived up to maturity (%) of control; Sterility = % reduction in seed set (% of control)

Macro- mutation frequency in M_2: The frequency of macro-mutation was recorded in terms of chlorophyll and viable morphological mutants. The chlorophyll mutations observed were albina, xantha, chlorina, viridis and sectorial. The frequency of chlorophyll mutations were in order of GN> GE>G>E (Table 2). The chlorophyll mutation frequencies induced by NG and its combination treatments were higher than EMS and its combination treatments, respectively which confirmed its description as 'super mutagen' (Swaminathan *et al.*, 1968).

Table 2 Mutagenic frequency, effectiveness and efficiency in M2 generation

Mutagenic treatments	No. of plants scored	Chlorophyll mutants		Morphological mutants		Total macro mutants		Mutagenic effectiveness (Mp/tc or Gy)	Mutagenic efficiency (Mp/s)
		Number	Frequency (%)	Number	Frequency (%)	Number	Frequency (%)		
E_1	37.24	21	0.56	48	1.29	69	1.85	0.926	0.352
E_2	3219	17	0.53	24	0.75	41	1.27	0.318	0.263
E_3	2484	20	0.81	12	0.48	32	1.29	0.216	0.297
N_1	3240	19	0.59	20	0.62	39	1.20	15.050	0.314
N_2	29.32	21	0.72	0	0.00	21	0.70	4.476	1.208
N_3	2503	18	0.72	14	0.56	32	1.28	3.994	0.223
G_1	3592	16	0.45	38	1.05	54	1.50	0.003	0.500
G_2	3454	22	0.64	30	0.87	52	1.54	0.002	0.031
G_3	2972	26	0.87	16	0.54	42	1.41	0.001	0.301
$G_2 E_1$	30.63	17	0.56	78	2.55	95	3.10	0.004	0.423
$G_2 E_2$	2771	30	1.08	72	2.73	98	3.72	0.005	0.378
$G_2 E_3$	2469	29	1.17	56	2.27	85	3.44	0.005	0.407
$G_2 N_1$	2879	23	0.80	44	1.53	67	2.33	0.003	0.397
$G_2 N_2$	2637	26	0.99	72	2.73	98	3.72	0.005	0.378
$G_2 N_3$	2358	34	1.44	52	2.21	86	3.65	0.005	0.325
Pooled over treatments									
E	9427	58	0.62	84	0.89	142	1.51	0.489	0.304
N	8675	58	0.67	34	0.39	92	1.06	7.840	0.582
G	10018	64	0.64	84	0.84	148	1.48	0.002	0.277
GE	8303	76	0.92	206	2.48	282	3.40	0.005	0.416
GN	7874	83	1.05	168	2.13	251	3.19	0.005	0.367

@ symbols of treatment as in Table 1, tc = time x conc. of chemical mutagen, Mp-Macro-mutational frequency (%); Gy - Grey of gamma ray; s - Sterility % in M_1

Eighteen types of morphological mutations affecting cotyledon, stem character, plant type, leaf character, branching behaviour, floral parts, capsule types and flower fertility were recorded. No morphological mutation was observed for 0.02% of NG treatment. The frequencies of morphological mutations were in order of GE > GN > E > G > N (Table 2). In general, the frequency of morphological mutations decreased with increase in the mutagen dose. This situation of "saturation effect" was also reported earlier (Sreeramulu, 1970), could possibly be due to gradual inactivation of the repair system with increasing doses of mutates and there by inducing higher lethality and sterility.

As regards to total macro-mutational frequency the order was GE> GN>E>G>N (Table 2). The frequency of chlorophyll, morphological and total macro-mutations in combined treatments were found to higher than their corresponding individual application of gamma rays, EMS and NG, except for chlorophyll mutation frequency in 700 Gy gamma ray + 0.25 EMS treatment.

The correlation coefficients of chlorophyll, morphological and total macro-mutation frequencies in M_2 with M_1 estimates showed that (Table 3) viability and lethality on M_1 has bearing on expression of mutation in M_2 generation suggesting that lethality and reduction of viability in M_1 was more due to chromosomal change than physiological injury. Sterility estimates of M_1 showed very negligible correlation with M_2 mutational frequencies suggesting that physiological damage in floral biology was probably the major cause of M_1 sterility.

Table 3 **Correlation coefficient (r) between M_1 estimates and M_2 macro mutational frequency**

M_1 estimates	M_2 mutation frequency		
	Chlorophyll mutation	Morphological mutation	Total macromutation
Viability	-0.730**	-0.182	-0.305
Lethality	0.616*	-0.087	0.053
Sterility	0.027	0.080	0.075

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

Mutagenic Effectiveness: The effectiveness of mutagens pooled over treatments indicated (Table 2) that NG was most effective mutagen for production of macro-mutations followed by EMS, both the combinational mutagenic treatments and gamma rays. The effectiveness of mutagens for all the single mutagenic treatments showed inverse dose relationship. While in combination treatment maximum effectiveness was found at medium dose and decreased as dose increased further. This inverse dose dependency of effectiveness is due to increase in biological damage (seedling injury, lethality and sterility) at a faster rate than viable mutation with the increase in dose. The effectiveness of combined treatments was lower than corresponding dose for individual application of NG and EMS, but higher than corresponding gamma ray 700 Gy treatment.

Mutagenic efficiency: Overall efficiency of mutagens (pooled over treatments) indicated that NG was most efficient mutagen followed by gamma rays + EMS, gamma rays + NG, EMS and gamma rays (Table 2). EMS and gamma rays at medium dose treatments showed minimum efficiency while at medium dose NG showed maximum efficiency. The mutagenic efficiency of combinational treatments showed a negative dose relationship. The efficiency of combined treatments was higher than individual application of gamma rays, EMS and NG treatments, except 0.02% NG.

Perusal of Table 2 indicated no correlation between effectiveness and efficiency of mutagens, i.e., a highly effective mutagen need not be highly efficient one. The lack of correspondence between mutagenic effectiveness and efficiency as observed from the present study was also reported in barley (Gaul, 1965) and rice (Kumar and Mani,1997) earlier, could possibly be due to the fact that effectiveness and efficiency of mutagenic is determined by the factors like genetic background of material, intercelluar condition and cell cycle.

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Quantification of pod and seed traits in Trombay groundnut genotypes

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Abstract

Proper characterisation of varieties is essential for the correct identification and differentiation, needed for certification and registration of varieties. Computer based image analysis provides additional morphometric descriptors based on quantification of plant parts. Image analysis was used to study the size and shape traits of pods and seed in 65 groundnut genotypes. Some of the Trombay Groundnut (TG) genotypes exceeded the checks in values of size and shape parameters and some had values lower than the checks. TG 19 had the largest pods and seed, while the small-leaf mutant had the smallest pods. TG 38B had the most round pods and seed, while TG-38A had elongated pods and Somnath, elongated seed.

Key words : Groundnut, *Arachis hypogaea*, image analysis, pod, seed

Introduction

Image analysis can be used as an additional tool for varietal characterisation especially of seed. It involves computer processing and analysis of digitised pictorial information. This technique quantities the physical appearance such as size and shape and allows multiple characters assessed simultaneously and objectively (Keefe and Draper, 1988). Besides, it has high discriminating ability, analytical speed, accuracy and more morphometric descriptors became easily available to the plant breeders (Kim *et al.*, 1997; Dehgham *et al.*, 1998; Keefe, 1999). It was employed for quantification and characterisation of seeds in rice, soybean, wheat, barley, mustard, pea, lentil, lucerne and linseed (Shatadal *et al.*, 1995; Cober *et al.*, 1997; Kim *et al.*, 1997; Dehgham *et al.*, 1998; Keefe, 1999).

Although variability for morphological traits is enormous in groundnut, it is limited in pod and seed. Hence, groundnut varietal identification at pod and seed levels poses difficulty to plant breeders, seed producing and certification agencies, traders and consumers. Image analysis could quantify seed based geometrical parameters. Such quantitative data would also facilitate in generating germplasm database. Image analysis being a non-destructive method, it can be helpful in studying inheritance pattern of seed related traits in segregating populations.

At Trombay, using induced mutation and recombination breeding, several distinct groundnut genotypes have been developed. The present study is an attempt to quantity size and shape parameters of pod and seed in Trombay Groundnut (TG) genotypes and check varieties using image analysis.

Materials and methods

The experimental material comprised of 65 genotypes consisting of 11 induced mutants and 47 improved lines of TG series and 7 check varieties (Spanish Improved, GAUG 10, SB XI, JL 24, ICGS 44, Robut 3301 and M 13). These were grown during *kharif* 1998 at BARC, Trombay. From the harvested and sun-dried produce, ten well developed pods and sound mature seeds were hand picked from each replication in each genotype. Seeds were oriented with hilum facing towards the camera, while beak of pods facing down and kept without touching each other. Measurements were taken by Biovis Image Plus software of digital analysis (M/s Expert Vision Labs. Pvt. Ltd., Mumbai). The different geometric parameters studied were:

Size

1. Area : Total number of points/pixels in the object.
2. Length : Total number of points/pixels in the major axis.
3. Width : The number of points/pixels in the minor axis.
4. Perimeter : Total number of border points/pixels of the object.

Shape

1. Roundness : 4π area / (Perimeter)^2
2. Elongation : Length/Width

The roundness is a measure of how closely an object approximates a circle. The roundness of a circle is 1.0. Generally in groundnut, large oval or elongated seeds are preferred as mechanical blanching is easier over round seeds (Bandyopadhyay and Desai, 2000). Observed

variation for all the traits was subjected to analysis of variance.

Results and discussion

Significant differences were observed for all the traits among the genotypes. Some of the TG genotypes surpassed the check varieties in size and shape parameters of pod and seed in both the upper and lower directions (Table 1).

Table 1 Mean and range for pod and seed traits in TG genotypes and check varieties

	Area (mm^2)	Length (mm)	Width (mm)	Perimeter (mm)	Roundness	Elongation
Pod						
Mean	289	27.6	12.7	71	0.69	2.16
Range	149-602	21.0 - 41.0	8.7 - 18.4	52 - 106	0.60 - 0.79	1.68 - 2.85
Spanish Improved	253	26.0	12.3	68	0.68	2.10
GAUG 10	252	23.5	12.7	63	0.78	1.90
SB XI	182	21.6	10.5	55	0.72	2.05
JL 24	243	26.2	11.6	66	0.68	2.25
ICGS 44	251	24.8	12.6	64	0.74	1.97
K 33	231	23.7	12.0	62	0.75	1.97
M 13	398	33.5	14.6	85	0.68	2.30
CD at 5%	17	1.0	0.4	3	0.01	0.08
Seed						
Mean	100	14.2	8.6	38	0.84	1.67
Range	62 - 184	10.9-21.0	6.7-11.0	30-54	0.74-0.90	1.39-2.16
Spanish Improved	83	12.7	8.1	35	0.85	1.60
GAUG 10	107	14.2	9.6	39	0.85	1.50
SB XI	71	11.3	7.7	31	0.88	1.49
JL 24	85	13.2	8.0	35	0.85	1.68
ICGS 44	94	13.1	9.0	36	0.88	1.49
K 33	94	13.3	8.8	37	0.87	1.53
M 13	132	18.5	9.0	46	0.75	2.06
CD (P=0.05)	6	0.5	0.3	2	0.02	0.09

Size parameters: TG 19 had the maximum pod area (602 mm^2), length (41 mm), width (18.4 mm) and perimeter (106 mm). The small-leaf mutant had the minimum pod area (149 mm^2), length (21 mm), width (8.7 mm) and perimeter (52 mm). Similarly for seed, TG 19 had the highest area (184 mm^2), length (21 mm), width (11 mm) and perimeter (54 mm). The *virescent* mutant had the least area (62 mm^2) and width (6.7 mm), TGE 1 and short 1 had the least length (1.9 mm) and TG-2, small-leaf and *virescent mutants had the least perimeter (30 mm). Viswanathan et al.* (1999) obtained a range of large pods with 28.2 - 33.1 mm length and 19.5 - 24.7 mm width through induced mutation.

Shape parameters: So far, seed shape has been described qualitatively based on visual observations. Visual shape identification and discrimination becomes difficult when a large number of samples having similar features are to be studied. Image analysis more objectively can quantify seed shape, facilitating genotypic discrimination. Higher the values of roundness or lower the values of elongation, more round the object will be. The TG genotypes had both rounder and more elongated pods and seed than the check varieties.

Pods and seed of TG 38B were most spherical with highest roundness (0.79 for pod and 0.90 for seed). TG 38A had the most elongated pods (roundness : 0.60) and Somnath had the most elongated seed (roundness : 0.74). The elongation values for pod were highest in TG 38A (2.85) and in Somnath for seed (2.16) while, the lowest in TG 13A (1.68) and in TG 9 for seed (1.39). These observations revealed that the least elongation values need not always indicate the most round pod or seed. At the same time, the highest elongation value usually indicates most elongated pod or seed. Thus, for selecting most spherical pod or seed, roundness parameters appear to be the most reliable descriptor.

Discrimination through image analysis: In the present study, TG 1 and TKG 19A were at par for pod length (35.8 mm and 36.0 mm), width (15.2 mm and 15.0 mm), area (436 mm^2 and 442 mm^2) and perimeter (90 mm and 89 mm). However, they were distinguished by the differences

in seed area (131 mm^2 and 140 mm^2) and width (9.1 mm and 9.8 mm). Likewise, Somnath and TG 22 had the same pod area (354 mm^2 and 367 mm^2) and perimeter (82 mm and 81 mm), but, they differed in pod length (33.5 mm and 31.3 mm) and width (13.3 mm and 14.4 mm). Although, TG 26, Spanish Improved and JL 24 had similar seed length (12.8 mm, 12.7 mm, 13.2 mm, respectively), area (89 mm^2, 83 mm^2, 85 mm^2, respectively) and perimeter (35 mm each), TG 26 was differentiated from Spanish Improved and JL 24 by varied seed width (8.5 mm, 8.1 mm, 8.0 mm, respectively).

TG 26, SB XI and ICGS 44 were at par for seed elongation (1.53, 1.49, 1.49, respectively) and seed roundness (0.86, 0.88, 0.88, respectively). However, TG 26 was distinguished from ICGS 44 by pod elongation (2.07, 2.05, 1.97, respectively) and from SB XI by pod roundness (0.75, 0.72, 0.74, respectively). Thus, using image analysis the genotypes with apparently similar traits could be discriminated due to additional size and shape descriptors. Similar technique was employed for discrimination of seeds in other crops like rice (Kim *et al.*, 1997); barley (Utku *et al.*, 1998) and lucerne (Dehghan *et al.*, 1998).

Correlation between size and shape descriptors: Size and shape appear to be independent aspect, since large or small seeds need not always be either round or elongated. However, in the present studies, the association between size and shape parameter was found. Large seed in the tested genotypes tended to be elongated as indicated by positive correlation between seed (i) area and elongation ($r = 0.409^{**}$), (ii) length and elongation ($r = 0.688^{**}$) and (iii) perimeter and elongation ($r = 0.526^{**}$) and negative association between seed roundness and (i) area ($r = -0.522^{**}$), (ii) length ($r = -0.769^{**}$) and (iii) perimeter ($r = -0.632^{**}$). Further, it was confirmed by the poor correlation between seed width and (i) elongation ($r = -0.079$) and (ii) roundness ($r = -0.065$). As expected roundness and elongation were negatively related (-0.876** for pod and -0.967** for seed). In soybean, Cober *et al.* (1997) found both positive and negative correlation between seed shape and size depending on seed orientations.

Thus, in the present study, quantification of size and shape traits for pods and seed through image analysis provided additional data for characterisation and discrimination of the genotypes.

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Genetic variability for plant type traits in *Brassica* species

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Abstract

Four species of *Brassica viz., Brassica juncea, B. napus, B. carinata* and *B. campestris* were evaluated over two years for plant type traits including basal branching. In *B. juncea* there was greater variation for plant height but not for seed yield. It was only next to *B. campestris* followed by *B. napus* for variation in basal branching trait. While, in *B. campestris* there was no genetic variation for basal branching trait, but it showed greater variation for days to flowering, total number of primary and secondary branches.

Key words: *Brassica*, basal branching, plant type, variability

Introduction

Breeding for stable and sustainable crop productivity demands in turn breeding for physiologically and morphologically efficient varieties /genotypes. In Oleiferous *Brassica*, particularly those grown in India, there is scope for improving their physiological efficiency (Rai, 1989). Labana (1984) suggested that an efficient plant type with harmonious source- sink relationships needs to be developed. *Brassica juncea*, a widely cultivated crop in the north India, bears more number of productive pods on secondary and tertiary branches than the main axis. In general, the pod bearing primary branches initiate at a good height from the base sometimes at 1 m. The main stem is not always strong enough to support the top-heavy shoot which is highly prone to lodging in the usual heavy winds before harvest resulting in avoidable yield loss. In areas of advanced agronomic crop management for pure cropping a desirable plant type should have a height of about 1 m. with compact growth habit and with branches having appressed siliqua filled with large number of bold seeds (Jain, 1984). Therefore, genotypes with medium plant height, basal branching i.e. branches within 30 cm from the base, more number of primary and secondary branches, profuse pod bearing and more number of bold seeds per pod should be looked for. In the present paper, a comparison was made on genetic variability for plant type traits particularly of basal branching in the four cultivated species of oilseed *brassica*.

Materials and methods

Four species of *Brassica viz., B. juncea, B. napus, B. carinata* and *B. campestris* each with 12 genotypes were evaluated over two years i.e., during winter seasons of 1990 and 1991. The experiment was laid out in a split plot design with species as main plots and genotypes as sub plots during both seasons. Each genotype was sown in two rows of 5 m length and the spacing was 45 cm between rows and 15 cm between plants.

Data were collected on various and morpho-physiological traits, which are of general and specific interest. The traits of general nature were days to first flowering (FT), plant height (HT), total number of primary (PB) and secondary (SB) branches, seed yield per plant (SY), and harvest index (HI). The plant type traits of specific interest were measured at the basal portion of the plant. A height of 30 cm from the ground was measured and it was referred as 'HI'. All those characters (PBI, SBI, SYI, HII) were termed as basal branching characters. Where, PBI=number of primary branches at HI; SBI=number of secondary branches at SYI=seed yield at H12 and HII=SYI/total biomass x 100.

The ANOVA was carried out following usual procedure of split plot analysis and the estimates of genetic variance were computed on expected mean square basis.

Results and discussion

Genetic variability is rational to plant breeding objective. The studies on variability for yield and its components are numerous, while those related to plant type attributes, particularly, basal branching are not available except for those of (Sun, 1946; Kasa and Kondra, 1986) where it was recognized as a trait.

The results presented in Table 1 showed that there were significant differences between species for all the traits studied. The genotypes within *B. campestris* showed significant variation for all the characters, while the intra-specific variation in *B. juncea* was significant for all except SB and SY. The variation was non significant in *B. napus* during one of the seasons for SB, SY, SYI and HII. While *B. carinata* genotypes showed no variation for all those traits connected with basal branching. Most of these results

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Table 1 ANOVA (mean squares) for 10 characters among four *Brassica* species

Source	df	FT	HT	PB1	SB1	SY1	HI1	PB	SB	SY	HI
Genotypes	47	**1359.5***	**7473.3***	**11.9***	**132.1***	**32.2***	**37.8***	**38.3***	**853.6***	**316.2***	**87.7***
		2822.3*	7910.7*	13.7*	136.4*	85.4*	124.3*	50.7*	1265.0*	235.0*	**68.1***
B. juncea	11	**276.4***	**1729.6***	**3.6***	**56.6***	**46.2***	**18.8***	**6.3***	**72.1**	**88.9**	**32.1***
		95.6*	4059.3*	2.6*	33.1*	47.2*	28.4*	10.4*	159.0*	118.9	**33.6***
B. napus	11	**354.6***	**455.6***	**3.0***	**16.7***	**2.3**	**3.3**	**4.8***	**14.5**	**93.7**	**47.1***
		1615.7*	1155.5*	1.9*	23.1*	28.7*	16.4*	11.8*	132.0*	221.7*	**32.9***
B. carinata	11	**1246.4***	**1103.3***	**0.5***	**7.5**	**0.6**	**0.2**	**64.3***	**841.7***	**156.3***	**21.1**
		3360.1*	1740.3*	0.4	9.5	1.5	0.4	92.9*	1852.5*	229.6*	53.2*
B. campestris	11	**391.4***	**1725.4***	**4.8***	**187.0***	**57.2***	**69.8***	**25.6***	**385.2***	**179.6***	**181.2***
		51.3*	1834.3*	7.9*	140.4*	68.2*	109.4*	12.5*	237.9*	130.4*	54.8*
Between spp.	3	**12979.0***	**98697.0***	**142.9***	**1087.3***	**114.2***	**254.0***	**228.8***	**8556.4***	**3051.7***	**341.7***
		25433.0*	91706.0*	167.9*	1380.9*	803.8*	1380.3*	326.0*	11086.0*	855.5*	396.0*
Error	94	**12.5**	**87.1**	**0.5**	**8.5**	**2.4**	**2.0**	**1.2**	**75.1**	**75.1**	**14.7**
		20.5	136.4	0.4	8.1	11.2	2.3	2.0	56.4	67.5	8.0

Bold (1st row) : Winter, 1990; Light (2nd row) : Winter, 1991

* Significant at 5% level.

were supported by the estimates of genetic variance (Table 2).

The magnitude of genetic variation was less in each species except *B. campestris* during winter 1990 than 1991. Such difference between years or locations are common in plant breeding experiments and known as environment interaction. In *B. juncea* there was greater variation for plant height but not for seed yield.

Greater variation for plant height was reported by Uddin *et al*. (1983) too, but the lack of variability for seed yield has been main concern of mustard breeders. Meanwhile, *B. napus* did not show consistency in genetic variation for basal branching characters (PBI, SBI, SYI and HII). On the other hand, *B. carinata* showed greater variation for days to flowering, primary (PB) and secondary (SB) branches and seed yield (SY), but with no genetic variation for basal branching characters. Similar kind of variation was observed by Labana *et al.* (1987) particularly for plant height and number of primary and secondary branches. *B. campestris* was highly variable species for all those traits including harvest index (HI), indicating that there is a greater scope for utilizing genes governing those traits in the improvement of other related species.

Basal branching was recognized as a trait, but there were no systematic studies. Sun (1946) reported that some varieties of *B. juncea* (var. *Oblanceolata)* were extremely low branched ones, while some others (*B. juncea* var. *gracilis* and *orthocarpa)* no branch up to 90 cm above the ground. He also reported that in the material studied, *B. napus* and *B. carinata* branch at low height. The present study showed that *B. juncea* was only next to *B. campestris* followed by *B. napus* for variation in basal branching traits. Keeping in mind the fact that *B. juncea* lacks genetic variability for seed yield, the breeding for basal branching and higher yielding types in *B. juncea* will depend on the presence and success of introgression of genes for those traits from other species of *Brassica.*

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Table 2 Estimates of genetic variance for 10 traits in four species of *Brassica*

Trait	*B. juncea*		*B. napus*		*B. carinata*		*B. campestris*	
	A	B	A	B	A	B	A	B
FT	88.0	25.0	114.0	531.7	411.3	1113.2	126.3	10.3
HT	547.5	1307.6	122.8	339.7	338.7	534.6	546.1	566.0
PB1	1.0	0.7	0.8	0.5	0	0	1.4	2.5
SB1	16.0	8.3	2.7	5.0	0.3@	0.5	59.5	44.1
SY1	14.6	12.0	0	5.8	0.6@	3.1@	18.3	19.0
HI1	5.6	8.7	0.4	4.7	0.6@	0.6@	22.6	35.7
PB	1.7	2.8	1.2	3.3	21.0	30.3	8.1	3.5
SB	1.0@	34.2	20.2@	25.2	255.5	598.7	103.4	60.5
SY	4.6	17.1	6.2	51.4	27.1	54.0	34.8	21.0
HI	5.8	8.5	10.8	8.3	2.1	15.1	55.5	15.6

A = Winter, 1990; B = Winter, 1991 @ = Negative estimate

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Heterosis of yield and yield components in castor hybrids

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Abstract

Heterosis over better parent (BP) and standard hybrid (SH) for seed yield and its attributes in castor was studied using line x tester mating design involving four females and 28 male parents under four environments. The magnitude of heterosis over BP and SH was high for seed yield/plant, number of capsules/plant, seed yield/main spike and number of capsules/main spike. The heterosis over BP and SH for seed yield/plant ranged from -67.78 to 87.89% and -64.79 to 107.04%, respectively. The cross combinations *SKP 93 x J 1, SKP 93 x 6-219-22 and VP 1 x H 0* exhibited significant and positive heterosis over BP and SH for seed yield/plant and also possessed high seed yield/plant. These crosses also had significant and positive heterosis for number of capsules/plant, number of capsules/main spike and seed yield/main spike and would be more desirable to exploit heterosis in castor.

Introduction

Commercial exploitation of heterosis in castor is regarded as a breakthrough in the field of castor improvement. Heterosis utilizing 100 % pistillate lines has been successfully exploited in castor and five hybrids have been released for general cultivation in Gujarat covering nearly 90% area under castor. Development of better hybrids using stable high yielding new pistillate lines will raise the yield ceiling of this crop. In order to achieve high yielding cross combination, it is essential to evaluate available promising diverse lines in their hybrid combinations for yield and yield components in varied cultural environments. Therefore, the heterosis over better parent and standard hybrid (GCH 4) was studied using four diverse pistillate lines and 28 inbreds of castor over four environments to improve its yield.

Material and methods

Four diverse pistillate lines *viz.*, VP 1, TSR 10R, SKP 25 and SKP 93 were crossed with 28 inbreds of castor in line x tester mating design during *kharif*, 1989. The resulting 112 hybrids along with 32 parents (28 lines + 4 testers) were evaluated in a randomized block design with three replications in four created environments (E_1 : sowing in the 1st fortnight of July as rainfed crop, E_2 : sowing in the 1st fortnight of July with supplementary irrigations, E_3 & E_4: sowing in the 1st week of August and September, respectively as irrigated crop) during *kharif*, 1990 at College Instructional Farm, GAU, Sardar Krushinagar. Each entry was planted in a single row of 12 dibbles keeping row to row 90 cm and plant to plant 60 cm distance. All the recommended package of practices were followed for raising the normal crop. Observations on five randomly selected competitive plants were recorded in four environments for 12 traits and their mean values were used for statistical analysis. The superiority of hybrid for various traits was observed over better parent (BP) and standard hybrid GCH 4 (SH) (Fonseca and Patterson, 1968).

Results and discussion

Results indicated (Table 1) that mean squares due to parents and hybrids were significant for all the 12 characters studied under four environments indicating considerable genetic variability among parents and hybrids. Parents vs. hybrids comparison was significant under all the four environments for all the characters (except number of capsules/plant in E_2 and oil content in E_1 and E_4) indicating presence of mean heterosis for all the characters. Error variances were observed to be homogenous for all the 12 traits as revealed by Bartlett's test of homogeneity of variance. Significant differences were observed among genotypes and environments for all the 12 characters. Genotype - environment interaction was also significant for all the traits except days to flowering and days to maturity.

Table 1 Analysis of variance showing mean sum of squares for 12 characters in castor under four environments

Source of	d.f.	variation	Mean sum of squares											
			Days to flowering	Days to maturity of MS	Plant height upto MS	No. of nodes upto MS	Length of main spike	No. of capsules/MS	Seed yield/MS	No. of branches/plant	No. of capsules/plant	Seed yield/plant	100 seed wt.	Oil content
Replications	2	E_1	118.7	13.9	62.3	7.7*	8.8	9.7	6.6	0.4	399.3*	34.1	5.0**	**0.67**
		E_2	6.3	1.0	190.8**	4.0	26.4*	62.9	2.8	2.0	526.5	34.9	1.7	**0.43**
		E_3	772**	22.7	88.0**	0.5	2.4	1010.3	33.6	10.0**	775.1	217.2	1.3	**0.04**
		E_4	992**	2.0	4.1	0.1	6.9	228.4*	71.7	4.5	2344.3**	**1421.6**	2.1	**0.33**
Parents	31	E_1	3227**	356**	1488**	21**	167**	1467**	552**	7.9**	7914**	2258**	29.5**	2.47**
		E_2	3770**	325**	512**	33**	202**	2630**	898**	7.3*	24416**	6411**	25.2**	4.02**
		E_3	4882**	387**	681**	29**	358**	1374**	1103**	41.1**	42219**	19690**	56.1**	2.55**
		E_4	3664**	334**	364**	17**	403**	1099**	826**	30.5**	40497**	20266**	65.2**	4.12**
Hybrids	111	E_1	1444**	135**	963**	33**	203**	1256**	420**	5.0**	6329**	1810**	18.7**	3.24**
		E_2	1665**	156**	975**	59**	163**	2403**	850**	12.9**	17946**	5857**	15.9**	3.16**
		E_3	2009**	196**	1005**	36**	417**	2791**	1120**	46.9**	32773**	15630**	34.3**	2.28**
		E_4	1779**	158**	791**	26**	397**	1532**	976**	39.4**	32961**	18854**	30.7**	3.75**
Parents vs. Hybrids	1	E_1	3533**	3809**	253**	118**	319**	5914**	2842**	51.4**	4364**	3495**	72.7**	0.20
		E_2	4422**	3852**	3897**	282**	791**	8678**	3934**	9.1**	427	708**	31.1**	21.00**
		E_3	47330**	3626**	381**	39**	103**	4299**	2442**	48.8**	256827**	226634**	55.8**	9.84**
		E_4	39440**	3552**	2596**	9**	1401**	6933**	6600**	21.0**	51050**	72852**	59.6**	1.23
Error	286	E_1	112.4	13.19	57.62	1.99	8.54	25.53	12.14	0.40	107.57	18.64	0.76	0.47
		E_2	110.7	7.86	33.61	2.43	7.21	32.45	14.68	0.86	180.72	58.64	0.90	0.50
		E_3	115.1	8.77	23.09	2.92	10.18	847.29	15.81	1.73	292.42	127.59	1.14	0.56
		E_4	114.4	6.66	18.32	2.24	13.03	56.65	43.62	1.88	269.97	207.85	0.86	0.52

*, ** Significant at P=0.05 and P=0.01 levels, respectively; MS = Main Spike; E_1 to E_4 showed four different environments as indicated in text

The variance of parents were significantly different indicating the more variability in parents for all the traits. The range of mean performance of hybrids was higher than parents for number of capsules/main spike, seed yield/main spike, number of capsules/plant, seed yield/plant and earlier in flowering and maturity indicating significant heterosis for these characters.

The range of heterosis, mean heterosis, number of significant heterotic crosses and best heterotic crosses over better parent and standard hybrid for 12 traits are presented in Table 2. Earliness in flowering and maturity is a highly desirable trait for the crop like castor. Hence, the crosses exhibiting heterosis in negative direction are of immense value. The hybrid SKP 25 x Bhagya showed highest heterosis for days to flowering (-28.19%) and days to maturity (-12.76%) over better parent. The magnitude of heterosis was highest for plant height in the hybrid SKP 25 x SH 21 over BP and SH, while maximum magnitude of heterosis for lower number of nodes was observed in the cross SKP 93 x SKI 12 and SKP 25 x SH 21 over BP and SH, respectively. Significant and highest positive heterosis over BP and SH was observed in the hybrid of VP 1 x Baker 147 for length of main spike, SKP 25 x Punjab 1 for number of capsules/main spike and VP 1 x Punjab 1 for number of effective branches/plant.

The cross VP 1 x VI 9 (GAUCH 1) and SKP 25 x EC 97700 depicted significant and highest positive heterosis over BP (114.22%) and SH (116.97%), respectively. Maximum heterosis was observed in the hybrid of SKP 93 x 6-219-22 and SKP 93 x J 1 over BP and SH, respectively. Hybrid TSR 10R x HO and SKP 93 x Punjab 1 exhibited significant and highest positive heterosis over BP and SH, respectively for 100 seed weight, whereas, SKP 93 x Punjab 1 and VP 1 x SH 41 exhibited significant and highest positive heterosis over BP and SH, respectively. Similar findings were reported by Dangaria *et al.* (1987); Mehta *et al.* (1991).

Heterosis for seed yield/plant ranged from -67.78 to 87.89% and -64.79 to 107.04% over BP and SH, respectively. The cross SKP 93 x J 1 exhibited significant and highest positive heterosis over BP (87.89%) and SH (107.04%) for seed yield/plant followed by SKP 93 x 6-219-22 and VP 1 x HO. These three hybrids also registered higher seed yield/plant. Such crosses are likely to give better transgressive segregants and could be used for further improvement.

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

It will be of considerable interest to know the cause of heterosis for seed yield in castor. A comparison of heterosis for seed yield/plant in five most heterotic crosses over better parent (SKP 93 x J 1, SKP 93 x 6-219-22, VP 1 x HO, TSP 10R x Aruna, SKP 93 x SKI 14) and over standard hybrid GCH 4 (SKP 93 x J 1, VP 1 x HO, SKP 93 x 6-219-22, SKP 93 x 48-1, SKP 93 x 2-73-11) along with heterosis in other related characters (Table 3) indicated that significant and positive heterosis over BP and SH (GCH 4) for seed yield/plant in three crosses *viz.*, SKP 93 x J 1, VP 1 x HO and SKP 93 x 6-219-22 was also accompanied by significant and high positive heterosis over BP and SH for number of capsules/main spike, number of capsules/plant and seed yield/main spike. In addition, significant and positive heterosis over BP for seed yield/plant in all the five crosses was accompanied by significant and positive heterosis for nodes up to main spike and significant and negative heterosis for days to flowering and days to maturity. Significant and positive heterosis over BP and SH was revealed by crosses SKP 93 x J 1 and VP 1 x HO for length of main spike and VP 1 x HO for 100 seed weight. Only one cross SKP 93 x 2-73-11 had significant and positive heterosis over BP for oil content. The cross SKP 93 x Punjab 1 had significant and highest positive heterosis over BP and SH both for oil content and seed yield/plant. This indicated the scope for the improvement of both the characters simultaneously.

Many top heterotic hybrids for different attributes involved parental combinations of high x high, high x low and low x low yielder. The present study further suggested that heterosis for yield should be through component trait heterosis. Hybrid vigour ov even small magnitude for individual yield components may have additive or synergistic effect on the end product. Thus, additive gene action of these characters ultimately resulted in high yield heterosis. Graffius (1959) has reported that the yield is the end product of multivariable interaction between yield components. Similar findings was also reported by Mehta *et al.* (1991). Thus, on the basis of *per se* performance and heterotic response, the crosses SKP 93 x J 1, VP 1 x HO and SKP 93 x 6-219-22 appeared to be more suitable for practical plant breeding programme to exploit heterosis.

Table 2 Range of heterosis, mean heterosis, number of significant hybrids in desired direction and best heterotic hybrid over BP and SH for various characters in castor

Character	*Heterosis over	Range of heterosis			Mean heterosis	No. of significant hybrids in desired direction	Best heterotic hybrid
Days to flowering	BP	-28.19	to	45.18	-3.59	52	SKP 25 x Bhagya
	SH	-31.64	to	43.87	8.16	**18**	SKP 25 x EC 103745
Days to maturity of main spike	BP	-12.76	to	17.86	0.95	**46**	SKP 25 x Bhagya
	SH	-13.24	to	2052	5.71	**14**	SKP 93 x RCG 5
Plant height upto main spike	BP	-69.09	to	87.20	0.30	**46**	SKP 25 x SH 21
	SH	-71.41	to	52.36	-9.42	**65**	SKP 25 x SH 21
Number of nodes upto main spike	BP	-28.14	to	120.86	28.90	**14**	SKP 93 x SKI 12
	SH	-52.68	to	76.92	0.27	**36**	SKP 25 x SH 21
Length of main spike	BP	-59.34	to	68.99	**-0.08**	36	VP 1 x Baker 147
	SH	-71.73	to	52.28	**-0.82**	27	VP 1 x Baker 147
Number of capsules/main spike	BP	-48.59	to	104.72	11.18	44	SKP 25 x Punjab 1
	SH	-44.67	to	120.34	29.18	63	SKP 25 x Punjab 1
Seed yield/main spike	BP	-37.39	to	114.22	15.57	59	VP 1 x VI 9
	SH	-46.33	to	116.97	35.08	81	SKP 25 x EC 97700
Number of effective branches/plant	**BP**	-63.33	to	60.62	-4.36	**28**	VP 1 x Punjab 1
	SH	-61.49	to	69.56	-11.97	**11**	VP 2 x Punjab 1
Number of capsules/plant	**BP**	-65.94	to	91.87	-5.66	**39**	SKP 93 x 6-219-22
	SH	-55.08	to	122.62	22.68	**83**	SKP 93 x J 1
Seed yield/plant	BP	-67.78	to	87.89	2.81	**52**	SKP 93 x J 1
	SH	-64.79	to	107.04	19.80	**79**	SKP 93 x J 1
100 seed weight	BP	-26.98	to	27.53	-2.29	**28**	TSP 10R x H 0
	SH	-23.91	to	28.84	1.07	**46**	SKP 93 x Punjab 1
Oil content	BP	-3.47	to	2.06	-0.87	4	SKP 93 x Punjab 1
	SH	-4.44	to	2.09	-1.15	2	VP 1 x SH 41

* BP = Better Parent; SH = Standard Hybrid (GCH 4)

Table 3 Comparison of best five hybrids over best parent and standard hybrid showing high heterosis for seed yield and their response to component characters in castor

Crosses	Mean seed *yield/plant*		Seed *yield/plant*	Days to *flowering*	Days to *maturity* of MS	Plant *height* upto MS	No. of *nodes* upto MS	Length of *main* spike	No. of *capsules/* MS	Seed *yield/* MS	No. of *branches/* plant	No. of *capsules/* plant	100 *seed* wt.	Oil *content*
SKP 93 x J 1	326.77	BP	87.89**	-8.25**	-5.85**	17.08**	36.63**	27.04**	63.16**	57.75**	6.94	68.20**	-16.29**	-1.65**
		SH	107.04**	2.73	2.28	-19.40**	10.08*	8.04*	75.47**	66.29**	-31.78**	122.62**	-3.23*	-1.23*
SKP 93 x 6-219-22	297.28	BP	84.82**	-13.18**	-5.43**	47.68**	53.57**	7.47	45.17**	45.44**	11.39	91.87**	-2.51	-3.18**
		SH	88.35**	3.54	2.72*	-6.52	11.18**	-4.68	31.78**	53.30**	-18.34**	70.84**	12.68**	-1.00
VP 1 x H 0	307.45	BP	80.48**	-20.44**	-8.12**	-4.60	120.86**	22.86**	25.65**	48.52**	-2.69	45.73**	21.27**	-1.98**
		SH	94.80**	-2.10	1.63	-13.35**	33.48**	11.43**	51.07**	68.36**	-18.95**	82.57**	8.76**	-1.29**
TSP 10R x Aruna	237.27	BP	66.78**	-21.47**	-5.56**	27.31	15.07**	10.63	-0.84	34.87**	-1.63	66.78**	-4.80**	0.90
		SH	50.33**	-2.29	1.27	-6.69	10.21*	-23.07**	13.29	8.10	22.62**	89.76**	-11.11**	-0.10
SKP 93 x SKI 14	247.32	BP	53.76**	-8.37*	-3.02*	42.49**	22.33**	-12.56*	8.95	1.05	-21.39**	66.72**	-7.02**	-0.53
		SH	56.70**	-11.79**	-3.90**	-11.56**	-1.42	-30.34**	3.19	14.41*	-42.30**	48.45**	7.47**	-1.31*
SKP 93 x 48-1	293.45	BP	34.51**	4.12	0.84	-22.22**	8.29	-9.62*	-8.78	-8.05	-15.20*	32.70**	-3.78**	-1.47*
		SH	85.93**	24.16	9.53**	-8.06*	-12.73**	-12.29**	3.93	20.60**	-35.21**	71.73**	11.19**	-1.47*
SKP 93 x 2-73-11	273.27	BP	16.30**	-7.08*	-1.00	-12.55**	28.61**	16.86**	54.27**	66.74**	-25.28**	1.47	3.60**	1.53**
		SH	73.14**	10.98**	7.54	-11.59**	3.62	0.71	40.54**	75.75**	-45.23**	51.35**	19.75**	0.74
SEm±			2.93	1.05	0.87	1.66	0.45	0.90	4.48	1.34	0.32	4.21	0.28	0.21

*, ** Significant at P=0.05 and P=0.01 levels, respectively; BP = Better Parent; SH = Standard Hybrid (GCH 4); MS = Main Spike;

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Genetic analysis of F_2 and transgressive segregants for yield in sesame

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Abstract

The wide range of F_2 variability for seed yield, branches/plant and capsules/plant in 55 crosses of 11 x 11 half-diallel set indicated potential of the crosses to throw large number of variable segregants. Positive transgressive segregants were found in 47 crosses. F_1 *per se* performance, relative heterosis and GCA effects of parents were found to be good indicators for predicting phenotypic variance and genetic advance for seed yield in F_2. Average GCA effects of parents had moderate degree of influence on the mean of 10% top yielding plants in F_2. No relationship was observed between segregation potential and parental diversity (D_2).

Key words : Transgressive segregation, sesame

Introduction

In any autogamous crop, the objective of recombination breeding is to develop pure line varieties. Recombination breeding involves hybridization, the long process of selection and critical evaluation. Early generation testing and selection has gained momentum in autogamous crops as additive genetic variance is more important (Cregan and Busch, 1977; Sexana and Sharma, 1983). Genetic analysis of segregation pattern and transgressive segregation in F_2 is helpful for determining pro-potency of different crosses, achieving efficiency in early generation selection and reducing population size in later generation. Establishment of any kind of relationship of parental and F_1 genetic parameters with F_2 segregation potential is helpful for early rejection of inferior crosses in F_1 itself. The present investigation is an attempt to estimate various F_2 genetic parameters with respect to variability and transgressive segregation and to determine their relationship with parents and F_1 hybrids, if any.

Materials and methods

The materials for the present investigation comprised 11 sesame parents (X 174-9, RT 4, UT 43, RAUSS 1, TC 25, EC 115785, Kanak, Zodade, Kayamkulam 1, B 67 and TNAU 11) and their 55 cross combinations in F_1 and F_2 generations derived through a half-diallel mating design. The 11 parents and 55 F_1s were raised in three-row plots in both summer and *kharif* seasons. The F_2s were raised in eight-row plots in *kharif* season only. All the experimental materials were grown in randomized block design with three replications with a wide spacing of 45 cm x 20 cm at the Central Research Station, OUAT, Bhubaneshwar. Observations were recorded on 10 randomly chosen competitive plants in parents and F_1s and 30 plants in F_2s for 11 quantitative characters in each replication. The mean values pooled over the two seasons in parents and F_1s were used for estimation of genetic divergence among parental lines following Mahalanobis's multivariate (D^2) analysis as described by Rao (1960), combining ability estimates as per Method 2, Model I of Griffing (1956) and relative heterosis as per standard procedure. The average variance of F_1 and its respective parents was taken as environmental variance (V_E) and the F_2 genetic variance for a cross was obtained by substracting V_E from the F_2 phenotypic variance (VF_2). The segregation pattern and breeding potential of the crosses were analysed in terms of the frequency of positive transgressive segregants (FPTS), % positive transgressive segregants (% PTS), mean of positive transgressive segregants (MPTS), average positive transgression over better parent mean (APT), mean of 10% top-yielding plants (MTP) and predicted genetic advance under selection (GA) for seed yield in F_2. The relationship of F_2 segregation parameters (VF_2, FPTS, APT, MTP and GA) for seed yield with genetic parameters of parents and F_1s such as, parental diversity (D_2), mean seed yield in F_1 (SY), relative heterosis (RH), average GCA effects (Av. GCA) and SCA effects in F_1, was measured by regression analysis.

Results and discussion

Variance parameters in F_2: The analysis of variance revealed that within parent and F_1 variances were due to environmental factors and within F_2 variances were of genetical origin, i.e., due to segregation. The parameters

of variability and GA in F_2 for seed yield, capsules/plant and branches/plant indicated wide range of variability, thereby offering ample scope for selection (Table 1).

Table 1 Range of parameters of variability, heritability (broad sense) and predicted genetic advance under selection for three characters in F_2 of a 11x11 diallel set in sesame

Parameter	Seed yield/plant (g)	Branches/ plant	Capsules/ plant
PCV (%)	24 - 79	35 - 89	23 - 52
GCV (%)	15 - 73	23 - 77	21 - 51
H^2_{bs} (%)	39 - 89	37 - 86	80 - 98
G.A. (g/plant)	1 - 6	1 - 3	9 - 50

Transgressive segregation for yield: Comparison of limits of variance in F_2s with those of respective parental range indicated the presence of transgressive segregation for 47 out of 55 crosses. The FPTS ranged from 2 in Kanak x Zodade to 22 in Zodade x TNAU 11 with 16 crosses having 10 or more than 10. The MPTS ranged from 6.3 g/plant in X 174-9 x RT 4 to 12.7 g/plant in EC 11585 x TNAU 11 with 26 crosses more than 10 g/plant. The APT of the crosses measured as difference of the MPTS and the better parent mean ranged from 2.9 g in X 174-9 x RT 4 to 6.8 g in RT 4 x RAUSS 1 with 27 crosses having more than 5.0 g. The range of MTP was 6.1 g to 12.5 g with 15 crosses having MTP of more than 10 g/plant. On simultaneous consideration of parameters of transgression (FPTS, MPTS and APT) along with MTP and GA, eight crosses were found to be potential for improvement of seed yield (Table 2).

Table 2 Transgressive parameters (FPTs, % PTS, MPT, APT, MTP & GA) of eight potential crosses for yield in F_2 of 11 x 11 diallel set in sesame

Cross	F_2 range (g)	F_2 mean (g)	Better parent value (g)	FPTS	% PTS	MPTS (g)	APT (g)	MTP (g)	GA (g)
Zodade x B 67	2.9-15.6	7.6	4.8	12	13.3	10.9	6.1	11.2	5.8
EC 115785 x TNAU 11	2.4-16.0	6.8	6.7	10	11.1	12.7	6.0	12.3	5.8
RT 4 x Kanak	2.1-14.8	6.7	6.7	15	16.7	11.7	5.0	12.5	3.9
TC 25 x Kanak	1.6-16.6	6.6	6.7	8	8.9	12.4	5.7	12.0	5.3
Zodade x TNAU 11	2.2-15.8	6.6	4.8	22	24.4	10.0	5.2	12.0	4.6
Zodade x kayamkulam 1	2.4-13.8	6.5	4.8	10	11.1	10.6	5.8	11.1	4.4
RT 4 x Zodade	2.4-13.2	6.5	4.8	16	17.8	11.3	6.5	11.6	4.9
TC 25 x B 67	1.6-11.6	4.9	4.3	20	22.2	9.8	5.5	11.4	4.9

Relationship of segregation potential of the crosses with parents and F_1 hybrids: The regression analysis to assess the relationship of the F_2 segregation potential of crosses with parental and F_1 genetic parameters (Table 3) indicated maximum influence of F_1 *per se* performance on F_2 variance (b=0.60**, R^2=24.2) and F_2 GA (b=0.46**, R^2=19.9) for seed yield. This finding supports the previous reports suggesting F_1 *per se* performance as a good indicator of superior crosses in later generations (Rathnaswamy and Jagathesan, 1984). The two parameters, RH (b=0.03*, R^2=8.9) and SCA effects (b=0.44*, R^2=8.3) in F_1 had shown some degree of influence on F_2 phenotypic variance. The average GCA effects of parents assessed in F_1 showed a maximum degree of influence on F_2 phenotypic variance (b=1.42**, R^2=20.6) and F_2 GA (b=0.56**, R^2=17.1) for seed yield. The average GCA had moderate degree of influence on MTP (b=0.49*, R^2=11.5). This finding revealed that GCA effects of parents involved in the cross combinations could be considered as good indicator to predict the potentiality of crosses in F_2 generation. The regression of F_2 parameters on parental diversity as measured by D^2 indicated no relationship between F_2 segregation potential and parental diversity (Table 3). Similarly, no significant

relationship was found between other F_2 segregation parameters with parental and F_1 genetic parameters.

The present investigation suggested that F_1 *per se* performance, relative heterosis and GCA effects of the parents may be used as good indicators for predicting segregation potential of the crosses in F_2 generation, so that, more attention can be diverted to handle a few superior crosses with large population to increase the frequency of transgressive or desirable segregants.

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Table 3 **Regression of F_2 variability parameters for yield on F_1 mean seed yield (SY), parental diversity (D_2), relative heterosis (RH), average GCA and SCA effects for yield in F1 of 11 x 11 dialles set in sesame**

Regression	a	b	R^2 (%)
VF_2 on SY	-0.52 ± 1.44	0.60 ± 0.12**	24.2
VF_2 on D^2	4.95 ± 0.61	0.00 ± 0.001	0.7
VF_2 on RH	4.48 ± 0.49	0.03 ± 0.01*	8.9
VF_2 on Av. GCA	5.26 ± 0.34	1.42 ± 0.38**	20.6
VF_2 on SCA	5.10 ± 0.37	0.44 ± 0.20**	8.3
FPTS on SY	10.04 ± 2.96	-0.23 ± 0.25	1.7
FPTS on D^2	6.44 ± 1.09	0.002 ± 0.002	1.9
FPTS on RH	7.36 ± 0.93	-0.002 ± 0.03	0.01
FPTS on Av. GCA	7.30 ± 0.68	-0.68 ± 0.77	1.5
FPTS on SCA	7.40 ± 0.69	-0.28 ± 0.38	1.0
APT on SY	2.31 ± 1.29	0.18 ± 0.11	5.1
APT on D^2	4.34 ± 0.49	0.00 ± 0.001	0.1
APT on RH	4.28 ± 0.42	0.01 ± 0.01	0.5
APT on Av. GCA	4.43 ± 0.30	0.34 ± 0.34	1.9
APT on SCA	4.35 ± 0.30	0.23 ± 0.17	3.5
MTP on SY	8.35 ± 0.93	0.06 ± 0.08	1.2
MTP on D^2	8.90 ± 0.34	0.00 ± 0.001	0.7
MTP on RH	9.49 ± 0.28	-0.02 ± 0.01	8.4
MTP on Av. GCA	9.07 ± 0.21	0.49 ± 0.23*	11.5
MTP on SCA	9.09 ± 0.22	-0.06 ± 0.12	0.4
GA on SY	1.44 ± 0.67	0.46 ± 0.16*	19.9
GA on D^2	2.92 ± 0.26	0.001 ± 0.00	5.7
GA on RH	3.21 ± 0.22	0.003 ± 0.01	0.5
GA on Av. GCA	3.29 ± 0.15	0.56 ± 0.17**	17.1
GA on SCA	3.25 ± 0.16	0.10 ± 0.09	2.1

*, ** *significant at 5% and 1% levels, respectively.*
a = intercept of the line of Y-axis; b = regression coefficient
R^2 = coefficient of determination

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Genetic variability and heritability for seed yield and its components in sesame (*Sesamum indicum* L.)*

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Abstract

The analysis of genetic parameters for 44 genotypes of sesame revealed high *Gcv*, *Pcv*, heritability and genetic advance as per cent of mean for seed yield per plant, total capsules per plant, capsules on main stem, capsules on primary branches, capsule length, total dry matter production per plant, secondary branches per plant, plant height and oil yield per plant indicating that selection could be effective for improving seed yield and yield attributes.

Key words: Sesame, variability, heritability, genetic advance.

Introduction

The success of any crop improvement programme essentially depends upon the nature and magnitude of the genetic variability present in the crop. The knowledge of nature and magnitude of genetic variability in the population is of immense value for planning efficient breeding programme to improve the yield potential of the genotypes. Genotypic coefficient of variation (*Gcv*) along with heritable estimates would provide a better picture of the amount of genetic advance to be expected by phenotypic selection. Similarly, the estimates of heritability alone will not be of much value for selection on phenotypic performance hence suggested that genetic gain should be considered in conjunction with heritability (Johnson *et al.*, 1955). Hence, considering these aspects, genetic variability studies were initiated with diverse sesame (*Sesamum indicum* L.) genotypes.

Materials and methods

During *rabi*, 1998-99, 44 diverse genotypes of sesame were sown in simple randomized block design with three replications at S.V. Agricultural College, Tirupathi. Each genotype was sown in two rows of 3 m length with a spacing of 30 cm between rows and 10 cm between plants. Five plants were selected at random in each genotype from each replication and data were recorded on yield and growth parameters (Table 1). The data were subjected to statistical analysis and various genetic parameters such as *Gcv*, *Pcv*, heritability and genetic advance were out as per Johnson *et al.*, 1955 and Hanson, 1963.

Table 1 Analysis of variance for seed yield and yield attributes in sesame genotypes

Character	Mean sum of squares	
	Replications	Treatments
Plant height	108.99	741.22**
Primary branches/plant	0.28*	0.56*
Secondary branches/plant	0.09	1.76**
Capsules on main stem	3.46	46.46**
Capsules on primary branches	1.19	110.97**
Days to 50 % flowering	37.64**	23.62**
Capsule length	0.21	0.54**
Total capsules/plant	1.42	225.45**
Seeds/capsule	99.34**	310.35**
1000-seed weight	0.36	0.24**
Seed yield/plant	0.15*	3.89**
Total dry matter/plant	6.70	52.52**
Harvest index	7.65	49.07**
Oil %	89.19**	20.90**
Oil yield/plant	0.03**	1.06**

* Significant (P=0.05); ** Significant (P=0.01)

Results and discussion

The analysis of variance revealed highly significant differences among the genotypes for seed yield and component characters indicating considerable genetic variation in the material (Table 1). The replication differences were significant for primary branches/plant, days to 50 % flowering, seeds/capsule, seed yield/plant, oil per cent and oil yield/plant. A perusal of genetic parameters (Table 2) revealed that seed yield/plant, oil yield/plant, capsules on primary branches; on main stem

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and total capsules/plant, dry matter production/plant and plant height had high *Gcv*, and *Pcv* values. Among them, oil yield/plant followed by capsules on primary branches and seed yield per plant had high *Pcv* and *Gcv* values suggesting that these characters are under the influence of genetic control. Hence, these characters can be relied upon and simple selection can be practiced for further improvement. These results were in consonance with Patil and Sheriff(1996). Moderate *Pcv* and *Gcv* values are observed for seeds capsule, capsule length, primary branches/plant and harvest index. The difference between Gcv and *Pcv* values were high for secondary branches/ plant and primary branches/plant indicating high variability which can be used as reliable measure of genotypic variability. The *Pcv* and *Gcv* were low for oil per cent, days to 50% flowering and 1000-seed weight and were in accordance with results of Shadakshari *et al.* (1995).

Table 2 **Mean, range, coefficient of variability, heritability, genetic advance and genetic advance as per cent of mean for seed yield and yield attributes in sesame**

Character	Mean	Range	Co-efficient of variation		Heritabilit (Broad sense) %	Genetic advance	Genetic advance as per cent of mean
			Genotypic (%)	Phenotypic (%)			
Plant height (cm)	73.89	45.60-116.80	21.15	21.52	96.57	31.63	42.81
Primary branches/plant (no)	2.50	1.60-3.80	15.81	19.62	64.95	65.75	26.25
Secondary branches/plant (no)	0.73	0.00-3.40	102.96	107.07	92.47	1.49	203.96
Capsules on main stem (no)	13.52	0.80-25.00	28.73	29.79	93.00	7.72	57.08
Capsules on primary branches (no)	16.99	5.20-40.20	35.45	36.44	94.66	12.07	71.05
Days to 50% flowering (days)	37.37	30.00-44.00	7.48	7.56	97.95	5.70	15.25
Capsule length (cm)	2.68	1.60-3.91	15.40	16.45	87.64	0.79	29.70
Total capsules/plant (no)	30.75	13.60-65.20	27.84	28.88	92.98	17.00	55.30
Seeds/capsule (no)	70.74	45.00-92.20	14.30	14.52	97.00	20.53	29.01
1000-seed weight (g)	3.29	2.38-4.40	8.91	9.19	79.36	0.49	15.02
Seed yield/plant (g)	3.26	1.27-6.35	34.74	35.30	96.82	2.29	70.41
Total dry matter/plant (g)	16.27	8.91-24.98	25.71	25.73	99.79	8.61	52.90
Harvest index (%)	20.01	10.38-33.22	19.96	20.68	93.15	7.94	39.69
Oil %	49.33	40.31-58.34	5.29	5.46	93.94	5.22	10.57
Oil yield/plant (g)	1.62	0.51-3.34	36.73	36.88	99.22	1.22	75.36

The high heritability was observed for total dry matter/plant followed by oil yield/plant, days to 50% flowering, seeds/capsule, seed yield/plant, plant height, capsules on primary branches, oil%, harvest index, capsules on main stem capsules/plant and secondary branches/plant. Similar kind of observations were reported by Patil and Sheriff (1996). Since heritability estimates are influenced by the environment, genetic material and also other factors hence their utility will be restricted. Thus, heritability values coupled with genetic advance would be more reliable and useful in formulating selection criteria.

High heritability with moderate genetic advance, was recorded for seeds/capsule indicating that the character was less influenced by environment but governed by both additive and non-additive gene action. Hence, simple selection is suggested for further improvement in the later generations. These results were in consonance with Shadakshari *et al.* (1995). Moderate heritability with high genetic advance was recorded for primary branches/plant indicated lesser influence of environment but prevalence of additive gene action. Hence, amenable for selection. Similar results were reported by Chandrasekhara (1990). High heritability coupled with low genetic advance was recorded for oil % indicating less influence of environment but prevalence of non-additive gene action for which simple selection will be less effective. Moderate heritability with low genetic advance for 1000-seed weight indicated less variability and non-additive gene action. Hence less amenable for selection.

Secondary branches/plant, capsules on primary branches, total capsules/plant, capsules on main stem, seed yield/plant, plant height, harvest index, dry matter productio/plant, capsule length, days to 50% flowering and oil yield/plant had heritability coupled with high genetic advance as per cent of mean indicating lesser influence of environment on these characters and prevalence of more additive gene action in their inheritance, hence, are amenable for simple selection. These results are in conformity with the reports of Govindaras *et al.*, (1990).

From the foregone discussion, it can be concluded that higher Gcv, *Pcv* heritability and genetic advance as per cent of mean were observed for seed yield/plant, total capsules/plant, capsules on primary branches, capsules on main stem, secondary branches/plant, dry matter production/plant, harvest index, capsule length, plant height and oil yield/plant indicating the prevalence of

additive gene action in the control of these characters and simple selection may be effective to improve these characters.

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Studies on fertilizer management in sesame based intercropping system under rainfed condition in different agro-ecosystems

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Abstract

The studies on fertilizer management in sesame based cropping system under rainfed condition were carried out in different agro-ecosystems under different soil types *viz.*, Inceptisol at Tikamgarh, Mauranipur, Vertisol at Jalgaon and Powarkheda during 1997 and 1998. The two sesame based intercropping systems as main plot and five fertilizer management practices as sub-plots were laid out in split plot design. The intercropping of sesame + urd bean in the row ratio of 3:3 or 2:2 or 4:2 recorded higher sesame equivalent yield with maximum net return and cost-benefit ratio at most of the locations. The significantly higher yield, net return and benefit cost ratio was recorded under 100% recommended fertilizer of both main crop and intercrop.

Key words : Fertilizer management, agro-ecosystem, intercropping, sesame

Introduction

Sesame is one of the important oilseed crops of India during rainy season. The crop is mostly raised under rainfed conditions without much of purchased inputs leading to low productivity. There is need to increase the income of sesame farmers by introducing new technologies such as intercropping (Kondap *et al.*, 1985). Intercropping is commonly suggested to enhance the efficiencies of resource use *viz.*, land water nutrient and light (Yadav and Prasad, 2000). To optimize the system productivity in intercropping, fertilizer management become important particularly because of the increasing trend in fertilizer prices. Studies on fertilizer management in intercropping system is very meagre. Hence, the present studies were carried out to find out the fertilizer management in sesame based intercropping system.

Materials and methods

The experiments were conducted at four locations *viz.*, Tikamgarh and Powerkheda (Madhya Pradesh), Jalgaon (Maharashtra) and Mauranipur (Uttar Pradesh). The soil types were Inceptisol at Tikamgarh and Mauranipur, Vertisol at Jalgaon and Powerkheda. The studies were carried out for two years in 1997 and 1998 at Tikamgarh and Jalgaon and 1997 and 2000 at Mauranipur, while at Powarkheda in 1998 and 1999. The treatments comprised of two important sesame base intercropping systems (M_1 and M_2 as main plot) adapted at there locations and five fertilizer management practices (as sub-plot). These ten treatments were arranged in split plot design with three replications (Table 1_. The crops were sown during first fortnight of July with the onset of monsoon at all the *locations*.

Results and discussion

Among the intercropping systems difference in sesame equivalent yield was not significant except at Jalgaon. However, intercropping of sesame + urdbean in the ratio of 3:3 or 4:2 recorded higher sesame equivalent yield with maximum net return and cost benefit ratio at Tikamgarh (486 kg/ha, Rs.4007/ha and 1.79), Mauranipur (803 kg/ha, Rs.10289/ha and 2.75) while, at Powarkhda, intercropping of sesame + urdbean or soybean in row ratio of 2:2 were almost found equal (Table 1). Whereas at Jalgaon, sesame + pigeonpea (3:1) intercropping system proved significantly better in terms of sesame equivalent yield with higher net return and benefit cost ratio (1408 kg/ha, Rs. 2331/ha and 3.86). Similar results were also reported by Bajpai *et al.* (1998), Hosmath and Patil (1999) and Sharma *et al.* (1998). The differences due to different fertilizer schedules were significant for sesame equivalent yield at all the locations. At Tikamgarh, the maximum yield, net return and benefit cost ratio (577 kg/ha, Rs. 5358/ha and 1.96) was recorded under 100% recommended fertilizer of both main crops and intercrop (based on the proportion of area occupied). Similar results were also recorded at Jalgaon (1263 kg/ha, Rs. 19387/ha and 3.29) and Mauranipur (920 kg/ha, Rs. 10959/ha and 2.69) whereas at Powarkheda, the highest sesame equivalent yield net returns and cost benefit ratio (704 kg/ha, Rs.9097 and 2.67) was recorded under 100% recommended fertilizer of main crop only in the intercropping system.

Table 1 **Effect of different fertilizer schedules on the various intercropping system on sesame equivalent yield, net return and benefit cost ratio at different locations**

Treatment	Sesame equivalent yield (kg/ha)				Net returns (Rs/ha)				B:C ratio			
	Tikamgarh	Powarkheda	Mauranipur	Jalgaon	Tikamgarh	Powarkheda	Mauranipur	Jalgaon	Tikamgarh	Powarkheda	Mauranipur	Jalgaon
Intercropping												
M_1	426	660	758	735	3099	8042	8311	8564	1.60	2.42	2.39	2.12
M_2	486	641	803	1408	4007	7787	10289	23310	1.79	2.44	2.76	3.86
CD (P=0.05)	NS	NS	NS	147	-	-	-	-	-	-	-	-
Fertilizer schedule												
S_1	226	523	590	831	260	6198	7180	11205	1.06	2.35	2.36	2.57
S_2	561	704	865	1158	5068	9097	9833	18004	1.90	2.67	2.65	3.22
S_3	577	665	920	1263	5358	7898	10959	19387	1.96	2.33	2.69	3.29
S_4	515	698	805	1137	3982	8662	8959	17251	1.76	2.59	2.51	2.97
S_5	426	687	758	972	3118	8719	8259	13986	1.63	2.61	2.46	2.83
CD (P=0.05)	79	87	49	109	-	-	-	-	-	-	-	-

Intercropping systems	Tikamgarh	Powarkheda	Mauranipur	Jalgaon
M_1	Sesame + Moongbean (3:3)	Sesame + Soybean (2:2)	Sesame + Soybean (4:2) or Moongbean (4:2)	Sesame + Sorghum (3:2)
M_2	Sesame + Urdbean (3:3)	Sesame + Urdbean (2:2)	Sesame + Urdbean (4:2)	Sesame + Pigeonpea (3:1)

Fertilizer schedule

S_1 Control

S_2 100% recommended fertilizer of main crop to the system

S_3 100% recommended fertilizer of both main crop and intercrop (based on the proportion of area occupied)

S_4 100% of the recommended fertilizer to main crop + 50% recommended fertilizer to intercrop (based on the proportion of area occupied)

S_5 100% of the recommended fertilizer to main crop and no fertilizer to intercrop (based on the proportion of area occupied)

Studies revealed that the application of full recommended fertilizer dose (on actual area basis) to both the component crops of intercropping system recorded significant increases in the sesame equivalent yield, maximum net return and cost benefit ratio at Tikamgarh, Jalgaon and Mauranipur, whereas at Powarkheda, application of full recommended fertilizer dose to the main crop to the system and no fertilizer to the intercrop proved superior.

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Effect of organic and inorganic fertilizers along with biofertilizers on *kharif* sesame (*Sesamum indicum* L.) under different soils and locations in India

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Abstract

The studies on integrated nutrient management in Sesame (*Sesamum indicum* L.) under different soil types *viz.*, Vertisols (Amreli, Jalgaon and Powarkheda), Alfisol (Vridhachalam) and Inceptisol (Jabalpur) were carried out from 1998-99 to 1999-2000 with 12 treatment combinations. The results revealed a significant improvement in sesame yield by the application of fertilizer in combination with manure at all the locations and soil types. The highest yield of sesame was recorded under 50% N through urea + 50% N through FYM + 50% phosphorus with soil application of PSB @ 600 g/ha + 100% potash under all soil types under study.

Key words : Sesame, Soil type, FYM, Pressmud, Cake, Compost, Seed treatment, *Azatobactor, Azospirillum*, PSB

Introduction

Sesame is one of the important Oilseed crops cultivated in most os the states of India. The average productivity of sesame is only 350 kg/ha. It is cultivated mostly in marginal and submarginal lands having low organic matter and poor soil fertility, Nutrient stress is one of the most important factor for low productivity of this crop. Integrated use of organic, inorganic and biofertilizers sustains productivity by improving soil physical conditions and may reduce costly inorganic fertilizer needs (Singh *et al.*, 1990). Inorganic fertilizers are important component of integrated nutrient management in oilseed crops and an increase in yield ranging from 26 to 300% in rainfed areas had been reported (Subba Rao, 1994). The organic manure (Mondal *et al.*, 1992) and biofertilizers are also responsible for getting the higher yield and reduce the costly input. In sesame, seed treatment with *Azospirillum* reduced the N requirement by 50% (Reddy and Sudhakara Babu, 1996) and in safflower an economy of 50% N, amounting to 20 to 30 kg N/ha can be achieved by the use of biofertilizers (Pisal *et al.*, 2000). Phosphorus solubilizing bacteria (PSB) inoculation with FYM gave higher yield in groundnut (Balasubramanian and Palaniappan, 1994). Hence, the present studies were carried out on integrated nutrient supply and management in sesame under rainfed condition on different soil types.

Materials and method

The studies were carried out under the All India Coordinated Sesame and Niger Improvement Project at five locations in different soil types *viz.*, vertisol at Amreli (Gujarat), Jalgaon (Mharashtra) and Powarkheda (Madhya Pradesh), alfisol at Vriddhachalam (Tamil Nadu) and inceptisol at Jabalpur (Madhya Pradesh). The experiment was conducted during *kharif* season for two years (1998-99 and 1999-2000) at Amreli, Jalgaon and Vriddhachalam and one year at Powarkheda (1998-99) and Jabalpur (1999-2000). There were 12 treatments comprising of control (no fertilizer), recommended 50% or 100% N through urea, 50% or 100% P and 100% K, 50% N through FYM or pressmud or castor cake or cotton cake or compost, seed treatment with *Azotobacter, Asozpirillum* and soil application with phosphorus solubilizing bacteria (PSB) and their combiantions and biofertilizers combined with 50% recommended N. The treatments were tested in randomized block design with three replications. The crop was sown during last week of June to first fortnight of July. The varieties used were Gujarat Til-1 at Amreli, Tapi at Jalgaon, TMV-4 at Vriddhachalam, TKG-21 at Powarkheda and TKG-22 at Jabalpur. The crop was fertilized with RDF @ 50:20:00, 50:00:00, 60:40:20, 25:13:13 and 60:40:20 (N:P:K) kg/ha at Amreli, Jalgaon, Powarkhda, Vriddhachalam and Jabalpur, respectively. The plot size was same at all the locations i.e., 3.6 x 5 m except at Amreli it was 5.1 x 4.5 m. Yield data were pooled over two years only and economics was worked out based on the pooled data and one year data of Powarkheda and Jabalpur.

Results and Discussion

The crop performance was significantly improved by the application of different treatments as compared to control at all the locations (Table 1). On vertisol at Amreli, significantly higher and the maximum yield (554 kg/ha)

Table 1 Response of different treatments on the yield, net return and B:C ratio on sesame under different locations

Treatment	Yield (kg/ha)					Net returns (Rs/ha)					B:C ratio				
	Amreli	Jalgaon	Vridha-chalam	Power-kheda	Jabalpur	Amreli	Jalgaon	Vridha-chalam	Power-kheda	Jabalpur	Amreli	Jalgaon	Vridha-chalam	Power-kheda	Jabalpur
Control	312	519	376	433	305	2600	6470	2896	4520	1850	1.71	2.65	1.68	2.09	1.43
100% rec.*N+(PK rec.)	468	905	874	961	891	5155	13785	11386	13590	12150	2.22	4.19	3.18	3.41	3.14
50% *N+50% N through FYM (P&K recomm.)	488	862	965	775	942	5240	12330	12667	9540	12850	2.21	3.50	3.23	2.60	3.14
50% *N+50% N through pressmud cotton cake/castor cake/compost+PK rec.	462	992	898	975	1047	4910	14727	11524	13680	14930	2.13	3.88	3.08	3.25	3.48
50% *N+*Azospirillum*+P&K rec.	431	707	834	769	802	4610	9987	10748	9890	10530	2.15	3.40	3.11	2.80	2.91
50% *N+*Azotobacter*+P & K rec.	436	775	720	798	813	4710	11347	8582	10470	10750	2.17	3.73	2.68	2.91	2.95
100% *N+PSB (50% P & 100% K)	489	772	869	961	967	5660	11075	11279	13490	13570	2.37	3.53	3.16	3.35	3.35
100% *N+PSB (no P & 100% K)	481	840	774	950	911	5600	12435	9874	13780	12960	2.39	3.85	3.04	3.64	3.46
50% *N+50% N through FYM+PSB (50% P & 100% K)	554	826	954	833	1071	6760	11400	12708	10850	15510	2.56	3.22	3.34	2.87	3.62
50% *N+*Azospirillum+Azotobacter*+ PSB (50% P + 100% K)	412	644	834	833	812	4150	6637	10888	11320	10880	2.01	3.04	3.20	3.12	3.03
50% *N+*Azospirillum*+PSB (50% P+100% K)	410	706	862	823	725	4110	9837	11970	11150	9160	2.00	3.30	3.27	3.10	2.71
50% *N+*Azospirillum+Asotobacter*+ PSB+(50% P & 100% K)	462	700	773	863	746	5130	9690	9679	11950	9580	2.25	3.25	2.93	3.25	2.79
SEm±	6.6	45.1	5.6	72	39										
CD (P=0.05)	20.5	140.2	17.8	211	115										

ost of production (Rs/kg) Amreli (20/-); Jalgaon (20/-); Vridhachalam (19/-); Pawarkheda (20/-); Jabalpur (20/-) * N applied through urea rec. = recommended

was recorded under 50% recommended N through urea + 50% N through FYM + PSB soil application + 50% recommended P and 100% K as compared to other treatments Whereas at Jalgaon, the highest yield (992 kg/ha) was recorded under 50% N through urea + 50% N through castor cake and recommended P and K and was closely followed by 100% recommended NPK (905 kg/ha). Similarly, at Powarkheda, the significantly higher yield (975 kg/ha) was noted under 50% N through urea + 50% N through cotton cake and P and K as per recommendation.

On Alfisol at Vridhachalam the higher yield (965 kg/ha) was recorded under 50% N through urea + 50% N through FYM and recommended P and K closely followed by 50% N through urea + 50% N through FYM + soil application PSB with 50% P and 100% K (954 kg/ha).

On inceptisol at Jabalpur, the significantly higher yield (1071 kg/ha) was recorded under 50% N through urea + 50% N through FYM + soil application with PSB and 100% P & K, closely followed by 50% N through urea + 50% N through compost (1047 kg/ha) and 100% N through urea + soil application with PSB + 50% P & 100% K (967 kg/ha).

It is evident that, response to application of recommended 50% nitrogen through urea + 50% nitrogen through FYM + 50% phosphorus + 100% potash and soil application of PSB @ 600 g/ha was observed at Amreli and Jabalpur. Similar findings are corroborated with Arunachalam and Venkatesan, 1984, Reddy and Sudhakara Babu, 1996; Chandawat *et al.*, 1998. While at Jalgaon and Powarkheda response to application of recommended dose of 50% nitrogen through urea + 50% nitrogen through caster cake or cotton cake and 100% recommended P & K gave highest yield whereas response at Vridhachalam was recorded under the application of 50% nitrogen through urea + 50% nitrogen through FYM + 100% recommended P & K or in addition to soil application of PSB inoculum with 50% recommended phosphorus. Response of fertilizers with combined application of organic manure was also reported by Mondal *et al.*, 1992 and Balasubramanian and Palaniappan, 1994.

Economics: Highest net returns were obtained in the treatments with recommended 50% N through urea + 50% N through FYM + 50% P + 100 % K and soil application of PSB at Amreli (Rs. 6760/ha), Vridhachalam and Jabalpur whereas at Jalgaon under the application of 50% N through urea + 50% N through castor cake + P and K as per recommendation. While, at Powarkheda recommended 100% N through urea, without P + 100% K and soil application of PSB. Benefit cost ratio also followed similar trend of net returns at all the locations.

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Uptake of major nutrients by soybean [*Glycine max* (L.) Merrill] at different stages of crop growth as influenced by sulphur application

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Abstract

The uptake on N,P.K, and S at different crop growth stages of soybean (cv. PK-472) as influenced by different levels (0,20,40, and 60 kg S/ha) and sources (ammonium sulphate and gypsum) of sulphur was studied in a field experiment conducted on a sulphur deficient clay soil. The studies indicated that uptake of N, P,K and S increased with increase in the level of S application with maximum values being recorded at 60 kg S/ha which was on par with 40 kg S/ha level. Between the sources of 'S' used, nutrient uptake was more with ammonium sulphate than gypsum at any stage of crop growth.

Key words: Sources, sulphur, sulphur uptake, soybean, crop growth

Introduction

Soybean, being a good source of proteins, fats, vitamins and minerals is a valuable food. Its phosphate, calcium, potassium and iron contents are high as compared to other cereals and legumes. Legumes and oilseed crops have been reported to respond to sulphur application. The effect of different levels and sources of sulphur on content and uptake of N,P,K and S in the vegetative and reproductive parts of soybean at different stages of crop growth have been studied on sulphur deficient soils of Rajendranagar to know the trend of uptake of major nutrients.

Materials and methods

A field experiment was conducted during *rabi* season of 1997-98 at college farm, Rajendranagar, with eight treatment combinations consisting of four levels (0, 20, 40 and 60 kg S/ha) and two sources of sulphur (Ammonium sulphate and Gypsum). The treatments were replicated thrice in a factorial randomized block design.

The experimental soil was clay in texture (sand 19%, silt 30%, clay 51%), pH, EC and organic carbon were 8.02, 0.26, dS m^{-1} and 0.57%, respectively. The available N, P_2O_5, K_2O and S were 207 (low), 32 (Medium), 370 (High) and 13.4 (Low) kg/ha respectively. The nitrogen contributed by ammonium sulphate was taken into account and accordingly a basal dose of 75:50:40 kg/ha ($N:P_2O_5:K_2O$) was applied through urea, diammonium phosphate (DAP) and muriate of potash (MOP). Sulphur was applied through ammonium sulphate and gypsum as per the treatments.

Soybean (cv.PK-472) was sown by adopting a seed rate of 60 kg/ha. Two seeds were dibbled per hill with a spacing of 30 and 10 cm between rows and plants respectively. The whole plant samples were collected at 30 and 60 days after sowing. Seed and stover samples were collected separately at maturity. The plant samples collected were dried in an electrical oven at 65°C and were powdered with the help of willey grinding machine. The powdered plant samples *viz.*, whole plants at 30 and 60 DAS; seed and stover samples collected at maturity were analysed for N,P,K and S by adopting standard methods.

Nitrogen in plant samples was estimated by micro Kjeldahl method (AOAC, 1970). For phosphorus and potassium analysis the plant samples were digested with triacid mixture (HNO_3: H_2SO_4:$HClO_4$ at 9:4:1 ratio) as per Tandon (1993) and Flame photometer method (Jackson, 1973) respectively. Plant samples were digested with diacid mixture (HNO_3 : $HClO_4$ at the ratio of 9:4) for analyzing sulphur by Barium sulphate turbidity method (Chesnin and Yien, 1951). The uptake of N,P,K and S at different stages was calculated using date of nutrient content and drymatter yields and expressed as kg/ha.

Results and discussion

N uptake: Uptake of N by soybean showed an increase with increased levels of sulphur application at all the stages of crop growth (Table 1). Significant increase in N-uptake over control was observed when sulphur was

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Table 1 Effect of sources and levels of sulphur on uptake of nitrogen (kg/ha) by soybean at different stages of crop growth

Sulphur levels (kg/ha)	Sulphur sources											
	30 DAS			60 DAS			Harvest					
							Stover			Seed		
	AS	G	Mean	AS	G	Mean	AS	G	Mean	AS	G	Mean
0	19.70	19.54	19.62	67.16	66.01	66.58	18.73	17.95	18.34	64.34	62.95	63.65
20	28.66	24.57	26.61	81.44	77.09	79.26	22.18	20.80	21049	76.70	68.57	**72.63**
40	41.00	31.95	36.48	95.66	81.15	88.41	27.74	24.76	26.25	98.86	89.51	**94.19**
60	45.11	**33.35**	39.23	97.97	84.39	91.18	31.15	27.16	29.15	102.56	90.15	**96.36**
Mean	33.62	27.35		85.56	77.16		24.95	22.67		85.62	77.80	
	SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)	
Sources(S)	0.22	0.46		0.35	0.76		0.15	0.32		0.45	**0.98**	
Levels (L)	0.30	**0.65**		0.50	1.07		**0.21**	0.45		0.64	**1.38**	
S x L	0.43	0.93		0.70	1.51		0.30	0.64		0.91	1.95	

AS : Ammonium Sulphate G: Gypsum

applied @ 60 kg ha $^{-1}$, in the increase being 99.9, 36.9, 58.9 and 1.3 % at 30,60 DAS; in stover and seed at harvest respectively. Nitrogen and Sulphur at required for the formation of protein. In order to maintain the balance of N and S in plants, uptake of one nutrient will certainly effect the uptake of another one. Shinde *et al.* (1982) also obtained increase in the nitrogen uptake of seed due to application of S. Application of S as ammonium sulphate resulted in higher N uptake than by gypsum. The increase in N uptake due to ammonium sulphate over gypsum was 22.9, 10.9, 10 and 10 % at 30, 60 DAS; in stover and seed at harvest respectively. The superiority of ammonium sulphate to other sources of sulphur could be attributed to the synergistic effect of N and S. Application of S in absence of N decreased the N concentration in mustard plant but when N added with S the effect was synergistic (Singh *et al.*, 1988).

P uptake: The data presented (Table 2) shows that the P uptake increased significantly with increase in the level of application of sulphur from 0 to 40 kg/ha after which the increase was not significant. The treatment where sulphur was applied @ 40 kg/ha showed significant increase in P uptake over control, the increase being 55.9, 45.3, 19.8 and 41 % at 30, 60 DAS; in stover and seed at harvest respectively. Higher availability of P with the application of 40 kg S/ha might have increased the uptake of P by soybean which might be due to their mutually competitive effect on the adsorption sites on the colloidal surfaces and resulted in increase in their concentration in soil solution. Similar results have been reported by Bansal (1991), Sharma and Gupta (1992). Application of S as ammonium sulphate resulted in higher P uptake values by gypsum. The increase in P uptake due to ammonium sulphate over gypsum were 16, 19.5, 11.1 and 13 % at 30, 60 DAS; in stover and seed at harvest respectively. Similar results were reported by Gupta and Singh (1983), Patel and Patel (1994).

K uptake: The data presented (Table 3) shows that there was an increase in K uptake with increase in the level of application of sulphur from 0 to 60 kg/ha. The treatment where sulphur was applied @ 60 kg/ha recorded significant increase in K uptake over control, the increase being 52,27.1,46.6 and 63.9 % at 30,60 DAS; in stover and seed at harvest respectively. This might be due to synergistic effect of sulphur on potassium uptake. Similar results were reported by Bansal (1991), Sharma and Gupta (1992). The increase of K uptake due to ammonium sulphate over gypsum being 23.6, 13.1, 17.8 and 12.2 % at 30, 60 DAS; in stover and seed at harvet respectively. Similar findings were reported by Shinde *et al.*, (1983); Sawarkar (1979).

S uptake: The data presented (Table 4) shows that there was an increase in S uptake with increase in the level application of sulphur from 0 to 60 kg/ha. The treatment where S was applied @ 60 kg/ha registered significant

increase in S uptake over control, the increase being 143.8, 66.7, 162.8 and 60.6 % at 30, 60 DAS; in stover and seed at harvest respectively. Several workers have reported that S containing aminoacids, drymatter yield and seed yield. The results of the present study are in confirmation with the findings of Shinde et al.(1982),

Table 2 Effect of sources and levels of sulphur on uptake of phosphorus (kg/ha) by soybean at different stages of crop growth

Sulphur levels (kg/ha)	Sulphur sources											
	30 DAS			60 DAS			Harvest					
							Stover			Seed		
	AS	G	Mean	AS	G	Mean	AS	G	Mean	AS	G	Mean
0	3.03	3.16	3.09	6.11	5.82	5.96	4.26	4.14	4.20	4.33	4.26	4.29
20	4.17	3.49	3.83	7.52	6.85	7.18	4.90	4.41	4.66	5.11	4.53	4.82
40.	5.30	4.34	4.82	9.71	7.62	8.66	5.39	4.69	5.03	6.53	5.57	6.05
60	5.51	4.51	5.01	10.30	7.87	9.09	5.56	4.84	5.20	6.70	5.72	6.21
Mean	4.50	3.88		8.41	7.04		5.02	4.52		5.67	5.02	
	SEm±	CD (P=0.05)		SEm±	CD (P=0.05))		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)	
Sources(S)	0.08	**0.18**		**0.13**	0.27		0.05	0.11		0.05	0.12	
Levels (L)	**0.12**	**0.25**		**0.18**	0.38		0.07	0.16		0.08	0.17	
S x L	0.16	0.35		**0.25**	0.55		0.11	0.23		0.11	0.24	

AS : Ammonium Sulphate G: Gypsum

Table 3 Effect of sources and levels of sulphur on uptake of potassium (kg/ha) by soybean at different stages of crop growth

Sulphur levels (kg/ha)	Sulphur sources											
	30 DAS			60 DAS			Harvest					
							Stover			Seed		
	AS	G	Mean	AS	G	Mean	AS	G	Mean	AS	G	Mean
0	7.42	7.07	7.25	14.47	13.43	13.95	24.41	22.10	23.25	23.63	23.09	23.36
20	9.38	8.08	8.73	16.29	15.18	15.73	28.31	24.94	26.62	28.05	24.68	26.36
40.	12.03	9.03	10.53	18.86	15.98	17.42	35.66	28.57	32.11	37.89	32.38	35.13
60	12.66	9.38	11.02	19.21	16.24	17.73	37.18	30.97	37.08	40.67	35.92	38.29
Mean	10.37	8.23		17.21	**15.21**		31.39	26.64		32.56	29.02	
	SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD P=0.05)	
Sources(S)	0.07	0.16		0.14	0.30		**0.13**	0.28		0.18	0.38	
Levels (L)	0.10	**0.22**		0.20	0.42		**0.19**	0.40		0.25	**0.53**	
S x L	0.15	0.31		0.28	0.60		0.26	0.57		0.35	0.76	

AS : Ammonium Sulphate G: Gypsum

Table 4 Effect of sources and levels of sulphur on uptake of Sulphur (kg/ha1) by soybean at different stages of crop growth

Sulphur levels (kg/ha)	Sulphur sources											
	30 DAS			60 DAS			Harvest					
							Stover			Seed		
	AS	G	Mean	AS	G	Mean	AS	G	Mean	AS	G	Mean
0	1.21	1.20	1.21	3.39	2.91	3.15	0.85	0.55	0.70	3.35	3.61	3.58
20	1.91	1.43	1.67	4.26	3.42	3.84	1.07	0.85	0.96	4.97	4.27	4.62
40.	3.06	2.08	2.57	5.55	4.67	5.11	1.90	1.32	1.61	6.05	5.13	5.59
60	3.47	2.43	2.95	6.12	4.92	5.52	2.07	1.61	1.84	6.21	5.28	5.75
Mean	2.41	1.79		4.83	3.98		1.47	1.08		5.19	4.57	
	SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)	
Sources(S)	0.06	0.13		0.08	0.18		0.04	0.09		0.08	0.17	
Levels (L)	0.09	0.19		0.12	0.26		0.06	0.13		0.11	0.24	
S x L	0.13	0.27		0.17	NSD		0.09	NS		0.16	0.35	

AS : Ammonium Sulphate G: Gypsum NS : Non significant

Bansal (1991), Sharma and Gupta (1992). Between the two sources of S used, ammonium sulphate recorded higher S uptake values at all the levels of supplied S than gypsum. The increase in S uptake due to ammonium sulphate over gypsum being 34.6, 21.3, 36.1 and 13.5 % 30, 60 DAS; in stover and seed at harvest respectively.

Between the two sources of sulphur tested, better growth and highest accumulation of 'S' in all the plant parts of soybean were observed with ammonium sulphate than with gypsum. This may be due to several times higher solubility of S present in ammonium sulphate than with gypsum. When gypsum is applied to the soil, the presence of calcium ions in soil solution reduces its solubility due to common ion effect. Nad and Goswami (1984) reported that S uptake in cowpea was higher from ammonium sulphate than from gypsum when applied at 30 and 60 ppm levels. Dhillon and Dev (1980) reported that with the application of ammonium sulphate as the S source not only the availability of S from the applied fertilizer increased but also the availability of S in the soil increased. The observations made in the present investigation too are in agreement with the above findings and it can be concluded that S application improves N,P,K and S nutrition of soybean crop and ammonium sulphate is better than gypsum as sulphur source for increasing the productivity of soybean.

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Impact of irrigation on sunflower (*Helianthus annuus* L.) productivity

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Abstract

The impact of moisture stress at different stages of sunflower, *Helianthus annuus* L. growth was investigated to identify the critical irrigation stages. The soil was loamy sand with pH 8.0, low in organic carbon and medium in phosphorus and potash. Highest mean seed yield (2167 kg/ha) was obtained with standard irrigation schedule i.e. seven irrigations, which was at par with six irrigations given at different stages. Irrigation missed at soft dough stage of seed caused 25% reduction in seed yield. It was closely followed by irrigation missed at 50 % flowering and at hard dough stage of seed, which caused 21 % reduction in seed yield. At these three stages of moisture stress, oil content, oil yield (kg/ha) and water use efficiency were substantially reduced. Fifty per cent flowering, soft and hard dough stages are very critical and the sunflower crop should not be allowed to suffer for want of moisuture at these stages.

Key words: Sunflower, irrigation, critical stages, water stress

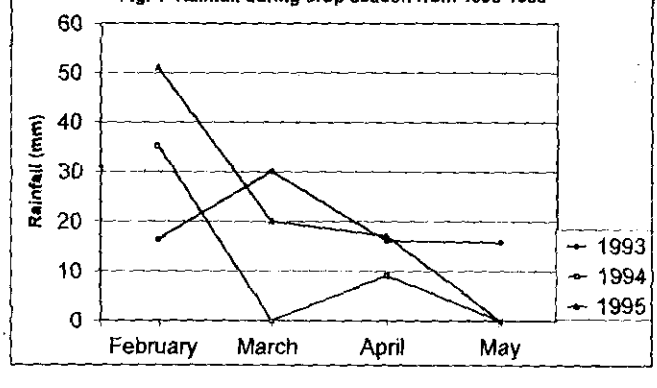
Introduction

Sunflower (*Helianthus annuus* L.) has emerged as a potential oilseed crop in Indian agriculture. The area under sunflower crop in India is increasing rapidly, not only in the southern states but also in the northern states like Punjab, Haryana and Uttar Pradesh. There are several favourable points like short growth period coupled with photo insensitivity enabling the cultivation of crop throughout the year and wide adaptability to different *agro-climatic* conditions and soil types. The most favourable season for growing this crop in Punjab is spring. The crop is prone to moisture stress leading to a substantial drop in the productivity (Ravishankar *et al.*, 1991) . In the light of the above, a field experiment was conducted to identify the critical growth stages, which are most sensitive to water deficit during spring season. Effect of water deficit on seed yield, its components and oil content was also investigated.

Material and methods

The experiment was carried out in the spring seasons of 1993 to 1995 at the Research Farm, Punjab Agricultural University, Ludhiana, Punjab. The soil was loamy with pH 8.0, low in available nitrogen, medium in phosphorus and potash. During all the three seasons, the crop was sown on 3 February 1993, 28 January 1994 & 1995, while harvesting was carried out in the first week of June. There were nine treatments, replicated thrice and tested in RBD (Table 1). These treatment at all the stages were compared with three practices i.e., no moisture stress, irrigation at 75 mm of pan evaporation and as per recommended package of practices (6-9 irrigations depending upon soil type, rainfall and weather prevalent), Punjab Agricultural University, Ludhiana. It may be noted that six irrigations were given at all the growth stages and seven according to recommended package of practices. At 75-mm pan evaporation, during 1993 and 1994, six irrigations were applied but during 1995 due to rains during the early growth stage (Fig 1), first irrigation was delayed and hence subsequent four irrigations were also delayed and in all five irrigations were sufficient during the whole crop season. At different stages of sunflower growth, data were recorded for seed yield its contributing factors and water use efficiency. Oil content was estimated using wide line NMR (Newport Analyser MK III A). Data were statistically analysed using normal procedures.

Fig. 1 Rainfall during crop season from 1993-1995



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Results and discussions

It is evident from the data that sunflower crop required 6 to 7 irrigations to realise the highest seed yield (Table 1). Highest mean seed yield (2167 kg/ha) was obtained with recommended irrigation schedule i.e., seven irrigations which was statistically at par with six irrigations given at 4-6 leaves, star, bud, 50% flowering, soft and hard dough stages. These treatment were significantly superior to the rest of the treatments. Earlier studies by Singh (1990) and Dhillon and Labana (1990) on the irrigation requirement of spring sunflower have shown that 6 to 9 irrigations were optimum for obtaining maximum seed yield.

Table 1 Effect of irrigation on water use efficiency, seed yield and oil content in sunflower hybrid MSFH-8 during spring, 1993-95

Treatment	No. of irrigations	Water used (cm)	Water use efficiency (kg/ha/cm)	Seed yield (kg/ha)			Mean	Mean oil content (%)	Mean oil yield (kg/ha)
				1993	1994	1995			
Irrigation at all growth stages	6	45.0	47.7	2130	2118	2188	2145	41.3	886
Moisture stress at 4 to 6 leaves	5	37.5	52.1	1864	1950	2043	1952	41.1	802
Star stage	5	37.5	53.4	1979	1968	2066	2004	40.9	820
Bud stage	5	37.5	51.9	1910	1927	2008	1948	40.6	791
50% flowering	5	37.5	54.1	1681	1678	1719	1693	40.1	679
Soft dough	5	37.5	42.8	1594	1597	1625	1605	39.7	637
Hard dough	5	37.5	45.1	1632	1727	1719	1693	39.7	672
At 75 mm evaporation	6	45.0	46.3	2049	2101	2100	2083	40.3	839
Recommended irrigations	7	52.5	41.3	2144	2153	2205	2167	41.3	895
CD (P=0.05)	-	-	-	146	87	158	75	-	-

Moisture stress at soft dough grain stage resulted in drastic in drastic reduction i.e. 25% of seed yield. It was closely followed by moisture stress at 50% flowering and at hard dough stage, which caused 21% reduction in seed yield. At these three stages of moisture stress, water use efficiency, percent mean oil content and oil yield (kg/ha) were substantially reduced.

It was further observed that head diameter and 100 seed weight were significantly reduced by moisture stress during different stages as compared with three standard practices (Table 2). Plant height was also significantly reduced when moisture stress was given at 4-6 leaves and star stages. Further stem girth was significantly reduced due to moisture stress at 4-6 leaves, star, bud and 50% flowering stages.

From the present study, it may be concluded that 50 % flowering, soft and hard dough stages are very critical and the spring crop of sunflower should not be allowed to suffer for want of moisture at these stages.

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Table 2 Effect of moisture stress on seed yield attributing characters in spring sunflower crop during 1993 to 1995

Treatment	Plant height (cm)	Stem girth (cm)	Head diameter (cm)	100-seed wt. (g)
Irrigations at all growth stages	149	7.1	13.7	6.5
Moisture stress at 4 to 6 leaves	135	6.6	12.5	5.8
Star stage	135	6.5	12.5	6.1
Bud stage	146	6.6	12.3	5.7
50% flowering	149	6.8	12.2	4.7
Soft dough	149	7.0	12.4	4.3
Hard dough	149	7.1	12.5	4.8
At 75 mm evaporation	149	7.0	13.5	6.3
Recommended irrigation	149	7.2	13.8	6.5
CD (P=0.05)	6.6	0.4	0.6	0.2

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Soil moisture studies of *rabi* groundnut (*Arachis hypogaea* L.) under date of sowing and irrigation schedules in low rainfall zone of Andhra Pradesh

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Abstract

Adjustment in sowing time relative to availability of irrigation water to avoid terminal soil moisture stress to crop always occupies a prominent role in irrigation agronomy. Field experiments conducted in low rainfall zone of Rayalaseema, Andhra Pradesh revealed higher seasonal consumptive use of water and irrigation requirement by groundnut. Crop water use was more during pod filling stage. However, latest sown crop on 30th January recorded significantly less pod yield than the crop sown during 1st November to 15th January. Water use efficiency of crop was proportional to the pod yield and was increased with increase in IW/CPE ratio from 0.6 to 1.0. Crop sown during 16th November to 16th December recorded high crop yield and water use efficiency indicating that ideal sowing time of *rabi* groundnut between 16th November to 16th December in this agroclimatic region.

Key words: Irrigation agronomy, groundnut, water use efficiency.

Introduction

Rabi groundnut (*Arachis hypogaea* L.) is grown under varied climatic conditions. The upper limit of groundnut productivity depends on crop weather relations during crop growth period and soil moisture availability which in turn depends on time of sowing. The period of water availability under well irrigation beyond January determines its sowing date and productivity. As such adjustments in sowing date relative to availability of irrigation water assume significance. *Rabi* groundnut if sown during November can be harvested during March, i.e., before the recharge capacity of wells goes down. Besides this scheduling of irrigation to meet the crop needs with minimum adverse effect on pod yields is also an important aspect of water economy in groundnut production. Hence, in depth studies are necessary to find out optimum time of sowing of groundnut which allows groundnut crop to pass through optimum weather conditions at different growth phases and without subjecting the crop to terminal soil moisture stress.

Materials and methods

Field experiments were carried out for two years (1994-95 and 1995-96) during *rabi* at Agricultural Research Station, Reddipalli low in Rainfall Zone of Andhra Pradesh. Soil of the experimental field is shallow in depth (20-25 cm), sandy loam in texture, slightly alkaline in reaction (7.5pH), low in available nitrogen (109.7 kg/ha), medium in available phosphorus (15.6 kg/ha) and potassium (176.7 kg/ha) with a bulk density of 1.45 g/cm^3. The field capacity and permanent wilting point of soil are 10.59 and 3.66 % respectively. The treatments included seven dates of sowing i.e., 1st November, 16th November, 1st December, 16th December, 31st December, 15th January and 30th January and three irrigation schedules i.e., IW/CPE ratios of 1.0, 0.8 and 0.6. The treatments were allotted in split plot design keeping date of sowing in main plot and level of irrigation in sub plots with three replications. The test variety was Spanish bunch vemana (K-134) with a duration of 100-110 days.

Three common irrigations were given, one prior to sowing and another 5 days after sowing (DAS) to ensure good germination and adequate stand establishment and at 25 DAS with 5 cm depth of irrigation water. Since then, the crop was irrigated as per the irrigation schedules. Evaporation data recorded in class A was made use of while scheduling irrigations.

Moisture content of soil drawn from 0-15, 15-30 and 30-45 cm depths from 25 DAS was determined before and after irrigation by thermogravimetric method. As the soil depth was shallow (20-25 cm), soil moisture was measured upto 45 cm depth only. Seasonal consumptive use of water was calculated as per procedure described by Michael *et al.* (1977). Soil moisture extraction pattern was calculated as per the procedure outlines by Dastane (1972). Groundnut pods from the net plot area were harvested as and when

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they matured in different treatments and yield was recorded. Total irrigation requirement was calculated by summing the quantity of water given and rainfall received during the crop growth period. Crop water use efficiency and field water use efficiency were calculated using the following formulae:

$$\text{Crop water use efficiency (kg/ha mm)} = \frac{\text{Pod yield (kg/ha)}}{\text{Evapotranspiration (mm)}}$$

$$\text{Field water use efficiency (kg/ha mm)} = \frac{\text{Pod Yield (kg/ha)}}{\text{Quantity of water (mm) applied to the field + rainfall received (mm)}}$$

Results and discussion

Soil moisture extraction pattern: *Soil moisture* extraction by the crop decreased with increase in depth of soil (Figs. 1 and 2). Soil moisture content extracted from 0-30 cm soil layer was increased with delay in sowings from 1st November to 1st December and further delay in sowing resulted no significant variation in moisture content. With increase in irrigation frequency from 0.6 to 1.0 IW/CPE ratio, the per cent contribution of top layer (0-15 cm) to the total consumptive use increased, owing to more evaporation losses from relatively wet soil surface. Relative contribution from the second soil layer varied slightly, indicating good spread of root system in that layer at all irrigation schedules. Similarly, variation in soil moisture extraction from the third layer was marginal due to shallow nature of the experimental field. The results also indicated that application of 5 cm depth of water at each irrigation was more than that required to bring the shallow red soil to field capacity leading.

From the results it is evident that time of sowing had considerable influence on seasonal consumptive use of water, total irrigation requirement, crop water use efficiency. Crop sown from 16th November to 166h December recorded high pod yield (pooled) and high crop water use efficiency indicating that *rabi* groundnut could be sown from 16th November to 16th December. *Rabi* groundnut if sown during November/December can be harvested by the end of March, well before the recharge capacity of wells goes down. If sowings are delayed upto January, terminal soil moisture stress due to shortage of irrigation water during April-May, coincide with pod filling phase of the crop, leading to poor pod yields and low crop water use efficiency. Earliest sowings with all irrigation schedules had higher crop water use efficiency than the corresponding irrigation schedules with January sowings. If the crop is subjected to soil moisture stress due to shortage of water at pod filling phase, irrigations could be scheduled at 0.8 IW/CPE ratio with marginal decrease in pod yield.

Seasonal *consumptive use of water (CU)*: Consumptive use of water (CU) was increased with delay in sowing from 1st November to 30th January. The late sown crop i.e., 30th

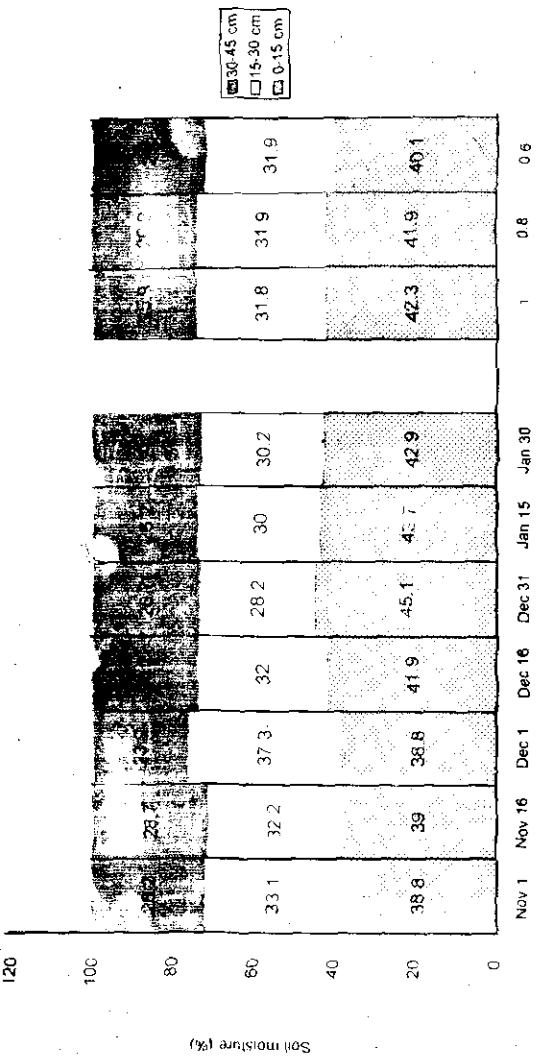

Fig. 1 Soil moisture extraction pattern (%) from different soil depths as influenced by sowing dates and irrigation schedules during 1994 - 95

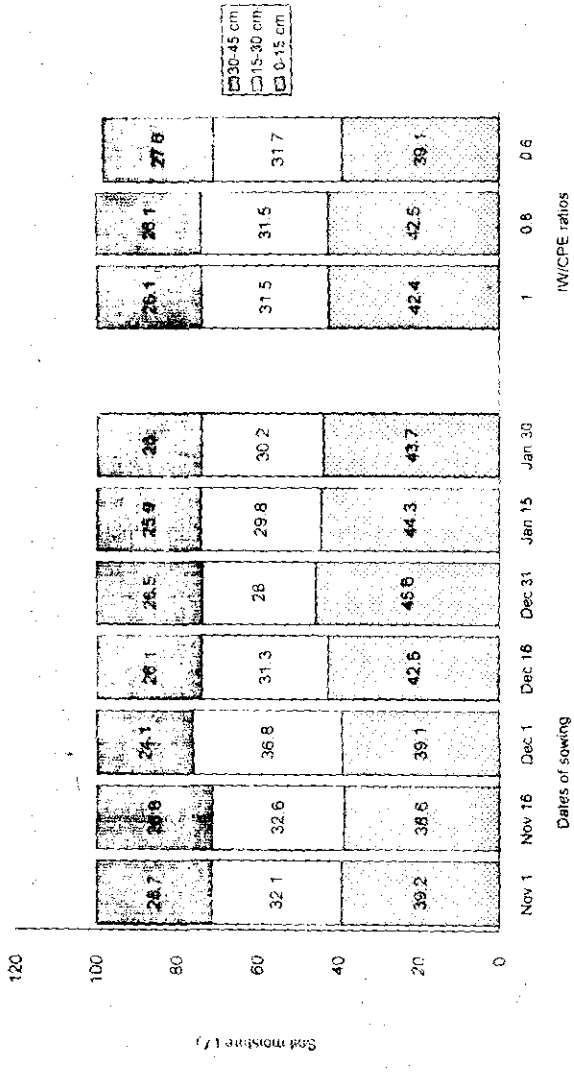

Fig. 2 Soil moisture extraction pattern (%) from different soil depths as influenced by sowing dates and irrigation schedules during 1995 - 96

January in first year (446.6 mm) and 31st December sown crop of second year (430.2mm) recorded maximum CU while 16th November sown crop recorded lowest CU during both the years. The CU during vegetative phase (S_1) was almost similar under all the sowing dates and irrigation schedules. However, during reproductive phase (S_2), there were marginal differences in CU when the crop sown till 16th December. Late sown crop resulted in higher CU than the crop sown early. Crop utilised more water during pod filling phase (S_3) than other two phases under all dates of sowing, indicating the importance of adequate water supply during pod filling. The CU progressively increased with increase in IW/CPE ratio. The mean CU at 0.6, 0.8 and 1.0 IW/CPE ratios were 388.9, 409.6 and 440.0 mm in the first year and the corresponding values in 1995-96 were 383.4, 415.3 and 444.7 mm respectively.

Total irrigation requirement: Total irrigation requirement was highest in crop sown in 15th January during first year and 30th January during second year (Table 2). Irrigation requirement increased with IW/CPE ratio from 0.6 to 1.0 . Irrigating the crop at IW/CPE ratio of 1.0 had the highest total irrigation requirement (705.8 and 737.6 mm) and it was higher by 15.2 and 14.4 % than 0.8 IW/CPE ratio and 35.7 and 33.6 % than 0.6 during 1994-95 and 1995-96 respectively. At least sowings, irrigation at 1.0 IW/CPE ratio had highest total irrigation requirement in both the years.

Leaf canopy was more with delayed sowings. Hence, increase in both CU and total irrigation requirement with delay in sowings was due to higher evapotranspiration (ET) losses owing to increase in leaf canopy. Increase in CU and total irrigation requirement at IW/CPE ratio of 1.0 was due to higher ET losses from relatively wet soil moisture regime.

Pod yield: Pooled analysis data of pod yield over two year (Table 3) brought about significant variations due to dates of sowing and irrigation schedules. Interaction of these treatments could not bring significant variation in pod yield. Six dates of sowing from 1st November to 15th January at 15 days interval resulted in comparable pod yields ranging from 1728 to 2047 kg/ha. Latest sown crop on 30th January recorded significantly less pod yield (1258 kg/ha) compared with the earliest six dates of sowing. Pool analysis data showed 62.7 % increase in pod yield with 16th December sown crop over latest sown crop on 30th January. Variations in pod yield due to sowing dates due to differences in diurnal variation in temperature with different sowing dates and their effect on various physiological processes particularly partitioning and respiration. The results are in conformity with the findings of (Bell *et al.*, 1993; Ntare *et al.*, 1993).

There was progressive and significant decrease in pod yield with decrease in IW/CPE ratio from 1.0 to 0.6 in both the years. Higher pod yield with IW/CPE ratio of 1.0 was due to improvement in yield attributes because of adequate soil available moisture (Rami Reddy, 1984; Patel and Patel, 1995). The pod yields with 30th January 30

Table 1 Seasonal consumptive use of water (mm) at different phenophases as influenced by sowing dates and irrigation schedules

Sowing date IW/CPE ratio	1994-95 Phenophases S_1	S_2	S_3	Total	1995-96 Phenophases S_1	S_2	S_3	Total
November 01/1.0	151.2	63.4	188.4	402.8	153.4	64.7	199.7	417.7
November 01/0.8	150.9	62.3	184.3	397.4	153.9	65.8	190.4	410.0
November 01/0.6	152.1	60.0	168.3	380.4	152.4	67.9	145.5	365.8
Mean	**151.4**	**61.9**	**180.3**	**393.0**	**153.2**	**66.1**	**178.5**	**397.8**
November 16/1.0	153.2	63.9	202.6	419.6	162.1	66.5	204.6	433.2
November 16/0.8	153.0	62.7	170.4	386.1	157.6	66.0	174.8	398.4
November 16/0.6	152.1	62.7	141.3	354.3	154.4	45.3	148.0	347.6
Mean	**152.8**	**62.5**	**171.4**	**386.7**	**158.0**	**59.3**	**175.8**	**393.0**
December 01/1.0	151.7	67.5	210.2	429.4	170.8	68.2	206.4	445.3
December 01/08	150.3	65.3	181.3	396.8	159.9	68.9	179.9	408.7
December 01/0.6	150.2	64.6	178.2	393.0	159.2	63.8	179.6	402.5
Mean	**150.7**	**65.8**	**189.9**	**406.9**	**163.3**	**67.0**	**188.6**	**412.2**
December 16/1.0	152.9	64.3	210.4	427.6	155.1	63.4	211.1	429.6
December 16/0.8	152.2	63.0	195.3	410.4	153.4	60.3	197.1	410.7
December 16/0.6	151.3	60.1	180.1	391.5	151.8	59.2	176.8	387.9
Mean	**152.1**	**62.5**	**195.3**	**409.4**	**153.4**	**61.0**	**195.0**	**409.4**
December 31/1.0	155.3	78.6	215.5	449.4	167.4	79.3	219.2	465.9
December 31/0.8	155.3	77.5	193.6	424.3	165.9	78.1	195.6	440.5
December 31/0.6	151.8	63.6	171.3	386.7	151.2	65.8	167.1	384.1
Mean	**154.1**	**73.2**	**193.4**	**420.2**	**161.5**	**74.4**	**194.0**	**430.2**
January 15/1.0	156.7	78.3	225.0	460.0	156.6	78.1	225.7	460.4
January 15/0.8	155.3	71.4	191.3	418.0	157.1	69.1	192.7	419.2
January 15/0.6	153.4	70.3	182.8	406.5	155.8	72.3	181.5	409.6
Mean	**155.1**	**73.3**	**199.7**	**428.1**	**156.5**	**73.2**	**200.0**	**429.7**
January 30/1.0	157.9	79.3	258.3	495.5	155.8	7938	223.6	461.1
January 30/0.8	156.8	76.3	201.3	434.4	157.5	78.4	183.6	419.5
January 30/0.6	155.1	7.3.1	201.3	434.4	157.4	78.4	183.6	419.5
Mean	**156.1**	**73.1**	**220.3**	**446.6**	**156.9**	**78.9**	**197.0**	**422.5**
Mean of irrigation schedules								
1.0				440.6				444.7
0.8				409.6				415.3
0.6				388.9				383.4

Table 2 **Total irrigation requirement (mm) of groundnut as influenced by sowing dates and irrigation schedules**

Treatment	1994-95				1995-96			
	IW/CPE ratio				IW/CPE ratio			
	1.0	0.8	0.6	Mean	1.0	0.8	0.6	Mean
Dates of sowing								
November 01	600.0	500.0	450.0	516.7	650.0	550.0	450.0	550.0
November 16	*650.0*	*550.0*	*450.0*	*550.0*	*650.0*	*600.0*	*550.0*	*600.0*
December 01	600.0	500.0	450.0	516.7	650.0	550.0	500.0	566.7
December 16	700.0	600.0	500.0	600.0	745.4	645.4	545.4	645.4
December 31	775.8	675.8	575.8	675.8	820.2	720.2	570.2	703.5
January 15	807.4	757.4	607.4	724.1	770.2	720.2	620.2	703.5
January 30	807.4	707.4	607.4	707.4	877.2	727.2	627.2	743.9
Mean	705.8	612.9	520.1		737.6	644.7	551.9	

sown crop even at IW/CPE ratio of 1.0 were less than that of the early sown crop irrigated at IW/CPE ratio of 0.8. Higher minimum temperatures might have exhausted the food reserves during respirating process, leading to poor pod yields with January sowings. Hence, it can be said that the adverse effects of weather with late sowings could not be mitigated by frequent irrigations of 1.0 IW/CPE ratio.

Table 3 **Pooled pod yield (kg/ha) as influenced by sowing dates and irrigation schedules**

Date of sowing	IW/CPE ratio			
	1.0	0.8	0.6	Mean
November 01	2026	1779	1570	1792
November 16	2253	1972	1570	1934
December 01	2480	2035	1556	2024
December 16	2336	2038	1766	2047
December 31	2142	1915	1523	1860
January 15	2009	1670	1007	1258
January 30	15731	1194	1007	1258
Mean	*2117*	*1800*	*1500*	
	Date	Irrigation		D x I
CD(P = 0.05)	364.30	308.42		NS

Crop water use efficiency: There were considerable differences (Table 4) in crop water use efficiency due to sowing dates and irrigation schedules. During 1994-95, crop sown on 16th November recorded highest (5.39 kg/ha mm) crop water use efficiency followed by 16th December (4.99 kg/ha mm) sown crop. During 1995-96, crop sown on December 16 had highest water use efficiency (5.12 kg/ha mm) followed by December 1 sowing (5.08 kg/ha mm). Latest sowings had lowest water use efficiency in both the years. This might be due to loss of water through ET and adverse conditions leading to drastic reduction in yield. In general, crop water use efficiency was proportional to the pod yield due to dates of sowing.

Crop water use efficiency increased with increase in IW/CPE ratio from 0.6 to 1.0 in both the years, recording highest efficiency with sowing date of 16th November. Latest sowings irrigated at 0.6 ratio had lowest water use efficiency. Early sowings even when irrigated at 0.6 ratio *recorded higher crop water use efficiency than late sowings* of January with 1.0 IW/CPE ratio as observed during 1995-96. In 1994-95 also, 1st November sowings with all the three irrigation schedules had higher crop water use efficiency than the corresponding irrigation schedules of late sowings of January. The results indicated dominance of weather over irrigation schedules on pod yields directly and crop water use efficiency indirectly.

Field water use efficiency: Field water use efficiency decreased with delay in sowing from 1st December to 30th January in both the years (Table 5). Highest field water use efficiency was with 16th November sown crop (3.80 kg/ha mm) in first year and 1st December sown crop (3.79 kg/ha mm) in second year. In general, field water use efficiency was low due to poor water holding capacity of shallow red soil. Decreased values from 1st December to 30th January was due to higher evaporative demand after March.

Table 4 **Crop water use efficiency (kg/ha mm) as influenced by sowing dates and irrigation schedules**

Treatment	1994-95				1995-96			
	IW/CPE ratio				IW/CPE ratio			
	1.0	0.8	0.6	Mean	1.0	0.8	0.6	Mean
Dates of sowing								
November 01	4.76	4.13	3.69	4.19	5.11	4.67	4.75	4.84
November 16	6.04	5.63	4.51	5.39	4.55	4.44	4.43	4.47
December 01	5.65	4.94	3.31	4.63	5.69	5.16	4.50	5.08
December 16	5.52	4.98	4.46	4.99	5.38	4.95	4.61	5.12
December 31	4.88	4.72	3.84	4.48	4.49	4.15	4.07	4.24
January 15	4.38	3.96	3.78	4.04	4.34	4.02	3.60	3.99
January 30	3.06	2.73	2.25	2.68	3.54	2.86	2.82	3.07
Mean	4.90	4.44	3.69		4.73	4.37	4.11	

Scheduling irrigation at 1.0 IW/CPE ratio increased the field water use efficiency in first year while in second year, the crop irrigated at 0.6 IW/CPE ratio recorded maximum (2.92 kg/ha m) field water use efficiency. 1st December sown crop irrigated at 1.0 IW/CPE ratio recorded highest water use efficiency in both the years.

Table 5 **Field water use efficiency (kg/ha mm) as influenced by sowing dates and irrigation schedules**

Treatment	1994-95				1995-96			
	IW/CPE ratio				IW/CPE ratio			
	1.0	0.8	0.6	Mean	1.0	0.8	0.6	Mean
Dates of sowing								
November 01	3.20	3.28	3.12	3.20	3.28	3.48	3.86	3.54
November 16	3.90	3.95	3.55	3.80	3.03	2.95	2.80	2.93
December 01	4.04	3.92	2.89	3.61	3.90	3.84	3.62	3.79
December 16	3.37	3.41	3.49	3.42	3.10	3.15	3.28	3.18
December 31	2.82	2.96	2.58	2.79	2.55	2.54	2.74	2.61
January 15	2.50	2.19	2.53	2.33	2.60	2.34	2.38	2.44
January 30	1.88	1.68	1.52	1.69	1.86	1.65	1.74	1.75
Mean	3.10	3.06	2.81		2.90	2.85	2.92	

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Production potential and economics of rainfed soybean (*Glycine max* L. Merr.) under different fertility levels and inoculation

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Abstract

An experiment conducted on clay loam soil during 1995 and 1996 to study the response of soybean (variety PK-472) to different levels of N (0, 20 and 40 Kg/ha), phosphorus (30 and 60 Kg/ha) and Rhizobium culture (with and without inoculation). The pods/plant, seed/pod, seed index (100 seed weight) and seed yield either increased significantly or tended to increase with an increase in levels of nitrogen, phosphorus and Rhizobium inoculation. The seed yield of soybean increased significantly upto 20 Kg N and 60 Kg P_2O_2/ha. The B:C ratio was highest due to application of 20 Kg N/ha and application of 30 Kg P_2O_5/ha. Inoculation with Rhizobium increased the seed yield of soybean by 11.87 and 13.05 % with highest B:C ratio of 2.78 and 2.96 during 1995 and 1996, respectively.

Key words: Soybean, Inoculation, Net returns, Rhizobium

Introduction

Soybean (*Glycine max* L. Merr.) is the most dominant rainy season crop of humid Southern Plain Zone of Rajasthan. The nutrient requirement is, however, not known whereas sub optimal dose in general is applied to soybean. It is recognised that combined application of bio-fertilizer and chemical fertilizers play key role in sustained the productivity of crops. Therefore, an effort was made to find out the level of nitrogen, phosphorus and Rhizobium inoculation for enhancing the soybean productivity.

Materials and methods

Two years field trial with "PK472" soybean was conducted with 3 levels of nitrogen (0, 20 and 40 Kg/ha), 2 levels of phosphorus (30 and 60 Kg/ha) and 2 levels of Rhizobium inoculation (600 g culture/ha and without inoculation) in randomised block design with factorial arrangement, replicated four times at Pratapgarh during rainy seasons of 1995 and 1996. The experimental soil analysed low organic carbon (0.16%), pH 7.7, available nitrogen 291.5 kg/ha, phosphorus 35 kg P_2O_5/ha and potash 210 kg/ha. The crop was sown on 17th July, 1995 and 12th July, 1996 and harvested on 10th and 7th November in 1995 and 1996, respectively.

The rainfall of 672 mm and 883 mm was received during 1995 and 1996, respectively. Recommended package of practices were followed. Observations on yield and yield attributes were recorded at the time of harvest.

Results and discussion

Yield Attributes : The yield attributes of soybean *viz.*, number of pods/plant, and seed index increased significantly up to 40 kg N/ha. Whereas number of seeds/pod increased significantly only up to 20 kg N/ha (Table 1).

The number of pods/plant and seed index were significantly higher with 60 kg P_2O_5/ha, whereas number of seeds/pod remained uninfluenced. Inoculation with rhizobium significantly increased the pods/plant and seed index while number of seeds/pod remained unaffected.

Seed Yield : Application of nitrogen @ 20 kg/ha significantly increased the seed yield over the control, but, it was found at par with 40 kg N/ha (Table 1). The yield increase at 20 and 40 kg N/ha was 5.75 % during 1995 and 5.28 and 8.25 % during 1996 compared with the control. The increase in seed yield could be attributed to cumulative effects of number of pods/plant and seed index. This is in agreement with the observations of Joyapaul and Ganesaraja (1990).

Phosphorus application @ 60 kg P_2O_5/ha increased the seed yield by 7.24 and 7.45 % over the control during 1995, respectively. Significant beneficial effects of P application on seed yield of soybean was also reported by Singh and Bajpai (1990).

Rhizobium inoculation increased the seed yield by 11.87 and 13.08 % over uninoculated during 1995 and 1996, respectively. This might be due to cumulative effect of rhizobium inoculation on yield attributes which ultimately resulted in higherr seed yield. This result confirm the findings of Dehatonde and Shava (1992).

Table 1 Effect of N, P and Rhizobium inoculation on yield and net returns of soybean

Treatment	Pods/plant		Seed/pod		Seed index		Cost of cultivation (Rs/ha)	Seed yield (kg/ha)		Net returns (Rs/ha)		B:C ratio	
	1995	1996	1995	1996	1995	1996		1995	1996	1995	1996	1995	1996
Nitrogen levels (kg/ha)													
0	49.40	47.12	2.14	2.12	10.20	9.80	3681	15.12	14.77	9344	9989	2.54	**2.71**
20	50.62	57.20	2.18	2.17	10.80	10.40	3821	15.99	15.55	9944	10489	2.60	**2.75**
40	62.18	59.00	2.20	2.19	11.60	11.40	3961	16.44	15.99	10222	10833	2.58	**2.73**
CD (*P*=0.05)	3.40	1.60	0.03	0.40	0.60	0.40		0.83	0.73	533	656		
Phosphorus levels (kg/ha)													
30	52.98	49.64	2.00	1.95	8.57	8.65	3596	15.33	14.88	9622	10167	2.68	**2.82**
60	60.48	59.21	2.34	2.36	13.13	12.40	4046	16.44	15.99	10111	10711	2.50	**2.65**
Cd (P=0.05)	2.85	2.00	NS	NS	0.20	0.20		0.66	0.59	433	533		
Rhizobium inoculation													
Uninoculated	52.35	50.35	2.09	2.04	9.45	8.95	3815	14.99	14.44	9100	9533	2.39	**2.90**
Inoculated	61.10	58.52	2.25	2.27	12.28	12.11	3827	16.77	16.44	10622	11333	2.78	**2.96**
CD (P=0.05)	2.85	2.00	NS	NS	0.20	0.20		0.66	0.59	433	533		
Selling Price of soybean	1995	Rs. 862 q/ha											
	1996	Rs. 925 q/ha											

Net returns : An application of 20 kg N/ha enhanced the net returns significantly over no application of nitrogen. Further increase in nitrogen level up to 40 kg/ha did not *resulted in significant enhancement of net returns*, the highest B:C also found with the application 20 kg N/ha. With regards to phosphorus, its application @ 60 kg/ha significantly increased the net returns during both the years but the B:C ratio was higher under the application of 30 kg P_2O_5/ha. Inoculation also increased the net return significantly over without inoculation with the highest B:C *ratio of 2.96*.

The seed inoculation with rhizobium and 20 kg N+60 kg P_2O_5 /ha was found most economical levels for soybean, *production in southern plain zone of Rajasthan*.

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Herbicidal management of weeds in groundnut (*Arachis hypogaea* L.)

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Abstract

A field experiment conducted during pre-*kharif*, 1997 in entisol of West Bengal revealed that *Cynodon dactylon* (L.) Pers., *Echinochloa colonum* (L.) Link., *Pennisetum pedicellatum* Trin., *Cyperus rotundus* L., *Cleome viscosa* L., *Euphorbia hirta* L. and *Physalis minima* L. were the dominant weeds and unchecked growth of weeds reduced the pod yield by 27.49 to 37.89% in groundnut. Though hand weeding twice at 20 and 40 days after sowing minimised not only weed count and biomass remarkably but also gave the highest pod yield (2246 kg/ha), it was found to be uneconomic to the farmers because of lower benefit : cost ratio (0.89 : 1.00). Pre-emergence application of alachlor at 0.96 kg a.i./ha proved to be the best weed management tool providing higher yield of pod (2185 kg/ha) and oil (717 kg/ha) with maximum benefit : cost ratio (1.29 : 1.00).

Key words: Herbicide, weed management, groundnut

Introduction

Weed infestation in groundnut (*Arachis hypogaea* L.) is one of the main factors for loss in yields to the tune of 13-80%. Weeds drain the fertilizers applied and moisture conserved before sowing and thus have a greatest competitive effect on crop. Although, Indian farmers are aware of these problems, they follow conventional had weeding and hoeing. Today, farmers are facing a lot of hardships financially due to hike in labour costs and unavailability of labour. Therefore, the present attempt has been made to identify a suitable weed management practice in groundnut.

Material and methods

An investigation was undertaken during pre-*kharif* of 1997 in humid subtropics of West Bengal at the Viswavidyalaya Farm, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur on Gangetic alluvial sandy loam soil (entisol) having pH 6.8, total N 0.052%, available P 18.95 kg/ha and available K 89.00 kg/ha. The experiment, consisting of seven treatments was laid out in a randomized block design with three replications (Table 1). The plot size was 4 m x 3 m.

Groundnut cv. JL-24 (Phule Pragati) seeds were treated with Seed+ (Cytozyme) at 3.0 g/kg of kernel inoculated with *Rhizobium* culture and sown on February 10, 1997 at the rate of 75 kg/ha with spacing of 30 cm x 15 cm. Fertilizers were applied at 20 : 40 : 40 kg N, P_2O_5 and K_2O/ha and full doses were incorporated to the soil as basal. The crop was harvested on 23rd May, 1997.

Weed sampling at an interval of 25 days was done from each plot by random use of 0.5 m x 0.5 m quadrant for taking weed count and weed biomass. Observations on yield and its parameters were recorded at harvest. Economics of weed management were worked out.

Results and discussion

Weed flora: The dominant weeds in crop were *Cynodon dactylon* (L.) Pers., *Echinochloa colonum* (L.) Link, *Pennisetum pedicellatum* Trin., *Cyperus rotundus* L., *Cleome viscosa* L., *Euphorbia hirta* L. and *Physalis minima* L.

Effect of treatments on weeds: A reference to weeds data in Table 1 reveals that all the herbicidal treatments recorded a significant reduction in both the population and biomass of weeds compared to weedy check at 25, 50 and 75 DAS and at harvest. The lowest weed count and biomass throughout the crop growth cycle was under hand weeding twice followed by alachlor 0.96 kg/ha applied as pre-emergence. The treatments hand weeding twice and alachlor 0.96 kg/ha also registered the highest weed control efficiency of 76.19 and 60.76%, respectively at harvest. Present findings got support from the studies of Ramakrishna *et al.* (1991), Sudhakar and Muniyappa (1991) and Itnal *et al.* (1993).

Table 1 Effect of treatments on weed growth in groundnut

Treatment	Weed count (No./m²)				Weed biomass (g/m²)			
	25 DAS	50 DAS	75 DAS	Harvest	25 DAS	50 DAS	75 DAS	Harvest
Trifluralin 0.48 kg/ha (PPI)	19.0	40.3	58.0	67.3	2.5	10.8	17.6	20.4
Bentazon 0.81 kg/ha (POE)	17.7	42.7	60.3	72.7	2.4	12.7	19.1	24.0
Alachlor 0.96 kg/ha (PE)	14.0	32.3	48.7	58.0	1.8	9.2	14.0	18.7
Metolachlor 1.0 kg/ha (PE)	19.3	40.3	57.7	68.7	2.7	12.5	19.0	23.2
Metribuzin 0.42 kg/ha (PE)	16.7	38.0	55.7	62.7	2.1	10.7	16.3	19.1
Hand weeding twice (20, 40 DAS)	8.8	12.0	28.7	37.7	1.1	3.1	7.4	10.1
Weedy check	41.3	78.3	96.7	109.0	5.9	20.8	31.2	42.5
SEm±	0.9	4.6	3.9	3.9	0.3	1.1	1.9	2.5
CD (P=0.05)	2.8	14.2	12.1	11.9	1.1	3.5	5.9	7.8

DAS : Days after sowing; PPI : Pre-planting incorporation; POE : Post-emergence; PE : Pre-emergence

Effect of treatments on crop: Each treatment significantly improved the yield and its parameters barring 100-pod weight over weedy check (Table 2). Hand weeding twice yielded significantly maximum number of pods/plant (12), pod weight/plant (14.4 g), 100-pod weight (120.3 g) and shelling percentage (74.8) which were reflected on the highest yields of pod (225 kg/ha) and oil (748 kg/ha) compared to the herbicide treatments. Amongst herbicides, alachlor at 0.96 kg/ha produced maximum yields of pod (2185 kg/ha) and oil (717 kg/ha) while the performance of metolachlor at 1 kg/ha was poor. More or less similar yield increase due to hand weeding and alachlor in groundnut was reported by Itnal *et al.* (1993) and Sudhakar and Muniyappa (1991). Better development of kernels due to higher dry matter accumulation in a situation of lesser weed competition might contribute to the higher shelling percentage registered by alachlor at 0.96 kg/ha (74.28%). Weedy check recorded significantly the lowest pod yield (1395 kg/ha), the reduction being 27.5 - 37.9% over different weed control treatments. Greater yield loss due to weed infestation in groundnut was also reported by Yaduraju *et al.* (1980).

Economics of weed management: Alachlor application at 0.96 kg/ha was more economical giving a maximum benefit : cost ratio of 1.29 : 1. Next in order was trifluralin at 0.48 kg/ha as pre-sowing application (1.26:1). The lowest benefit : cost ratio was recorded by hand weeding twice due to more labour requirement (Table 2).

The present findings suggested that pre-emergence application of alachlor at 0.96 kg/ha may provide better cost effective weed management in groundnut.

Table 2 Yield parameters, pod and oil yield and benefit : cost ratio under different treatments in groundnut

Treatment	Yield parameters				Yield (q ha⁻¹)		Benefit : cost ratio
	Pod no./plant	Pod wt./ plant (g)	100-pod wt. (g)	Shelling (%)	Pod	Oil Yield	
Trifluralin 0.48 kg/ha (PPI)	10.7	12.9	120.1	73.8	20.9	6.8	1.26 : 1.00
Bentazon 0.81 kg/ha (POE)	9.99	11.8	120.0	73.7	19.4	6.2	1.04 : 1.00
Alachlor 0.96 kg/ha (PE)	12.0	14.4	120.2	74.3	21.9	7.2	1.29 : 1.00
Metolachlor 1.0 kg/ha (PE)	10.1	12.2	119.9	72.9	19.2	6.1	1.04 : 1.00
Metribuzin 0.42 kg/ha (PE)	11.7	14.1	120.1	73.9	21.4	6.9	1.24 : 1.00
Hand weeding twice	12.0	14.4	120.3	74.8	22.5	7.5	0.89 : 1.00
Weedy check	7.4	8.8	119.6	68.2	14.0	4.0	0.60 : 1.00
SEm±	0.6	0.7	0.7	0.6	0.9	0.3	
CD (P=0.05)	1.82	2.00	NS	1.88	2.71	0.83	

DAS : Days after sowing; PPI : Pre-planting incorporation; POE : Post-emergence; PE : Pre-emergence

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Effect of fertilizer and phosphorus solubalising bacteria on the yield of soybean (*Glycine max* L. Merr.)

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Abstract

The experiment was conducted at Zonal Agricultural Research Station, Chhindwara during *kharif* seasons of 1995 and 1996 in a clay loam soil under rainfed conditions. The findings revealed that nodule number and its weight/plant, plant height, number of branches, number of pods and seed index improved with inoculation/application of PSB and fertilizers. Simply inoculation of seed with phosphorus solubalizing bacteria (PSB) enhanced the yield by 185 kg/ha. Its soil application raised it by 252 kg/ha over control 1381 kg/ha. Soil application of PSB at 15 days after sowing proved superior to seed or soil inoculation and with 60 or 45 kg P_2O_5/ha resulted in better yield than lower level of phosphorus. Soil application of PSB at 15 days after sowing recorded the highest C:B ratio of 45.47 followed by its application at the time of sowing (34.41).

Key words : Phosphorus, solubalizing bacteria, soybean, bio-fertilizer

Introduction

Soybean crop is being cultivated in light to medium heavy soils of Satpura plateau zone Madhya Pradesh covering an area of 2.97 lakh ha. In general, the crop is supplied with sub-optimal or imbalanced nutrients, mainly nitrogen and phosphorus. Souring prices of fertilizers in the recent past has hampered the balance use of fertilizers for growing the crop. Phosphorus solubalizing bacteria as biofertilizer has been used successfully in different crops. It helps in making phosphorus available in soil. It is pollution free, non-hazardous, cheap, makes the soil phosphorus available to growing plants which is in fixed form. Whatever phosphorus is applied to soil is not utilized fully by the crop since most of the part remains in the soil as fixed P. Geretsen (1948) was the first to demonstrate that plants took up more phosphate from insoluble phosphatic fertilizers in the presence of microorganism. To make use of this fixed form and native phosphorus PSB has been found to be useful. Keeping this in view the present study was undertaken to find out the effect of fertilizer and PSB on the yield of soybean.

Materials and methods

The experiment on the effect of fertilizer and PSB on the yield of soybean was conducted in clay loam soil at Zonal Agricultural Research Station, Chhindwara during *kharif* seasons of 1995 and 1996 under rainfed conditions. The soil was medium in fertility i.e., available carbon 0.66%, nitrogen 258 kg/ha, phosphorus 16 kg/ha and potassium 480 kg/ha having pH 7.2 and conductivity 0.35 d/Sm. Ten treatments imparted included seed, soil inoculation with PSB and combination of soil and seed inoculation with 100%, 75% and 50% of recommended P at 60 kg P_2O_5/ha (Table 1). The recommended levels of N (20 kg N/ha) and K (20 kg K_2O/ha) were applied as basal. These were replicated thrice following randomised block design. PSB culture having *Pseudomonas*, *Bacillus* sp. *Straita* etc., with bacterial population of 10^7 per g was used for this purpose. Culture and soil (1:50) was drilled at the time of sowing and later 15 days after sowing beside the rows. The experiment was sown in 1st week of July during both the years. Nitrogen 20 kg, phosphorus 60 kg P_2O_5 and potassium 60 kg K_2O/ha were applied. The carriers used for nitrogen, phosphorus and potassium were urea, superphosphate and muriate of potash, respectively. To treat the seeds gur slurry was first sprinkled on seeds followed PSB culture. Soybean seeds @ 100 kg/ha was drilled in lines with fertilizer cum seed drill. Inoculated seed of variety JS, 71-5 was used in the experiment. The crop was raised following recommended cultural and plant protection measures. The crop was harvested at maturity. Total rains of 689 and 816 mm were received during the crop growth period in 1995 and 1996. Maximum temperature prevailed was 30.3°C and 29.6 °C and minimum 25.6°C and 23.8°C. The relative humidity recorded was 80.9 and 88 % with 43 and 42 rainy days, respectively for both the years. The yield contributing characters and yield data were subjected to statistical analysis and discussed.

Table 1 Effect of fertilizer and PSB on the yield attributing characters and yield of soybean

Treatment	Plant height (cm)			No. of branches/plant			No. of pods/plant			No. of nodules/plant			Nodule wt.(g)/plant			1000 seed wt.(g)			Seed yield (kg/ha)			C:B Ratio
	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean	
Control	48	26	34	3	3	3	20	17	19	23	23	23	0.22	0.20	0.210	110	134	122	695	2067	1381	-
Seed Ino. (20 g/kg)	50	26	38	3	3	3	23	19	21	28	23	26	0.22	0.22	0.220	113	138	126	932	2200	1566	24.21
Soil Ino. (2 kg/ha)	52	28	40	3	3	3	24	20	22	34	25	30	0.23	0.21	0.220	114	138	126	1008	2258	1633	34.71
Soil Ino. At 15 DAS	57	30	43	3	3	3	24	21	23	36	28	32	0.25	0.22	0.235	115	138	127	1119	2300	1709	45.47
Soil Ino. + 100% P_2O_5	55	35	45	4	4	4	25	24	25	36	28	32	0.24	0.23	0.235	119	143	131	1151	2583	1867	1.81
Soil Ino.+75% P_2O_5	51	33	42	4	3	3	25	22	23	35	27	31	0.24	0.22	0.230	119	133	129	1071	2500	1785	1.89
Soil Ino.+50% P_2O_5	51	31	41	3	4	3	24	22	23	29	25	27	0.23	0.22	0.225	113	138	125	782	2275	1528	0.37
Seed Ino.+100%P_2O_5	67	34	51	4	4	4	26	25	25	39	30	35	0.26	0.24	0.250	121	145	133	1167	2733	1950	2.29
Seed Ino.+75% P_2O_5	59	30	44	3	4	4	24	24	24	35	37	31	0.22	0.23	0.225	118	140	129	992	2650	1821	2.14
Seed Ino.+50% P_2O_5	58	30	44	3	4	4	24	23	24	32	34	28	0.22	0.22	0.220	117	139	128	818	2533	1675	1.72
SEm±	2.3	1.7		0.2	0.2		1.4	1.6		1.2	1		0.009	0.016		1.5	2.1		034	067		0.51
Cd (P=0 05)	6.9	5.2		0.7	0.5		4.1	4.8		3.6	3		0.027	NS		4.5	6.2		102	208		1.52

Cost of commodities (Rs/kg) : N - 7.08, P_2O_5 - 18.75, K_2O - 7.16, culture Rs. 6 per packet and seed - 8.50. All other field operations were considered common for all treatments.

Results and discussion

The data presented in the Table 1 depicted significantly higher yield in treated plots over control during both the years. The parameters plant height, branches, pods, nodule and its weight and seed weight were significantly influenced except nodule weight in 1996 due to the effect of treatments. The plant height was recorded to be higher in the previous year than in the second year while number of branches and seed index were more during second year. The highest mean height of 50 cm, branches 4 and pods per plant 25 were observed with seed inoculation and 100% P_2O_5 followed treatment of soil inoculation and same level of phosphorus application over other treatments and control. Nodule number (35) and its weight (0.25g) per plant were also higher with the same treatment. Seed weight was highest of 133 g with treatment of 100% P_2O_5 and seed inoculation with PSB. The yield was highest (1950 kg/ha) with the treatment of 100% P_2O_5 and seed inoculation of PSB (2 kg/ha) followed by soil application + 100% P_2O_5 (1867 kg/ha). The next in order was 75% P_2O_5 + seed inoculation (1821 kg/ha). The control recorded the lowest mean yield of 1381 kg/ha. The yields of soybean recorded in different treatments were lower in previous year due to rust attack at pod and grain formation stage than in second year. Overall there was effect of PSB on yield of soybean whether used as seed or soil inoculation. This increase in yield may be ascribed to contributions made by different characters and soil phosphorus made available by biofertilizer. Significantly highest C:B ratio of 45.47 was recorded with treatment of soil inoculation at 15 DAS followed by same application at sowing (34.71) and seed inoculation (24.21). The next in order was seed inoculation + 100% P_2O_5 (2.29) and with 75% P_2O_5 (2.14). The results are supported by the findings of Guar (1984) who reported 10-30% increase in yield of Bengal gram with inoculation of microphos alone and Mudalagiyappa *et al.* (1995) found increase in yield of groundnut with phosphate solubilizers. Findings are also corroborated with the results of PSB use which increased niger seed yield (Anonymous, 1999-2000).

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Nutrient (NPK) uptake, availability and balance sheet as influenced by various groundnut based cropping systems under well irrigation

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Abstract

A field experiment was conducted through *kharif*, *rabi* and summer seasons of 1996-97 and 1997-98 at Regional Agricultural Research Station, Tirupati to study the nutrient dynamics in the groundnut based cropping systems under well irrigation. At the end of the second year of experimentation, there was increase in soil available nitrogen and phosphorus in all the system. Available potassium also increased in all the systems except S_2 (Rice-groundnut-finger millet), S_5 (Groundnut-rice-pearl millet), S_9 (Sunflower-groundnut-rice) and S_{10} (Groundnut-green gram-maize). Maximum nitrogen uptake was with S_1 (Groundnut-groundnut-groundnut) followed by S_2. The phosphorous and potassium uptake was maximum in S_2 followed by S_5 and S_9. Lowest NPK uptake was observed with S_7 (Green gram-sunflower-groundnut). Nitrogen and potassium balance was negative in all the system, whereas phosphorous balance was positive except in S_2 and S_5 at the end of 2 years of 6 crops. The final soil status of NPK was gain in all the systems except in S_2, S_5, S_9 and S_{10} in which soil potassium was lost.

Key words: Groundnut based cropping systems, dynamics of NPK, well irrigation.

Introduction

Groundnut is the most important edible oilseed crop contributing to 67 % of the total edible oilseeds and 59 % of the total edible oil produced in the country. It is one of the important commercial crops grown under irrigation. The area irrigated under this crop has virtually doubled in the last decade with 0.48 million hectares in Andhra Pradesh and 0.10 million hectares in southern zone of Andhra Pradesh. Groundnut crop has recently spread to new areas and found its place in different cropping systems.

In Andhra Pradesh, the area under well irrigation is 1.3 million hectares (30% of the irrigated area). In southern agro-climatic zone of the state, well irrigation occupies considerable area of 0.24 million hectares. The possibilities of increasing cropping intensity under wells are immense due to assured ground water in different seasons. Multiple cropping involves higher cropping intensity and exploitation of nutrients either from the soil or from the added source or both. But different cropping systems influence differently the NPK uptake depending on the crop and its biomass production and nutrient availability. In intensive crop rotations nutrient balance is to be worked out since it would indicate the extent to which the crop in the sequence enriches or exhausts the soil, so that it will be helpful in formulating suitable manurial schedules. However, much progress has not been made to evaluate different groundnut based cropping systems for their effect on nutrient balance. Therefore, it was felt necessary to study the influence of different groundnut based cropping systems on the dynamics of NPK availability, uptake and balance under irrigation.

Materials and methods

Field experiments were conducted through *kharif*, *rabi* and summer seasons of 1996-97 and 1997-98 to study the effect of different groundnut based cropping systems on the nutrient balance under well irrigation on sandy clay loam soil at Regional Agricultural Research Station, Tirupati. The soil was strongly alkaline in reaction, low in available nitrogen, medium in available phosphorus and potassium. Ten cropping systems were evaluated in Randomized Block Design with three replications.

System	*kharif* (Cr^1)	*rabi* (Cr^2)	Summer (Cr^3)
S_1	Groundnut	Groundnut	Groundnut
S_2	Rice	Groundnut	Fingermillet
S_3	Pearlmillet	Groundnut	Sunflower
S_4	Maize relay	Groundnut	Greengram-Sunhemp
S_5	Groundnut	Rice	Pearlmillet
S_6	Groundnut	Fingermillet	Sesamum
S_7	Greengram	Sunflower	Groundnut
S_8	Fingermillet	Maize	Groundnut
S_9	Sunflower	Groundnut	Rice
S_{10}	Groundnut	Greengram	Maize

Recommended and suitable high yielding short duration varieties were selected for sowing in this experiment. Raasi, DHM-!, ICMH-451, Kalyani, APSH-11, x79-1 and ML 267 of rice, maize, pearl millet, finger millet, sunflower, sesame and green gram respectively were used for all seasons as per the system. For groundnut JL-24 was used in *kharif* and *rabi* while, TMV-2 in summer. Nutrients supplied were 120-60-40; 90-40-40; 80-50-30; 40-30-30 and 20-50-50 kg N-P_2O_5-K_2O kg/ha for rice and maize, pearl millet and finger millet, sunflower, sesame, green gram, respectively for all seasons as per the system. For groundnut 20-40-50 kg N-P_2O_5-K_2O/ha were supplied during *kharif* and 30-40-50 during *rabi* and summer.

In every season post-harvest soil samples were collected from 0-15 and 15-30 cm depths, dried under shade, gently powdered to pass through 2 mm sieve and analysed for the available nitrogen (Subbaiah and Asija, 1956), available phosphorus (Watanabe and Olsen, 1965) and available potassium (Standford and English, 1959). Plant samples taken for weighment of drymatter were chopped and ground to powder. The powdered material analysed for nitrogen (AOAC, 1970), phosphorus (Jackson, 1973) and potassium (Jackson, 1973). The nutrient balance in the cropping systems were worked out as per the procedure adopted by Sadanandan and Mahapatra (1974) and Yadav (1981).

Results and discussion

Soil available nutrients (NPK): The cropping systems influenced appreciably the availability of nitrogen, phosphorus and potassium. Significant increase in available nitrogen under all the systems was registered at the end of experimentation at both the depths compared to their initial values. Higher soil available nitrogen (Table 1) was in S_7 followed by S_{10} and S_1 whereas least value was with S_6 at the end of the second year of experimentation. The higher value in S_7, S_{10} and S_1 may be due to inclusion of two legumes in the sequence whereas in S_6 the crops of fingermillet and sesame have utilised the available nitrogen efficiently which was corroborated by the fact that the available nitrogen was least in these systems. The lower up take of nitrogen in S_7 had resulted in large residual nitrogen as indicated by the higher available nitrogen values. Sadanandan and Mahapatra (1973) reported increase in total nitrogen due to groundnut, soybean and green gram.

The soil available phosphorus at both the depths was increased in all the systems and it was high in S_2 and low in S_9 at the end of second year of experimentation (Table 1). The higher soil available phosphorus in S_2 may be due to the transformation of unavailable forms of phosphorus into available forms in the puddled systems. Raghavulu and Sreeramamurthy (1975) reported similar results.

Soil available potassium at both the depths was significantly influenced by cropping systems, at the end of second year of experimentation. The available potassium declined in S_2, S_5, S_9 and S_{10} compared to initial values (Table 1). This was because of higher uptake of potassium in these systems. The higher available potassium in S_4 was due to less uptake of the nutrient in the system. Patel *et al.* (1973) and Sadanandan and Mahapatra (1974) were also of the same opinion.

Nutrient uptake (NPK): The mean values of uptake was computed and the uptake of nitrogen was the highest (Table 2) in S_1 (477.2 kg/ha) closely followed by S_2 (439.4 kg/ha) whereas for phosphorus and potassium, the uptake was high with S_2 and S_5. For the three nutrients the least uptake was in S_7. The high nitrogen uptake in S_1 was obviously due to three crops of groundnut, which fixed some nitrogen but used greater quantities of nitrogen to give higher production of protein and oil. In S_2, the combination of rice-groundnut-fingermillet, removed more phosphorus for rice and groundnut and more potassium for rice and finger millet. The least in S_7 was due to low yield in the systems and consequent lower uptake of nutrients.

Nutrient balance (NPK): The nitrogen balance was negative for all the cropping systems, most negative being in S_1 and the least in S_8 (Table 3). This can be understood, as the uptake was very high in S_1 and low in S_8. The negative balance in these systems was due to higher removal of nitrogen in all the systems than added through manures and fertilizers. The available nitrogen status in the soil was a gain in all the systems at the end of two years compared to initial value which was due to greater addition than removal in all the systems. Sadanandan and Mahapatra (1973), Singh and Awasthi (1978), Mongia and Gangwar (1991) also observed negative balance of nitrogen at the end of intensive cropping systems.

The balance sheet for phosphorus after two years of cropping was positive (Table 4) for all the systems except S_2 and S_5 due to inclusion of crops like rice, groundnut, finger millet/pearl millet with higher uptake of phosphorus. The positive phosphorus balance was due to greater addition than removal in all the systems. Thakur *et al.* (1990) and Mongia and Gangwar (1991) also observed positive phosphorus balance, after intensive cropping.

Potassium balance was negative (Table 5) in all the systems which almost followed the trend of nitrogen due to high uptake of potassium as cereals in the systems removed more potassium and the amount of potassium applied was comparatively low. The available potassium status in the soil was increased in all the systems except in S_2, S_5, S_9 and S_{10}. The higher depletion of potassium by cereals like rice, pearl millet, finger millet and maize has resulted in declining available potassium status. Negative potassium balance after intensive cropping was also reported by Thakur *et al.* (1990) and Mongia and Gangwar (1991).

Table 1 Effect of cropping systems on soil available nutrients (NPK kg/ha)

Cropping system	Nitrogen				Phosphorus				Potassium			
	A		B		A		B		A		B	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
S_1 GN-GN-GN	195.5	103.0	251.3	132.8	17.3	7.6	21.8	7.2	134.3	78.3	163.3	89.9
S_2 R-GN-FM	194.2	104.0	247.7	151.6	13.8	3.9	21.2	8.7	121.8	74.9	118.4	85.8
S_3 PM-GN-SF	197.4	105.1	244.6	126.5	17.6	6.9	23.3	9.2	106.2	90.2	142.9	77.6
S_4 M(r)SH-GN-GG	194.4	104.5	227.9	132.8	13.3	6.6	15.8	4.2	122.1	78.8	179.7	93.9
S_5 GN-R-PM	192.3	101.9	233.1	150.5	13.1	4.3	17.3	6.3	136.7	73.4	130.7	85.8
S_6 GN-FM-S	197.3	107.2	212.2	148.4	14.0	6.9	15.2	4.8	155.2	70.2	167.4	106.2
S_7 GG-SF-GN	200.7	108.2	256.1	134.9	14.9	4.8	15.8	7.2	134.8	74.3	147.0	81.7
S_8 FM-M-GN	197.6	106.6	253.0	128.6	17.9	4.3	19.1	7.8	132.9	69.4	140.3	65.3
S_9 SF-GN-R	194.6	104.0	245.2	122.3	20.2	7.3	20.9	8.7	108.2	89.8	98.0	61.3
S_{10} GN-GG-M	191.2	101.9	254.2	126.5	18.5	7.9	20.3	8.7	153.1	65.3	151.1	81.7
Mean	195.5	104.6	242.5	135.5	16.1	6.1	19.1	7.3	130.5	76.5	141.3	82.9
SEm±	10.27	12.63	7.49	4.06	1.20	0.62	1.55	0.79	5.57	3.66	15.10	6.15
CD (P=0.05)	NS	NS	22.3	12.1	3.6	1.8	4.6	2.4	16.6	10.9	44.9	18.3

A : Pre-experiment; B : Post-experiment (after two years)

Table 2 Total nutrient uptake by the cropping systems (kg/ha)

Cropping system	Nitrogen			Phosphorus			Potassium		
	1996-97	1997-98	Mean	1996-97	1997-98	Mean	1996-97	1997-98	Mean
S_1 GN-GN-GN	**458.3**	496.0	477.2	47.3	53.3	50.3	163.0	166.7	164.9
S_2 R-GN-FM	**427.5**	451.3	439.4	64.9	69.5	67.2	253.9	276.9	265.4
S_3 PM-GN-SF	**319.3**	360.9	440.1	53.2	51.5	52.4	169.5	156.9	163.2
S_4 M(r)SH-GN-GG	**335.5**	377.2	456.4	55.6	58.7	52.2	158.2	165.9	162.0
S_5 GN-R-PM	**408.7**	357.9	383.3	66.5	53.6	65.0	229.9	219.0	224.5
S_6 GN-FM-S	**311.2**	289.5	300.4	49.6	45.6	47.6	191.8	166.9	179.4
S_7 GG-SF-GN	**213.8**	301.2	257.5	27.5	37.8	32.6	90.8	125.0	107.9
S_8 FM-M-GN	**240.5**	282.7	261.6	51.0	52.7	51.8	164.7	169.4	167.0
S_9 SF-GN-R	**382.5**	380.3	381.4	65.8	62.3	64.0	191.6	179.7	185.6
S_{10} GN-GG-M	**307.3**	326.3	316.8	41.3	49.6	45.4	151.1	150.2	150.6
Mean	**340.5**	362.3	-	52.3	**53.5**	-	176.4	177.7	-
SEm±	**5.92**	10.45	-	1.61	**1.94**	-	4.97	5.46	-
CD (P=0.05)	26.52	31.06	-	4.8	5.8	-	14.8	16.2	-

Table 3 Available nitrogen (N) balance sheet in different cropping systems (kg/ha)

	Cropping system	Initial N in soil	Total N applied in two years	Total N removed by crops in two years	N in soil at the end of two years	Computed balance	Change in available N status of soil net gain(+) loss(-)
S_1	GN-GN-GN	**195.5**	160.0	954.3	251.3	-794.3	+55.8
S_2	R-GN-FM	**194.2**	480.0	878.8	247.7	-398.8	+53.5
S_3	PM-GN-SF	**197.4**	400.0	680.1	244.6	-280.1	+47.2
S_4	M(r)SH-GN-GG	**194.4**	340.0	712.7	227.9	-372.1	+33.5
S_5	GN-R-PM	**192.3**	460.0	766.6	233.1	-306.6	+40.8
S_6	GN-FM-S	**197.3**	300.0	600.7	212.2	-300.7	+14.9
S_7	GG-SF-GN	**200.7**	260.0	515.0	256.1	-255.0	+55.4
S_8	FM-M-GN	**197.6**	480.0	523.2	253.0	-43.2	+55.4
S_9	SF-GN-R	**194.6**	460.0	762.8	245.2	-302.8	+50.6
S_{10}	GN-GG-M	191.2	320.0	633.6	254.0	-313.6	+62.8

Table 4 Available phosphorus (P) balance sheet in different cropping systems (kg/ha)

	Cropping system	Initial P in soil	Total P applied in two years	Total P removed by crops in two years	P in soil at the end of two years	Computed balance	Change in available P status of soil net gain(+) loss(-)
S_1	GN-GN-GN	17.3	104.9	100.6	21.8	4.3	+4.5
S_2	R-GN-FM	**13.8**	122.4	134.4	21.2	-12.0	+7.4
S_3	PM-GN-SF	**17.6**	113.6	104.7	23.3	8.9	+5.7
S_4	M(r)SH-GN-GG	**13.3**	131.1	104.3	**15.8**	26.8	+2.5
S_5	GN-R-PM	**13.1**	122.4	130.1	**17.3**	-7.7	+4.2
S_6	GN-FM-S	**14.0**	96.1	95.2	**15.2**	**0.9**	+1.2
S_7	GG-SF-GN	**14.9**	122.4	65.3	**15.8**	57.1	+0.9
S_8	FM-M-GN	**17.9**	122.4	103.7	**19.1**	18.7	+1.1
S_9	SF-GN-R	**20.2**	131.1	128.1	**20.9**	**3.0**	+0.7
S_{10}	GN-GG-M	18.5	131.1	90.9	20.3	40.2	+1.8

Table 5 Available potassium (K) balance sheet in different cropping systems (kg/ha)

	Cropping system	Initial P in soil	Total P applied in two years	Total P removed by crops in two years	P in soil at the end of two years	Computed balance	Change in available P status of soil net gain(+) loss(-)
S_1	GN-GN-GN	134.3	263.1	329.7	163.3	-66.6	59.0
S_2	R-GN-FM	121.8	228.0	530.8	118.4	-302.8	-3.4
S_3	PM-GN-SF	106.2	210.5	326.4	142.9	-11.59	36.7
S_4	M(r)SH-GN-GG	122.1	228.0	324.1	179.7	-96.1	57.6
S_5	GN-R-PM	136.7	228.0	448.9	130.7	-220.9	-6.0
S_6	GN-FM-S	155.2	210.5	358.7	167.4	-148.2	12.2
S_7	GG-SF-GN	134.8	192.9	215.8	147.0	-22.9	12.2
S_8	FM-M-GN	132.9	228.0	334.1	140.3	-106.1	8.0
S_9	SF-GN-R	108.2	210.5	371.3	98.0	-160.8	-10.2
S_{10}	GN-GG-M	153.1	210.5	301.3	151.5	-90.8	2.0

Conclusion

From the results, it is concluded that recommended doses of nitrogen and phosphorus are sufficient to the intensive cropping systems as the balance sheet for these nutrients was positive. Whenever the cereals are included in the intensive cropping systems, higher doses of potassium are to be applied to compensate the potassium balance in the soil, as the cereals depletes more potassium.

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Effect of cytozyme seed$^+$ on the nodulation and yield of soybean (*Glycine max* L. Merrill.)

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Abstract

Field experiments were conducted at the Viswavidyalaya Farm, Kalyani during summer 1997 and 1998 to study the effect of seed treatment with Cytozyme Seed$^+$ (a bio-stimulant) on yield and yield attributes and nodulation in soybean. The data revealed that seed treatment with Cytozyme Seed$^+$ @ 1.5 ml/kg of seed along with *Rhizobium* culture @ 8 g/kg of seed or Mancozeb (Dithane-45) @ 3 g/kg of seed or both enhanced the grain yield of soybean by 11.7%, 15.1% and 25.6%, respectively over the untreated control. The sole seed treatment with Cytozyme Seed$^+$ @ 1.5 ml/kg of seed increased the number of branches/plant, number of nodules/plant, pods/plant and seed weight/plant applied either alone or in combination with *Rhizobium* culture and *Rhizobium* culture + Mancozeb over the untreated control.

Key words : Rhizobium, soybean, nodulation, cytozyme, seed$^+$, bio-stimulant

Introduction

Earlier in survival oriented agriculture emphasis was on risk oversion but not in production oriented agriculture emphasis has to be on efficient use of resource land, light and water (Dhingra *et al.*, 1991). In the present stabilization of land situation and with soil health problems of intensive cropping, soybean, a leguminous crop which can supply both 'oil' and 'dal' and a crop which can be fitted with any upland crop sequences in alluvial West Bengal, there is an urgent need to increase its production and area of cultivation either as sole or as intercrop with any shallow rooted crop. The present yield of this most important world crop is not satisfactory. In most of the soybean growing areas there is a large gap between research yield and farmers yield and this is mainly because farmers are not yet used the full resources they have in their hands due to lack of knowledge. Seed treatment, one of the hand available resource, can able to enhance the yield of soybean by increasing nodulation, plant vigour and resistance against pests (Bulletin - Seed$^+$, Cytozyme Laboratories, Inc., April, 1996). Seed treatment with Cytozyme Seed$^+$ (a bio-stimulant) improves seedling emergence and vigour through synergistic effect of its components. In the present investigation an attempt has been taken to study the effect of Cytozyme Seed$^+$ applied either alone or in combination with *Rhizobium* culture and/or with Mancozeb on the nodulation and grain yield of soybean.

Materials and methods

Field experiment was conducted during the consecutive summer seasons of 1997 and 1998 at the Viswavidyalaya Farm, Kalyani, Nadia. The soil of the experimental site was typical Gangetic Alluvium with sandy loam in texture (sand - 62.9%, silt 21.4% and clay 15.7%) having total N-0.063%, organic carbon -0.52%, available P-25.9 kg/ha and K-193.8 kg/ha. Soil was slightly alkaline in reaction (pH 7.4), soybean cv. PK-327 @ 80 kg/ha was sown on 14th and 10th February during 1997 and 1998, respectively, at a spacing of 30 cm x 15 cm. The crop was fertilized with 5 kg N, 40 kg P_2O_5, 40 kg K_2O and 30 kg S/ha as basal; 10 kg N/ha at 30 DAS (flowering stage) and rest 5 kg N/ha at 60 DAS (pod development stage) (Soybean Research, BCKV, 1970-71). The crop was irrigated thrice and adequate plant protection measures were followed.

The treatments consisted of untreated control (T_1), sole seed treatments of *Rhizobium* culture (NC-92) @ 8 g/kg of seed (T_2), Cytozyme Seed$^+$ @ 1.5 ml/kg of seed (T_3) and Mancozeb @ 3 g/kg of seed (T_4) and a combination of *Rhizobium* with Cytozyme Seed$^+$ (T_5), *Rhizobium* with Mancozeb (T_6) and all three seed treatments (T_7). For fungicide treatment a slurry with water + Mancozeb was prepared and then seeds were mixed thoroughly and kept in a cool place for overnight. The requisite amount of Cytozyme Seed$^+$ mixed in 1:4 parts of water and sprayed uniformly on the seeds and kept in a cool place. For *Rhizobium* culture the *Rhizobium* strain *Rhizobium japonicum* was mixed with seed adding a little water and

kept it in a cool place before sowing. The treatments were replicated thrice following randomised block design in a plot size of 4 m x 4 m. The observations recorded were branches/plant, number of nodules/plant (at 40 and 80 DAS), pods/plant, test weight (g/100 seeds), seed weight (g/plant) and grain yield (kg/ha). The data were statistically analysed by using statistical methods suggested by Panse and Sukhatme (1957).

Results and discussion

Table 1 revealed that the highest average number of branches/plant (5.6) was recorded with T_7 where seed treatment was done with *Rhizobium* culture + Mancozeb + Cytozyme Seed$^+$ and it was significantly different overall other treatments. Significantly higher number of branches over untreated control were also recorded with T_3 (seed treated with Cytozyme Seed$^+$ alone), T_5 (combined seed treatment with *Rhizobium* culture + Cytozyme Seed$^+$) and T_6 (combined seed treatment with *Rhizibium* culture + Mancozeb) but, they showed no significant difference among themselves. The lowest number of branches (3/plant) was recorded with T_4 (seed treatment with Mancozeb alone) and gave non-significant result with T_1 (untreated control) and T_2 (*Rhizobium* culture alone).

Significant variations amongst the treatments were also observed in number of nodules/plant recorded at 40 and 80 DAS. At 40 DAS, the combined treatment of *Rhizobium* culture, Cytozyme Seed$^+$ and Mancozeb (T_7) gave significantly higher average number of nodules/plant (49) over all other treatments excepting T_6 (46; seed treated with combined treatment of *Rhizobium* culture and Mancozeb) where it gave statistically at par result. The sole treatment with *Rhizobium* culture (T_2) also gave significantly higher number of nodules/plant (41) over sole seed treated plots like Cytozyme Seed$^+$ (T_3; 30) and Mancozeb (T_4; 28) and the same also over the untreated control (T_1; 27.76). The latter three treatments (T_4, T_1 and T_3) showed no significant variations among themselves. At 80 DAS, all the combined seed treated plots (T_5, T_6 and T_7) showed significantly higher average number of nodules over the sole and untreated control plots (T_4, T_3 and T_1). The sole *Rhizobium* culture treated plot (T_2) showed statistically no variation in nodule number with sole Cytozyme Seed$^+$ treated plot and their combined plots (T_5 and T_6). This also gave significantly more number of nodules over untreated control (T_1) and seed treated with Mancozeb (T_4). Similar type of observation was also recorded by Jain *et al.* (1988) in *kharif* legumes.

The seeds treated with *Rhizobium* culture + Cytozyme Seed$^+$ + Mancozeb (T_7) gave significantly higher number of pods/plant (44) over all other sole treatments - *Rhizobium* culture (T_2; 34), Cytozyme Seed$^+$ (T_3; 38), Mancozeb (T_4; 31) and also over untreated control (T_1; 32). This again gave statistically no variations with other two combined treated plots, *Rhizobium* culture + Mancozeb (T_6; 41) and *Rhizobium* culture + Cytozyme Seed$^+$ (T_5; 43). The latter two combined seed treated plots (T_5 and T_6) also gave significantly higher number of pods/plant over all other untreated control (T_1) plots and sole seed treated plots (T_4 and T_2) excepting T_3 where seed was treated with Cytozyme Seed$^+$. Cacciari *et al.* (1989) also recorded similar results while working with *Azospirillum* and *Arthrobacter.*

The untreated control plot (T_1) showed significantly lowest seed weight per plant (4.7 g) over all other sole (T_2 and T_3) and combined seed treated plots (T_5, T_6 and T_7) but statistically same with sole Mancozeb treated plot (T_4; 5.2). The combined seed treatment (T_7 = T_2 + T_3 + T_4) also showed significantly highest seed weight per plant over untreated control (T_1), sole treated plots (T_2, T_3 and T_4) and combined plot (T_6) excepting the combined treatment plot T_5 (6.4) where it gave statistically at par seed weight. The test weight of grains because of the seed inherent genetical capacity, however, showed no significant differences amongst the treatments.

Table 1 also depicted that the combined treatment T_7 (T_2 + T_3 + T_4) gave significantly higher grain yield (1698 kg/ha) over the untreated and sole as well as combined treatment plots. The all three seed treated plot (T_7) showed an increase in yield of 9.13 - 25.59% over all other treatments. The other two combined treated plots (T_5 and T_6) also showed an increase in grain yield over untreated control to an extent of 15.08% (T_5) and 12.43% (T_6). They also recorded an insignificant yield variation over the sole treated plots T_2 (seed treated with *Rhizobium* culture) and T_3 (seed treated with Cytozyme Seed$^+$). This increase yield of combined treatments may be due to increase in plant vigour, shoot and root length, weight and number of pods and seed weight/plant. The economic analysis also revealed that all three combined seed treatment (T_7) showed better (B:C ratio 0.45) followed by sole treatment of seed by Cytozyme Seed$^+$ alone (0.42 BC ratio) over al other treatments (0.16 - 0.35 B:C ratio). Similar results on other crops were also observed by Ramamoorthy *et al.* (1999); Pramila Rani and Kodandaramaiah (1996); Dahatond and Shava (1992); Namdeo *et al.* (1991) and Thakur and Hasan (1972).

From this experiment it can be concluded that seed treatment with Cytozyme Seed$^+$ either alone or combined with Mancozeb or Rhizobium may enhance the soybean production by 11.7% (only Cytozyme Seed$^+$) or 12.4 - 25.6% (combination with other seed treatments) and the benefit cost ratio supporting this by recording the same trend of result.

Table 1 **Effect of seed treatment on average number of branches, nodules number, number of pods, seed weight/plant, test weight and grain yield of soybean during 1997 and 1998**

Treatment	Branches/ plant	No. of nodules/plant		Pods/ plant	Seed weight (g/plant)	Test weight (g/100 seeds)	Grain yield (kg/ha)	Increase of yield over control (%)	B:C ratio
		40 DAS	80 DAS						
T_1 Untreated control	3	28	57	32	4.7	8.76	1352	-	0.21
T_2 Seed treatment with *Rhizobium* culture @ 8 g/kg of seed	4	41	77	35	5.4	8.93	1456	7.69	0.29
T_3 Seed treatment with Cytozyme Seed+ @ 1.5 ml/kg of seed	5	30	68	38	5.9	9.07	1510	11.68	0.42
T_4 Seed treatment with Mancozeb @ 3 g/kg of seed	3	27	59	31	5.2	8.91	1360	0.59	0.16
T_5 $T_2 + T_3$	5	45	83	43	6.4	9.11	1556	15.08	0.35
T_6 $T_2 + T_4$	5	46	84	41	6.2	9.11	1520	12.43	0.23
T_7 $T_2 + T_3 + T_4$	6	49	89	44	7.1	9.22	1698	25.59	0.45
SEm±	0.2	1.2	4.2	1.8	0.2	0.09	0.45	-	-
CD (P=0.05)	0.5	3.4	12.2	5.3	0.7	NS	1.31	-	-

NS = Not significant.

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Macrometeorological models for yield prediction of soybean [*Glycine max* (L.) Merr.] In the semi-arid tropics

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Abstract

An experiment was conducted during *rabi* 1996 and 1997, *summer* 1997 *and kharif* 1997 to develop yield prediction models of five soybean genotypes *viz.*, MACS-201, MACS-58, PK-472, MACS-13 and MACS-330. The number of weather parameters recorded during vegetative (phase-1), reproductive (phase-2) and maturity (phase-3) phases on soybean plants needed for yield prediction values at harvest showed considerable variation for different genotypes. The seed yield of soybean can suitably be predicted with high degree of captured variances in the range of 77 to 99 % as indicated by the coefficients of determination (R^2) in the semi-arid tropics, for the genotypes tested. The regression models to predict yield were not the same for every genotype which explained the strong genotype- environment interaction.

Introduction

Growth and seed yield of soybean can be predicted from genotype (G) and environment (E) interaction by a suitable model (James *et al.*,1991). A model is an equation or set of equations representing the behaviour of a G x E system provides an explanation for underlying growth and development processes of genotypes (Vaidya, 1998). Baier (1973) described two basic approaches for modelling the impact of meteorological variability on crop yield *viz.*, (i) the physiological approach based on detailed knowledge of the biological and physical processes which take place within a given time interval in the plant / soil system and in the immediate atmospheric and soil environment and (ii) the statistical or correlative approach based on application of regression techniques to sample yield from an area and a sample of weather or climatic data from the same. Baier (1979) further elaborated that the crop weather models are classified into three categories viz., (a) crop growth simulation models, (b) crop weather analysis models and (c) empirical models. Of these three categories, the multiple regression technique with independent weather variables influencing the crop yield has been proved as the efficient tool for yield prediction (Kulkarni and Acharya, 1986). Therefore, the crop weather analysis model with multiple regression techniques following a step wise regression approach was selectively adopted in the present endeavour.

Materials and methods

Field experiment was conducted during *rabi* 1996 and 1997, summer 1997 and *kharif* 1997 at the student farm, ANGRAU, Hyderabad. The soil was low in available N (150 kg/ha), medium in P_2O_5 (40 kg/ha) and K_2O (210 kg/ha). The layout was a randomized block design. Treatments were a combination of five soybean genotypes *viz.*, MACS-201, MACS-58, PK-472, MACS-13 and MACS-330 with four dates of sowing at 20 days interval in every season and replicated three times. To keep experiment free from pests and diseases, the plant protection measures as per recommendation were adopted. The soybean growth stages described by Fehr *et al.* (1971) were monitored regularly. In each plot 5 plants were examined for occurrence of a particular physiological event. The regression models through step-down approaches were developed as per Zaman *et al.* (1982).

Results and discussion

Models with different macrometerological parameters during vegetative (phase-1), reproductive (phase-2) and maturity (phase-3) phases of the crop were developed to predict the yield of five soybean genotypes. The regression models to predict yield were found not the same for every genotype (Table 1).

The step down regression approach indicated that the maximum temperature at maturity was the best predictable parameter for seed yield of soybean genotype PK-472. The evening relative humidity and the heliothermal unit prevailing during maturity were the most prominent weather

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parameters to predict the seed yield of MACS-330. The yield of MACS-58 was best predicted by morning relative humidity and mean temperature at the vegetative phase along with heliothermal units at the maturity phase. More weather parameters were needed to be equated for efficient yield prediction of MACS-13. The morning relative humidity and minimum temperature at the vegetative phase, morning relative humidity at the reproductive phase, maximum temperature at maturity phase and heliothermal units at all the 3 phases predicted the yield of this genotype. The essential macro weather parameter for perfect yield prediction of long maturity, affluently grown MACS-201 genotype were the evening relative humidity at the vegetative phase, heliothermal units at the reproductive phase and maximum temperature at the maturity phase.

The soybean genotypes sown at different dates and seasons recorded significant differences in the yield (Table 2). The genotype MACS-201 produced significantly more yield than others in the *rabi*, summer and *kharif* seasons. The genotype MACS-330 produced 39, 41 and 39% low yield than MACS-201 while it was also significantly inferior to MACS-58, PK-472 and MACS-13. The crop produced more yield in *rabi* than the *kharif* and least in summer. Maximum yield was recorded in *rabi*, if sown on 15th October. The yield reduced significantly with fortnightly delayed sowing until 14th December. The crop sown on 25th January produced significantly more yield than later dates until 6th March in summer. The production increased by sowing the crop in *kharif* seasons. The best time was 25th June while delayed sowing upto 4th August reduced the yield significantly. The study indicated that MACS-201 was the best genotype while MACS-58 or PK-472 could be the next preferred options. The crop is the best suited for sowing in *rabi* on 15th October, 25th January in summer and 25th June in *kharif*. The models developed for yield prediction of five genotypes with different macrometerological parameters are ought to be tested at different locations within a region before they are widely used as rightly pointed out by Ritchie and Alagarswamy (1989). It is deducted that model validation is the essential criterion test which leads to uncertainty in the prediction for the same genotype at different locations.

***Table 1* Prediction models for seed yield of soybean genotypes with macrometerological parameters**

Genotype	Prediction models	R^2
MACS-201	$Y=6370.20 - 73\ RH_{21} - 5.57\ HTU_2 - 93.85\ MAT_3$	0.93
MACS-58	$Y = 6899.70 - 21.84\ RH_{11} - 62.83\ MT_1 - 10.89\ HTU_3$	0.95
PK-472	$Y = 6373.5 - 128.52\ MAT_3$	0.90
MACS-13	$Y = 7115.90 - 27.53\ MIT_1 - 22.21\ RH_{11} - 4.51\ HTU_1 - 3.22\ RH_{12} - 3.00\ HTU_2 - 66.31\ MAT_3 - 7.45\ HTU_3$	0.99
MACS-330	$Y = 1899 + 1.27\ RH_{23} - 5.63\ HTU_3$	0.77

MIT_1	=	Minimum temperature at vegetative phase-1	MAT_3	=	Maximum temperature at maturity phase-3
MT_1	=	Mean temperature at vegetative phase-1	RH_{11}	=	Relative humidity (morning) at vegetative phase-1
RH_{12}	=	Relative humidity (morning) at reproductive phase-2	RH_{23}	=	Relative humidity (evening) at maturity phase-3
RH_{21}	=	Relative humidity (evening) at vegetative phase-1	HTU_1	=	Heliothermal units at vegetative phase-1
HTU_2	=	Heliothermal units at reproductive phase-2	HTU_3	=	Heliothermal units at maturity phase-3

Table 2 Effect of sowing dates on seed yield of soybean genotypes in different seasons

Genotype	Yield (kg/ha)						
	Date (1996 & 1997)	*Rabi* (1996)	*Rabi* (1997)	Date (1997)	Summer (1997)	Date (1997)	*kharif* (1997)
MACS-201		2551	2571		1525		2301
MACS-58		2471	2487		1475		2228
PK-472		2450	2465		1463		2207
MACS-13		2351	2364		1385		2114
MACS-330		1563	1574		901		1407
SEm±		26	28		16		24
CD (P=0.05)		76	81		46		70
	15th Oct.	2563	2584	5th Jan.	1425	5th June	2150
	4th Nov.	2391	2401	25th Jan.	1538	25th June	2307
	24th Nov.	2186	2200	14th Feb.	1295	15th July	1968
	14th Dec.	1968	1983	6th Mar.	1141	4th Aug.	1781
SEm±		41	41		36		51
CD (P=0.05)		102	104		105		147

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Effect of different levels and sources of sulphur on drymatter production, yield, protein and oil content of soybean [*Glycine max* (L.) Merrill] in vertisols

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Abstract

In a field experiment conducted on sulphur deficient clay soil, four levels of sulphur (0, 20, 40 and 60 kg S/ha) was applied to soybean cultivar PK-472 through ammonium sulphate and gypsum. The drymatter production, seed and stover yield, protein as well as oil content increased with increasing levels of sulphur and optimum response to sulphur was recorded at 40 kg S/ha. Between the sources of S tested, ammonium sulphate was found to be relatively better than gypsum in respect of seed yield, oil and protein content. Application of 40 kg S/ha through ammonium sulphate was found to be more beneficial.

Key words: Sulphur, soybean, vertisols

Introduction

Sulphur fertilization is most critical for seed yield, oil and protein synthesis and for improvement of quality of produce by their enzymatic and metabolic efforts (Kumar *et al.*, 1981). Soybean is a high yielding pulse crop rich in both protein and oil and required large quantities of sulphur application. Beneficial effect of sulphur application to soybean and other legumes in sulphur deficient soils was reported by Saggar and Dev (1974). The soils are deficient in sulphur in southern Telangana Zone of A.P. Therefore, a study was made to find out the optimum dose and source of sulphur for soybean crop for optimum seed yield, protein and oil content.

Material and methods

A field experiment was conducted during *rabi* season of 1997-98 at the College Farm, Rajendranagar with eight treatment combinations consisting of four levels (0, 20, 40 and 60 kg S/ha) and two sources of sulphur (Ammonium sulphate and Gypsum). The treatments were replicated thrice in a factorial randomized block design.

The experimental soil was clay in texture (sand 19%, silt 30%, clay 51%), pH, EC and organic carbon were 8.02, 0.26 dS $^{-1}$ and 0.57%, respectively. The available N, P_2O_5, K_2O and S were 207 (low), 32 (medium), 370 (high) and 13.4 kg/ha (low), respectively. The nitrogen contributed by ammonium sulphate was taken into account and accordingly a basal dose of 75:50:40 kg/ha ($N:P_2O_5:K_2O$) was applied through urea, diammonium phosphate (DAP) and muriate of potash (MOP). Sulphur was applied through ammonium sulphate and gypsum as per the treatments.

Soybean (cv PK-472) was sown by adopting a seed rate of 60 kg/ha. Two seeds were dibbled per hill with a spacing of 30 x 10 cm. The dry matter yields of crop at 30 and 60 days after sowing (DAS) were recorded by harvesting 5 plants from 3rd row on either side of the plots. The dry matter production per hectare at these stages were computed and expressed as kg/ha. At maturity, the plot-wise seed and stover yields were recorded separately after drying them in the sun and yields were expressed in kg/ha. The protein content (%) was estimated by multiplying the per cent concentration of nitrogen in the seed with 6.25 (Walinga *et al.*, 1989). Oil content (%) in soybean was estimated by Nuclear Magnetic Resonance Spectroscopy Technique (Tiwari *et al.*, 1974).

Results and discussion

Drymatter production: The data presented in Table 1 indicate that there was an increase in drymatter production (at 30 and 60 DAS) with increase in the level of 'S' applied with maximum production being recorded at 60 kg S/ha which was on par with 40 kg S/ha. The mean drymatter produced due to the application of 40 kg S/ha was more by 25.1 and 16.3 % over control at 30 and 60 DAS, respectively. Application of sulphur significantly increased the N uptake, stimulated the photosynthetic activity and synthesis of chloroplast protein which might have resulted in higher drymatter production. Similar increase in

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drymatter yield with 40 kg S/ha has been reported by several workers (Mishra and Agarwal, 1994; Singh and Singh, 1995).

Table 1 **Effect of sources and levels of sulphur on drymatter production (kg/ha) of soybean at 30 and 60 DAS**

Sulphur level (kg/ha)	Sulphur source					
	30 DAS			60 DAS		
	AS	G	Mean	AS	G	Mean
0	1515	1503	1509	2261	2238	2249
20	1737	1585	1661	2506	2448	2477
40	2040	1737	1888	2773	2459	2616
60	2041	1737	1889	2784	2461	2622
Mean	1833	1641		2581	2401	
	SEm±	CD (P=0.05)		SEm±	CD (P=0.05)	
Source (S)	4.64	9.96		6.06	13.00	
Level (L)	6.56	14.08		8.57	18.39	
S x L	9.28	19.91		12.12	26.01	

AS : Ammonium sulphate; G : Gypsum

Between the two sources of sulphur, irrespective of levels of 'S' tried, ammonium sulphate proved to be superior in recording higher drymatter yields at all the stages of crop growth, the increase over gypsum being 11.7 and 7.5 % at 30 and 60 Das, respectively. Superiority of ammonium sulphate over the other sources such as gypsum and single super phosphate (SSP) was observed in soybean (Dhillon and Dev, 1980) and in other crops like sunflower (Sreemannarayana *et al.*, 1994). Among the interactions, application of ammonium sulphate @ 40 and 60 kg S/ha were on par and recorded significantly higher drymatter yields over other combinations.

Seed and stover yield: The seed and stover yield of soybean increased with increase in the level of applied sulphur from 0 to 40 kg/ha, after which a non-significant increase in yield was observed (Table 2). At 40 kg S/ha, mean seed and stover yields showed significant increase over control, the increase being 17.4 and 8.9 %, respectively. Similar results were also reported by Mishra and Agarwal (1994) and Ganeshamurthy (1996). Between the two sources of 'S' used, ammonium sulphate recorded higher seed and stover yields at all the levels of applied sulphur than gypsum, the increase over gypsum being 7.3 and 6.7%, respectively. Among the sources of 'S', ammonium sulphate proved to be a better source of 'S' as it is more soluble and releasing the sulphate ions immediately into soil solution for absorption by soybean to produce better yields. Similar results were reported by Sreemannarayana and Sreenivasa Raju (1993) and Yadav *et al.* (1996).

Oil content: Application of sulphur @ 40 and 60 kg/ha recorded significantly higher oil content in seed which were on par with each other (Table 3). The per cent increase in oil content due to 40 and 60 kg S/ha over control was 17.9 and 19.9, respectively. In fatty acid synthesis, acetyl-co enzyme A is converted to malonyl co-enzyme. The activity of this enzyme depends upon sulphur supply. Moreover, acetyl co-enzyme A itself contains sulphur and sulpho-hydryl group (Karle *et al.*, 1985). This might be the reason for increasing the oil content of soybean with sulphur application. This confirms the findings of Mishra and Agarwal (1994) and Ganeshamurthy (1996).

Protein content: The protein content of soybean enhanced significantly with increasing levels of sulphur upto 40 kg/ha, after which a non-significant increase was observed (Table 3). The per cent increase in protein content due to 40 and 60 kg S/ha over control was 26 and 28.6, respectively.

Kumar *et al.* (1981) reported an increase in protein content with the application of sulphur. Sulphur is a constituent of essential amino acids methionine, cysteine and cystine. Sulphur also helps in conversion of these amino acids into high quality protein (Chopra and Kanwar, 1966). Appropriate structure is essential for protein formation and sulphur provides di-sulphide (S-S) bonds for cross linkage of two polypeptide chains and thus helps in formation of proteins (Allaway and Thompson, 1966). Hence, application of sulphur helps in increasing the protein content of soybean. These results confirmed the findings reported by several other workers (Mishra and Agarwal, 1994; Ganeshamurthy, 1966). Between the sources of 'S' used ammonium sulphate resulted in higher oil content and protein content in soybean at any level of 'S' compared with respective levels of 'S' from gypsum. The increase in oil and protein content due to ammonium sulphate over gypsum being 5.1 and 2.3% respectively. Similar increase in oil and protein content due to application of 'S' through ammonium sulphate was observed in other oilseed crops like mustard (Sharma *et al.*, 1991) and sesame (Yadav *et al.*, 1996).

Table 2 **Effect of sources and levels of sulphur on stover and seed yields (kg/ha) of soybean**

Sulphur level (kg/ha)	Sulphur source					
	Stover yield			Seed yield		
	AS	G	Mean	AS	G	Mean
0	1419	1381	1400	1313	1290	1301
20	1530	1425	1477	1461	1334	1397
40	1585	1465	1525	1592	1465	1528
60	1589	1468	1528	1595	1466	1530
Mean	1531	1435		1490	1389	
	SEm±	CD (P=0.05)		SEm±	CD (P=0.05)	
Source (S)	0.029	0.062		0.058	0.124	
Level (L)	0.041	0.088		0.082	0.176	
S x L	0.058	0.124		0.116	0.249	

AS : Ammonium sulphate; G : Gypsum

Though the crop showed increase in the values of all the above parameters with increase in the level of 'S' application the degree of increase was only upto 40 kg S/ha level, after which a non-significant increase was observed. It is therefore, concluded that the application of 40 kg S/ha through ammonium sulphate is helpful in achieving higher productivity with better soybean quality with respect to oil and protein contents.

Table 3 **Effect of sources and levels of sulphur on oil and protein content (%) of soybean**

Sulphur level (kg/ha)	Sulphur sources					
	30 DAS			60 DAS		
	AS	G	Mean	AS	G	Mean
0	18.20	18.30	18.30	30.62	30.50	30.56
20	20.11	19.52	19.81	32.81	32.12	32.46
40	22.28	20.87	21.58	38.81	38.19	38.50
60	22.98	20.90	21.94	40.19	38.44	39.31
Mean	20.92	19.90		35.61	34.81	
	SEm±	CD (P=0.05)		SEm±	CD (P=0.05)	
Source (S)	0.38	0.81		0.35	0.76	
Level (L)	0.53	1.14		0.50	1.07	
S x L	0.75	NS		0.70	NS	

AS : Ammonium sulphate; G : Gypsum; NS : Non-significant

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Bio-chemical changes during seed development of safflower (*Carthamus tinctorius* L.) as influenced by methods and schedules of irrigation

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Abstract

The moisture, hundred seed weight and crude fibre content decreased whereas hundred seed weight on dry basis and total lipids increased with advancement in seed maturity. Protein content increased from 15 days after flowering (DAF) to 30 DAF whereas it decreased from 30 DAF to 45 DAF. Methods of irrigation, *viz.*, ferrow and flood did not have significant effect on various biochemical parameters except total lipids which was slightly higher in M2 on both fresh and dry weight basis. In various irrigation schedules, hundred seed weight (fresh and dry basis), protein and total lipid (fresh and dry basis) were higher where irrigation was given at branching, flowering and seed development stages, whereas crude fibre was higher at no irrigation after common irrigation. Moisture was higher at irrigation at seed development as compared with rest of the treatments. Protein content in defeated meal increased upto 30 DAF and thereafter decreased upto maturity (45 DAF). But crude fibre content decreased with concomitant progress in the seed maturity. Irrigation at the critical stages of crop growth had also given higher protein content at 30 DAF and lower at 45 DAF. Imposition of the stress at all the critical stages of crop growth gave maximum value for crude fibre content of seed, in case of flood irrigation, irrigating crop at the branching stage gave the highest crude fibre.

Key words: Safflower, development stages, bio-chemical changes, irrigation schedule.

Introduction

As the safflower is a rich source of vegetable oil, it is necessary to increase its yield through various agrotechniques *viz.*, irrigation and fertilizer management (Mandal *et al.*, 1990), planting dates and row-spacings (Abel, 1976) etc. In Gujarat efforts are continued to increase safflower yield through these agrotechniques (Patel, 1994; Thakkar, 1994) It is well known that safflower thrives well under scanty moisture conditions and responds well to irrigation applied at critical growth stages. According to the results available, the productivity level of safflower can be boosted upto 2 to 2.5 tonnes/ha under minimal irrigations given according to time bound schedule. But systematic studies have not been conducted on the effect of irrigation on the bio-chemical constitutents of safflower seed oil at different maturity stages of the crop. The present investigation was therefore undertaken.

Materials and methods

The experiment was conducted during *rabi* season of 1995-96 at the College Agronomy Farm, Gujarat Agricultural University, Anand.

Methods of irrigation: The furrow method (M_1) was compared with traditional method (M_2) of irrigation.

Schedules of irrigation: Eight schedules of irrigation based on growth stages were selected (Table 1).

A recommended dose of fertilizers (50:25:0, N:P:K kg/ha) was given prior to sowing. Cultural practices were done as per the package of practices recommended for safflower cultivation. In the later stage of crop growth. Aphid was controlled through spraying of Malathion 50 EC @ 0.3 ml/l water. To control *Alternaria* leaf spot, Mancozeb 0.25% was sprayed @ 0.5 g/l water.

Developing seeds were harvested at different intervals *viz.*, 15 days after flowering (15 DAF) (S_1), 30 days after flowering (30 DAF) (S_2) and 45 days after flowering (45 DAF) (S_3).

Observations on fresh and dry weight of seeds were recorded and moisture content was worked out. Dry seeds were analysed for protein (AOAC, 1970), crude fibre (Maynard, 1970), total lipid (Baxi, 1989) and lipid profile (Barrett *et al.*, 1963; Blank *et al.*, 1964) were estimated as per the standard methods. Analysis of samples was carried out in triplicate. The laboratory analytical data of replicated samples for individual characters were subjected to statistical analysis of variance (Snedecor and Cochran, 1967).

Results and discussion

Effect of maturity stages: The harvesting of crop at 15(S_1), 30 (S_2) and 45 (S_3) days after flowering resulted in significant variation in all the biochemical attributes studied (Table 1). Among these attributes seed moisture, 100 seed weight (fresh wt. basis) and crude fibre showed decreasing trend as the seed maturity advanced, while 100 seed weight on dry weight basis and lipid contents showed increasing trend. However, the protein content was the highest at 30 DAS.

The different lipid components of safflower lipids Triacylglycerols (TG), free fatty acid (FFA), Sn-1-2(2,3) diacylglycerols (DG), Monoacylgycerols (MG) and polar lipids (PL) as quantified by TLC at different maturity stages in different methods and schedules of irrigation are computed on per cent weight basis and gram per total lipid basis and presented in Table 2. Triacylglycerol level increased significantly whereas, phospholipid decreased significantly with maturity. Free fatty acid content was significantly higher in S_2 stage as compared with S_1 and S_3 stages. On g/total lipid basis DG content increased with maturity. *Monoglycerols were found only at S_1 stage of* maturity.

Table 1 **Effect of maturity stages, irrigation methods and schedules**

Treatment	Moisture (%)	100 seed weight		Protein (%)	Crude fibre (%)	Total lipid (%)	
		Fresh (g)	Dry(g)			Fresh (g)	Dry(g)
Maturity stages (S)							
S_1 (15 DAF)	64.3	7.6	2.7	13.6	44.7	3.6	10.1
S_2 (30 DAF)	28.0	7.1	5.1	30.1	40.2	17.0	23.7
S_3 (45 DAF)	5.5	5.4	5.1	23.7	36.2	32.0	33.9
SEm±	0.18	0.1	0.04	0.09	0.1	0.05	0.09
CD(P=0.05)	0.51	0.1	0.012	0.24	0.22	0.15	0.24
Irrigation methods (M)							
M_1 (Furrow)	32.7	6.7	4.3	22.5	4.3	17.4	22.4
M_2 (Floor)	32.5	6.7	4.3	22.5	40.4	17.4	22.7
SEm±	0.15	0.0	0.0	0.07	0.06	0.04	0.1
CD (P=0.05)	NS	NS	NS	NS	NS	0.13	0.20
Irrigation schedules (I)							
I_0	31.6	6.4	4.2	21.5	41.2	16.0	20.2
I_1	33.0	6.6	4.3	21.5	41.3	17.0	21.6
I_2	32.3	6.8	4.4	21.5	40.8	17.5	22.3
I_3	33.2	6.9	4.3	21.5	40.7	17.9	23.3
I_4	32.9	6.7	4.2	22.0	40.5	17.9	22.8
I_5	33.0	6.6	4.2	22.9	39.9	17.9	23.2
I_6	32.1	6.7	4.4	24.3	9.5	17.9	23.2
I_7	32.7	6.9	4.4	24.6	38.9	18.6	24.0
SEm±	3.3	0.08	0.14	0.14	0.13	0.09	0.14
CD (P=0.05)	0.83	0.23	0.40	0.40	0.37	0.25	0.40
Significant interaction	SxI, SxMxI	SxI, SxMxI	SxM, SxI, MxI, SxMxI	SxM, SxI, MxI, SxMxI	SxI, SxMxI	SxM, SxI, MxI, SxMxI	SxM, SxI, MxI, SxMxI
C.V.%	3.9	5.2	2.7	2.7	1.1	2.1	2.6

I_0 = (No irrigation after common irrigation) Control
I_1 = Irrigation at branching
I_2 = Irrigation at flowering
I_3 = Irrigation at seed development
I_4 = Irrigation at branching and flowering
I_5 = Irrigation at branching and seed development
I_6 = Irrigation at flowering and seed development
I_7 = Irrigation at branching flowering and seed development

Table 2 Effect of maturity stages, irrigation methods and schedules on lipid profile of safflower seed lipids

Treatment	Lipid profile*									
	Per cent weight basis					g/total lipid basis				
	TG	FA	DG	MG	PL	Tg	FFA	DG	MG	PL
Maturity stages (S)										
S_1 (15 DAF)	47.9	7.0	6.9	8.3	29.9	4.7	0.7	0.7	0.8	3.0
S_2 (30 DAF)	70.9	12.6	6.7	0.0	9.6	16.7	3.0	1.6	0.0	2.3
S_3 (45 DAF)	82.5	7.3	6.7	0.0	3.5	28.0	2.5	2.3	0.0	1.2
SEm±	.015	0.12	0.08	0.06	0.19	0.08	0.03	0.02	0.01	0.04
CD (P=0.05)	0.44	0.33	NS	0.18	0.56	0.22	0.08	0.06	0.03	0.12
Irrigation methods (M)										
M_1 (Furrow)	67.6	9.1	6.7	2.7	13.9	16.5	2.0	1.5	0.3	2.0
M_2 (Floor)	66.6	8.8	6.9	2.8	14.8	16.4	2.1	1.6	0.3	2.3
SEm±	0.13	0.1	0.07	0.05	0.16	0.06	0.02	0.02	0.01	0.03
CD (P=0.05)	0.36	NS	0.19	NS	0.45	NS	NS	0.05	NS	0.10
Irrigation schedules (I)										
I_0**	67.3	8.8	6.9	3.1	13.6	14.5	1.8	1.4	0.3	1.9
I_1	68.7	8.0	7.0	3.3	12.9	16.0	1.8	1.6	0.3	1.9
I_2	67.7	8.6	7.2	2.7	13.8	16.4	2.0	1.6	0.3	2.1
I_3	66.0	9.8	7.2	2.6	14.5	16.6	2.3	1.6	0.3	2.4
I_4	67.0	8.6	7.0	2.5	14.7	16.9	2.0	1.5	0.2	2.2
I_5	67.6	8.8	6.5	2.4	14.7	16.9	2.1	1.5	0.3	2.2
I_6	66.9	9.2	6.2	2.6	16.1	16.8	2.2	1.4	0.3	2.3
I_7	65.6	9.8	6.1	2.7	15.5	17.5	2.4	1.5	0.3	2.3
SEm±	0.25	0.19	0.13	0.11	0.32	0.13	0.05	0.03	0.01	0.07
CD (P=0.05)	0.72	0.54	0.38	0.3	0.91	0.36	0.13	0.09	0.04	0.19
Significant interaction	SxM,SxI MxI, SxMxI	SxM,SxI MxI, SxMxI	SxM, MxI, SxMxI	SxI,	SxM,SxI MxI, SxMxI	SxI, SxMxI	SxM, SxzI, MxI, SxMxI	SxM, SxI, MxI, SxMxI	SxI, MxI, SxMxI	SxM, SxI, SxMxI
C.V.%	1.3	7.3	6.8	13.1	7.7	2.6	7.8	7.3	18.2	10.8

* Average = Average of two replications; ** For details, see Table 1

These results indicate that as the seed matures the moisture begins to decrease. This is obviously due to synthesis and storage of macromolecules such as protein, carbohydrate, nucleic acid and most probably lipid in case of oilseeds. The results indicate that dry weight of seed increases upto physiological maturity. This is obviously due to accumulation of dry matter with continuous fall in moisture percentage. In the present investigation, the synthesis of total lipid was accompained by decrease in seed moisture content from S_1 to S_2 stage of maturity but the fall in moisture content from S_2 to S_3 stage was not concomitant with the increase in lipid synthesis. Thus, the decrease in protein and crude fibre content from S_2 to S_3 maturity stage may be associated with mobilization of protein for lipid synthesis (Mehta *et al.*, 1993).

The increase in lipid content from S_1 to S_2 stage was much faster than the fall in seed moisture content between these stages of seed maturity. This is because of the fact that lipid is not the only material being stored during seed development. These changes in total lipid content are in agreement with those reported by Ichihara and Noda (1980) for safflower.

Results indicated sigmoidal for TG synthesis. Similar pattern has been reported earlier for safflower by Ichihara and Noda (1980). They have reported that seeds at 18 DAF have been found to accumulate TG very rapidly and it became the predominant lipid component at seed maturity.

The results indicated that at initial stage of maturity the fatty acid synthesis was more which decreased significantly during later stage of seed development because of their incorporation into various lipids. These results represented the findings of Ichihara and Noda (1980) with minor exception i.e. FFA was maximum at 16-18 DAF and than decreased upto 30 DAF. This result also find supports from the finding of Sanders (1980) in groundnut, Mckillican (1966) in rape and Sangwan *et al.* (1986) in soybean.

This may probably be due to the role of Sn-1,2(2,3) DG in TG synthesis. Ichihara and Noda (1980) also reported that diacylglycerols reached the highest rate of synthesis at 15 DAF and than maximum incorporation occurred into TG at

18 DAF. This type of changes have also been reported in groundnut (Sanders, 1980; Baxi, 1989) and linseed and soybean (Slack and Browse, 1984).

This may probably be due to its conversion into phosphatidate and finally into TG via DGs synthesis through glycerol-3-phosphate pathway of TG synthesis.

The higher percentage of polar lipids at the early stage may possibly be due to the rapid cell division and hence earlier synthesis of cell membranes and membrane bound organelles, including starch granules, protein bodies, oleosomes and other cellular membranes. Phospholipids (which are major component of polar lipids in oilseeds) are intermediates in the formation of TG (Ichihara and Noda 1980). Evidence for its involvement in synthesis and incorporation of unsaturated fatty acids in TG in developing oilseeds has been presented (Slack and Browse, 1984).

Through the percentage data gives information on proportional changes during seed development, it does not give all the information e.g. a fall in the percent value of any one component may not be due to its actual fall in concentration but due to a increase in another component resulting in relative proportional changes. When the data are expressed as gram per total lipid in the seed at each stage of maturity a different picture emerges. The components TG and DG increased in the lipid through S_1 to S_3 (mature) stage, whereas MG and PL decreased with seed maturity and than decreased at maturity (Table 2).

These results reveal that the dry matter accumulation is more upto 30 DAF and than at lower rate upto maturity. Synthesis of TG continues but the levels of intermediates in its pathway i.e. FFA, DG, PL etc. are generated at much lower rates. Since these are still being utilized for TG synthesis their actual level decreases during the transition from S_2 to S_3 stage of maturity. This type of trend was observed by Baxi (1989) in groundnut.

Effect of methods of irrigation: The total lipid content averaged over stages of M_2 method of irrigation was significantly higher than the M_1 method of irrigation on both fresh and dry weight basis. Other parameters studied were non-significant (Table 1).

Significant differences were found in TG, DG and PL in safflower lipids due to different irrigation methods but non-significant in case of FFA and MG on per cent weight basis whereas, on g per total lipid basis, significant differences were found in DG and PL between two methods of irrigation. TG was significantly higher in M_1 method whereas DG and PL were higher in M_2 method of irrigation (Table 2).

The results indicate that the furrow method provides more available water to plants as compared to traditional flood method of irrigation. Patel (1994) also reported the similar results in safflower. The accumulation of lipid in safflower seed in general was accompained by decrease in moisture content due to methods of irrigation. These results indicate that the conventional flood method of irrigation had given higher lipid content than furrow method or irrigation.

Effect of irrigation schedules: Among various irrigation schedules I_7 (irrigation at branching, flowering and seed development) gave the highest 100 seed weight, protein and total lipids whereas, moisture and crude fibre content were found the highest at I_3 and I_1, respectively (Table 1).

Different lipid components were significantly altered by irrigation scheduled at different critical stages of crop growth. Among different schedules, I_1 recorded significantly the highest concentration of TG, while I_3 and I_4 recorded identical (9.77%), significantly the highest content of FFA. The percentage of DG was the highest under I_3 schedule, which being on par with I_0, I_1, I_2 and I_4 schedules differed significantly from rest of the combinations. MG content was significantly higher in I_1, than the rest of the combination except I_0. The polar lipids were the highest under I_7 which were significantly more than rest of the treatments barring I_4, I_5 and I_6 schedules.

The different lipid fractions expressed on g per total lipid basis revealed that I_7 recorded maximum values for TG, FFA and MG, which differed significantly from other treatments except I_3 and I_4 for FFA, I_1, I_2, I_3 and I_6 for MG. In case of DG and PL fractions, I_3 registered maximum concentrations, which were on par with I_1 and I_2 for DG and I_4, I_5, I_6 and I_7 for PL fraction.

A comparison of seed moisture content at these schedules of irrigation show that with holding irrigation during seed development stages led to higher moisture content compared to other schedules of irrigation.

It appears that the supply of irrigation at I_7 schedule i.e. irrigations at branching, flowering and seed development stages gave higher total lipid content. This could be due to frequent irrigation at I_7 schedule, which might have helped in mobilizing soil phosphorus to a greater extent and thereby positively affecting lipid synthesis. Erie and French (1969) and Patel (1994) have also observed that frequent irrigation helps in higher uptake of P by safflower and thus more lipid synthesis.

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Soil test based fertilizer prescription for maximum yield and profit in sunflower (*Helianthus annuus* L.) in vertisols of Andhra Pradesh

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Abstract

With the objective of developing soil test based fertilizer recommendations for attaining maximum yield profit and a desired rate of return from sunflower 'MAHYCO - 8' in vartisols of Nandyal under residual moisture conditions, a Soil Test Crop Response correlation study was conducted during *kharif*, 1996. The correlations among the different soil and fertilizer variables and seed yield were examined for developing a prediction model through different variables. Multiple regression models of seed yield have been developed using which fertilizer adjustment equations for prescribing soil test based optimum fertilizer doses for attaining maximum yield, profit and desired rate of return have been derived. A ready reckoner indicating optimal fertilizer doses at varying soil test values for attaining maximum yield, profit and a desired rate of return from sunflower crop in vertisols have been calibrated for easy interpolation of fertilizers doses.

Key words: Sunflower, fertilizer prescription, vertisols, soil test, crop response

Introduction

Sunflower is an important oil seed crop grown under both irrigated and rainfed conditions in Andhra Pradesh. The crop responds to application of inorganic fertilizers. Judicious use of inorganic sources of N, P and K nutrients is considered as the best option for sustainable soil fertility management (Rao and Subramanian, 1994; Dev, 1997; Rao *et al.*, 1997; Subba Rao *et al.*, 1998). Baby Akula and Bapi Reddy (1998) highlighted conjunctive use of organic and inorganic fertilizers to obtain high yields of castor under rainfed conditions. Similarly, there is a need to develop optimum fertilizer doses for attaining maximum yield and profit from sunflower crop (Dhawan *et al.*, 1989, Fyzee *et al.*, 1993; Subba Reddy *et al.*, 1993). Although different varieties of sunflower are grown in the state, there is no soil test based fertilizer recommendation using inorganic fertilizers in Vertisols under rainfed conditions. Hence, there is a need for developing a basis of soil test based prescription of doses for attaining different levels of sunflower seed yield after standardising the correlation among different variables. With this objective, studies on 'Soil Test Crop Response' correlation on sunflower in Vertisols of Nandyal under rainfed situation have been carried out (Ramamoorthy *et al.*, 1967). An attempt has been made to develop prediction models and derive optimal fertilizer doses at varying soil test values.

Materials and Methods

A field experiment on sunflower (MAHYCO-8) variety with 27 different fertilized treatments comprising of N, P and K fertilizers and 3 unfertilized treatments was conducted in a Vertisol at Regional Agricultural Research Station, Nandyal in Kurnool district during *kharif*, 1996. The experiment was conducted in the field where an exhaust crop of sorghum was raised during *kharif*, 1995 to stabilize the fertility and create soil fertility gradients. Thus there were 30 plots in each of the four fertility gradients. The 30 fertilizer treatments were superimposed to each of the plots in each gradient. Initial soil samples from each plot (from 0-15 cm) were analysed for N, P, K and organic carbon (%) by procedures laid out by Subbaiah and Asija (1956); Olsen *et al* (1954); Jackson (1973) and Walkley and Black (1934) respectively. Seed and stalk yields were recorded for each treatment, and plant samples were analysed for N, P and K contents and their uptake computed the data were analysed by standard statistical procedures and the effects of different treatments have been assessed (Sreedevi, 1997).

Organic carbon (%) was found to range between 0.09 and 0.38 with a mean of 0.23%, while alkaline permanganate N ranged between 92 and 195 kg/ha with a mean of 133 kg/ha. Olsen's P ranged between 5.4 and 21.6 with a mean of 15.9 kg/ha, while Ammonium acetate K had a range of 237 to 489 with a mean of 404 kg/ha in the field experiment.

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The seed yield was derived at harvest from each treatment. The mean yields were found to be 1068, 1185, 1288 and 1266 kg/ha in the four gradients respectively. The seed yield was found to range between 717 and 1625 kg/ha with a mean of 1202 kg/ha. The plant uptake of N has ranged between 67.1 and 190.7 with a mean of 117.2 kg/ha. The plant uptake of P was found to range between 2.8 and 9.5 with a mean of 6.3 kg/ha. The plant uptake of AK has ranged between 57.6 and 168.4 with a mean of 1-3.7 kg/ha.

Correlation analysis is used to study relations among different variables of soil, plant and fertilizer nutrients, while regression analysis is used to examine the rate of change in yield for an unit change in different variables. The soil test values, fertilizer doses and their interactions are used in the development of soil test crop response prediction models and further calibrations of optimal fertilizer doses at varying soil test values (Maruthi Sanker, 1986). A fertilizer schedule for interpolating optimal fertilizer doses at different soil test values for attaining maximum yield, maximum profit or any desired rate of return can also be prepared for making soil test based recommendations.

Results and discussion

Correlation analysis: The estimates of correlation among different variables are given in Table-1. The seed yield was found to be significantly correlated with all variables except organic carbon and fertilizer K. Plant uptake of nutrients had a significant correlation with soil nutrient except the relation between uptake N and organic carbon. Similarly, plant uptake of nutrients had a significant relation with fertilizer nutrients was found to be non-significant for all the three nutrients. The correlations have thus clearly indicated that the multiple regression models of seed yield can be developed with different regressors of soil and fertilizer variables and their interactions as independent variables.

Model calibration and fertilizer optimisation: Using soil and fertilizer variables and their interactions, multiple regression equations have been calibrated for predicting seed yield through different equations regressor variables (Velayutham and Rani Perumal, 1976; Velayutham *et al.*, 1976; Velayutham, 1979). The optimum fertilizer doses of N, P and K nutrients would be varying depending on the requirement of maximum yield, maximum profit and desired rate of return. A multiple regression equation of sunflower seed yield with fertilizer N, P and K nutrients has been calibrated and is given as follows:

$$Y=430^{**}+21.52^{**}FN-0.14^{**}FN^2+4.99^{**}FP-0.05FP^2-1.87FK+0.07FK^2 \quad \text{----------Equation (1)}$$

($R^2 = 0.59^{**}$, $\sigma = 121.1$, C.V. (%) = 10.1)

Table 1 Estimates of correlation among soil, plant uptake and fertilizer variables, seed yield and oil (%) of sunflower at Nandyal

Variables	Correlation
Yield, Uptake N	0.65**
Yield, Uptake P	0.87**
Yield, Uptake K	0.56**
Yield, O.C.(%)	0.18
Yield $KMnO_4$-N	0.39**
Yield, Olsen's P	0.42**
Yield, Amm.Ace K	0.41**
Yield, FN	0.62**
Yield, FP	0.28**
Yield, FK	0.01
Uptake N, O.C.(%)	0.11
Uptake N, KMnO4-N	0.37**
Uptake N, FN	0.45**
Uptake P, Olsen'sP	0.48**
Uptake P, FP	0.31**
Uptake K, Amm.Ace K	0.31**
Uptake K, FK	0.12
O.C.(%), $KMnO_4$-N	0.41**
O.C.(%), FN	-0.15
$KMnO_4$-N,FN	0.09
Olsen'P, FP	0.04
Amm.Ace K, FK	-0.05

* and ** indicate 5 and 1 % level of significance respectively.

On differentiating this equation with respect to fertilizer nitrogen, a dose of 77 kg of N/ha was obtained for maximum yield. Similarly 50 kg P_2O_5/ha was obtained as dose for maximum yield The optimum fertilizer K could not be derived due to non-existence of diminishing returns to K application. The fertilizer adjustment equations derived without using soil test values for maximum profit are given below:

$$FN = 77 - 3.6\,R$$
$$FP_2O_5 = 50 - 10.2\,R$$

Where R = ratio of cost of a unit of fertilizer and value of a unit of seed yield of sunflower. Taking R value as 0.80 for N (Rs.&.0/Rs.10) and 1.6 for P_2O_5 (Rs.16/Rs.10), optimum fertilizer doses for maximum profit per hectare were found to be 74 and 34 kg/ha respectively. Although fertilizer K had no significant effect on seed yield and had no diminishing returns, the mean fertilizer K (15 kg K_2 O/ha) can be considered as an optimum fertilizer K since there was a marginal increase in seed and stalk yield at 15 kg K_2O/ha application. These values are applicable for the average soil test values of the experimental field viz., 131, 15.8 and 400 kg/ha of soil N ($KMnO_4$), P (Olsen's method) and K (Ammonium acetate method) respectively for an expected yield of 1206 kg/ha .

Apart from fertilizer doses, soil test values of N, P and K nutrients would also influence the sunflower yield. Hence, multiple regression equations of seed yield with soil and

fertilizer N, P and K variables have been calibrated and are given below:

$$Y = 137 + 267.2\ SN + 9.66^{**}\ SP + 0.18\ SK + 22.14^{**}\ FN - 0.15^{**}\ FN^2 + 5.21^{**}\ FP - 0.06^{*}\ FP^2 - 2.97\ FK + 0.11\ FK^2$$

———Equation(2)

(O.C(%)-N, Olsen's P, Ammonium acetate K)

($R^2 = 0.75^{**}$, $\sigma = 94.5$, C.V.(%) = 7.9)

On differentiating equation (2) partially with respect to fertilizer N and P, we get fertilizer adjustment equations for deriving optimum fertilizer doses for maximum yield, maximum profit and a desired rate of return. The fertilizer adjustment equations are as follows:

FN = 74 - 3.3 R

FP_2O_5 = 52 - 10.0 R

FK_2O = Not possible due to lack of (+-) response type

$$Y = 172 + 0.022\ SN + 11.25^{**}\ SP + 0.18\ SK + 22.15^{**}\ FN - 0.15^{**}\ FN^2 + 5.03^{**}\ FP - 0.05^{*}\ FP^2 - 2.45\ FK + 0.09\ FK^2$$

-----Equation (3)

($KMnO_4$ - N, Olsen's P, Ammonium acetate K)

($R^2 = 0.75^{**}$, $\sigma = 96.1$, C.V.(%) = 8.0)

On differentiating equation (3) partially with respect to fertilizer N and P, we get fertilizer adjustment equations for deriving optimum fertilizer doses for maximum yield, maximum profit and a desired rate of return. The fertilizer adjustment equations are as follows:

FN = 74 - 3.3 R

FP_2O_5 = 52 - 10.0 R

FK_2O = Not possible due to lack of (+-) response type

The multiple regression equations of seed yield with soil and fertilizer N,P and K variables and their interactions are given below:

$$Y = -188 + 1160.1^{**}\ SN + 16.73^{**}\ SP + 0.54\ SK + 27.32^{**}\ FN - 0.16^{**}\ FN^2 + 8.89^{**}\ FP - 0.06^{**}\ FP^2 - 3.78\ FK + 0.098\ FK^2 - 14.75^{**}\ FN\ SN - 0.22^{**}\ FP\ SP + 0.003\ FK\ SK$$

------ Equation (4)

(O.C(%) - N, Olsen's - P, Ammonium acetate K)

(R2=0.80**, σ=87.2, CV (%) = 7.3)

On differentiating equation (4) partially with respect to fertilizer N and P, we get fertilizer adjustment equations for deriving optimum fertilizer doses for maximum yield, maximum profit and a desired rate of return. The fertilizer adjustment equations are as follows:

FN = 85 - 46.1 SN - 3.1 R

FP_2O_5 = 74 - 1.8 SP - 8.3 R

FK_2O = Not possible due to lack of (+-) response type

$$Y = -29 + 0.75\ SN + 17.37^{**}\ SP + 0.16\ SK + 24.04^{**}\ FN - 0.15^{**}\ FN^2 + 8.16^{**}\ FP + 0.05^{*}\ FP^2 - 3.36\ FK + 0.075\ FK^2 - 0.01\ FN\ SN - 0.20^{**}\ FP\ SP + 0.003\ FK\ SK$$

------- Equation (5)

($KMnO_4$ - N, Olsen's - P, Ammonium acetate K)

($R^2 = 0.77^{**}$, $\sigma = 92.2$, C.V.(%) = 7.7)

On differentiating equations (5) partially with respect to fertilizer N and P, we get fertilizer adjustment equations for deriving optimum fertilizer doses for maximum yield, maximum profit and a desired rate of return. The fertilizer adjustment equations are as follows:

FN = 80 - 0.03 SN - 3.3 R

FP_2O_5 = 82 - 2.04 SP - 10.0 R

FK_2O = Not possible due to lack of (+—) response type

Using the fertilizer adjustment equations, a ready reckoner of fertilizer doses at varying soil test values for attaining maximum yield, maximum profit and desired rate of return is given in table 2. The optimum fertilizer N for maximum yield was found to be varying between 74 and 77 kg/ha when the soil N was varying between 200 and 90 kg/ha. The optimum fertilizer P for maximum yield was found to be varying between 9 and 74 kg/ha when the soil P was varying between 48 and 4 kg/ha. The optimum fertilizer N and P for maximum profit were found to be varying between 72 and 75 kg/ha and 3 and 68 kg/ha respectively. The optimum fertilizer N and P for a desire rate of return of 2.0 were found to be varying between 70 and 74 kg/ha and 5 and 62 kg/ha respectively at the same range of soil test values as described above. It was observed that there was no fertilizer P requirement beyond a soil test value of 36 kg/ha. The optimum fertilizer K doses could not be derived due to the lack of non-existence of (+–) responsive type. The study has thus provided scope for assessing the relationships among different soil and fertilizer variables, plant uptake of nutrients and seed yield. It has also provided scope to develop prediction models of seed yield and optimum soil test based fertilizer doses for attaining different levels of sunflower yield in Vertisol under rain fed condition.

Table 2 Ready reckoner of soil test based fertilizer doses for attaining different levels of sunflower yield in a vertisols at Nandyal

$KMnO_4$-N	Fertilizer N (kg/ha)			Olen'sP	Fertilizer P_2O_5(kg/ha)		
	MY	MP	DRR		MY	MP	DRR
90	77	75	74	4	74	68	62
100	77	75	73	8	66	60	54
110	77	75	73	12	58	52	46
120	76	75	73	16	49	43	37
130	76	74	72	20	41	35	29
140	76	74	72	24	33	27	21
150	76	74	72	28	25	19	13
160	75	73	72	32	17	11	5
170	75	73	71	36	9	3	0
180	75	73	71	40	0	0	
190	74	72	71	44			
200	74	72	70	48			

MY : Maximum yield; MP : Maximum profit; DRR: Desired rate of return

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Yield - Evapotranspiration functions for groundnut (*Arachis hypogeae* L.)

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Abstract

Field experiment were conducted in groundnut for two years (1992 -93 and 1993 -94) to evaluate various forms of seasonal crop water production functions without considering the time of water deficit during the crop growing season. Seasonal evapo-transipiration had a significant correlation with grain yield and dry matter yield. The R^2 varied from 0.880 to 0.985 and from 0.959 to 0.985 for pod and dry matter yield respectively, on pooled basis in different crop water production functions. Non-linear functions *viz.*, quadratic and cubic functions did not perform well as compared to Power, Linear, Stewarts S_1 and S_2 functions. It was therefore proposed that the linear functions in view of simplicity are making decisions on water resource development.

Key Words : Water, evapotranspiration, groundnut, water production function

Introduction

Water is essential for crop production and efficient use of available water must be made for maximising crop yields per unit amount of water. The functional relationship between crop yield and water use is expressed by a water production function. A large number of studies have been conducted on water production functions based on independent variables like evapotranspiration (Eta), transpiration (T) and applied water (W) (Vaux and Pruitt, 1983;Praveen Rao *et al.*, 1994). Such Knowledge is needed to make decisions on timing of water releases and allocation of water among crops, for evaluation of crop/cropping patterns under variable water supply circumstance and for determining the extent of command area of an irrigation scheme. Very limited work has, however been done in groundnut crop in evaluation of seasonal water production functions. The major goal of this study was, therefore, to compare the ability of seven forms of water production functions to simulate and predict the yield response of groundnut in relation to Eta.

Materials and methods

Field experiments were conducted during water season of 1992-94 on a sandy loam soil at Collage farm, College of Agriculture, Acharya N.G. Ranga Agricultural University, Hyderabad (17.19°N, 78.23° E and 543 m altitude). There were seven irrigation treatments designed to allow evapotranspiration deficits to develop in one more of the three specific crop-growth subperiods. In any given crop-growth subperiods, the crop in a given treatment was either irrigated (W) based on soil-crop-climatic data (Table 1) to ensure evapotranspiration proceeded at maximum rate or it was not irrigated at all (D). Thus, the crop in treatments D-W-W, W-D-W, W-W-D, D-D-W, W-D-D and D-W-D, if irrigated (W), the field irrigation schedule followed was similar to that adopted in fully irrigation control, W-W-W treatment. The seven irrigation treatments were laid out in a randomised block design with four replications.

The experimental soil was low in N (210 kg/ha), P (19.2 kg/ha) and high in K (304 kg/ha) with a soil pH 7.5, E.C 0.2 dSm^{-1} and bulk density 1.61 Mg/m^3. The average soil moisture retentivity at- 0.03 Mpa, -1.5 Mpa and available water storage capacity in 60 cm of crop root zone depth was 17.19 %, 6.29 % and 105.0 mm respectively. The ground water table was below 10 m in depth from the soil surface and did not contribute to water use. Variety ICGS 11 was sown on 3.11.92 and 11.11.93 in the first (1992-93) and second year (1993-94) respectively, adopting a spacing of 30 x 10 cm to achieve a desired plant population of 3.33 lakh plants ha^{-1}. Other recommended measures of production including fertilizer (40 kg N, 20 kg P_2O_5, 40 kg K_2O/ha and 500 kg gypsum/ha) and plant protection measures were carried out. For estimating Eta, the soil moisture under different treatments was monitored starting from sowing to harvest before and after each irrigation by following gravimetric method (Praveen Rao, 1993). The crop was harvested on 29.2.93 and 9.3.94 in the first year (1992-93) and second year (1993-94) respectively.

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Table 1 Field irrigation schedule in W-W-W treatment at individual growth subperiods of groundnut

Crop-growth sub-period	Duration in days	Eto (mm/day)	Kc	Etm (mm/day)	Crop root zone depth (cm)	Sa.d (mm)	P	Irrigation interval=(Sa.d.P/Etm)	IRR (mm)
					1992-93				
Vegetative (3.11.92 to 5.12.92)	33	4.08	0.750	3.06	45	79	0.700	18	55.0
Flowering-pegging & pod addition (6.12.92 to 19.1.93)	45	3.98	1.025	4.10	60	105	0.590	15	61.5
Pod filling (20.1.93 to 1.3.93)	40	4.70	0.800	3.76	60	105	0.625	17	64.0
					1993-94				
Vegetative (11.11.93 to 16.12.93)	36	3.97	0.750	3.00	45	79	0.700	18	54.0
Flowering-pegging & pod addition (17.12.93 to 30.1.94)	45	4.03	1.025	4.10	60	105	0.590	15	61.5
Pod filling (31.1.94 to 9.3.94)	37	5.24	0.800	4.20	60	105	0.580	15	63.0

Kc : Crop coefficient; Sa.d : Available soil moisture (mm) in crop root zone depth; P : Critical soil moisture level; IRR : Irrigation water depth

The crop yield water functions of the following type were developed and evaluated.

$Ya = a+b\ (Eta)$ (1)

$Ya = a+b\ (Eta) + c\ (Eta)^2$ (2)

$Ya = a+b(Eta)+c(Eta)^2+d(Eta)^3$ (3)

$Ya = a+b\ (ET)^b$ (4)

$Ya = a=b\ (1-Eta/ETm)$ after Stewart 1972 (5)

$(1-Ya/Ym)= a+b\ (1-Eta/ETm)$ after Stewart *et al.* 1977 (6)

$Ya = a+b\ [1-(1-Eta/ETm)^2]$ after Singh *et al.* (1987) (7)

Where

Ya = Pod yield or dry matter yield (Kg ha^{-1})

Ym = Maximum pod yield or dry matter yield **associated** with Etm (i.e., from W-W-W treatment)

Eta = Seasonal evapotranspiration (mm)

Etm = Maximum seasonal evapotranspiration (mm) associated with Ym (i.e., from W-W-W treatment)

a = intercept on the Y-axis

b, c and d = Regression coefficients reflecting the magnitude of variation in 'ya' with change in the independent variable.

Statistical parameters viz., regression constants, coefficients, standard error of regression coefficient of determination (R^2), variance ratio for testing R^2 (F-value) were computed for comparing the functions (Table 2 and Table 3).

Results and discussion

Perusal of the emperical estimates of the regression analysis in Table 2 and 3 revealed that the seasonal water production functions as expressed by Linear (eq. 1), Quadratic (eq. 2), Cubic (eq. 3), Power (eq. 4), Stewarts S_1 (eq. 5), Stewart *et al.*, 1977 S_2 (eq. 6) and Singh *et al., 1987* (Eq. 7) were statistically acceptable with regard to the fitting of observed pod yield and dry matter yield data of groundnut. The explained total variation as indicated by values of the R^2 varied yield from 0.871 to 0.989 in 1992-93, 0.883 to 0.982 in 1992 -94 and 0.880 to 0.985 on pooled basis for pod yield and from 0.949 to 0.984 in 1992-93, 0.936 to 0.981 in 1993-94 and 0.959 to 0.985 on pooled basis for dry matter yield. The variance ratio (F-value) for testing R^2 values were statistically in all the functions both for pod and dry matter yield.

The R^2 values in different years and on pooled basis ranged from 0.982 to 0.988 in pod yield and from 0.980 to 0.985 in dry matter yield for the quadratic and cubic functions, but, one or both the regression coefficients for these two functions were statistically non-significant. Therefore, it can be inferred that the non-linear functions expressed by quadratic and cubic functions did not represent the data well for groundnut.

The Stewarts S_1 and S_2 functions (eq. 5 and 6) may be expressed and written in the form of linear function (eq. 1). Probably, this could be the reason that the R^2 and F-values both for Stewarts (eq. 5 and 6) and linear function (Eq. 1) were similar. The regression coefficients in these linear functions (eq. 5 and 6) were highly significant and the F_2 value was 0.985 (1992-93), 0.979 (1993-94) and 0.982 (pooled) for pod yield and 0.956 (1992-93), 0.978 (1993-94) and 0.971 (pooled) for dry matter yield. According to Stewart *et al.* (1977) and Praveen Rao *et al.* (1991), the 'b' value in S_2 function reflects the sensitivity of the crop yield to water deficits. Quantification of yield response sensitivity coefficients (b) in S_2 function for a given crop and variety facilitates prediction of crop yield under variable water supply circumstances at a new site by the following relationship.

$Ya = Ym \times 1 - [\ b\ (Etm - Eta / Etm)\ ]$ (8)

The parameters needed at the new planting site are Ym and Etm besides 'b' values. Such a yield prediction in advance of planting allows one to select most productive or profitable crop and also in efficient management of available limited water resources.

The function proposed by Singh et al. (Eq. 7) modifying the stress factor (independent variable) in Stewarts function assumed a non-linear relationship between crop yield and seasonal Eta, though exhibited statistically acceptable

Table 2 Emperical estimates for testing seasonal water production functions for pod yield of groundnut

Water production function	Regression constants, coefficients and test statistics								R^2	F-value for testing R^2
	a	t(a)	b	t(b)	c	t(c)	d x 10^{-6}	t(d)		
					1992-93					
Linear	-1.16685	6.120	0.011203**	18.040					0.985	325.4**
Quadratic	-0.38432	0.510	0.005208NS	0.908	0.0000108NS	1.050			0.988	164.9**
Cubic	-1.51517	0.323	0.18441NS	0.339	-0.0000385NS	0.191	0.06NS	0.245	0.988	84.1**
Power	-8.84562	20.174	1.68399**	21.826					0.989	476.4**
Stewart S_1	0.99820	49.032	-1.37810	18.040					0.985	325.4**
Stewart S_2	0.00180	1.138	1.37810	18.040					0.985	325.4**
Singh *et al.*	-1.46103	3.882	2.34325	5.891					0.871	33.9**
					1993-94					
Linear	-1.31342	5.901	0.010446**	15.236					0.979	232.1**
Quadratic	-0.33248	0.301	0.003544NS	0.464	0.0000115NS	0.907			0.982	112.4**
Cubic	-0.11938	0.017	0.001315NS	0.018	0.000019NS	0.077	-0.01NS	0.030	0.982	56.2**
Power	-9.79096	15.356	1.81430	16.329					0.981	266.6**
Stewart S_1	1.00238	38.122	-1.45585	15.236					0.979	232.1**
Stewart S_2	-0.00238	0.767	1.45585**	15.236					0.979	232.1**
Singh *et al.*	-1.72752	4.376	2.61233**	6.153					0.883	37.8**
					Pooled					
Linear	-1.23932	6.008	0.010811**	16.547					0.982	273.8**
Quadratic	-0.40778	0.435	0.004720NS	0.702	0.0000105NS	0.910			0.985	132.6**
Cubic	-1.44279	0.262	0.016161NS	0.268	-0.0000300NS	0.141	**0.05NS**	**0.191**	0.985	67.1**
Power	-9.31697	16.897	1.74939**	18.120					0.985	328.3**
Stewart S_1	1.0048	43.574	-1.41763**	16.547					0.982	273.8**
Stewart S_2	-0.00048	1.206	1.41763**	16.547					0.982	273.8**
Singh *et al.*	-1.61336	4.205	2.49754**	6.609					0.880	36.8**

NS = Non significant at P = 0.05; ** = Significant at P = 0.01

Table 3 Emperical estimates for testing seasonal water production functions for dry matter yield of groundnut

Water production function	Regression constants, coefficients and test statistics								R^2	F-value for testing R^2
	a	t(a)	b	t(b)	c	t(c)	d x 10^{-6}	t(d)		
					1992-93					
Linear	-0.96041	1.467	0.022162**	10.390					0.956	107.9**
Quadratic	-5.52406	3.080	0.057213NS	4.262	-0.0000632NS	2.626			0.984	121.1**
Cubic	-5.69939	0.513	0.059264NS	0.461	-0.0000709NS	0.149	0.01NS	0.016	0.984	60.5**
Power	-5.74973	7.985	1.31116**	10.349					0.955	107.1**
Stewart S_1	1.04226	34.631	-1.17688**	10.390					0.956	107.9**
Stewart S_2	-0.04226	1.404	1.17688**	10.390					0.956	109.7**
Singh *et al.*	-1.18931	7.450	2.14245**	10.124					0.949	102.5**
					1993-94					
Linear	-1.77911	3.733	0.022059**	15.028					0.978	225.8**
Quadratic	-3.42433	1.397	0.033619NS	1.984	-0.0000192**NS**	**0.683**			0.980	101.9**
Cubic	-9.81538	0.641	-.100479NS	0.633	-0.0002443**NS**	**0.459**	**0.25NS**	**0.424**	0.981	54.1**
Power	-6.75956	9.924	1.45780**	12.281					0.968	150.8**
Stewart S_1	1.02203	44.394	-1.27713**	15.028					0.978	225.8**
Stewart S_2	-0.02203	0.957	1.27713**	15.028					0.978	225.8**
Singh *et al.*	-1.43562	5.622	2.35958**	8.592					0.936	73.8**
					Pooled					
Linear	-1.34693	2.513	0.022028**	12.973					0.971	168.3**
Quadratic	-4.85357	2.448	0.047714NS	3.355	-0.0000444NS	1.815			0.984	124.4**
Cubic	-9.50661	0.834	0.099149NS	0.795	-0.0002267NS	0.516	**0.21NS**	**0.416**	0.985	65.8**
Power	-6.23601	8.799	1.38168**	11.135					0.961	124.0**
Stewart S_1	1.03154	40.559	-1.22323**	12.973					0.971	168.3**
Stewart S_2	-0.03154	1.240	1.22323**	12.973					0.971	168.3**
Singh *et al.*	-1.32294	6.768	2.26183**	10.789					0.959	116.4**

NS = Non significant at P = 0.05; ** = Significant at P = 0.01

results with regard to fitting of actual data; it had lower R^2, F and t-values (b/SEb) when compared to linear, Stewarts S_1 and S_2 and power functions both for pod and dry matter yield.

Several workers (Barrett and Skogerboe, 1980; Singh *et al.*, 1987; Praveen Rao *et al.*, 1994) opined that the marginal yield should decrease with increase in seasonal Eta. Therefore, the relationship between crop yield and seasonal Eta should be non-linear. With the consideration of non-linearity, the Singh *et al.* Function (eq. 7) may be considered appropriate for groundnut. However, the linear functions (eq. 1, 4, 5 and 6) showed superior performance over non-linear functions (eq. 2, 3 and 7) hence, may be considered practically more useful to predictive purposes in view of their simplicity for groundnut crop.

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Screening of *Jatropha* species against the major defoliators of castor (*Ricinus communis* L.)

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Abstract

Castor production in India is constrained by the vulnerability of the released varieties/hybrids to lepidopteran pests. In order to find out reliable sources of resistance for introgression into cultivars of the monotypic genus, *Ricinus*, members of the related genus, *Jatropha*, were screened against the leaf eating caterpillars. The *Jatropha* species showed varied levels of resistance to the different pests. Regardless of the pest, castor supported maximum survival, pupation and larval growth while *Jatropha integerrima* proved superior in terms of maximum mortality, very low weight gain with or without pupation. The other promising sources include *J. integerrima* Var. Rosea for castor semilooper and Bihar hairy caterpillar, *J. podagrica* for the hairy caterpillars and *J. curcas* for red hairy caterpillar.

Key words: Castor, *Jatropha*, lepidopteran pests, resistance

Introduction

Castor (*Ricinus communis* L.), an important non-edible oilseed crop has assumed paramount importance as a source of vegetable, industrial and medicinal oil all over the world. Concerted breeding efforts in India resulted in the development of a number of high yielding varieties/hybrids of regional and multi-locational importance. However, vulnerability of these improved cultivars to a multitude of insect pests and diseases is a major limitation to castor production. Castor belongs to a monotypic genus *Ricinus*, and the genetic variability for the various biotic stresses in the available germplasm is limited. Hence, new sources of disease and pest resistance and tolerance to stress environments are in constant demand by the breeders. Morphologically, certain members of the genus *Jatropha* (*Euphorbiaceae*) possess resemblance to castor and have attracted interest for cultivation worldwide to having no known major disease or insect pests and its non-palatability to livestock even during times of drought (Jones and Miller, 1991). The present study has been undertaken with the objective of assessing the reaction of *Jatropha* species native to India to the major lepidopteran pests of castor.

Materials and methods

A six year record on the natural incidence of insect pests on *Jatropha* species was maintained. Artificial screening was carried out in the laboratory under no choice conditions. Leaves of castor (cv. VP-1) and *Jatropha* species *viz.*, *J. curcas*, *J. integerrima*, *J. integerrima* var. Rosea, *J. gossypifolia*, *J. multifida* and *J. podagrica* were used in the study. The third instar larvae of castor semilooper (*Achoea janata*), neonates of Bihar hairy caterpillar (*Spilosoma obliqua*) and red hairy caterpillar (*Amsacta albistriga*) were released on the leaves of different samples kept in rectangular jars maintained at 25 °C. The leaves were changed every day. The treatments were randomized with three replications each. For castor semilooper, ten larvae were used per treatment while for the other two pests thirty larvae were used per treatment. Data was recorded at three days interval on survival (%), days to pupation, maximum larval weight gain (mg), frequency of pupation (%) and pupal weight (mg). Data was subjected to analysis of variance and means were separated according to Duncan's Multiple Range Test (DMRT) at $\alpha \leq 0.05$.

Results and discussion

The *Jatropha* species were relatively free from pest attack except for sporadic appearance of leaf miner on *J. curcas* and seasonal incidence of leaf webber on *J. integerrima* and *J. gossypifolia*. Occasionally scales were observed on *J. integerrima*. There was no incidence/appearance of leaf eating caterpillars on either the seedlings or mature plants of the *Jatropha* species under study.

Screening against castor semilooper (*Achoea janata*): The reaction of 3rd instar semilooper larvae in terms of survival frequency, larval and pupal weight gains on the leaves of castor and different *Jatropha* species is presented in Table 1. The survival frequencies ranged from 16.7 to 86.7%, larval survival was least (16.7%) on *J. integerrima* followed by *J. integerrima* var. Rosea (30%),

while it was maximum (86.7%), on *J. multifida*. Survival on castor and *J. curcas* was also high (80%) and was not significantly different from that obtained on *J. multifida*. Increase in larval weight varied between 306.5 and 767.4 mg. Weight gain of the larvae was maximum (767.4 mg) on castor which was not significantly different from that obtained on *J. multifida* (728.8 mg). Increase in the larval weight was least in *J. integerrima* var. Rosea (306.5 mg) followed by *J. integerrima* (335.0 mg) while all other species showed intermediate larval weights. Pupal weights followed similar trend and statistical analysis revealed a strong positive correlation between larval and pupal weights (correlation = 0.937***; student's T value = 11.68). Pupation was delayed on *J. integerrima* and *J. integerrima* var. Rosea (12-14 days). In castor, larvae pupated within 4-6 days, while in other *Jatropha* species, *viz.*, *J. curcas*, *J. gossypifolia*, *J. multifida* and *J. podagrica*, it varied from 6-8 days.

Table 1 Reaction of *Ricinus* and *Jatropha* to castor semilooper (*Achoea janata*)

Genotype	Survival (%)	Days for pupation	Larval weight gain (mg)	Pupal weight (mg)
Castor	80.0^{a}	4-6	767.4^{a}	708.7^{a}
J. curcas	80.0^{a}	6	569.6^{b}	514.5^{b}
J. integerrima	16.7^{b}	14	335.0^{c}	242.7^{c}
J. int. var. Rosea	30.0^{b}	12-14	306.5^{c}	202.3^{c}
J. gossypifolia	63.3^{a}	6-8	586.2^{b}	551.5^{b}
J. multifida	86.7^{a}	6	728.8^{a}	632.9^{a}
J. podagrica	70.0^{a}	6-7	684.9^{ab}	661.3^{a}
CV (%)	23.2	-	12.9	9.0

Experimental design : ANOVA-1
Means in a column followed by same letters are not significantly different according to DMRT at α = 0.05.

Screening against bihar hairy caterpillar (*Spilosoma obliqua*): The survival frequency of the Bihar hairy caterpillar larvae varied from 12.2 to 89.5% (Table 2). Mortality was maximum on *J. integerrima* var. Rosea followed by *J. integerrima* and *J. podagrica* and was not significantly different from each other. Larval survival was maximum on castor followed by *J. curcas* and was not significantly different from that of castor. Larval pupation was greatly influenced by the genotype. Pupation was delayed significantly on *J. integerrima* and *J. podagrica* (22-28 days) while the larvae failed to pupate on *J. integerrima* var. Rosea. Weight gain of the larvae varied between 187.1 and 637.1 mg. Larval weight gain on *Jatropha* species was significantly less than that on castor and was least on *J. integerrima* var. Rosea. Pupal weights showed a positive correlation with larval weights (correlation = 0.733***; student's T value = 4.697).

Screening against red hairy caterpillar (Amsacta albistriga): The survival frequency of the red hairy caterpillar larvae varied from 0 to 97.8% (Table 3). Survival was maximum on castor. Interestingly, among the *Jatropha* species, *J. integerrima* var. Rosea had maximum frequency of surviving larvae followed by *J. multifida*. Maximum mortality was recorded on leaves of *J. curcas* followed by *J. integerrima* and *J. podagrica*. Larval weight gain as maximum on castor followed by that on *J. multifida*. Although, the survival frequency of red hairy caterpillar larvae was higher on *J. integerrima* var. Rosea than on *J. multifida*, yet, the larval weight was higher on *J. multifida*. Leaves of *J. curcas*, *J. integerrima*, *J. gossypifolia* and *J. podagrica* failed to facilitate pupation of the red hairy caterpillar larvae.

Table 2 Reaction of *Ricinus* and *Jatropha* to Bihar hairy caterpillar (*Spilosoma obliqua*)

Genotype	Survival (%)	Days for pupation	Larval weight gain (mg)	Pupal weight (mg)
Castor	89.5^{a}	12	637.1^{a}	378.9^{a}
J. curcas	81.2^{a}	15	454.1^{b}	231.2^{bc}
J. integerrima	23.7^{c}	22-28	258.1^{c}	217.4^{c}
J. int. var. Rosea	12.2^{c}	No pupation	187.1^{d}	-
J. gossypifolia	57.4^{b}	14	501.0^{b}	222.8^{c}
J. multifida	63.3^{b}	16	496.5^{b}	271.5^{ab}
J. podagrica	26.4^{c}	22-28	264.8^{c}	219.1^{c}
CV (%)	9.2		7.4	9.9

Experimental design : ANOVA-1
Means in a column followed by same letters are not significantly different according to DMRT at α = 0.05.

Table 3 Reaction of *Ricinus* and *Jatropha* to red hairy caterpillar (*Amsacta albistriga*)

Genotype	Survival (%)			Larval wt. gain		Pupation (%)
	III instar	IV instar	V instar	IV instar	V instar	
Castor	97.8^{a}	97.8^{a}	97.8a	0.49^{a}	1.04^{a}	97.8^{a}
J. curcas	0^{e}	0^{f}	0^{d}	0^{d}	0^{d}	0^{d}
J. integerrima	33.3^{d}	0^{f}	0^{d}	0^{d}	0^{d}	0^{d}
J. int. var. Rosea	80.3^{b}	57.8^{c}	56.8^{b}	0.19^{c}	0.45^{c}	36.6^{c}
J. gossypifolia	55.6^{c}	18.9^{d}	0^{d}	0.18^{c}	0^{d}	0^{d}
J. multifida	71.2^{b}	67.8^{b}	55.6^{b}	0.29^{b}	0.80^{b}	55.6^{b}
J. podagrica	24.4^{d}	7.7^{e}	7.7^{c}	0.19^{c}	0.42^{c}	0^{d}
CV (%)	8.6	10.3	11.7	6.6	7.0	13.2

Experimental design : ANOVA-1
Means in a column followed by same letters are not significantly different according to DMRT at α = 0.05.

Screening of castor and *Jatropha* species against the lepidopteran pests of castor showed varying levels of resistance. Castor supported maximum survival with highest larval and pupal weight gain for all the pests. For castor semilooper, two species of *Jatropha viz.*, *J. multifida* and *J. podagrica* gave similar response as that of castor in terms of survival (%), larval weight gain, pupal weight and the time for pupation. Semilooper fecundity was comparatively lower in three *Jatropha* species, *viz.*, *J. curcas*, *J. multifida* and *J. gossypifolia*, while it was

considerably reduced in *J. integerrima* and the variety Rosea. Similarly, for the other two pests, larval survival and fecundity was least in *J. integerrima*. Pest resistance is most often cited as the reason for utilizing wild species in many crop plants. Development of backcross derived germplasm via introgression of single pest resistance genes from wild species is universally known for most crop species, such as for aphid in *Arachis* (Amin, 1985) and *Hordeum* (Weibull, 1987); Boll weevil resistance in *Gossypium* (Jenkins *et al.*, 1978) and planthoppers in rice (Jena and Khush, 1990). Plant resistance to insect pests is a complex phenomenon that results from a series of interactions between plants and insects which include non-preference, antibiosis, antixenosis and tolerance (Dhaliwal *et al.*, 1993). The exact nature of the resistance conferred by *Jatropha* needs to be unravelled by examining the various toxic components which are found in all the plant parts of most of the species. Nevertheless, identification of potential sources of resistance is important for any sound breeding programme. Although, the barriers to crossability between members of allied genera are strong, yet novel techniques of gene transfer being developed during the past two decades can aid in successful introgression of desirable genes into cultivated castor.

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Effect of sclerotinia rot on some seed characteristics and fatty acid composition in rapeseed-mustard

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Abstract

Effect of Sclerotinia rot on oil yield and quality was observed in four cultivars of rapeseed-mustard namely Culture-2, (*Brassica napus*); Tobin, (*Brassica campestris*) ; Varuna, (*Brassica juncea*) and HPC-1, (*Brassica carinata*). The oil content was significantly less in seeds of all the cultivars infected with Sclerotinia rot and reduction was directly proportional to maturity period of the respective cultivar. The 100 siliqua weight and 1000 seed weights was also reduced in Culture-2 and Varuna. The fatty acid profile of oil from infected cultivar seeds showed variation in comparison to normal oil due to premature ripening of seeds and disturbances in translocation of metabolites through stem pith as a result of Sclerotinia infection.

Key words: Sclerotinia rot, rapeseed mustard, oil content, fatty acids

Introduction

Sclerotinia rot caused by *Sclerotinia sclerotiorum*(Lib.) deBary, is becoming a serious disease of crucifers in some parts of India. The pathogen mainly attacks the stem of the plants at flowering stage and causes heavy yield losses (Roy and Saikia, 1976). The infection on the stem and inside pith results in stunting or wilting of plants accompanied by premature ripening. Simultaneously, the disease interferes with the normal translocation of metabolites resulting in loss of oil yield and change in its fatty acid composition. Hence present study was undertaken to assess the effect of the disease on some seed characteristics, oil yield and quality, in different cultivars of rapeseed-mustard.

Materials and methods

Four cultivars of rapeseed mustard, Culture-2, (*B. Napus*); Varuna (*B. juncea*); HPC-1, (*B. carinata*) and Tobin, (*B. campestris*) were taken for this study. The samples of healthy, and diseased plants having severely damaged main stem with disease, were harvested at maturity from the experimental plots at Oilseeds Research Station, Kangra, H.P. Siliqua weight, and test weight were measured. Oil content of seed samples was determined by Nuclear Magnetic Resonance (NMR) technique (Medsen, 1976). Oil was extracted in petroleum ether using Soxhlet apparatus. Methyl esters of each oil sample were prepared by the method of Luddy *et al.* (1968) and stainless steel column (305 cm X 3.175 mm) packed with 20% diethylene glycol succinate (DEGS) absorbed on 60-80 mesh chromosorb W. The temperature of column, injector and detector was kept at 190 °C, 200 °C, 210 °C respectively, and nitrogen (carrier gas) flow rate of 35 ml/min was maintained.

Results and discussion

Culture-2 had the highest seed oil content (44.8%) followed by Tobin (43.6%), Varuna (40.4%) and HPC-1 (36%) in healthy plants. The oil content was significantly reduced in the seeds from infected plants of all four cultivars (Table 1) and HPC-1 showed highest loss in oil content (34.4%). The loss in oil yield in four cultivars was directly proportional to the days required for their maturity indicating inverse relationship of oil synthesis to day for which plant gets exposed to disease up to maturity. It has been found in mustard seeds that there is a slow accumulation of total lipids up to 28 days after flowering (DAF). Then up to 56 DAF the period is marked with rapid accumulation of lipids and thereafter it is nearly constant (Gupta *et al.*, 1991). As Sclerotinia infection starts at flowering stage it brought about significant loss of oil yield in present investigations. Further, as different cultivars of rapeseed-mustard matured at different periods the duration of Sclerotinia infection might have caused differential oil loss in four cultivars of rapeseed-mustard. The 100 siliqua weight and 1000-seed weight were significantly reduced in infected plants of Culture-2 and Varuna only.

The level of palmitic and oleic was higher in infected seeds of Culture-2, Tobin and Varuna in comparison to seeds of healthy plants (Table 2), however in HPC-1 the levels of these two fatty acids were lower in seeds of infected plants. Linoleic acid was lower in seeds of infected plants in all four cultivars in comparison to healthy seeds. Linolenic and eicosenoic acid was higher in diseased Tobin

and HPC-1, whereas in case of Culture-2 and Varuna it was lower than in seeds of healthy plants. Tobin being double zero (erucic acid <2%, glucosinolates <3o μ moles/gm defatted cake) did not have erucic acid where as Culture-2 being a low erucic acid cultivar had lower levels of this acid. In Varuna the erucic acid in infected seeds was lower than in healthy seeds where as in HPC-1 healthy seeds had slightly lower erucic acid than diseased seeds.

Table 1 Effect of Sclerotinia rot on oil content and other seed parameters in rapeseed-mustard

Plant Status / Cultivar	Oil content (%)			100 siliqua wt. (g)			1000 seed wt. (g)		
	H*	I*	Cultivar mean	H	I	Cultivar mean	H	I	Cultivar mean
B. napus (Culture-2)	44.8	35.2	40.0	6.5	2.4	4.4	3.5	2.51	3.0
B. campestris (Tobin)	43.6	39.6	41.6	3.3	3.4	3.4	2.2	2.01	2.1
B. juncea (Varuna)	40.4	32.2	36.3	4.3	1.3	2.8	4.2	2.00	3.1
B. carinata (HPC-1)	36.0	23.6	29.8	2.4	0.9	1.6	3.0	2.04	2.5
Plant Status mean CD (P=0.05)	41.2	32.7		4.1	2.0		3.2	2.14	
Cultivar (C)			1.78			NS			NS
Plant Status (P)			1.26			1.6			0.9
Interaction (CXP)			2.51			NA			NS

H*=Healthy and I*=Infected are the plant status; NS=Non significant; Each value is mean of three determinations

Table 2 Effect of Sclerotinia rot on the fatty acid composition (%) of oil in seeds of rapeseed-mustard

Fatty acids, plant status / Cultivar	Palmitic acid			Oleic acid			Linoleic acid			Linolenic+Eicosenoic acid			Erucic acid		
	H*	I*	Cultivar mean	H	I	Cultivar mean	H	I	Cultivar mean	H	I	Cultivar mean	H	I	Cultivar mean
B. napus (Culture-2)	3.0	4.0	3.5	28.5	39.2	33.9	27.0	21.4	24.2	34.6	24.6	30.1	7.0	9.8	8.4
B. campestris (Tobin)	9.3	14.3	11.8	27.8	31.3	29.6	40.2	16.5	28.4	22.6	37.9	30.3	0.0	0.0	0.0
B. juncea (Varuna)	3.7	5.6	4.7	12.9	20.7	16.8	19.7	19.1	19.4	23.7	22.6	23.2	40.0	32.0	36.0
B. carinata (HPC-1)	11.2	9.8	10.5	12.2	10.7	11.5	23.5	20.4	22.0	21.3	25.9	23.6	31.8	33.2	32.5
Plant Status mean CD (P=0.05)	*6.8*	*8.4*		*20.4*	*25.5*		*27.6*	*19.4*		*25.6*	*28.0*		*19.7*	*18.8*	
Cultivar (C)			0.25			1.03			0.80			0.66			0.70
Plant Status (P)			0.18			0.73			0.57			0.46			0.57
Interaction (CXP)			0.35			1.45			1.14			0.93			1.21

H*=Healthy and I*=Infected are the plant status Each value is mean of three determinations

Palmitic, linoleic and linoleic acids were maximum at early stage of seed development mainly because these fatty acids were considered to be components of memberane lipids of chloroplasts in mustard seeds (Gurr *et al.*, 1972 and Sukhija *et al., 1983)*. As maturity advances, these fatty acid decrease because there is gradual accumulation of triglycerides (Gurr *et al.*, 1972). Erucic acid which is present as traces in initial stages of seed development increases thereafter regularly with gradual accumulation of total lipids (Gupta *et al.*, 1991) and its accumulation is due to active conversion of oleic to erucic acid by two consecutive steps of chain elongation (Norton and Harris, 1975; Downey, 1987). The observed changes in levels of different fatty acids in infected plants of rapeseed mustard might have been caused due to premature ripening of seeds. The interference in translocation of various metabolites as a result of damaged pith due to Sclerotinia infection at flowering stage may have also contributed towards altered level of various fatty acids in infected plants. However there is a need to monitor levels of these fatty acids at different stages of plant development and progression of Sclerotinia infection to establish the exact relationship amongst these two.

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Role of pycnidiospores of *Macrophomina phaseolina* (Tassi) Goid the incitant of root rot of castor

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Abstract

Among different media tested for pycnidial production by *Macrophomina phaseolina* (Tassi) Goid, formation of pycnidia was rapid and bigger in size on steam sterilzed stem bits of castor in 98 hours after inoculation. On water-agar-leaf medium pycnidia formation was observed 116 hrs after inoculation. More than 50% of pycnidiospores retained their viability up to 90 days and decreased to 3.3% after 170 days. Spray inoculation of pycnidiospores on injured plants showed leaf blight symptoms and stem lesions. The intensity of disease increased with increase in age of plants.

Key words: Castor, *Macrophomina phaseolina*, pycnidiospores

Introduction

The *Macrophomina phaseolina* (Tassi) Goid incitent of charcoal rot in many crop plants. The fungus has a predominant sclerotial stage and a less frequently occurring pycnidial stage in its life cycle. Although the significance of the sclerotial stage in the pathogenicity is well documented in most of the crops, there is considerable evidence that the pycnidial stage is also capable of infecting its hosts and producing symptoms such as leaf spots/leaf blights in some hosts of the fungus (Khan and Kauser, 1960; Ghaffar, 1964).

Although pycnidia of this fungus have been observed in many hosts, yet they are not produced in conventional media. The fungus may however sporulate on special media. In the present investigation different media were tried for induction of pycnidial formation with a view to know the longevity of pycnidiospores, their viability in relation to time at a constant temperature, and their role in secondary infection.

Materials and methods

Growth media : Pycnidial production was tested on four different media, Potato Dextrose Broth (PDB), modified czepek's Dox agar, Oat meal agar (OMA) and Castor stem extract (CSE). Potato dextrose broth was prepared in 50 ml conical flasks. The other media were dispersed into sterile petriplates @ 20 ml/plate. A 5 mm agar disc was cut with a sterile cork borer from seven days old culture growth on PDA and transferred aseptically to the centre of each petriplate and conical flask containing media and then incubated at 27±1°c.

Water agar-leaf medium as suggested by Srinivasan *et al.* (1971) was prepared. Instead of wheat leaves, bajra leaves were used in the preparation of the medium. The procedure described by Vishwa Dhar and Sarbhoy (1991) for inducing pycnidial production in *Rhizoetonia bataticola* isolated from soybean was tried using castor isolate and castor stem pieces.

Pycnidial production was recorded at 12 hours interval using stereobinocular microscope. Three replications were maintained for each medium. On an average 50 pycnidia and 100 pycnidiospores were measured.

Longevity of pycnidiospores

Longevity of pycnidiospores was studied as per the procedure described by Vishwa Dhar and Sarbhoy (1989). Castor stem bits with artifically induced pycnidia were stored at 28 °C. Pycnidiospores released from such pycnidia were observed for their germination at 20 days interval. Ten pycnidia were picked and placed in water for liberation of pycnidiospores. The pycnidiospore concentration was adjusted so as to have atleast 20-25 spores under a single microscopic field. Later, this suspension was placed on cavity slides and incubated at room temperature for 10 hours. Two hundred pycnidiospores were observed at random for recording germination per cent.

Role of pycnidiospores in secondary infection

Five healthy plants per pot were used for this study. Pycnidia produced on castor stem bits were crushed in sterile water. The pycnidiospore concentration was

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adjusted to $3x10^5$ spores per ml and sprayed on 15 days old plants by using hand automizer. Three replications each consisting of 15 plants were maintained. Spraying was done on plants after injuring the leaves and stems with a fine sterilized needle. Another set of plants with injured leaves and stems were sprayed with sterile water only to serve as control. High humidity was maintained by covering plants with polythene bags for 48 hrs. Plants were observed for symptom development at an interval of 5 days.

Results and discussion

Of different media tested, pycnidial formation was rapid (98 hrs after inoculation) and were larger in size (142-210 x 90-110±1 μm) on steam sterilized castor stem pieces (Table 1). On water-agar-leaf medium, pycnidial production was observed after 116 hours and were smaller in size. *Macrophomina phaseolina* isolated from castor did not form pycnidia on other media tested. The fungus produced pycnidia on bajra leaf bits placed on water agar and sclerotial bodies on the medium.

Table 1 **Effect of different growth media on pycnidial production of *M. phaseolina***

Medium	Time taken for pycnidial formation (hrs)	Size of pycnidia (μm)	Size of pycnidiospores (μm)
Steam sterilized castor stem bits	98	142-210 x 90-110±1	24-30 x 8-10±1
Water-agar leaf medium	116	105-200 x 82-100±1	16-25 x 5-8±1
Potato dextrose broth	Not formed	-	-
Modified Czepek's Dox Agar medium	Not formed	-	-
Oat meal agar	Not formed	-	-
Castor stem extract	Not formed	-	-

Of the six culture media tested for inducing pycnidial production in lab, only castor stem bits and water-agar-leaf medium supported their formation suggesting that in conventional media the pycnidia are produced on host surface. Although, pycnidia of this fungus have been observed on many hosts, pycnidia were not produced on ordinary media (Kulkarni *et al.*, 1962; Mathur, 1967; Kulkarni and Patil, 1968; Abuelgasim and Zeidan, 1985). However, the fungus was observed to sporulate on special media (Ashworth, 1969; Kulkarni and Patil, 1968). Srinivasn *et al.* (1971) reported that many soil borne fungi which lose their ability to sporulate in ordinary agar medium, sporulate profusely on water-agar-leaf media. In the present investigation also castor isolate was induced to form pycnidia on both castor stem bits and water-agar-leaf medium for the first time. The large sized pycnidia formed on castor stem bits might be due to natural preference of the host from which it was isolated.

More than 50 % pycnidiospores retained their viability upto 90 days. The viability of pycnidiospores decreased to 3.3%, 170 days after formation. The pycnidospores gradually lose their viability with increase in age at 28°C (Table 2).

The pycnidispores lost their viability with increase in age. Sunderaraman (1929) working with a groundnut isolate noted that pycnidospores were viable upto 14 months at room temperature while, the pycnidospores of poato isolate upto 3-4 months only (Bhargava, 1965).

Table 2 Longevity of pycnidiospores

Age of pycnidiospores (days)	*Germination (%)
10	90.33 (71.92)
30	87.33 (69.16)
50	82.00 (64.90)
70	73.66 (59.14)
90	56.00 (48.44)
110	49.66 (44.80)
130	34.33 (35.86)
150	18.33 (25.32)
170	3.30 (10.40)

* Mean of three replications. Values in parenthesis are angular transformed values
CD (P=0.05) : 2.43; SEm± : 1.10

Artificially injured plants spray inoculated with spore suspension developed leaf blight symptoms (Table 3). The symptoms on leaves were observed on older leaf margins within two weeks of inoculation were circulated to irregular the brown to reddish brown lesions (45 mm). When dry and lesions appeared yellowish brown and papery in texture. Neither pycnidia nor sclerotia were observed on infected leaves. However, the pathogen could be reisolated from such leaves. Stem infection was noted as a small lesions in the initial stages of disease development. Pycnidia were observed on the surface of stem. When the diseased plants were split longitudinally sclerotial bodies were observed in pith region, root damage was also observed. The disease increased with increase in age of the plant. At 65 DAS, 100% incidence of the disease was recorded.

Table 3 Role of pycnidiospores in secondary infection

Age of plant (days)	Disease incidence (%)
25	23.20 (28.68)
35	42.03 (40.40)
45	66.60 (54.74)
55	93.40 (74.68)
65	100.00 (90.00)

Values in parenthesis are angular transformed values
CD (P=0.05) : 2.43; SEm± : 1.10

Spray application of pycnidiospores resulted in symptom production in other crops such as beans and soybean (Luttrell, 1946; Vishwa Dhar and Sarbhoy, 1987) indicating that the pycnidospores produced in early infected plants under field conditions serve as secondary source of infection.

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Combined effectiveness of organic amendments and *Trichoderma viride* for the control of root rot of sesame

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Abstract

Among the various amendments tested, soil application of neem cake (150 kg/ha) was found to be superior in reducing the root rot *Macrophomina phaseolina* (Tassi.) Goid of sesame both under pot culture (25.1 %) and field (6.9%) conditions. The grain yield was increased to 573.3 kg/ha and was on par with pressmud (566.9 kg/ha). Combined efficacy of these two amendments individially and with the biocontrol agent, *Trichoderma viride* was tested in three seasons under natural field conditions. Among the treatments, soil application of neem cake (150 kg/ha) + *T.viride* seed treatment (4 g/kg) significantly reduced the incidence of root rot (14.51%) over untreated control (46.45%) and increased the grain yield to the tune of 36.4 %. This was followed by soil application of pressmud (12.5 t/ha) + seed treatment with *T.viride*. The same trend was observed in all the three seasons.

Key words: Organic amendments, *Trichoderma viride*, root rot, grain yield

Introduction

Among the various diseases infecting the sesame root rot caused by *Macrophomina phaseolina* (Tassi.) Goid infects the crop at all stages of growth (Al-Ani *et al.*, 1970). About 5to 100% of yield loss due to the disease was reported by Vyas (1981). Chemical control of the disease failed to eliminate the soil-borne inoculum of *M.phaseolina*. Many attempts have been made to control the disease with various organic amendments (Gemawat and Varma, 1971; Dinakaran *et al.*, 1995 a) and bio-control agents (Sankar, 1994; Sethuraman and Muthusamy 1994; Dinakaran *et al.*,1995b) separately. Application of *Trichoderma viride* muitiplied on groundnut shell greatly reduced root rot of mungbean, *M.phaseolina* followed by coirpith and pressmud (Raguchander *et al.*, 1993). In the present study, attempts were made to test the efficacy of soil amendments in combination with the biocontrol agent, *T.viride* for the control of sesame root rot.

Materials and methods

Six amendments *viz.*, farm yard manure (12.5 t/ha), pressmud (12.5 t/ha), decomposed coconut coirpith (12.5 t/ha), sunnhemp green leaf manure (12.5 t/ha), poultry manure (1.0 t/ha) and neem cake (150 kg/ha) were tested under both sterilized (pot culture) and unsterilized (field) soil (Table 1). The *M. phaseolina* inoculum multiplied in sand-maize medium was incorporated to sterilized pot soil @ 50 g/kg (Gamal El-Din *et al.*, 1984). The seeds of TMV 3 were sown in pots and a minimum population of 40 plants was maintained for each treatment and this was replicated four times. Seed treatment with carbendazim (2 g/kg) and untreated control were also included as treatments for comparison with amendments. Incidence of root rot was recorded periodically and the final count was made on 80 days after sowing. A field trial was also conducted during *rabi* 1994-95 with the same set of treatments. Observations on root rot incidence and grain yield were recorded and analysed statistically.

Table 1 **Effect of organic amendments on the control of root rot of sesame during *rabi*, 1994-95**

	Treatment	Pot culture Root rot (%)	Field condition	
			Root rot (%)	Grain yield (kg/ha)
T_1	Farm yard manure (12.5 t/ha)	29.4 (32.8)	12.2 (20.4)	548.9
T_2	Pressmud (12.5 t/ha)	28.5 (32.1)	8.5 (17.0)	566.9
T_3	Decomposed coconut coirpith (12.5 t/ha)	34.7 (36.0)	14.8 (22.6)	530.0
T_4	Sunnhemp green leaf manure (12.5 t/ha)	55.2 (48.0)	18.5 (25.5)	513.3
T_5	Poultry manure (1.0 t/ha)	47.4 (43.5)	17.0 (24.3)	520.3
T_6	Neem cake (150 kg/ha)	25.1 (29.9)	6.9 (15.2)	575.3
T_7	Carbendazim (2 g/kg of seed)	35.4 (36.5)	12.6 (20.8)	544.7
T_8	Control	85.7 (67.8)	27.8 (31.9)	474.2
	SEm±	1.08	0.56	5.15
	CD (P=0.05)	4.46	2.38	22.1

Figures in parenthesis are arcsine transformed values.

To study the combined efficacy of organic amendments and *T. viride*, field trials were conducted during *kharif* 1995, *rabi* 1995-96 and *kharif* 1996 with 6 treatments. The ground variety TMV 3 was sown and each treatment was replicated four times. Incidence of root rot was recorded at regular intervals and the final observation was taken at 80 DAS. Yield data were also recorded and analysed.

Results and discussion

The role of organic amendments in reducing the soil-borne diseases has been well established (Gemawat and Varma, 1971; Lewis and Papavizas, 1977; Samiyappan, 1988; Dinakaran *et al.*, 1995a). Incidence of root rot was significantly less in both sterilized (25.1%) and unsterilized (6.9%) soils. Yield was high (575.3 kg/ha) due to soil application of neem cake followed by soil treatment with pressmud (569.9 kg/ha). However, both were on par with each other (Table 1). Incorporation of organic amendments to soil might have destroyed the propagules of *M. phaseolina* directly (Lumsden *et al.*, 1983) or would have influenced the antagonistic microbial population in the rhizosphere, which inhibited the pathogen indirectly (Linderman and Gilbert, 1975). Ramakrishnan (1981) reported reduction in propagule density of *R. solani* from 340 to 120/g by the addition of FYM and neem cake. Dwivedi and Singh (1986) reported that neem cake, castor cake and mahua cake reduced the population of *M. phaseolina* in soil. Nakkeeran (1992) found that soil amended with neem cake and FYM increased the population of *Trichoderma spp* by 3.2 fold. The present investigation also proved the efficacy of soil amendments especially neem cake and pressmud in suppressing *M. phaseolina* infection in sesame.

In the second experiment, the two best amendments of the previous trials *viz.*, neem cake and pressmud were tested with *T. viride* seed treatment in combinations. The results indicated that soil application of neem cake combined with *T. viride* seed treatment registered the least mean incidence of root rot (14.51%) and also increased the grain yield to the tune of 36.4% over untreated control (Table 2). It also recorded the highest cost-benefit ratio of 1.35. This was followed by soil application of pressmud + *T. viride* seed treatment. Rukmani and Mariappan (1990) found that farmyard manure, coir waste, name cake, mahu cake and pressmud application along with *T. viride* contained root rot of blackgram. The ability of *T. viride* to be effective in small quantities as seed treatment might probably be associated with their ability to grow and sporulate in the rhizosphere in large numbers to fight against the pathogen. Incorporation of organic amendments served as a substrate for better growth and proliferation of antagonists in rhizosphere soil. Samiyappan (1988) reported that *T. viride* was effective in controlling root rot of black gram caused by *M. phaseolina*. He also stated that *T. viride* showed poor survival in rhizosphere when applied as seed treatment, which might be due to the sensitivity to soil biological factors. *T. viride* multiplied in wheat-bean medium and applied in soil furrows was able to proliferate by using food bases. The results obtained in the present study have indicated that soil incorporation of neem cake (150 kg/ha) combined with seed treatment with *T. viride* (4 g/kg) was found to be effective in reducing the root rot disease and increasing the grain yield.

Table 2 Testing the combined efficacy of soil amendments and biocontrol agent against sesame root rot

Treatment	*Kharif*, 1995			*Rabi* 1995-96			*Kharif*, 1996			Pooled mean		
	Root rot (%)	Grain *yield* (kg/ha)	*C:B ratio*	Root rot (%)	Grain *yield* (kg/ha)	*C:B ratio*	Root ot (%)	Grain *yield* (kg/ha)	*C:B ratio*	Root rot (%)	Grain *yield* (kg/ha)	*C:B ratio*
Press mud (12.5 t/ha)	36.1 (36.9)	449.0	0.69	26.0 (30.7)	512.5	0.91	32.4 (34.7)	458.3	0.71	31.5 (34.1)	473.3	0.77
Neem cake (150 kg/ha)	33.0 (35.0)	458.3	0.84	24.5 (29.7)	520.9	1.09	27.7 (31.7)	470.8	0.89	28.4 (32.1)	483.3	0.94
T. viride (4 g/kg of seed)	26.1 (30.6)	477.7	1.18	16.5 (23.9)	540.6	1.47	21.6 (27.7)	485.4	1.22	21.4 (27.4)	501.3	1.29
Pressmud (12.5 t/ha) + *T. viride* (4 g/kg of seed)	18.7 (25.6)	553.6	1.06	11.8 (20.0)	614.5	1.29	20.5 (26.8)	531.3	0.98	17.0 (24.2)	566.4	1.11
Neemcake (150 kg/ha) + *T. viride* (4 g/kg of seed)	16.5 (24.0)	564.4	1.26	11.4 (19.7)	620.8	1.49	15.5 (23.2)	577.1	1.31	14.5 (22.3)	587.4	1.35
Carbendazim (2 g/kg of seed)	31.4 (34.0)	473.8	1.16	26.8 (37.4)	546.9	1.49	21.6 (27.7)	472.9	1.16	24.4 (29.5)	497.9	1.27
Untreated control	55.9 (48.4)	380.4	0.74	37.4 (37.7)	482.3	1.20	46.0 (42.7)	492.2	0.96	46.5 (42.9)	430.6	0.97
SEm±	0.92	5.9	-	0.45	5.2	-	0.73	5.7	-	0.42	3.2	-
CD (P=0.05)	3.87	24.7		1.87	22.0		3.05	23.9		1.67	12.9	

Figures in parenthesis are arcsine transformed values

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Effect of plant extracts, bioagents, rotational crops and their root exudates on *Sclerotium rolfsii* causing stem rot of groundnut

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Abstract

Among different plant extracts, 1:20 dilution of *Parthenium hysterophorus, Polyalthia longifolia* and *Azadirechta indica* inhibited the mycelial growth of *Sclerotium rolfsii* significantly. Bioagent *Trichodema harzianum* culture filtrate and Sorghum root exudate prevented the germination of sclerotia maximally (0.00-22.5 and 0.00-12.5% respectively). In crop rotation studies Sorghum-Groundnut system was found effective in decreasing the stem rot satisfactorily.

Keywords: Extracts, filtrate, exudate, rotational crops, stem rot, groundnut

Introduction

Stem rot of groundnut caused by *Sclerotium rolfsii* is a major threat in groundnut production system. The disease is widespread in its distribution (Kolte, 1984), 75-80 % yield loss has been reported (Mayee and Datar, 1986; Mehan and McDonald, 1990). Different parts of *Allium cepa* (Pariya and Chackravarthi, 1977), *Parthenium hysterophorus, Plyalthia longifolia* (Annapurna *et al.*, 1983) and *Azadirechta indica* have been reported to limit the growth of *S. rolfsii*. Further, bioagents *Trichoderma* has been frequently reported to restrict the growth of *S. rolfsii* by many workers (Elad *et al.*, 1983; Agarwal *et al.*, 1992; Mukhopadhaya *et al.*, 1992). Crop rotation with soybean and maize caused reduction in disease incidence (Cooper, 1956; Pearson *et al.*, 1987; Rodriguez-Kabana *et al.*, 1991). These constitute the components of integrated management of soil borne diseases. Present studies under taken to know the influence of these on stem rot pathogen *in vitro* so that the information generated may be better utilized in integrated management under field conditions.

Materials and methods

The investigations were carried out at the Department of Plant Pathology, University of agricultural Sciences, Dharwad during 1998-99.

(a) Evaluation of plant extract against *S.rolfsii*

Extracts from 15 plant species were made by crushing fresh leaves in sterile distilled water in a ration of 1:1 w/v, the extracts were passed through two layers of muslin cloth. The filterate thus obtained was collected as undiluted extract (Ezhilan *et al.*, 1994), the extract were diluted to 5,10, and 20 % strength and used for evaluation by poison food technique (Sharvelle, 1961). The experiment was conducted at 27 ± 1^0c for six days. The radial growth of mycelium was measured and inhibition (%) was calculated based on growth in unamended control.

(b) Effect of culture filtrate of *Trichoderma* on *S.rolfsii*

The bioagent *Trichoderma harzianum* was isolated from rhizosphere soil of groundnut at main research station, Dharwad. Ten g of composite sample was used in serial dilution for isolation. Dilutions of 10^{-2} and 10^{-3} were used. One ml of the dilution was poured on solidified PDA medium contained in plate. *Trichoderma harzianum* colonies were examined under microscope. The culture was purified by hyphal tip culture method, sub cultured and used in the studies. *Trichoderma harzianum* was grown on PDA broth for twelve days and filtrate was passed through Whatman No 1 filter paper and filtrate was collected. The stock filtrate and 1:10 and 1:20 dilution were used to test their effect on germination of sclerotia of *S.rolfsii* by previously soaking them in the filterate for 24 hr. Bodies soaked in sterile distilled water served as control. Ten bodies were used per treatment and replicated thrice. The germination was recorded after incubation of PDA. It was expressed as per cent germination.

(c) Effect of root exudates

The seedlings of Sorghum, Maize, Bajra, and Soybean were raised in series of polythene bags filled with washed sand for 20 days. Twenty seedlings were removed along with root system and washed thoroughly in running water. The roots of seedlings were dipped in 20 ml sterile water in test tubes for 24 and 48 hr. The exudate collected was used for testing the germination of sclerotia. Undiluted filtrate and dilution of 1:10 and 1:20 were evaluated. In each concentration 10 bodies were soaked for 24 hr and

later transferred on to PDA plates. The bodies soaked in sterile water served as control. The plates were incubated at 27 ^{0}C for six days and germinated sclerotia were counted and per cent germination was recorded.

(d) Effect of rotational crops

Sterilized soil was mixed uniformly with 4% inoculum of S.rolfsii which was previously multiplied on sand-corn medium and filled in 45 x 30 cm pots. The seedlings of Sorghum, Maize, Bajra, and Soybean (rotational crops) were raised in these pots for 45 day. Later plants were uprooted and buried in same pots and watered to make soil wet. Thirty days period was given for decomposition of crop debris followed by sowing of groundnut cv. JL-24. Groundnut crop grown here no rotation crop was raised earlier served as control. The treatments were replicated four times. The seedling emergence (%) and disease incidence (%) in groundnut crop were recorded on 12 and 60 days after sowing, respectively.

Results and discussion

(a) Effect of plant extracts

Among aqueous plant extracts tested (Table 1) significant inhibition of mycelial growth over control was recorded in *Parthenium hysterophours* (78.9%) followed by *Polyalthia longifolia* (62.2%) in 20% concentration. The other effective extracts were Clerodendron inerme (35.4%) and *Azadirechta indica* (25.3%) the latest inhibition was in *Dutura stremonium* (8.6%) at the same concentration. The similar trend was observed with respect to other dilutions tested.

Table 1 Effect of cold aqueous plant extracts on mycelial growth of *sclerotium rolfsii*

Plant extract	Mycelial Growth (mm)			Inhibition over control (%)		
	Concentration			Concentration		
	5%	10%	20%	5%	10%	20%
Azadirechta indica	82.0	73.0	67.0	8.9	18.9	25.6
Achorus calamus	81.5	76.0	79.5	9.4	13.0	12.0
Adhatoda Viscica	81.0	82.0	78.0	10.0	8.9	13.3
Allium cepa	81.0	81.0	78.5	10.0	10.0	12.8
Agave americanum	76.5	75.0	74.0	15.0	16.7	17.8
Argemone mexicana	77.0	70.0	72.0	14.4	22.2	20.0
Bougainvillea spectabilis	88.0	84.0	81.5	13.1	7.7	9.4
Calotropis gegantea	80.5	80.0	79.0	10.6	11.1	11.7
Clerodendron ineme	77.0	73.5	58.0	14.1	20.0	35.5
Datura stremonium	81.0	83.5	82.0	10.0	6.66	8.6
Etythina indica	78.5	79.5	80.0	12.8	11.7	11.7
Glycedia maculata	75.0	72.0	80.0	16.7	20.0	11.7
Ocimum sanctum	82.5	78.5	74.0	8.3	12.8	17.8
Parthenium hysterophyrus	29.5	23.0	19.0	67.8	74.4	78.9
Polyalthia longifolia	39.0	35.0	34.0	56.7	61.1	62.2
Control	91.0	90.0	90.0	-	-	-
SEm±	-	-	-	0.6	0.7	0.9
CD (P=0.05)	-	-	-	2.5	3.1	3.6

(b) Effect of culture filtrate of *Trichoderma harzianum*

The results (Table 2) revealed that undiluted filtrate of *T. harzianum* showed total inhibition of germination of sclerotia. The diluted culture filtrate of 1:10 and 1:20 recorded 12.50 and 22.50 % inhibition respectively, where as germination was normal in untreated bodies (water soaked).

(c) Effect of root exudates

In root exudates obtained after 24 and 48 hr of incubation of seedlings, undiluted sorghum exudate was more effective and prevented the *Sclerotial* germination completely (Table 3). Whereas 30% Sclerotia germinated in undiluted exudate of Maize. The dilution of exudates resulted in increased germination of sclerotia irrespective of its source. On the other hand the exudate of Bajra and Soybean were not effective in preventing germination (50 and 55 %, respectively). Higher germination was evident in higher dilutions. The exudate obtained after longer incubation were found to affect sclerotia germination more acutely (Table 3). Especially Sorghum exudate completely inhibited *Sclerotial* germination at 1:10 dilution. Even at 1:20 appreciable reduction was noticed (2.50%). Maize exudate was next in order.

Table 2 **Effect of *Trichoderma harzianum* culture filtrate on sclerotia body germination**

Dilution of Filterate	Germination of Sclerotia (%)
Undiluted	0.0(2.50)*
1:10	12.5 (20.46)
1:20	22.5 (26.57)
Control	100 (90.00)
SEm±	1.02
CD (P=0.01)	4.24

* Figures in parenthesis are angular transformation.

(d) Effect of rotational crops

The rotational crops affected the incidence of stem rot in groundnut significantly (Table 4) Low incidence of disease was recorded in Sorghum rotated treatment (33.2%). The incidence was also differed significantly with Maize and Bajra rotation, which recorded 42.8 and 44.6 % disease respectively. Seedling emergence was also high in sorghum and Maize debris incorporated treatments.

Table 3 Effect of different root exudates on per cent germination of sclerotia of *Selerotium rolfsii*

Crop	Root Exudate 1a Diluations			Root Exudate 1 b Diluations		
	1:0	1:1	1:2	1:0	1:1	1:2
Sorghum	0.0	17.5	27.5	0.0	0.0	12.5
Maize	30.0	30.0	37.5	17.5	17.5	20.0
Bajra	50.0	60.0	77.8	50.0	62.5	72.6
Soybean	55.0	72.5	80.0	60.0	80.0	80.0
Control	100.0	100.0	100.0	100.0	100.0	100.0
SEm±	1.0	1.2	1.2	1.3	0.9	1.1
CD (P=0.05)	3.8	4.9	4.9	6.5	3.8	4.7

1a = Exudate collected after 24 hr.; 1b = Exudate collected after 48 hr.

Table 4 Effect of rotational crop debris on groundnut emergence and stem rot incidence

Rotational crop	Seedling emergence(%)	Disease incidence (%)
Sorghum	60.64 (75.00)	33.18 (30.06)
Maize	57.47 (70.00)	42.77 (46.22)
Bajra	56.03 (67.50)	44.60 (49.38)
Soybean	47.18 (52.50)	55.36 (67.32)
Control	47.97 (55.00)	61.48 (76.84)
SEm±	5.90	2.73
CE (P=0.05)	11.0	5.10

Figures in the parenthesis are transformations.

The present investigation revealed that aqueous extracts of *Parthenium hysterophours* and *Polyalthia longifolia* in all concentrations showed significant inhibition of mycelial growth of S. *rolfsii*. This is in agreement with previous work of Annapurna *et al.*, (1983) who have indicated that inhibition was due to antibacterial compounds in plant extracts. Thus, these plants extracts hold promise for incorporation in integrated disease management. The undiluted culture filtrate of T. *harzianum* has reduced the germination of sclerotia significantly. Metabolites of the bioagent are having adverse effect on pathogen's perpetuation. This mechanism may be exploited for the management of the disease to the best of its advantage. Further, the results of present investigations indicated that Sorghum root exudate followed by Maize was highly effective in preventing the germination of sclerotia, a potential source of disease. This suppressive effect may be attributed to the production of water soluble toxic substances and production of hydrocynic acid at root region (Bose, 1933). These crops were also found useful in rotational studies with Groundnut. Cooper (1956) and Wokocha (1988) also reported decline in infection by S.*rolfsii* when Groundnut was grown in rotation with Corn and Wheat. The disease management studies involving these components in IDM in field situation are under progress.

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Physiological analysis of yield variations in rainfed castor (*Ricinus communis* L.)

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Abstract

A study was conducted for two years during *kharif* (1995-97) under rainfed conditions to assess the production potential of five castor genotypes *viz.*, var. Aruna, 48-1, DCS-9 and hybrids: GCH-4, DCH-30. Out of which, 48-1 and GCH-4 exhibited greater yield potential. These two genotypes also recorded significantly higher plant height, node number, LAI, total dry matter and CGR. Though 48-1 was at par with GCH-4 for vegetative growth, its yield of different spike orders was significantly less than hybrid, GCH-4 which could be due to sink limitation which is evident by low capsule number and low HI values.

Key words: Castor, genotypes, growth, physiological analysis, yield

Introduction

Castor (*Ricinus communis* L.) is an important industrial oil of India. This crop is mostly grown in rainfed situations with poor agronomic management. There is wide variation in the productivity of castor, the physiological basis of which has not been investigated. A thorough knowledge of assimilative power, sink capacity and translocation of assimilates help in understanding the variations in productivity. Hence a field experiment was conducted to study various morpho-physiological plant characters and yield variations among five genotypes of castor.

Materials and methods

A field experiment was conducted on alfisols for two years (1995-96, 1996-97) under the rainfed conditions at the experimental farm of the Directorate of Oilseeds Research, Hyderabad to evaluate the production potential of five castor genotypes which included varieties (Aruna, 48-1, DCS-9) and hybrids (GCH-4, DCH-30). The experiment was laid out in a randomized block design with four replications with a spacing of 90 x 30 cm and the plot size was 9.0 x 3.6 m. The crop received the recommended dose of NPK fertilizers (40:40:0 kg N, P_2O_5, K_2O/ha). Half of the N and the entire dose of P were applied as basal dose, while the remaining N was applied at 40 DAS, and an additional 20 kg N was applied after 1st picking. Observations were recorded on various growth characters such as plant height, node number up to primary spike, leaf number, leaf area index, total dry matter at 30 days interval starting from 30 DAS. The seed yield of different spike orders was also recorded.

Results and discussion

Morpho-physiological characters: The data on plant height upto primary spike, node number, leaf number, leaf area index (LAI), total dry matter (TDM) and crop growth rate (CGR) are presented in Table 1. In general, the crop performance in terms of vegetative growth i.e., plant height, node number, leaf number and TDM etc., was more during 1996-97. In 1995-96, height upto primary spike, node number, leaf number and LAI were significantly higher in 48-1 and GCH-4 compared to all other genotypes. In 1996-97, 48-1 recorded significantly higher plant height, node number and LAI, but the leaf number was significantly more in Aruna. Total dry matter was on par in the genotypes 48-1, DCS-9, GCH-4 and DCH-30, but significantly higher than that in the variety Aruna. Crop growth rate was higher in 38-1 (8 g/m^2/d) followed by GCH-4 (7 g/m^2/d). Yield showed positive and significantly higher correlation with leaf number (0.75), LAI (0.76), leaf weight (0.69), spike weight (0.92) and TDM (0.87). Positive association of plant height and number with yield was reported by Muthiah *et al.* (1982).

Yield of different spike orders: Yield is the manifestation of various physiological processes occurring over time in plants. Yield of different spike orders, total seed yield and harvest index (HI) are presented in Table 2. In normal year of 1995-96, primary and secondary order contribution was more than tertiary and quaternary order branches. In 1996-97, yields were very low, as there was severe infestation of secondary and tertiary order spikes with botrytis disease. Primary and quaternary order branches contribution as more to total seed yield than secondary and tertiary order branches. Yield loss from secondary and tertiary order branches was compensated by quaternaries though total yield was less than the year 1995-96. Yields of primary and quaternary order branches were

Table 1 Morpho-physiological characters of different genotypes of castor

Genotype	Height upto primary spike (cm)			Node no. upto primary spike			Leaf number (120 DAS/plant)			Leaf area index (90 DAS)			Total dry matter (g/pl) at harvest			Crop growth rate 90-120 DAS/gm²/d		
	1995-96	1996-97	Mean	1995-96	1996-97	Mean	1995-96	1996-97	Mean	1995-96	1996-97	Mean	1995-96	1996-97	Mean	1995-96	1996-97	Mean
Aruna	50	70	60	10	12	11	41	70	56	1.62	2.27	1.95	111.5	215.7	163.6	7.06	1.58	4.32
48-1	61	103	82	13	16	15	42	49	45	2.67	2.37	2.52	202.9	306.9	254.9	10.36	8.05	9.21
DCS-9	37	50	43	10	12	11	36	49	43	1.21	2.06	1.64	126.6	334.1	230.4	9.45	4.38	6.92
GCH-4	48	73	61	11	13	12	37	44	41	1.81	2.38	2.10	206.7	333.5	270.1	10.86	7.34	9.10
DCH-30	43	45	44	9	10	10	25	47	36	1.39	2.37	1.88	1114.7	333.1	223.9	4.37	0.12	2.25
Mean	48	68		11	13		36	52		1.74	2.29		152.5	304.6		8.45	4.29	
SEm	2.3	7.4		0.71	0.51		3.86	3.15		0.31	0.19		6.61	8.45		2.16	1.02	
CD(P=0.05)	11.4	31.9		3.05	2.18		11.90	13.60		0.97	NS		8.67	36.53		6.65	2.47	

Table 2 Yield (g/m²) of different spike orders in varieties and hybrids of castor

Genotype	Primaries			Secondaries			Tertiaries			Quaternaries			Total seed yield (g/m²)			Capsule number/plant			Harvest index (%)		
	1995-96	1996-97	Mean	1995-96	1996-97	Mean	1995-96	1996-97	Mean	1995-96	1996-97	Mean	1995-96	1996-97	Mean				1995-96	1996-97	Mean
Aruna	59	32	45.5	77	14	45.5	22	3	12.5	17	16	16.5	173.4	64.0	118.7	142	77	110	41.9	8.0	24.9
48-1	59	26	44.5	101	24	62.5	67	27	47.0	39	61	50.0	266.3	139.5	202.9	127	108	118	35.6	12.3	24.0
DCS-9	59	30	44.5	81	6	43.5	30	2	16	29	29	29.0	198.7	67.3	133.0	107	58	83	42.4	5.4	23.9
GCH-4	88	59	73.5	143	14	78.5	68	22	45	52	67	59.5	351.7	162.1	256.9	154	114	134	45.9	13.1	29.5
DCH-30	63	65	64	85	12	48	19	3	11	26	26	26	190.3	105.6	148.0	115	67	91	44.8	8.6	26.7
Mean	65	43		97	14		41	11		33	40		236.1	107.7		129.0	85.0		42.1	9.6	
SEm	5.2	4.3		15.0	1.1		3.9	0.7		0.9	1.3		19.63	8.32		10.66	10.75		2.53	1.09	
CD (P=0.05)	22.4	18.7		46.2	4.7		17.15	3.18		4.05	5.74		84.79	41.72		NS	35.07		NS	NS	

significantly more in hybrid GCH-4 in 1995-96. The results were non-significant among the other genotypes studied. GCH-4 and 48-1 recorded significantly higher seed yield of secondary and tertiary order branches and total sed yield compared to other genotypes during this year. In 1996-97, primary seed yield was significantly more in hybrids GCH-4 and DCH-30 and quaternary seed yields were more in GCH-4. The botrytis infestation was relatively less in 48-1, so this variety recorded significantly higher seed yield of secondary and tertiary order branches. Total seed yield of GCH-4, DCH-30 and 48-1 were on par and significantly more than Aruna and DCS-9. Distinct yield variation in various orders of inflorescence in castor was also reported by Weiss (2000). HI values were non-significant among the different genotypes studied. In general, 48-1 had significantly higher vegetative growth in terms of leaf number, LAI, leaf, stem dry weight (data not presented). Yield of different spike orders and total seed yield were significantly lower than GCH-4. This shows that there might be sink limitation or poor translocation of assimilates from source to sink which is evident by low capsule number than GCH-4. Bhatt and Reddy (1981) reported a positive and direct effect of number of capsules per spike on seed yield per plant. Uprety et al. (1979) also indicated that grain yield in cowpea was not only influenced by TDM but also the manner in which the photosynthates were distributed within the plant. If there is no sink limitation, the performance of variety 48-1 is on par with the hybrid GCH-4.

From the above results, it could be inferred that among the different genotypes tested, variety 48-1 recorded significantly higher vegetative growth than hybrid GCH-4, but, its yield of different spike orders was significantly lower than GCH-4, which showed that there might be sink limitation or poor translocation of assimilates from source to sink which is evident by low capsule number. Thus, if there is no sink limitation, it has efficient translocation of assimilates, variety 48-1 is on par with hybrid GCH-4 and superior to hybrid DCH-30.

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Conjunctive use of surface water with saline ground water in safflower (*Carthamus tinctorius* L.) on salt affected black soils

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Abstract

A field experiment was conducted during winter 1997-98 and 1998-99 at Khanpur farm of CSSRI, RRS, Anand, Gujarat to study the effect of conjunctive use of saline ground water and best available water (BAW) on the yield and yield attributing characteristics of safflower (*Carthamus tinctorius* L.) cv. Bhima. The results indicated that the branching stage is more sensitive to saline water irrigation followed by flowering and grain filling stage. If one BAW irrigation is available, it should be applied at branching stage, if two BAW irrigations are available, these should be applied at branching and flowering stages. There is net reduction in salinity in all the treatments as compared to fallow land.

Key words : Safflower, conjunctive use, irrigation, salinity

Introduction

Safflower, *Carthamus tinctorius* L. a *rabi* season oilseed crop, is capable of producing good yield even on marginal land in drought condition (Bansal and Katara, 1993). It is mostly grown as dry land crop on conserved moisture, but seed yield increased by 83 % and 183% respectively with application of 2 and 3 irrigation (Anonymous, 1983-85). This crop can also be grown on saline black soil with salinity 4 dSm^{-1} (Singh and Bhargava, 1994). There are reports that 90% seed yield of safflower (in comparison of yield of best available water) could be achieved with waters of EC (Electrical conductivity) of 3.8 to 4.2 dSm^{-1} . Hence there is great scope for utilization of shallow saline ground water for raising the salt tolerant crop like safflower. Saline ground water can be used by three different methods (1) where the salinity of the ground water is below the threshold value this can directly be applied for the crop (2) when the ground water salinity is above the threshold value, this can be blended with best available water (BAW) (3) applying of the fresh water (BAW) at salinity sensitive growth stages and making use of saline water at comparative salt tolerant stages. In the third option, there is scope to optimize the quality and quantity of saline water to be applied to the crops looking into both the availability of saline water and the soil type and crop conditions. The present investigation was carried out to identify (1) the sensitive growth stages of safflower to saline water application (2) to determine the ideal combination of saline water and BAW for optimum crop yield and checking the further increase in soil salinity.

Material and methods

A field experiment was conducted during the *rabi* season of 1997-98 and 1998-99 at CSSRI, RRS, Khanpur, Anand to study the effect of conjunctive use of saline water and BAW on the yield and yield attributes of safflower (*Carthamus tinctorius* L. cv Bhima). The experimental soils have sand 29%, silt 30.8%, clay 40.2% and pH 7.5. The electrical conductivity, SAR of soil saturation extract, the ground water salinity and ground water depth are presented in the figure 1.A total of three irrigation were applied at branching, flower initiation and grain filling stage using the saline ground water of 4 dSm^{-1} and best available water (BAW) in rotation at different crop growth stages. The treatment combinations were T_1 - BAW at all the three stages; T_2 - saline water at branching stage (BR) + rest BAW; T_3 - saline water at flower initiation stage (F_1) + rest BAW; T_4 - saline water at grain filling stage (GF) + rest BAW; T_5 - saline water at BR and F_1 + rest BAW; T_6 - saline water at BR and GF + rest BAW; T_7 - saline water at F_1 and GF + rest BAW; T_8 - saline water at all three stages. The treatment combinations were replicated thrice in Randomized Block Design. The plot size was 2.5 m x 2.5 m, each plot was separated by two meter spacing in order to check the seepage from neighboring plot . Five cm each irrigation was applied at the branching and flower initiation stages and 6 cm irrigation was applied at grain filling stage. Various yield parameters such as primary and secondary branches per plant, height, number of heads per plant, 1000-seed weight, seed yield per hectare were recorded. The seed oil content was estimated by using the NMR . The composite soil sample was collected before the sowing and after the crop harvest and analyzed for pH, EC and SAR (Richards, 1954).

Results and discussion

The number of primary and secondary branches per plant, plant height, number of heads per plant, 1000 seed weight decreased with increase in the number of saline water application (Table 1). At a constant level of saline water irrigation, irrespective of their application at any stage of crop growth, there was no significant difference in the plant height, number of branches per plant. At a constant level of saline water application, saline water applied at branching stage (T_2) resulted decrease in the 1000-seed weight and number of heads per plant as compared to the saline water application at other two stages (T_3 and T_4). The seed yield and stover yield decreased with increased in frequency of saline water application and highest yield of 825 kg/ha seed and 2805 kg/ha stover was recorded with the application of three best available water (T_1). Application of one saline water at grain filling stage and rest two BAW (T_4) resulted significantly higher seed yield of 775 kg/ha over the treatment (T_2) 745 kg/ha. Similarly application of saline water at flower initiation and grain filling stages (T_7) resulted in higher seed yield of 688 kg/ha was recorded in the treatments (T_1) and (T_8),respectively. Up to two saline water applications, there was no significant difference in seed oil content (%) among the treatments. However, there was significant reduction in the oil content (T_8) as compared to other treatments. The results revealed that saline water irrigation given at early stages showed a strong effect on safflower, where as the crop exposed at grain filling stage proved to be more tolerant to saline water irrigation. The results also revealed that the salt tolerance of different stages of safflower are in the order of grain filling stage > flower initiation > branching. Under high ground water situation flowering and pod formation stages of Indian mustard (*Brassica juncea*) are relatively more sensitive to saline water irrigation (Nayak *et al.*, 2001). The seed formation stages of Dill (*Anethum graveolens*) is more sensitive to saline water irrigation than vegetative stage (Nayak *et al.*, 2000).

Table 1 Effect of saline water irrigation on the yield and yield attributes of Safflower (Pooled data of both the years)

Treatment	Plant height (cm)	No. of branches/ plant		No. of head/ plant	1000 seed wt. (g)	Yield (kg/ha)		Oil	
		Primary	Secondary			Seed	Stover	Yield (kg/ha)	%
T_1	83	14	34	31	46	825	2805	241	29
T_2	72	12	26	25	45	745	2559	212	29
T_3	72	11	27	26	45	765	2590	220	29
T_4	71	12	27	27	46	775	2585	225	29
T_5	68	9	21	19	44	635	2178	178	28
T_6	68	10	23	22	44	685	2200	194	28
T_7	69	10	23	22	44	688	2208	195	28
T_8	62	10	20	18	43	495	1649	136	28
CD (P=0.05)	11	1.1	0.9	1.1	0.5	21	92	12	1.2

The surface soil salinity of all the treatments at the time of harvest (Fig. 2) increased over control with a increase in the frequency of saline water irrigation. However, there was a net reduction in the surface soil salinity at the time of harvest in all the treatments (Fig. 2) over fallow land (Fig. 1). Hence there is a little scope for further increase in the soil salinity with the use of poor quality water for safflower cultivation.

The above study revealed that in the absence of good quality water, safflower can be grown on saline black soil with the use of saline water in conjunction with the best available water. The branching and flowering stages are the most critical stages for saline water application. Therefore, it is suggested that if one BAW irrigation is available, it should be applied at branching stage, if two BAW irrigation are available, they should be applied at branching and flowering stages.

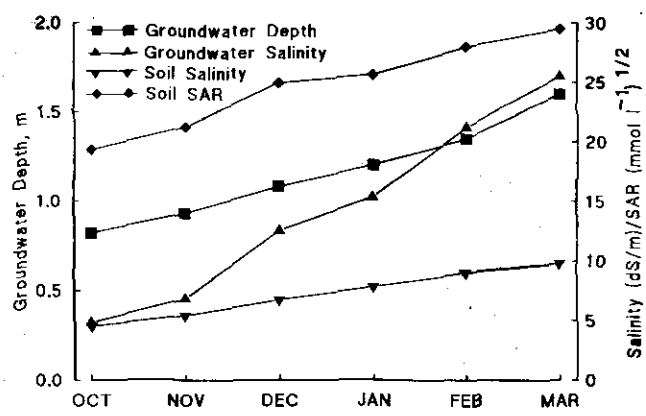

Fig 1 Temporal variation of ground water depth, salinity and soil

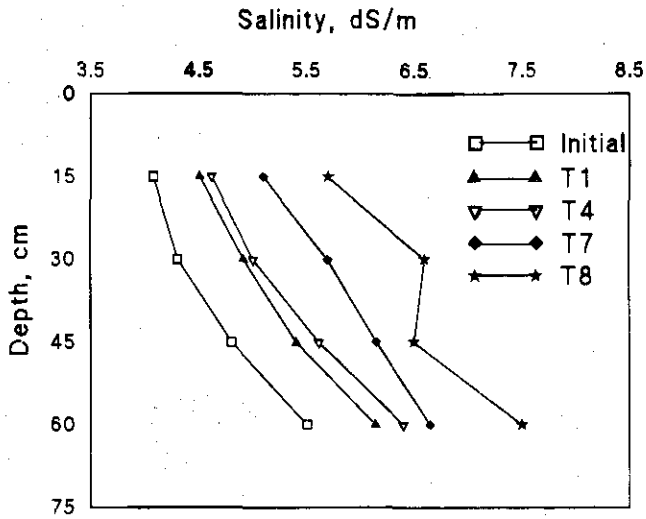

Fig 2 **Effect of conjunctive use of surface and ground water on the salinity under safflower crop**

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Short communication

Effect of salinity on germination and early seedling growth of mustard [*Brassica juncea* (L.) Czern & Coss]

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Among the oilseed crops, mustard [*Brassica juncea* (L.) Czern & Coss] is an important *rabi* oilseed crop which is widely grown in the northern belt of the country. About 1.2 million hectares land is salt affected in Uttar Pradesh. Indian mustard has some tolerance to high concentration of salts in these soils though the germination of the seed is adversely affected. The inability of a given variety to germinate and establish the seedling under such situation is a major limiting factor in the crop production. The salt tolerance in mustard varies from variety to variety (Kumar and Malik, 1983; Chopra and Chopra, 1992). An investigation was therefore, undertaken on various mustard genotypes to find out the effect of salinity on germination and seedling growth stages and to identify genotypes which have better tolerance for the said situation.

An experiment was conducted for two years i.e., 1992-93 and 1993-94 at the Oilseed Research Unit, C.S. Azad University of Agriculture & Technology, Kanpur under laboratory conditions in petridishes adopting completely randomized design with eleven mustard genotypes *viz.*, Varuna, Rohini, Vardan, Vaibhav, RK 8502, RK 8604, RK 8605, RH 8814, RH 8816, RH 8602 and NDR 8501 at three concentrations of salinity *viz.*, 150, 225 and 300 me/L along with control (distilled water) each treatment repeated four times. Two filter paper circles of 10 cm diameter were placed at the bottom of glass petridishes and duly moistened with a thin film of salt solution of desired salinity. Twenty five seeds of uniform size, treated with 0.02 % $HgCl_2$ solution to avoid fungus growth were evenly placed on the filter paper in each petridish. The petridishes contained 10 ml of distilled water or the solution of either of the three concentrations of salinity. The salt solutions were prepared by dissolving NaCl, $CaCl_2$, $MgCl_2$ and $MgSO_4$ (using Na : Ca + Mg ratio as 1:1, Ca : Mg as 1:3 and Cl : SO_4 ratio as 7:3 on meL^{-1} basis) in distilled water. Seed germination was recorded daily up to 10 days after sowing. In the end, observations were recorded on the root and shoot length. The samples were dried in an electric oven to a constant weight at 70°C and dry weights were recorded on per five seedling basis.

The seedling vigour index was computed by adopting the formula suggested by Abdul-Baki and Anderson (1973) and expressed as number.

Seedling vigour index = Germination % x mean dry weight of seedling

The speed of germination was calculated by using the formula suggested by Mageuive (1962).

Speed of germination = (No. of seeds germination on/first day) + (No. of seeds germination on / second day) + ... + (No. of seeds germinated on / final day)

In general, germination percentage declined in all the genotypes with increase in salinity (Table 1). However, few genotypes *viz.*, Varuna, NDR-8501 and RH-8816 recorded sufficiently higher (90-91%) germination than the other genotypes tested at 225 me/L but at higher level of salinity (300 me/L) Varuna maintained its superiority over all the genotypes screened. At lower salinity level (150 meL^{-1}) a number of genotypes *viz.*, RH-8816, NDR-8501, Varuna, Vaibhav, RK-8605 and RH-8814 recorded more than 90% germination. Rai (1977) observed similar effects of salinity on germination of Indian mustard and safflower seeds.

The shoot length was also found to decrease in all genotypes with increase in salinity (Table 1). The genotype NDR-8501 which is a released variety for salt affected soils, recorded maximum (5.1 cm) shoot length followed by Varuna (4.2 cm) which maintained its superiority over the other genotypes. Cultivars NDR-8501, Varuna and RK-8605 produced the maximum shoot lengths as compared to other genotypes at all salinity levels.

Genotypes NDR-8501, Varuna, RK-8605, RH-8602 and RH-8816 showed higher root lengths, while Vaibhav and RK-8604 produced the shortest root lengths (Table 1) at all levels of salinity. At lower level of salinity (150 me/L), RK-8605 maintained maximum root length as in control. Alka *et al.* (1981) observed decrease in shoot and root lengths with the increase in salinity levels in barley crop. Similar results were also observed in the present case in respect of root length of mustard.

Table 1 Salinity effect on germination percentage, shoot and root lengths in mustard (two years pooled data)

Genotypes/salinity (me/L)	Germination					Shoot length (cm)					Root length (cm)				
	0	150	225	300	Mean	0	150	225	300	Mean	0	150	225	300	Mean
Varuna	100	96	90	79	91.3	6.1	5.0	3.8	2.1	4.2	7.0	6.3	3.4	2.4	4.7
Rohini	96	90	82	58	81.5	4.5	3.5	2.1	2.0	3.0	6.5	5.0	2.0	2.1	3.9
Vardan	98	96	82	63	84.7	4.1	3.4	2.5	2.1	3.0	6.2	3.8	2.2	1.5	3.4
Vaibhav	98	96	76	56	81.5	4.8	4.3	2.9	2.1	3.5	4.4	3.0	1.9	1.5	2.7
RK-8502	88	84	52	37	65.3	4.5	3.9	2.5	2.0	3.2	5.6	3.8	2.4	1.8	3.4
RK-8604	92	79	66	55	73.0	3.8	2.1	2.1	1.8	2.4	5.1	2.5	1.9	1.6	2.7
RK-8605	94	94	84	64	84.0	5.6	4.1	3.6	2.6	3.9	6.6	6.6	2.8	2.3	4.6
RK-8602	78	78	62	48	66.5	3.7	2.9	2.2	1.1	2.4	7.5	6.1	2.8	2.3	4.6
RK-8814	100	95	78	58	82.7	4.5	3.5	2.9	2.1	3.2	5.7	3.8	2.8	1.8	3.5
RK-8816	100	100	91	64	88.7	4.4	3.5	2.8	2.1	3.2	6.6	5.3	3.3	2.2	4.3
NDR-8501	100	98	91	70	89.7	6.3	6.1	5.1	3.0	5.1	6.9	6.1	4.0	2.6	4.9
Mean	95.4	91.9	77.1	59.4		4.7	3.9	3.0	2.2		6.1	4.7	2.8	2.0	
CD (P=0.05)					2.5					0.1					0.1
Variety (V)					1.5					0.1					0.1
Salinity (S) V x S					2.1					0.1					0.1

Table 2 Salinity effect on dry weight (mg) of seedlings, speed of germination and seedling vigour index in mustard (two years pooled data)

Genotypes/salinity (me/L)	Dry weight (mg)/5 seedlings					Speed of germination					Seedling vigour index				
	0	150	225	300	Mean	0	150	225	300	Mean	0	150	225	300	Mean
Varuna	34.2	29.6	25.0	24.2	28.2	23.9	19.3	15.6	11.1	17.4	681.7	569.8	450.0	384.2	521.4
Rohini	31.2	25.1	23.0	20.7	25.0	20.7	15.8	09.5	08.8	13.6	599.6	451.5	381.5	249.9	420.6
Vardan	23.7	18.9	16.0	14.0	18.1	22.5	18.3	11.5	09.3	15.4	464.2	361.5	257.6	176.8	315.0
Vaibhav	33.6	29.4	24.5	16.5	26.0	23.6	18.6	12.9	08.0	15.7	658.5	564.8	370.4	224.4	454.5
RK-8502	26.1	21.0	18.7	14.9	20.1	20.5	18.7	10.4	08.5	14.5	463.3	350.4	233.0	118.2	291.2
RK-8604	25.5	21.1	18.2	14.1	19.7	22.2	15.6	11.4	07.6	14.2	466.0	333.3	245.3	171.2	303.9
RK-8605	29.0	25.9	22.5	21.6	24.7	23.0	20.7	13.5	10.1	16.8	592.0	512.9	360.6	256.8	430.5
RK-8602	24.2	20.7	17.5	12.4	18.7	21.0	19.2	13.9	09.0	15.7	370.5	321.0	219.6	130.9	260.5
RK-8814	26.5	22.7	20.1	15.7	21.2	21.4	16.1	11.4	08.3	14.3	530.0	431.8	316.6	193.3	367.9
RK-8816	26.7	23.1	20.7	18.0	22.1	20.2	19.1	14.8	08.7	15.7	535.0	446.7	379.0	239.8	400.1
NDR-8501	31.2	27.6	25.1	24.5	27.1	24.8	20.5	15.0	12.8	18.2	625.0	539.7	456.2	380.0	500.0
Mean	28.4	24.1	21.0	17.8		22.1	18.4	12.7	09.2		544.1	443.9	333.6	229.5	
CD (P=0.05)					0.9					0.7					17.6
Variety (V)					0.6					0.4					10.6
Salinity (S) V x S					0.8					0.6					15.0

The mean dry weight of five seedlings (Table 2) was recorded for all the genotypes. It was observed that as salinity levels increased, dry weight of seedlings significantly decreased in all the genotypes screened. Genotypes Varuna, NDR-8501, Vaibhav, Rohini and RK-8605 showed higher dry weights as compared to other genotypes at all levels of salinity. Maliwal and Paliwal (1984) observed similar effects of salinity on seedlings growth in various cultivars of maize, rice, sorghum, cotton and tobacco crops.

From the data presented in Table 2, it is evident that, in general, speed of germination decreased with increase in salinity level more or less in all the genotypes screened. This was more pronounced at higher salinity levels of 225 and 300 me/L. As speed of germination represents the earliness in completion of germination, decrease in its value exhibits the delayed germination of crop. Genotypes NDR-8501, Varuna and RK-8605 exhibit significantly higher speed of germination, while Rohini, RK-8604 and RH-8814 showed lower values for speed of germination at all levels of salinity. The highest speed of germination (20.7) was recorded by RK-8605 at lower salinity level (150 me/L) but at higher level (300 me/L), the values of 10.1, 12.8 and 11.1 were recorded in RK-8605, NDR-8501 and Varuna, respectively which maintained their superiority over the other genotypes. These results are in conformity

of the results of Abel and Mackerize (1964) who reported that salinity decreased the rate of emergence in soybean.

Seedling vigour index decreased significantly in all genotypes with increase in salinity (Table 2). Among the screened genotypes, Varuna and NDR-8501 showed significantly higher seedling vigour index whereas, RH-8602, RK-8502 and RK-8604 exhibited lower seedling vigour index.

The interaction effect of the treatment *vis-a-vis* genotypes presented in the Table 1 and 2 clearly showed a favourable response in respect of all the parameters studied and it is concluded that Varuna and NDR-8501 are the best cultivars of mustard suitable for salt affected soils.

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Short communication

Selection for low glucosinolate content in brassica oilseeds under low sulphur application can be self defeating

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Glucosinolates in cultivars of Indian mustard is likely to become a strong non -tariff barrier for lucrative mustard meal export market, emphasis now is on development of low glucosinolate cultivars. The alleles for low glucosinolate content have now been introgressed in *Brassica juncea* from B.campestris cv. Tobin (Banga, 1996). A major problem, encountered in several breeding programmes in India is the unstability of glucosinolate content over generations and locations in adequately inbreeding lines of mustard. As most important function of glucosinolates is to act as storage for sulphur via enzymatic recycling (Schnng, 1993),its accumulations in plants is strongly influenced by sulphur supply. In this communication, we report data from analysis of some low glucosinolate mustard genotypes to emphasize that selection environment for identification of suitable donors and screening of segregating generations must carry elevated sulphur levels in the soil.

Twelve glucosinolate lines were grown under high sulphur application (40 and 80 kg/ha) to study its impact on glucosinolate expression. Total meal glucosinolates was estimated as per thymol method (Brezinzki and Mendelewski, 1984).

Table 1 Variation for glucosinolate content (µg defatted meal) under different rates of sulphur application in the soil

Genotype	Sulphur (40 kg/ha)	Sulphur (80 kg/ha)
CM 60-3	42.8	44.3
CM 60-8	24.4	25.0
CM 60-12	44.3	48.3
CM 60-18	19.9	23.5
CM 60-35	42.8	48.2
CM 4-6-9	33.6	43.6
CM 59-42-21	29.0	30.0
CM 59-42-39	19.9	19.3
CM 59-42-65	24.4	35.0
CM 5-34-6	24.4	25.0
CM 99-34-6	32.0	40.5
CM 99-34-13	16.8	16.2

Sulphur application influenced glucosinolate expression in majority of genotypes, at least for three (CM 4-6-9, CM 59-42-65 and CM 99-34-6) it was highly significant (Table 1). Increased content of glucosinolates under high sulphur application can be attributed to be the influence of certain modifiers with low penetrance. Such modifiers can modulate the expression of low glucosinolate alleles and result in genotypic unstability. Genotypes showing variable values of glucosinolates under high sulphur application should not be used as donor for low glucosinolate. According to past studies, the pod walls are the major sites of biosynthesis of glucosinolate in seeds. A block in pathway of glucosinolate biosynthsis in pod walls of double low varieties would result in low concentration of glucosinolates in seeds and a large accumulation of sulphur, mainly as sulphate in pod walls. A leaky metabolic block in the unstable low glucosinolate types (CM 4-6-9, CM 59-42-65 and CM 99-34-6) can result in the unstability of this character under varying sulphur conditions causing some translocation of sulphur from pod walls of developing seeds. Such a positive correlation between sulphur and glucosinolate has been earlier reported (Schnng and Heneklavs, 1994). Therefore, we strongly advocate that screening for stable donors and segregation populations from low x high glucosinolate crosses must be carried out under high sulphur application to eliminate the influence of modifier genes and to improve efficiency of selection for low glucosinolate.

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Short communication

Effect of planting geometry on growth and yield of sunflower (*Helianthus annuus* L.)

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Optimum spacing of plants between and within the rows is of paramount importance in sunflower. The information on this aspect in *kharif* season for sandy soils of southern Telangana region of Andhra Pradesh is meagre. Hence, an attempt was made to determine the ideal spacing requirement for sunflower to realise higher yield.

A field experiment was conducted during *Kharif* season of 1996 on a sandy loam soil at Agricultural College campus of ANGRAU Rajendranagar, Hyderabad. The treatments consisted of five inter-row spacings - 30 cm, 45 cm, 60 cm, 75 cm, 90 cm and three intra-row spacings - 10 cm, 20 cm, and 30 cm. Thus 15 treatment combinations were laid out in a randomised block design with three replications. The plot size was 6.0 m x 4.5 m. The soil was slightly alkaline in reaction (pH 8.1) having poor fertility with low available nitrogen (169 kg/ha N). Nitrogen was applied through urea in two splits, one-third as basal and other two-third at 30 days after sowing. Phosphorus and potassium were applied basally in the form of single super phosphate and muriate of potash @ 60 and 40 kg/ha P_2O and K_2O_5. The test variety Morden was sown on 12.08.96. The rainfall received during the crop was 530.3 mm spread over 27 rainy days. The crop growing season was harvested on 17.11.96.

Spacings exhibited significant influence on crop growth, yield components and yield of sunflower (Table 1). The plants reduced in height and produced less number of leaves with successive increase in now width by 15 cm from 30 to 90 cm. This trend was reverse for leaf area per plant indicating large expansion of leaf lamina. The capitulum diameter also extended enormously and thereby accommodated more number of seeds. The larger leaf area per plant due to the competition free environment probably enabled the crop to use the growth promoting resources efficiently which contributed to improved size of the capitulum and number of seeds. The translocation of metabolites from source to sink might have also been greatly improved by adopting wider row spacings as indicated by the substantial improvement in 100-seed weight. The seed yield per plant increased with winder rows. Similar observations were also recorded by Narwal and Malik (1986). Sunflower produced seed yield of 36.3 g/plant at a spacing of 30 cm. The per plant yield increased more than two folds to 80.0 g at a spacing of 90 cm between the rows. But, maximum seed yield of 1072 and 972 kg/ha was realized in sunflower spaced at 45 cm and 60 cm between the rows. The yield reduced significantly at 75 cm and 90 cm row spacing. This indicated that the per hectare production was overcompensated by the large number of plants per unit area at 45 cm or 60 cm despite low yield per plant than at 75 cm or 90 cm row spacing. The crop sown at a spacing of 30 cm also produced significantly low yield per hectare (815 kg/ha). This reduction may be due to intense competition that decreased the seed yield per plant more severely. Hence more number of plants per unit area in this spacing could not compensate for the yield loss/plant.

Sunflower grown at a spacing of 20 cm between the plants within the rows produced significantly more number of leaves with larger area than at 30 cm spacing. But, the capitulum diameter increased significantly, accommodated more number of seeds, increased the 100-seed weight and enhanced the seed yield per plant at 30 cm intra-row spacing. In spite of these beneficial effects the per plant yield did not compensate the higher yield per hectare due tp the low plant population per unit area than the yield obtained from the crop spaced at 10 or 20 cm.

On the basis of the above experimental results, it can be indicated that the 45 cm or 60 cm inter-row spacing and 10 cm or 20 cm intra-row spacing may be optimum for realizing optimum yield of rainfed sunflower variety Morden grown on poor fertility alfisols of southern Telangana zone of Andhra Pradesh.

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Table 1 Growth and yield of rainfed sunflower as influence by different spacing between and within the rows

Treatment	Plant height (cm)	Leaves/ plant	Leaf area/ plant (cm^2)	Capitulum diameter (cm)	Seeds/ capitulum	100-seed weight (g)	Seed yield/ plant (g)	Seed yield (kg/ha)
Inter-row spacing (cm)								
30	83.6	83.20	1619	12.3	549	4.0	36.3	815
45	81.4	20.71	1645	14.6	625	5.1	40.8	1072
60	77.2	19.21	1773	15.4	780	5.7	55.7	972
75	74.5	17.88	2049	17.4	961	5.9	62.3	847
90	74.2	15.20	2093	20	1300	6.0	80.0	723
SEm±	4.2	0.21	43	0.5	49	0.1	2.9	052
CD (P=0.05)	8.7	0.42	87	0.9	100	0.2	5.8	105
Intra-row spacing (cm)								
10	78	20	1767	15.4	775	5.2	53.6	952
20	80	20	1971	15.9	805	5.3	53.0	931
30	77	19	1769	16.6	949	5.5	58.5	774
SEm±	3.3	0.16	33	0.4	38	0.1	2.2	40
CD (P=0.05)	NS	0.33	68	0.7	78	0.14	4.5	82
Interaction								
SEm±	7.4	0.36	74	0.77	85	0.15	4.9	89
CD (P=0.05)	NS	0.74	151	NS	174	0.32	NS	183

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Short communication

Effect of nitrogen scheduling on yield and economics of GCH-5 castor under irrigated condition

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Castor is an important non edible oilseed crop of the state and country. Nitrogenous fertilizers play most important role in crop production per unit area and are economically remunerative in castor. The application of 75 kg N/ha in three splits was recommended for castor to get optimum yield and maximum net profit in North Gujarat under irrigated conditions Patel *et al.* (1991).

GSC-5 is a recently released hybrid for irrigated conditions for Gujarat state. Which gives about 17.7 % higher yields as compared to the presently cultivated hybrid GCH-4. The hybrid has higher vegetative growth as compared to currently grown hybrids in the state. It is necessary to find out the optimum nitrogen level for this hybrid to achieve the maximum yield potential.

The experiment was conducted during the *kharif* season of 1995 through 1997 at Main Castor and Mustard Research Sation, Gujarat Agricultural University, Sardar Krushinagar. The soil had 176 kg available N, 43.27 kg available phosphorus/ha, 217 kg available potassium/ha and pH 7.8.

The experiment was laid out in randomised block design with 3 replications. The details of N rates and its time of application are given in Table 1. Castor hybrid "GCH-5" was dibbled at spacing of 90 cm x 60 cm. A basal dose of phosphorus @ 50 kg/ha was applied through DAP. During crop growth period the amount of rain received in rainy season was 582, 349 and 810 mm in 27, 26 and 24 rainy days respectively in 1995, 1996 and 1997, respectively.

Castor showed significant response to nitrogen application during all the years and also in pooled analysis. Similarly, DOR (1995) and Patel (1994) reported that castor responded to higher N application upto 125 kg/ha. The pooled data however, revealed that treatment T_{10} (N 200, 50 kg N/ha as basal and 30 kg N/ha at 40,70,100,130 & 150 DAS) gave the highest seed yield of 4307 kg/ha but it was at par with T_3, T_9 and T_{11}. The results are in conformity with the findings of DOR (1995), Joshi *et al.* (1980) and Patel (1985).

Economics of the different treatments (Table 2) showed that the maximum additional net returns (Rs.14059/ha) were recorded with the application of 200 kg N/ha (T_{10}) in six (50 kg N/ha as basal and 30 kg N/ha at 40, 70, 100, 130 & 150 DAS) splits. The highest net ICBR (1:28.92) was, however, observed with the application of 120 kg N/ha in three equal splits (40 kg N/ha as basal and at 40 and 100 DAS).

It was concluded that considering the yield and net ICBR, application of 120 kg N/ha (40 kg N/ha as basal and at 40 and 100 DAS, along with 50 kg P_2O_5/ha to castor hybrid GCH-5 is recommended under irrigated conditions in North Gujarat.

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Table 1 Castor seed yield (kg/ha) as influenced by Nitrogen levels and it time of application

Treatments N (Kg/ha)	Time of Nitrogen application (DAS)						Yield (Kg/ha)			
	Basal	40	70	100	130	150	1995	1996	1997	Pooled
80 (3 Splits)	40	20	-	20	-	-	2478	3560	2492	2843
80 (6 Splits)	40	8	8	8	8	8	2703	3748	2510	2987
120 (3 Splits)	40	40	-	40	-	-	4393	4500	3098	3997
120 (6 Splits)	40	16	16	16	16	16	3377	3785	2865	3343
120 (4 Splits	40	20	-	30	-	30	3288	3656	2808	3251
160 (4 Splits)	40	40	-	40	-	40	4241	4154	2835	3743
160 (6 Splits)	40	24	24	24	24	24	3898	4178	2993	3690
160 (5 Splits)	40	30	30	-	30	30	3582	4068	2914	3522
200 (4 Splits)	50	50	-	50	-	50	3912	4329	3584	3941
200 (6 Splits)	50	50	30	30	30	30	4251	4659	4011	4307
200 (6 Splits)	50	20	45	20	45	20	3860	4171	3650	3894
75 (3 Splits)	37.5	18.75	18.75	-	-	-	3083	3492	2682	3086
CD (P=0.05)							584.2	584.9	452.5	429.8
Y X T										524.7

***Table 2* Economics of different treatments**

N levels (kg/ha)	*Seed yield* (kg/ha)	Additional yield (kg/ha) over lowest level	Additional cost (Rs/ha) over lowest level	Incremental benefit over lowest level (Rs/ha)	Additional net return over lowest level (Rs/ha)	Net ICBR
80	2843	-	-	-	-	-
80	2987	-	-	-	-	-
120	3997	911	380	11388	11008	28.96
120	3343	257	530	3213	2683	5.06
120	3251	165	430	2063	1633	3.80
160	3743	657	767	8213	7446	9.70
160	3690	604	867	7550	6683	7.70
160	3522	436	817	5450	4633	5.67
200	3941	855	1104	10688	9584	8.68
200	4307	1221	1204	15263	14059	11.67
200	3894	808	1204	10100	8896	7.38
75	3086	-	-	-	-	-

Prices of inputs : Rs/ha
Urea : 3.88
DAP : 8.30

Labour charges : Rs. 50/day
Castor seed : Rs. 12.50/kg

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Short communication

Effect of irrigation schedules and moisture conservation practices on seed yield and water use efficiency of sunflower (*Helianthus annuus* L.)

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A field experiment was conducted during the winter season of 1995-96 at IGAU Raipur to find out suitable irrigation schedule and appropriate moisture conservation practice for the efficient use of water in sunflower. The soil of experimental field was clayey having field capacity, permanent wilting point and bulk density 28.94%, 16.81 and 1.22 q/cc, respectively. The treatments comprised with four irrigation schedules *viz.* Irrigation at 0.8 IW:CPE ratio, irrigation at 0.4 IW : CPE ratio, irrigations at bud initiation (BI) and flower development stages (BI+FD) and irrigation at flower initiation stage (FI) and three moisture conservation practices *viz.*, ridges and furrows (RF), rice straw mulching (RSM) @ 6 t/ha and soil mulching (SM). The experiment was laid out in strip plot design with three replications having irrigation schedule as main and moisture conservation practices as sub-plot treatments. The "Morden" variety of sunflower was sown on December 31, 1995 and harvested on April 24, 1996. A pre sowing irrigation of 6 cm was given to all the treatments. Thereafter 6 cm depth was maintained for irrigation schedule treatment of 0.8 and 0.4 IW:CPE and 8 cm for irrigation given at BI + FD and FI. The rainfall of 2.98 cm was received during the crop period.

The higher seed yield was recorded with and IW:CPE ratio of 0.8 followed by IW:CPE of 0.4 and irrigation applied at BI+FD and FI stage only and the differences were significant at each level. Higher yield obtained under 0.8 IW:CPE ratio resulted from higher number of seeds per head, 500 - seed weight and lower sterility percentage (Table 1). These yield components contributed towards the higher seed yield. Similar findings were also reported by Singh *et al.* (1995). Irrigation scheduled at 0.8 IW:CPE ratio recorded the highest irrigation and water requirement followed by irrigation given at BI+FD, 0.4 IW:CPE and FI, respectively. The higher water use efficiency (WUE) at an IW:CPE ratio of 0.4 was stemmed from less water loss due to evapotranspiration under limited supply. The findings are in accordance with those of Patel and Singh(1980).

Application of rice straw mulching (RSM) significantly increased the number seeds per head, 500-seed weight and seed yield (Table 1). Rice straw mulching reduced the soil temperature and evaporation of soil water provided soil moisture for a longer period, which improved the yield attributes and finally seed yield. The beneficial role of rice straw mulch for moisture conservation has been also reported by Das *et al.* (1994).

Interaction between irrigation schedules and moisture conservation practices revealed that irrigation at 0.8 IW:CPE along with rice mulching produced the maximum seed yield of 2229 kg/ha and was significantly superior over rest of the treatment combinations (Table 2). The sterility percentage also gave the similar interaction effects.

It was concluded that sunflower during winter season needs to be irrigated at 0.8 IW:CPE ratio to harvest the maximum seed yield. The application of rice straw mulching @ 6 t/ha appeared the most effective for moisture conservation for sunflower.

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Table 1 Effect of irrigation schedules and moisture conservation practices on seed yield, irrigation (IR) and water requirement (WR) and water use efficiency (WUE) of sunflower

Treatment	Seeds/ head (no)	Sterility (%)	500-seed weight (g)	Seed yield (kg/ha)	IR (cm)	WR (cm)	WUE (kg/ha-cm)
Irrigation schedule							
IW:CPE 0.8	924	17.60	38	2048	36	41.34	49.53
IW:CPE 0.4	818	22.34	34	1696	18	23.34	72.68
BI+FD	865	28.62	33	1571	22	27.34	57.48
FI	792	35.51	31	1154	14	19.34	59.69
CD (P=0.05)	83	3.05	1.0	46.0	-	-	-
Moisture conservation							
RF	851	25.49	34	1630	22.5	27.84	60.19
RSM	866	21.92	36	1706	22.5	27.84	62.91
SM	832	30.65	32	1515	22.5	27.84	56.43
CD (P=0.05)	NS	1.77	1.0	20.0	-	-	-

Table 2 Interaction effect of irrigation schedules and moisture conservation practices on sterility percentage and seed yield

Moisture conservation	Irrigation schedule							
	IW:CPE 0.8	IW:CPE 0.4	BI+FD	FI	IW:CPE 0.8	IW:CPE 0.4	BI+FD	FI
	Sterility (%)				Seed yield (kg/ha)			
RF	18.10	21.91	28.45	33.5	20.97	1691	1570	1164
RSM	15.95	19.14	25.24	27.3	22.29	1722	1604	1220
SM	18.74	25.99	32.17	45.7	18.17	1626	1540	1078
CD (P=0.05)for I at the same level of M			4.28			66		
CD (P=0.05)for I at the same level of M			3.47			55		

I = Irrigation schedules mean (s); M = Moisture conservation practice (s).

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Short communication

Influence of seeding time, fertilizer and plant density on yield and N uptake of sunflower (*Helianthus annuus* L.)

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Sunflower, being a photoinsensitive oilseed crop can be successfully grown throughout the year. The significant variation in temperature during summer season (seeding to maturity) make it essential to decide the optimum time of seeding for winter crop. The advantage of timely sown crop in terms of yields depends on the availability of nutrients in the soil and plant stand in the field. Therefore, and investigation was undertaken to study the effect of seeding time, fertility levels and plant population on yield and N uptake of sunflower.

A field experiment was conducted at IGAU, Raipur, during *rabi*/summer season of 1997 in a split plot design with three replications. The soil of the site was clay loam having 0.46% organic carbon and 210,22 and 260 kg/ha of available N, P and K, respectively. The pH of the soil was 6.5. The treatments comprised six dates of seeding in main plots and four combinations of fertility levels and plant population were studied in sub plots (Table 1). The sunflower variety "Morden" was taken as test crop. The entire amount of P and K and half of the N was applied as basal dressing. The remaining quantity of N was given at bud initiation stage. The sunshine hours and temperature was recorded from seeding to maturity under different seeding times. The heat unit was calculated as Max temperature + Min temperature/2 as suggested by Nagai (1962).

The crop received 2680, 2719, 2779, 2799, 2890 and 2990°C heat units when seeded on December 5, 15 and 25 January 5, 15 and 25, respectively for the maturity. The sunshine hours on respective seeding dates were 1135, 1138, 1112, 1063, 1083 and 1091.

The date of seeding had significant effect on yield attributes and seed yield (Table 1). Crop sown on December 5 and 15 being at par produced significantly more height, leaves head diameter, 1000 seeds weight, seed yield and N uptake than delayed seeding. The crop received 2680 and 2618 °C heat units under December 5 and 15 seedlings, respectively. The seeding of sunflower on December 25 and January 5 found to be equally effective for above parameters with the heat units of 2779 and 2799 °C respectively. Seeding on January 15 (2890 °C) and 25 (2999 °C) reduced the seed yield significantly as compared to earlier seeding due to reduction in seed number, head diameter and number of leaves. However, higher heat unit under delayed planting adversely affected the yield attributes and finally seed yield. Giri (1996) also reported a significant reduction in growth and translocation of photosynthates from source to sink. The regression analysis also indicated the declining trend of seed yield due to increased heat unit (R^2=0.98) Furthermore, expected yield under different heat unit at other agro-climatic conditions can be calculated from the equation: $Y= 24988.38-13.86x +0.002x^2$ where Y= yield and x= Heat unit °C. The effects of sunshine hours on sunflower were not visible clearly.

The fertility level combined with plant population showed a significant effect on yield attributes, seed yield and N uptake of sunflower. The application of 150 % higher NPK along with 33% extra plant population (EPP) produced the highest yield attributes, seeds yield and N uptake, which was significantly superior to other treatments. The application of 50% reduced phosphorus and potassium above with 100 % nitrogen to the recommended plant population (RPP) produced seed yield (1080 kg/ha) and N uptake similar to that of 100% NPK applied to RPP (1128 kg/ha). The application of 150% N along with 100% P and K under 33% EPP was found significantly better than these treatments. The increase in head diameter, seeds per head, 1000 seeds weight and N uptake due to application of nutrients contributed for the increased seed yield.

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Table 1 Influence of seeding time, fertiliser and plant density on yield attributes, Yield and N uptake of sunflower

Treatment	Plant height at harvest (cm)	Leaves/ plant at 90 DAS (No)	Head diameter (cm)	Filled seeds/head (No.)	1000seeds weight (g)	Seed yield (kg/ha)	N uptake (kg/ha)
Date of seeding							
December 05	135	25	17	791	59	1635	41.45
December 15	133	24	16	714	59	1615	41.10
December25	130	22	13	700	56	1347	36.60
January 05	128	21	12	693	56	1305	36.15
January 15	124	19	9	671	52	889	31.69
January 25	121	17	8	630	52	769	27.10
CD (P=0.05)	2.20	1	2	13.0	2	209	1.54
Fertility and plant population							
N 100%+p and K 50%+RPP	125	19	11	677	54	1083	34.45
N 100%+ P and K 100%+RPP	128	20	12	680	56	1128	34.48
N100%+ P and K100%+33% EPP	130	22	13	692	57	1378	36.02
N 100%+ P and K 150%+ 33% EPP	132	23	15	702	57	1517	37.40
CD (P=0.05)	1.49	1.03	1.21	5.00	1.56	121	1.08

100%NPK-80:60:40 kg/ha; RPP - Recommended plant population (45x20 cm) ; Extra plant population (30x20cm).

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Short communication

Prediction of evapotranspiration of groundnut through empirical formulae

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Crop water requirement estimates are very important for project planning and irrigation scheduling. Actual evapotranspiration (Eta), a major constituent of crop water needs is primarily the atmospheric evaporative demand (meteorological elements) under adequate water supply condition. On this premise, several published empirical methods based on one or more meteorological elements for predicting Eta are widely used with reasonable success due to their simplicity (Doorenbos and Pruitt, 1977; Sharma, 1985). Hence, these estimates of potential evaporative demands (Eto) could be related conveniently with crop Eta for predicting the crop water needs under wider climatic conditions which can be used by project engineers and farmers for irrigation management. Hence, an attempt has been made to semi arid conditions at Hyderabad.

Field experiment was conducted during winter season of 1992-93 and 1993-94 at Agricultural College farm, Acharya N.G. Ranga Agricultural University, Hyderabad, India. The soil of the experimental site was sandy loam in texture, neutral in reaction, low in available nitrogen (210.0 kg/ha), phosphorus (19.2 kg/ha) and high in available potassium (304.0 kg/ha). The average soil moisture retentivities at -0.03 Mpa and -1.5 Mpa and available water storage capacity in 60 cm of crop root zone depth were 17.19 %, 6.29 % and 105.30 mm respectively. The bulk density of the soil was 1.61 mg/m^3. The ground water table was below 10 m deep from the soil surface and did not contribute to water use. Groundnut variety ICGS 11 was sown on 3.11.92 and 11.11.93 in the first (1992-93) and second (1993-94) year respectively adopting a spacing of 30 x 10 cm to achieve a desired plant population of 3.33 lakh plants/ha. Other recommended measures of production including fertilizer (40 N, 20 P_20_5, 40 K_20 kg/ha and 500 kg/ha gypsum) and plant protection measures were carried out. Crops were harvested on 1.3.1993 and 9.3.1994, respectively.

There were seven irrigation treatments designed to allow Eta deficits to develop in one or two of the three specific crop-growth subperiod i.e. vegetative (0-35 DAS), flowering-pegging and pod addition (35-80 DAS) and pod filling (80-118 DAS) of groundnut along with one fully irrigated control (W-W-W) treatment wherein Eta deficit was nit. In any given growth subperiod, a given treatment was either fully irrigated (W) based on soil-crop-climatic data (Table 1) so that Eta proceeded at maximum rate or it was not irrigated (Eta deficit) at all (D). If irrigated, the irrigation schedule duplicated that followed for the crop in W-W-W (fully irrigated control) treatment and Etm for the following irrigation interval was assumed. If unirrigated, in that treatment, Eta rate may have fallen below the Etm rate and the absolute different was expressed for the period as Eta deficit (Etd). The treatments were laid out in a randomised block design with four replications. A 7.5 cm parashall flume was installed to deliver the required quantity of water in each plot. The precipitation of 97 mm and 37 mm was received during vegetative crop growth subperiod during 1992-93 and 1993-94 respectively and necessary changes in irrigation water supply were done accordingly. Crop evapotranspiration (Eta) was monitored gravimetrically starting from sowing to harvest before and after each irrigation from 0 to 60 cm soil depth (effective root zone depth was 60 cm) in increment of 15 cm soil layer. The reference crop (grass) evapotranspiration (Eto) for the corresponding irrigation intervals was computed by empirical methods *viz.*, Modified Penman and Adjusted Pan evaporation method as per the procedure outlined by Doorenbos and Pruitt (1977) and also by Hargreaves method (Hargreaves and Samani, 1982). Thus, the relationship between crop Eta (dependent variable) and reference crop evapotranspiration (Eto) (independent variable) was established by using a linear regression model (Gomez and Gomez, 1984). The significances of intercepts and slopes of individual regression line were tested at 0.05 probability with 21 degrees of freedom.

Results elucidated that crop evapotranspiration (Eta) showed a positive and significant correlation with reference crop evapotranspiration (Eto) estimated by different empirical methods in both the years and on pooled basis (Table 2). The coefficient of determination (R^2) in crop Eta ranged from 99.1 to 99.7 % in Hargreaves, 99.0 to 99.6 % in Modified Penman and 99.1 to 99.7 % in Adjusted Pan evaporation methods in different years and on pooling the results. The variance ratio for testing R^2 and regression

coefficients were highly significant (P=0.01). The regression slopes i.e. 'b' coefficients for a given relationship (Table 2) between years were found to be statistically homogeneous. In spite of this, an attempt was already made in the paper to develop the relationship based on pooled data for practical use. This suggests that the predictive capability of the functions in very high and any of the empirical methods evaluated could be used for reliable estimation of evapotranspiration (Eta) of groundnut grown during winter season at Hyderabad.

Table 1 Field irrigation schedule in W-W-W treatment at individual growth subperiods of groundnut (Doorenbos and Kassam, 1979)

Crop-growth subperiod	Duration in days	Eto (mm / day)	Kc	Etm (mm / day)	Crop rootzone depth (cm)	Sa.d (mm)	P	i=(Sa.d.P/Etm)	IRR (mm)
				1992-93					
Vegetative (3.11.92 to 5.12.92)	33	4.08	0.750	3.06	45	79	0.700	18	55.0
Flowering-pegging & pod addition (6.12.92 to 19.1.93)	45	3.98	1.025	4.10	60	105	0.590	15	61.5
Pod filling (20.1.93 to 1.3.93)	40	4.70	0.800	3.76	60	105	0.625	17	64.0
				1993-94					
Vegetative (11.11.93 to 16.12.93)	36	3.97	0.750	3.00	45	79	0.700	18	54.0
Flowering-pegging & pod addition (17.12.93 to 30.1.94)	45	4.03	1.025	4.10	60	105	0.590	15	61.5
Pod filling (31.1.94 to 9.3.93)	37	5.24	0.800	4.20	60	105	0.580	15	63.0

1. Eto = Reference crop evapotranspiration calculated by weather parameters (mean of 10 years) following Modified penman method.
2. Kc = Crop coefficient values at different sub periods of corn
3. P = Fraction of available soil water within the total available water (85 mm)
4. Depth of irrigation water (IRR) = Readily available water (P.Sa) x root zone depth (D)

Table 2 Regression of actual crop evapotranspiration of groundnut (fully irrigated control W-W-W) on reference crop evapotranspiration (Eto) derived by different methods

	Variables	Regression constants, coefficients and test statistics				R^2	F value for testing R^2
		a	t(a)	b	t(b)		
i)	Crop Eta : Eto derived by Hargreaves method						
	1992-93	-15.713963	1.906	0.806501**	31.297	0.994	979.50**
	1993-94	-26.146000	4.422	0.885417**	48.781	0.997	2379.59**
	Pooled	-21.084826	3.116	0.846937**	40.412	0.991	1633.13**
ii)	Crop Eta : Eto derived by Modified Penman						
	1992-93	-24.757544	2.583	0.858302**	27.750	0.992	770.06**
	1993-94	-17.984070	2.634	0.890856**	41.187	0.996	1096.37**
	Pooled	-21.722778	3.022	0.875906**	38.113	0.990	1452.60
iii)	Crop Eta : Eto derived by Adjusted Pan evaporation						
	1992-93	-34.98-953	5.635	0.876334**	44.346	0.997	1966.57**
	1993-94	-60.172043	5.793	0.984153**	30.702	0.994	942.61**
	Pooled	-47170010	6.360	0.929996**	40.017	0.991	1601.36**

Further, the reference crop evapotranspiration estimated by Modified Penman method showed a positive and significant correlation with Eto estimated by Hargreaves and Adjusted Pan evaporation methods (Table 3). The explained variation (R^2) in Eto of Modified Penman method ranged from 99.8 to 99.9 % in Eto by Hargreaves and 99.1 to 99.7 % in Eto by Adjusted Pan evaporation method. It is apparent that R^2 values are very high which suggest that only the best fit regression was presented in the paper. Further, it is well known that the R^2 value indicates close correlation between the actual and estimated values of the dependent variable. Hence, there seems no reason to conduct another test of significance (which is carried out by paired 't' test) of differences between them.

Thus for conditions approximated by this experiment, the Modified Penman, Hargreaves and Adjusted Pan evaporation derived estimates of Eta may be used satisfactorily for irrigation scheduling to winter groundnut. However, for computation of Eta estimates by modified Penman method, required measured input data on all the meteorological parameters viz., solar radiation, temperature, relative humidity and wind velocity which may

limit its utility for wider application. On the other hand, pan evaporation estimates are easily available, reliable, more convenient to measure and also combine the effect of all the meteorological parameters into a single entity. Likewise, the reference crop Eta estimates by Hargreaves method can be easily computed and it require measured data only on temperatures. Hence, for precise estimates of groundnut crop water requirement under semi arid conditions of Hyderabad, either Hargreaves or Pan evaporation methods could be adopted satisfactorily, since most of the meteorological observatories are 'B' class which do not record various parameters required to calculate Eto by Modified Penman method.

In crisp, it is concluded that out of aforesaid three tested empirical methods Adjusted Pan evaporation method would be practically more convenient and useful for predicting crop evapotranspiration of groundnut and its irrigation scheduling at Hyderabad.

Table 3 **Regression of reference crop evapotranspiration of groundnut derived by Modified Penman method on reference crop evapotranspiration derived by Hargreaves and Adjusted Pan evaporation method**

	Variable	Regression constants, coefficient and test statistics				R^2	*F value for testing* R^2
		a	t(a)	b	t(b)		
i)	Crop Eto derived by Modified Penman method : Crop Eto derived by Hargreaves method						
	1992-93	-11.383898	3.802	1.064848**	110.231	0.999	12150.87**
	1993-94	9.194390	2.442	1.006228**	84.380	0.999	7119.98**
	Pooled	-0.664260	0.188	1.033883**	91.328	0.998	8340.8**
ii)	Crop Eto derived by Modified Penman method : Crop Eto derived by Adjusted Pan evaporation method						
	1992-93	11.483213	1.596	0.980086**	42.209	0.997	1781.60**
	1993-94	44.156067	4.397	0.900563**	28.308	0.992	801.34**
	Pooled	28.374197	3.879	0.938000**	40.124	0.991	1609.93**

** Significant (P=0.01)

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Short communication

Response of wheat and mustard to varying levels of boric acid under intermediate zone of Jammu and Kashmir

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Cultivation of mustard in the intermediate zone of Jammu is mostly practiced after harvesting of maize which is a erosion permitting crop, rendering the low yield of mustard. Erosion of most fertile top soil also caused deficiency of available boron. Mustard is very susceptible to boron deficiency (Tisdale *et al.*, 1993). Both wheat and mustard crops are grown in this zone following maize. But, the information regarding boron nutrition of these crops under this agro-climatic condition is lacking. That is why, it was considered worthwhile to conduct a field experiment during *rabi*, 1996-97 and 1997-98 at RARS, Rajouri which is situated in the intermediate zone at 960 m above MSL.

Soils were low in available boron (Hot 0.02 M $CaCl_2$ extractable boron was 0.27 mg/kg), clay (14%) and organic matter (0.41%). The pH of soils was 6.7, EC was 0.25 dSm^{-1}. Mustard cultivar KOS-1 and wheat cv. HS-240 were sown at a spacing of 45 cm apart rows and later equal population was maintained with recommended doses of NPK @ 80, 40 and 20 kg/ha. Five different doses of boric acid solution i.e., 0.0, 0.05, 0.10, 0.15 and 0.20% were applied through foliar application at pre-flowering stage and repeated after every 15 days. The field experiment was replicated four times in a randomized block design.

The analysis of variance (Table 1) indicated that all the treatments (B_1, B_2, B_3 and B_4) were significant in both the years 1997 and 1998 in mustard, whereas in case of wheat these treatments did not differ significantly. Gupta (1979) reviewed similar information as wheat being the member of gramineae family required very low amount of boron as compared to mustard, the member of cruciferae family. The treatment B_3 (0.15% boric acid) recorded the highest seed yield of mustard i.e., 2720 and 2840 kg/ha in 1997 and 1998, respectively. The same treatment was as good as B_2 in both the years. In wheat, the treatment B_3 recorded the highest yield of 2570 and 2660 kg/ha in the 1997 and 1998, respectively. The same treatment was at par with B_4 in both the years. The treatment B_3 showed the highest increase of 119.3 and 160.5 % mustard seed yield over their respective controls in 1997 and 1998 and similar trend was also noticed in wheat crop.

Table 1 **Effect of different levels of boron on the yield of mustard and wheat**

Treatment	Mustard (KOS-I)						Wheat (HS-240)	
	Yield (kg/ha)		No. of branches/plant		No. of siliqua/plant		Yield (kg/ha)	
	1997	1998	1997	1998	1997	1998	1997	1998
B_0	1240	1090	2.8	2.5	107	100	1980	2070
B_1	1660 (33.8)	1510 (38.5)	3.7	3.4	140	130	2060 (4.0)	2240 (8.2)
B_2	2470 (99.2)	2540 (133.0)	4.3	4.6	204	229	2340 (18.2)	2260 (9.2)
B_3	2720 (119.3)	2840 (160.5)	5.9	5.4	226	259	2570 (29.8)	2660 (28.5)
B_4	2150 (73.4)	2480 (127.5)	6.6	5.4	290	219	2490 (25.8)	2610 (26.0)
CD(P=0.05)	3.75	451	0.7	0.6	18.7	19.2	NS	NS

B_0 = 0; B_1 = 0.05; B_2 = 0.10; B_3 = 0.15 and B_4 = 0.20% boric acid.
Figures in parenthesis denote per cent increase over control.

The highest number of branches/plant (5.9) were recorded in the treatment B_3 in 1998 whereas 6.6 in treatment B_4 in the year 1997 in mustard. The same trend was also observed in case of number of siliqua/plant in both the years. The significant correlation coefficient of boron concentration with seed yield of mustard (r = 0.76, 1997 and r=0.87, 1998) and wheat (r=0.93, 1997 and 1998) were observed. This clearly indicated that application of boron increased grain yield significantly in this intermediate zone of mustard and wheat crops. Sinha *et al.* (1991) also reported similar observation.

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Short communication

Growth, agronomic efficiency and yield of mustard (*Brassica juncea*) as influenced by phosphorus and boron

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Rapeseed and mustard is one of the major winter crops of *tarai* region of W.B. High fixation of phosphorous, high rate of leaching of plant nutrients due to high rainfall causes deficiency of phosphorus and boron. Deficiency of these nutrients results in sterility, thus, decreasing fruitset (Sinha *et al.*, 1990). Therefore, proper phosphorus and boron fertilization is needed to boost up the productivity of mustard in this region. Hence, the present investigation was undertaken with the objective to study the effects of phosphorus and boron on growth dynamics, agronomic efficiency and yield of Indian mustard.

The field experiment was carried out on the *tarai* soils at the Research Farm of BCKVV, North Bengal Campus, Coochbehar district of W.B. during winter season of 1995-96. The soil was well drained sandy loam, acidic in reaction (pH 6.4), having 0.82% organic C, 0.09% total N, 9.6 kg/ha of available P, 127 kg/ha of available K and 0.42 pp, available B. The treatments comprising of four levels of phosphorus (0, 20, 40 and 60 kg P_2O_5/ha applied through SSP) and three levels of boron (0, 10 and 20 kg borax/ha)were tested in a factorial RBD with three replications. Recommended doses of nitrogen (80 kg/ha) and potassium (40 kg K_2O/ha) were applied uniformly. Mustard cv. RW 351, a yellow flower cultivar, was sown on 14th November in rows spaced at 30cm. The crop was thinned at 15 DAS and plant-to-plant spacing of 10cm was maintained to get desired plant population of 0.3 million/ha. Two irrigations were given, at 30 DAS (rosette stage) and 75 DAS (pod development stage). The crop was harvested on March. Observations were recorded on various growth parameters, yield components and yield. Oil content was estimated through Soxlet's extraction method and oil yield was calculated. The agronomic efficiencies (AE) of phosphorus and boron were determined with the help of formula: (Yield in the fertilized plots - Yield in control plots)/ amount of fertilizer nutrient applied.

The growth parameters *viz.*, plant height, number of branches/plant, LAI and dry matter accumulation/m^2 increased significantly with the increase in levels of phosphorus up to 60 kg P_2O_5/ha (Table 1). However, in case of boron only dry matter accumulation significantly increased up to 20 kg/ha of borax application. Better availability of phosphate and boron in the soils during the active growth period of crop, increased cell division and cell elongation which probably led to better crop growth, LAI and dry matter accumulation (Sinha *et al., 1990).*

The yield components *viz.*, number of siliquae/plant and number of seeds/siliqua also increased significantly with the increasing levels of phosphorus and boron up to 60 kg P_2O_5/ha and 20 kg borax/ha, respectively. The thousand seed weight did not differ with the phosphate levels but boron levels significantly influenced the 1000-seed weight. Significant response to seed oil content due to phosphorus may be due to its explicit role in the synthesis of fats and oils but boron could not influence the oil content significantly. Similar results are also reported by Sinha *et al.* (1990) and Sakal *et al.* (1991). The seed, stover and oil yield varied significantly with the levels of phosphours and boron up to 60 kg P_2O_5/ha and 20 kg borax/ha, respectively due to better development of siliquae and seeds/siliqua. The increase in seed yield was 24.17, 57.06 and 68.87% at the 20,40 and 60 kg P_2O_5/ha over control; 38 and 53% at 10 and 20 kg borax/ha over control, respectively. The results are in conformity with the findings of Sinha *et al.* (1990). The interaction effect of phosphorus and boron on seed yield of mustard was not significant. Seed yield was highly correlated with phosphorus levels (r=0.97*) and boron levels (r=0.94*). Interestingly, there were strong positive correlation of seed yield and leaf area index (r=0.95* and 0.99*), dry matter accumulation (r=0.98* and 0.82*), number of siliquae/plant (r=0.98* and 0.00*) and number of seeds/siliquae (r=0.93* and 0.99*) for levels of phosphate and borax, respectively. The quadratic response equations were also developed as follows :

$Y = 892.65 + 6.650 X - 0.070 X^2$ ($R^2 = 0.97^*$) for levels of phosphate

$Y = 1036.33 + 3.698 X - 0.119 X^2$ ($R^2 = 0.94^*$) for levels of borax

The economic optimum doses were calculated to be 47.3 kg P_2O_5/ha and 15.5 kg borax/ha, for phosphate and borax, respectively. Agronomic efficiencies of phosphate and borax increased up to 40 kg P_2O_5/ha and 10 kg borax/ha, respectively; then it decreased at the highest dose applied.

Table 1 Growth and yield parameters, agronomic efficiency and yield of mustard as influenced by levels of phosphorus and boron

Treatments	Plant height (cm)	No. of branches/ plant	Leaf area index	Drymatter accumulation (g/m^2)	No. of siliquae/ plant	No. of seeds/ siliqua	1000-seed weight (g)	Oil content (%)	Yield (kg/ha)			Agronomic efficiency (kg seed/kg nutrient applied)
									Seed	Stover	Oil	
Phosphorus (kg P_2O_5/ha)												
0	122.6	7.5	1.4	230.5	114.7	8.1	3.7	35.2	906	3260	318.9	-
20	143.5	10.4	2.6	335.4	168.3	11.6	3.8	37.8	1125	4013	425.2	10.95
40	168.3	12.7	3.5	405.3	209.4	12.8	3.9	39.7	1423	5117	564.9	12.92
60	185.7	14.6	5.2	437.8	245.9	13.9	3.9	40.1	1530	5416	613.4	10.40
CD (P=0.05)	*14.4*	*1.7*	*1.5*	*31.4*	*32.3*	*0.8*	*NS*	*1.6*	*104*	*292*	*44.7*	
Boron (kg borax/ha)												
0	145.2	106	2.1	355.2	108.9	8.6	2.9	37.8	1037	3373	391.9	-
10	151.4	11.7	2.6	366.7	218.9	12.9	4.3	38.1	1431	4751	545.2	39.40
20	152.3	12.2	2.9	418.9	260.7	14.5	4.8	38.4	1587	5475	609.4	27.50
CD (P=0.05)	NS	NS	NS	35.3	33.8	1.3	0.4	NS	138	665	59.2	-

Its enhancement might be due to the favourable effect of phosphorus and boron on apparent recovery fraction and physiological efficiency of the crop. As agronomic efficiency is governed by both the seed yield differences over control and amount of nutrient applied, beyond 40 kg P_2O_5/ha and 10 kg borax/ha, the rate of increase in seed yield was not proportionate with the increment in fertilizer nutrient applied.

Thus, the present study indicated that application of phosphorus @ 47.3 kg P_2O_5/ha and boron @ 15.5 kg borax/ha in conjunction with 80 kg N/ha and 40 kg K_2O/ha is beneficial in improving yield of mustard in the *tarai* region of West Bengal.

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Short communication

Response of linseed (*Linum usitatissimum* L.) varieties under varying irrigation schedules in swell-shrink soils

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In Chhattisgarh region, linseed is mostly popular as *utera* crop where its productivity is hardly more than half t/ha. However, due to its industrial value it is also catching the attention of farmers having irrigation facility. The present scenario of linseed in the region indicates that average productivity is very low (208 kg/ha) as compared to average productivity of Madhya Pradesh (296 kg/ha) and India (299 kg/ha). Productivity of linseed is quite low in this region because it is commonly grown in receding soil moisture condition after rice harvest. Increase in productivity could be brought by suitable varieties and irrigation schedules (Agrawal *et al.*, 1997).

A field experiment was carried out during post rainy season of 1996-97 at Indira Gandhi Agricultural University, Raipur after the harvest of rice. The soil was vertisols with available N, P_2O_5 and K_2O content of 222.9 kg/ha (low), 19.21 kg/ha (medium) and 407.16 kg/ha (high), respectively with pH 7.3. The field capacity, permanent wilting coefficient and bulk density were 31.3%, 15.8% and 1.31 g/cc, respectively. A split plot design with three replications was followed. The experiment constituted of 5 irrigation schedules (no irrigation, one irrigation at 35 DAS, one irrigation at 50 DAS, one irrigation at 70 DAS and two irrigation at 35 and 70 DAS) as main plot and 3 varieties (Kiran, RLC-47 and RLC-47) as sub plot treatments. The crop was sown in rows at 25 cm spacing using 20 kg seed/ha. Recommended fertilizers (60:30:20 kg NPK/ha) were applied to the crop. Half N and full dose of phosphorus and potash was applied as basal dose through urea, single super phosphate and muriate of potash, respectively. The remaining half quantity of N was top dressed at 35 DAS. Irrigation of 6 cm was given, at each irrigation. Water measured by water meter. The crop was sown in November 22, 1996 and harvested on March 19, 1997. During the crop period 31.8 mm rainfall was received.

Two irrigation applied at 35 and 70 DAS gave significantly higher grain yield than no irrigation and one irrigation either at 35, 50 or 70 DAS. This can be attributed to more plant stand, plant height, primary branches/plant, capsules/plant and 1000-grain weight in two irrigation, which significantly decreased by no irrigation. However, plant stand, primary branches/plant, capsules/plant and straw yield under one irrigation at 35 DAS were at par with two irrigations (Table 1). Singh *et al.* (1997) reported similar results. Increase in grain yield of linseed due to irrigation water might be due to fact that water helped in better utilization of nutrients in soil. Moreover, the above mentioned yield-attributing characters have positive association with grain yield of linseed as reported by Gupta and Godawat (1981).

Table 1 Growth, yield attributes and yield of linseed as influenced by irrigation schedules and varieties

Treatment	Plant stand (000/ha)	Plant height (cm)	Primary branches/plant	Capsules/ plant	Seeds/ pod	1000-grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)
Irrigation								
No irrigation	783	45.0	2.7	20	7.4	5.4	797	1608
One irrigation at 35 DAS	962	49.9	2.9	30	7.9	6.0	1458	2784
One irrigation at 50 DAS	927	48.0	2.3	26	7.6	5.4	1047	1404
One irrigation at 70 DAS	830	44.6	2.8	24	7.6	5.4	846	1788
Two irrigations at 35 and 70 **DAS**	983	55.7	3.2	32	8.2	6.2	1652	2988
CD (P=0.05)	30	3.06	0.3	3	NS	0.1	75	207
Variety								
Kiran	871	46.8	2.8	25	7.7	5.6	1004	1771
RLC-46	874	50.2	2.8	26	7.7	5.6	1208	2294
RLC-47	946	48.9	2.8	28	7.8	5.7	1269	2269
CD (P=0.05)	17	2.50	NS	1.8	NS	0.04	68	102

Variety RLC-47 was found significantly superior to kiran but at par with RLC-46 in relation to grain and yields. This was attributed to significantly higher plant stand, capsules/plant and 1000-grain weight. The results conforms the findings of Agrawal *et al.* (1997). The interaction effect showed that variety RLC-46 and RLC-47 though produced comparable grain yield with two irrigations at 35 and 70 DAS but it was significantly superior over other combinations of varieties and irrigation schedules (Table 2).

Table 2 **Grain yield (kg/ha) of linseed as influenced by irrigation and variety interaction**

Irrigation	Variety		
	Kiran	RLC-46	RLC-47
No irrigation	759	759	873
One irrigation at 35 DAS	1371	1428	1576
One irrigation at 50 DAS	89	1110	1143
One irrigation at 70 DAS	653	882	1004
Two irrigations at 35 and 70 DAS	1347	1861	1747
CD (P=0.05)		136	

From the above findings, it can be inferred that variety RLC-46 and RLC-47 are capable of giving higher yield in Vertisols when supplied with two irrigations at 35 and 70 DAS. Similarly, under limited irrigation availability, one irrigation at 35 DAS be applied.

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Short communication

Effect of weed management practices on yield of irrigated linseed (*Linum usitatissimum* L.)

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Linseed (*Linum usitatissimum* L.) is an important (*rabi*) oilseed crop of Chhattisgarh region for rice fallow as well as intercropping situation. It is largely grown on marginal and sub marginal lands. The reasons for low productivity are ineffective weed management apart from other input resource constraints. There is an ample scope for increasing its production by effective weed management. Yield loss upto 3 to 4% due to weed infection has been reported in linseed (Tomar *et al.*, 1990). Chemical weed control holds promise for economic and effective methods of controlling weeds at the critical stages of the crop growth. Hence, the present study was undertaken to identify the suitable weed management technique in irrigated linseed in order to increase its productivity in the region.

A field experiment was conducted during rabi seasons of 1996-97 and 1997-98 at Research farm, IGAU, Raipur. The soil of experimental field was clayey (Vertisols) with pH 8.2. It was medium to available N (32.0 kg/ha) and P (12.0 kg/ha) and high in K (58.0 kg/ha) contents. The experiment was laid out in randomized block design with four replications. The treatment consisted of isoproturon @ 1.0 kg/ha, isoproturon @ 1.0 kg/ha + 2,4-D @ 0.5 kg/ha, 2,4-D @ 1.0 kg/ha, 2,4-D @ 1.0 kg/ha + isoproturon @ 0.5 kg/ha, hand weeding at 20 and 40 DAS and unweeded check. The herbicides were applied as post emergence (35 DAS). Fertilizer dose of 60:30:20 NPK was applied through urea, single super phosphate and muriate of potash, respectively. Half N and full dose of phosphorus and potash were applied basal and remaining N was top dressed at 35 DAS. Linseed (cv. Kiran) was sown on 23 and 14 November in the two consecutive years with a seed rate of 20 kg/ha and row spacing of 25 cm. The crop was irrigated twice at 40 and 70 DAS. The total rainfall received during crop season was 31.8 and 188.0 mm during 1996-97 and 1997-98, respectively.

All the weed control treatments significantly lowered the dry matter production of weeds. Among different treatments, hand weeding at 20 and 40 DAS significantly controlled the weeds and also recorded lower dry matter production of weeds which was at par with the application of isoproturon @ 1.0 kg/ha and maximum was recorded under unweeded check during both the years. The highest weed control efficiency was estimated in hand weeding (73.1%) followed by isoproturon (65.5%) and lowest (1.8%) when 2,4-D alone was applied @ 1 kg/ha (Table 1). Considerable control of *Physalis minima* weed was observed in the application of isoproturon alone herbicide treated plot whereas 2.4-D herbicide was unable to control it. As regards to other weed species like *Melilotus alba, Echnichloa colonum, Digera arvensis, Acalypha indica* and *Exophorus* species were controlled to a greater extent by isoproturon in comparison to 2,4-D herbicide.

Grain yield differed significantly due to weed control treatments during second year only while in the first year non of the weed control treatments gave any significant different on seed yield (Table 1). The growth and yield attributes such as plant height, capsules/plant and 1000 grain weight also remained unaffected due to different weed control treatments (Table 2). This may be owing to less crop-weed competition. In general, there was low winter rains which could not provide favourable environment for weed growth. In the year 1997-98, significantly higher seed yield was noted under the hand weeding (20 and 40 DAS) treatment which was at par with the application of isoproturon alone @ 1.0 kg/ha as post emergence. These results corroborated the findings of Badiyala and Bhateria (1999). The yield attributes responsible for higher yield in these treatments seems to be due to the influence on capsules/plant and seeds/capsule. Effective weed control at critical stage of crop growth would have resulted in increased growth and yield parameters (Srinivasan *et al.*, 1992). In general, very poor yield was harvested during 1997-98 because of unusual heavy and prolonged winter rains. The crop was also badly affected by *Alternaria blight* disease.

It can be concluded that the maximum yield could be recorded from hand weeding treatment. Application of isoproturon herbicide can also bring about not only 60% WEC but also 18% yield increase.

Table 1 Effect of weed control on grain and straw yields of linseed and dry matter of weeds, weed control efficiency as well as net profit

Treatment	Grain yield, kg/ha		Straw yield, kg/ha		Dry matter of weeds, kg/ha		WCE, %		Net profit, Rs/ha	
	1996-97	1997-98	1996-97	1997- 98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
Isoproturon @ 1.0 kg/ha	12.50	325	941	2813	110	172	59.7	71.2	13040	196
Isoproturon @ 1.0 kg/ha + 2,4-D @ 0.5 kg/ha	1240	319	951	2808	163	226	40.3	62.1	12801	-2
2,4-D@ 1.0 kg/ha	1130	313	930	2294	220	584	19.4	2.2	11559	214
2,4-D @ 1.0 kg/ha + isoproturon @ 0.5 kg/ha	1080	315	972	2477	170	242	37.7	59.5	10663	42
Hand weeding (20 & 40 DAS)	1310	348	1039	3090	75	157	72.5	73.7	13289	-64
Unweeded check	1110	267	903	2294	273	597	-	-	11476	-221
CD (P=0.05)	NS	27.7	40.8	356.3	45	114	-	-	-	-

Table 2 Effect of weed control on growth and yield attributes of linseed

Treatment	Plant height, cm		Branches/plant, No.		Capsules/plant, No.		Seeds/capsule, No		1000-grain weight, g	
	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
Isoproturon @ 1.0 kg/ha	58.8	74.8	3.20	3.55	43.3	31.4	7.49	8.03	5.44	4.69
Isoproturon @ 1.0 kg/ha + 1.1 2,4-D @ 0.5 kg/ha	57.5	70.4	3.45	2.65	44.2	29.1	8.29	6.85	5.49	4.56
2,4-D@ 1.0 kg/ha	53.7	67.4	3.13	2.35	40.2	20.8	7.93	5.83	5.30	4.63
2,4-D @ 1.0 kg/ha + isoproturon @ 0.5 kg/ha	54.9	69.5	3.07	2.55	51.6	22.5	8.23	6.13	5.41	4.59
Hand weeding (20 & 40 DAS)	56.6	70.9	3.75	2.95	44.7	30.3	7.92	7.93	5.44	4.69
Unweeded check	54.8	65.0	3.22	2.05	37.5	19.8	7.46	5.78	5.31	4.54
CD (P=0.05)	NS	3.3	0.33	0.68	NS	5.03	0.51	0.92	NS	NS

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Short communication

Effect of plant geometry and topping on growth and yield of summer sesame

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Diversity in sesame production has necessiated to find out an avenue for yield improvement through suitable agronomic practices. One way of increasing productivity in sesame is by increasing the number of branches leading to increase in total number of capsules per plant (Ghosh and Sen, 1980). When apical growth is arrested through topping of growing point or spraying with chemicals the natural auxins in plant is transferred to lateral buds facilitating more number of secondary and tertiary branches. It is felt necessary to develop an improved technology package, which is of low cost deserving investigation to improve the yield. Hence the present experiment was taken up.

A field experiment was conducted during *summer* 1998 at S.V. Agricultural College farm, Tirupati. The soil contained 248 kg/ha available N, 21.8 kg/ha available P_2O_5 and 182 kg/ha available K_2O. The soil was sandy loam in texture having pH of 7.6. The experiment was taken up in randomized block design with factorial concept involving three levels of plant geometry (30 x 10 cm, 40 x 7.5 cm an 50 x 6.0 cm) and three levels of topping (no topping, at 20 DAS and topping at 30 DAS). A common dose of 60-40-40 kg N, P_2O_5 and K_2O/ha was applied. Entire P_2O_5 and K_2O were applied as basal, while nitrogen was applied in two equal splits @ 30 kg before sowing and the remaining at 25 DAS. The sesame variety Gauri was sown on 1st March 1998 and harvested on 27th May 1998.

There was no significant difference in plant height with plant geometry (Table 1). Which may be due to less or no competition for growth factors because the population levels in all the treatments were same. The results are in agreement with the findings of Sarma (1994). Total dry matter production was more with 40 x 7.5 cm and was on par with 30 x 10 cm. Significantly higher leaf area index was with 30 x 10 cm due to utilisation of spacing effectively by tapping solar radiation. Production of primary, secondary branches were not much influenced by plant geometry.

Plant height decreased at early topping (20 DAS). This might be due to arrest of early vigour of apical meristem and activation of lateral buds. Total dry matter production was highest with early topping which might be due to more number of branches per plant (Table 1). Which led to triggering of production of more secondary and tertiary branches. The results were in agreement with Narayana Gowda and Jayanthi (1988). Topping at 20 DAS recorded less number of primary branches which might be due to availability of limited growing points on topped main stem. More secondaries and tertiaries were produced in early topping and this may be due to limited production of primaries and more photosynthates available for production of secondaries and tertiaries.

There was no significant difference in total number of capsules per plant due to plant geometry (Table 2). The results are in agreement with findings of Satyanarayana *et al.*, (1978). The data pertaining to seeds per capsule and 1000 seed weight revealed that there was no significant difference due to plant geometry. Harper (1961) considered this to be an internal or physiological homeostasis with respect to the organ that is essential for reproduction and dispersal. Seed yield due to plant geometry with maintaining same population revealed that there was no significant effect on seed yield. This might be due to non significant effect of plant geometry on yield attributing factors. There was no significant difference in stalk yield and harvest index. Which may be attributed to maintenance of population in all the treatments.

Topping at 20 DAS recorded higher number of capsules per plant. This might be due to more number of branches, increased leaf area index and photosynthetic efficiency thereby more photosynthates would have been diverted to the capsule forming nodes. Higher dry matter production, leaf area index and yield attributes resulted in higher seed yield with topping at 20 DAS. The above results corroborated with the findings of Haile Tewolde *et al.*, (1994). Topping at 20 DAS recorded higher stalk yield mainly because of higher vegetative growth and foliage density as a result of more leaf area and dry matter accumulation. Highest harvest index was recorded at 20 DAS due to higher seed yield compared to rest of the treatments.

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Table 1 Effect of plant geometry and topping on growth of summer sesame

Treatment	Plant height (cm)	Total dry matter production (g/plant)	Leaf area index	Number of productive branches (at maturity)			
				Primary	Secondary	Tertiary	Total
Plant Geometry							
30 x 10 cm	100	12.9	3.14	3.9 (1.96)	3.3 (1.82)	0.4 (0.60)	7.6 (2.76)
40 x7.5 cm	101	12.9	3.10	3.9 (1.96)	3.6 (1.88)	0.6 (0.72)	8.1 (2.85)
50 x 6.0	102	12.5	3.08	3.9 (1.96)	3.6 (1.89)	0.6 (0.73)	8.1 (2.86)
CD (P=0.05)	NS	0.1	0.01	NS	0.02	0.01	0.02
Topping							
No topping	104	11.9	3.05	4.2 (2.05)	2.8 (1.67)	0.1 (0.39)	7.1 (2.67)
Topping 20 DAS	98	13.7	3.17	2.7 (1.66)	5.0 (2.24)	1.0 (1.02)	8.8 (2.97)
Topping at 30 DAS	101	12.6	3.11	4.8 (2.18)	2.7 (1.67)	0.3 (0.62)	7.9 (2.83)
CD (P = 0.05)	2.09	0.14	0.01	0.03	0.02	0.01	0.02

NS = Non significant; Figures in parenthesis are square root transformed values

Table 2 Effect of plant geometry and topping on yield attributes and yield of summer sesame

Treatment	Total number of capsules/plant	Seeds/ capsule	1000 seed weight	Seed yield (Kg/ha)	Stalk yield (Kg/ha)	Harvest index
Plant geometry						
30 x10 cm	41	44	2.41	803	1579	33.70
40 x 7.5	41	44	2.41	791	1584	33.16
50 x 6.0 cm	39	44	2.40	761	1526	33.08
CD (P =0.05)	NS	NS	NS	NS	NS	NS
Topping						
No topping	35.14	43.94	2.412	699	1486	31.93
Topping at 20 DAS	46.97	43.84	2.405	886	1665	34.67
Topping at 30 DAS	39.18	44.05	2.403	770	1538	33.35
CD (P =0.05)	2.96	NS	NS	61	74	1.35

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Short communication

Production potentials of dryland intercropping systems under different proportion of groundnut, sunflower and pearlmillet

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Groundnut is the major oil seed crop in dryland alfisols with unstable production due to undependable rainfall in time and space leading to a partial or total crop failure. Intercropping is therefore, practiced for yield stability (Willey, 1979). Farmers usually intercrop pigeonpea with groundnut in different row proportions to meet the domestic needs besides elimination of total crop failure. Intercropping groundnut with pigeonpea in 7:1 row proportion appears to be the remunerative system (Chikkanna, 1982).

In the recent past, sunflower has gained importance in Rayalaseema. Pearlmillet is also grown as intercrop in groundnut in alfisols receiving rains upto first fortnight of October only. Information on ideal row proportions of groundnut in intercropping systems involving sunflower and pearlmillet may lead to yield advantage leading to remunerative crop production in dryland agriculture. Hence, it was felt necessary to study the production potentials of intercropping systems involving groundnut, sunflower and pearlmillet at different row proportions.

A field experiment was conducted during *kharif* 1991-92 on sandy loam soil of Tirupathi campus of Acharya N.G. Ranga Agricultural University. Soil of the experimental field was low in organic carbon (0.113%) and available nitrogen (98.75 kg/ha) and medium in available P_2O_5 (32.25 kg/ha) and available K_2O (155 kg/ha). The experiment was laid out in simple randomised block design with 12 treatments, replicated thrice. Groundnut (TMV-2), Sunflower (Morden) and pearlmillet (WC-C-75) were tested as sole crops and sunflower and pearlmillet as intercrops with groundnut at 1:1, 2:1, 3:1 and 4:1 row proportions, keeping groundnut + pigeonpea (LRG-30) 7:1 system as check. Plant population of component crops was maintained at 100 % of sole crop populations by adjusting the intra-row spacings. The 100 % population of groundnut, pigeonpea, sunflower and pearlmillet were 3,33,333; 55,555; 74,074 and 1,48,148 plants/ha respectively. A total of 1165.5 mm rainfall was received during the crop period in 40 rainy days. Fertilizers were applied to supply 20-40-20, 25-50-0, 60-40-30 and 60-30-20 kg N, P_2O_5 and K_2O/ha (urea, single super phosphate and muriate of potash) for groundnut, pigeonpea, sunflower and pearlmillet respectively for sole as well as intercropping systems at sowings. Necessary plant protection measures were taken against pests and diseases.

Leaf area index, total dry matter production per plant were recorded at 25, 50, 75 days after sowing and at maturity in groundnut and 20, 40, 60 days after sowing and at maturity in sunflower and pearlmillet. Light measurements were made with solarimeter within inter and intra-rows at 50, 75 days after sowing and at maturity. Per cent light interception (PLI) was calculated by substracting the per cent light interception out of incident from hundred. Pod, haulm yields of groundnut and seed, stover/stalk yields of pigeonpea, sunflower and pearlmillet were recorded. All the data were analysed statistically by the method of analysis of variance as suggested by Panse and Sukhatme (1985). Critical difference for the significant sources of variation was calculated at 5 % level of significance.

Sole groundnut had higher LAI than when it was intercropped (Table 1). Rao (1987) reported similar results. Different row proportions of groundnut and pearlmillet recorded relatively lower LAI compared to corresponding proportions of groundnut and sunflower. This was due to greater shade effect of pearlmillet on its component crops compared with sunflower. Intense competition for growth resources at 1:1 row proportion reduced the LAI compared with wider row proportions. LAI of sunflower and pearlmillet was also higher as sole crops and it decreased with increase in row ratios from 1:1 to 4:1 due to increased competition as a result of reduced intra-row spacings leading to reduced leaf number and size (data not presented).

Total dry matter production per plant of groundnut was higher as sole crop compared with that as a component crop (Table 1). Rao (1985) and Rao (1987) reported similar results. Due to severe competition, groundnut intercropped with pearlmillet produced less dry matter compared to sunflower and pigeonpea. Low photosynthetic efficiency due to greater competition with increased plant density

might have resulted in lower dry matter production per plant of groundnut in 1:1 row arrangement of either groundnut + sunflower or groundnut + pearlmillet. Total dry matter produced with sole groundnut was at par with groundnut + pigeonpea 7:1 system indicating complementary interaction of the system involving groundnut and pigeonpea. Total dry matter production of systems did not differ in early stages (up to 40 days). At other stages it was higher with sole cropping in both sunflower and pearlmillet. The dry matter production of both the intercrops decreased with increase in row proportions from 1:1 to 4:1 due to reduced photosynthetic efficiency as a result of decrease in LAI.

Light interception in inter and intra-rows of groundnut increased with increase in age of crop upto 75 DAS followed by a decrease towards maturity. Higher dry matter production and more plant spread due to sole cropping increased the PLI (Table 2). Light interception between groundnut and sunflower rows at different row proportions was higher compared to sole crops of groundnut and sunflower. Similarly, light interception between groundnut and pearlmillet rows at different row proportions was higher compared to sole crops of groundnut and pearlmillet. Differences in plant stature and increased plant density might have resulted in higher light interception between groundnut and inter crop rows. Higher PLI between groundnut and sunflower might be due to greater foliage of pearlmillet. Light interception between intercrop plants in the system was higher compared to their sole crops due to reduced intra row spacings in intercropping leading to higher plant density which inturn increased shading. PLI between intercrop plants increased with increase in row proportions from 1:1 to 4:1 due to increase in shading from 1:1 to 4:1 row proportions. Higher light interception between pearlmillet than sunflower might be due to closer spacing and greater foliage of pearlmillet.

Table 1 Leaf area index and dry matter production of groundnut and intercrops

Treatments	Groundnut				Intercrops			
	Days after sowing							
	25	50	75	Maturity	20	40	60	Maturity
				I. Leaf area index				
Sole GN	0.49	1.58	2.83	1.18	-	-	-	-
Sole SF	-	-	-	-	0.94	2.18	3.18	2.04
Sole PM	-	-	-	-	1.28	2.29	4.76	3.29
GN+PP (7:1)	0.47	1.55	2.80	1.15	-	-	-	-
GN+SF (1:1)	0.42	1.47	2.60	0.90	0.89	2.04	2.97	1.99
GN+SF (2:1)	0/45	1.47	2.62	0.94	0.75	1.93	2.81	1.89
GN+SF (3:1)	0.45	1.49	2.73	1.07	0.71	1.78	2.58	1.66
GN+SF (4:1)	0.46	1.53	2.77	1.14	0.68	1.47	2.36	1.49
GN+PM (1:1)	0.37	1.20	2.27	0.88	1.09	2.10	4.59	3.19
GN+PM (2:1)	0.40	1.23	2.28	0.90	0.96	2.01	3.73	2.91
GN+PM (3:1)	0.41	1.32	2.60	0.94	0.82	1.65	3.46	2.39
GN+PM (4:1)	0.44	1.41	2.65	0.98	0.68	1.28	2.85	1.86
SEm±	0.01	0.01	0.03	0.02	SF 0.04 PM 0.03	0.05 0.02	0.03 0.04	0.02 0.05
CD (P=0.05)	0.03	0.03	0.07	0.06	SF 0.10 PM 0.07	0.13 0.6	0.07 0.12	0.05 0.09
				II. Total dry matter production per plant (g)				
Sole GN	3.5	10.8	22.5	25.3	-	-	-	-
Sole SF	-	-	-	-	4.9	19.0	32.4	42.4
Sole PM	-	-	-	-	5.2	16.6	69.6	74.2
GN+PP (7:1)	3.5	10.3	21.0	23.6	-	-	-	-
GN+SF (1:1)	2.8	8.7	17.3	20.5	4.8	17.6	28.7	38.9
GN+SF (2:1)	2.9	9.7	18.9	22.0	4.6	16.7	26.2	36.0
GN+SF (3:1)	3.0	9.9	20.0	23.1	4.6	16.2	25.7	34.4
GN+SF (4:1)	3.3	9.9	21.3	23.9	4.4	15.0	23.2	32.1
GN+PM (1:1)	2.9	7.9	16.1	19.4	4.8	15.1	53.9	60.0
GN+PM (2:1)	2.9	8.3	17.8	20.3	4.4	12.4	50.0	53.8
GN+PM (3:1)	3.4	8.7	19.1	21.7	4.3	10.7	49.8	53.0
GN+PM (4:1)	3.5	9.6	20.4	22.8	4.0	9.7	28.4	34.[illegible]
SEm±	0.5	0.5	0.08	0.7	SF 0.5 PM 0.6	1.5 1.4	2.3 5.8	2.5 5.8
CD (P=0.05)	NS	1.3	2.0	1.8	SF NS PM NS	NS NS	6.1 15.2	6.6 15.3

GN : Groundnut; SF: Sunflower, PM : Pearlmillet; PP : Pigeonpea

Table 2 Percent light interception in sole in intercropping systems

Treatment	Between groundnut rows			Between groundnut plants			Between groundnut & intercrop rows			Between intercrop plants		
	Days after sowing											
	50	75	Maturity	50	75	Maturity	50	75	Maturity	50	75	Maturity
T_1 Sole GN	75.8	82.4	78.5	75.9	84.5	81.9	75.8	82.4	78.5	-	-	-
T_2 Sole SF	-	-	-	-	-	-	75.3	74.9	73.4	84.2	81.3	79.3
T_3 Sole PM	-	-	-	-	-	-	86.3	84.1	79.1	87.2	84.3	83.4
T_4 GN+PP (7:1)	75.6	82.2	78.2	74.5	84.2	81.4	-	-	-	-	-	-
T_5 GN+SF (1:1)	-	-	-	68.0	79.6	78.1	83.4	81.6	78.1	85.6	83.9	82.9
T_6 GN+SF (2:1)	73.4	79.8	76.5	69.3	80.2	79.7	80.5	79.2	77.6	86.2	84.5	83.6
T_7 GN+SF (3:1)	74.2	80.6	77.4	70.8	81.9	80.8	78.6	77.4	76.9	87.4	85.6	84.5
T_8 GN+SF (4:1)	75.4	82.1	78.1	73.7	83.8	81.2	76.5	75.2	76.2	88.3	86.8	84.9
T_9 GN+PM (1:1)	-	-	-	67.4	78.2	76.2	91.5	89.9	86.1	89.9	86.3	85.5
T_{10} (GN+PM (2:1)	72.3	78.8	75.6	68.9	79.6	77.4	90.6	88.6	85.4	90.4	87.8	86.6
T_{11} GN+PM (3:1)	73.9	79.4	76.2	70.4	80.3	78.5	90.4	87.8	83.2	90.6	88.6	87.3
T_{12} GN+PM (4:1)	75.1	80.9	77.9	72.6	82.4	79.3	89.9	86.7	81.9	91.5	89.9	88.5
SEm+	0.7	0.9	0.7	0.8	0.9	0.8	SF 0.6 PM 1.2	0.5 0.9	0.8 1.9	1.0 1.2	0.5 0.9	1.0 1.1
CD (P=0.05)	1.8	2.2	1.8	2.0	2.3	2.1	SF 1.6 PM 3.2	1.3 2.3	2.2 3.0	2.5 3.2	1.4 2.5	2.6 2.8

GN: Groundnut; SF:Sunflower; PM: Pearlmillet; PP: Pigeonpea.

Higher pod yield (1553 kg ha^{-1}) was with sole crop of groundnut. Reduction in pod yield was more due to its intercropping with pearlmillet and least with pigeonpea (Table 3). Pigeonpea did not compete with groundnut due to temporal differences in growth habit. Hence, pod yield with this system was comparable with sole groundnut. In both groundnut + sunflower and groundnut + pearlmillet intercropping systems, pod yield increased with increase in row proportions from 1:1 to 4:1. Intense competition for growth resources adversely affected yield attributes resulting in poor pod yield in 1:1 row arrangements. Seed yield of sunflower (794 kg/ha) and pearlmillet (1914 kg/ha) were higher as sole crops. Yield of both the crops as intercrops decreased with increase in row proportions from 1:1 to 4:1 due to intense competition at reduced spacing between the plants.

Table 3 Sole crop yields, intercrop yields and pod equivalent yield (kg/ha)

Treatments	Groundnut		Intercrops		Groundnut pod equivalent yield
	Pod	Haulm	Seed	Stalk / stover	
T_1 Sole GN	1553	2282	-	-	1553
T_2 Sole SF	-	-	794	1317	794
T_3 Sole PM	-	-	1914	3571	718
T_4 GN+PP (7:1)	1486	2193	617	2079	2103
T_5 GN+SF (1:1)	1189	1701	527	968	1716
T_6 GN+SF (2:1)	1303	1915	501	860	1804
T_7 GN+SF (3:1)	1392	2013	472	785	1864
T_8 GN+SF (4:1)	1477	2046	381	691	1858
T_9 GN+PM (1:1)	858	1426	1781	3441	1526
T_{10}GN+PM(2:1)	1005	1664	1685	3127	1637
T_{11}GN+PM(3:1)	1189	1772	1580	3014	1782
T_{12}GN+PM(4:1)	1226	1907	1246	2514	1693
SEm+	30	30	SF 10 PM 24	25 30	27
CD (P=0.05)	74	75	SF 27 PM 63	65 79	65

GN: Groundnut; SF: Sunflower; PM: Pearlmillet; PP:Pigeonpea.

Maximum groundnut pod equivalents (2103 kg/ha) was with *groundnut + pigeonpea* 7:1 (*Table* 3). Among the three intercropping systems, higher pod yield equivalents was with groundnut + sunflower 3:1 which was on par with 2:1 and 4:1 ratios of groundnut + sunflower. Pod equivalent yields with groundnut + sunflower system were relatively higher compared to groundnut + pearlmillet system.

From the study it is evident that groundnut + pigeonpea 7:1 system would be more productive followed by groundnut + sunflower at 3:1 row arrangement in terms of optimum growth and yield of component crops.

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Short communication

Effect of integrated nutrient management on productivity and soil fertility in sunflower + pigeonpea intercropping system under rainfed condition

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In India next to food, oilseeds and pulses are considered as major agricultural crops. India stands first in world in area and production of both oilseeds and pulses. The per capita consumption of pulses and oilseeds in India is 14 and 6.5 kg as against the Recommended level of 38 and 20 kg, respectively. In order to alleviate the shortage, India is importing 10-12 lakh tonnes of edible oil every year. The shortage of pulses and oilseeds has aggrevated the problem of malnutrition (Hegde and Kiresur, 1999). Thus, there is an urgent need to increase the production of both oilseeds and pulses to meet the requirements by adopting improved production practices.

The experiment was conducted at Main Research Station, University of Agricultural Sciences, Dharwad on vertisol with pH 7.7 ; E.C. 0.28 ds/m; organic carbon 0.61%; available N 150 kg/ha; P_2O_5 32 kg/ha and K_2O 313 kg/h under rainfed conditions during *Kharif* 1998. The experiment had fifteen treatment combinations comprising three organic sources (FYM, vermicompost and poultry manure) and five inorganic fertilizer levels to pigeonpea only (100, 75, 50, 25 and 0% RDF) and 100% RDF to sunflower kept same for all treatments.

The crops were raised with recommended package of practices. The grain and straw samples were analysed for total N, P and K uptake by the crops. Organic carbon, available N, P and K were analysed by standard methods. Grain yield of net area were converted to hectare basis. The total productivity of the system has been presented in terms of sunflower seed-equivalent yield.

The experiment results showed, (Table 1) integration of either FYM, vermicompost or poultry manure with 100% RDF to both sunflower and pigeonpea and any one of the organic manures in conjunction with 100% RDF to sunflower and 50% to pigeonpea were on par indicating the reduction of 50% RDF to an intercrop i.e., pigeonpea by use of organic sources (Veerabadran and Rajendran, 1993).

Table 1 Seed yields of sunflower and pigeon pea and sunflower seed equivalent yield (q/ha)

Organics	Sunflower Seed yield (q/ha)				Pigeonpea seed yield (q/ha)				Sunflower seed equivalent yield			
Sunflower + Piginpea	FYM	VMC	PM	Mean	FYM	VMC	PM	Mean	FYM	VMC	PM	Mean
100% RDF + 100% RDF	12.42	14.25	13.81	13.49	8.61	8.81	8.98	8.80	22.10	24.16	23.92	23.39
100% RDF + 75% RDF	12.15	14.15	13.55	13.28	8.32	8.67	8.38	8.46	21.51	23.90	22.98	22.79
100% RDF + 50% RDF	11.75	13.84	12.52	12.70	8.02	8.52	8.58	8.37	20.77	23.42	22.17	22.12
100% RDF + 25% RDF	11.69	12.48	11.92	12.03	7.89	7.85	8.45	8.06	20.56	21.31	21.44	21.10
100% RDF + no RDF	11.12	11.48	11.57	11.39	7.21	7.48	7.45	7.38	19.24	19.89	19.95	19.69
Mean	11.83	13.24	12.68	12.58	8.01	8.27	8.37	8.22	20.84	22.54	22.08	21.82

Comparison of means

Source	Org	Inorg	Org. X Inorg	Org.	Inorg	Org. X Inorg	Org.	Inorg	Org. X Inorg
S.Em ±	0.43	0.55	0.95	0.19	0.24	0.42	0.46	0.59	1.03
C.D. (P=0.05)	N.S.	N.S.	N.S.	N.S.	0.70	N.S.	1.33	1.72	N.S.

N.S. = Non - significant
RDF = Recommended dose of fertilizer
FYM = Farmyard manure
VMC = Vermicompost
Pm = Poultry manure

Considering the total productivity of the system in terms of sunflower seed equivalent, it is evident that 50% RDF of pigeonpea in sunflower + pigeonpea intercropping system could be substituted by one of the organic sources (Kumar and Yadav, 1995).

Organic carbon content increased due to application of organic manures along with 100 % RDF to both crops i.e., 0.642% (Table 2). Results are in conformity with the findings of Gour *et al.* (1992); Helkaih *et al.* (1981). Application of poultry manure + 100 % RDF to both crops recorded significantly higher available soil nitrogen followed by Vermicompost + 100 % RDF to both crops. This might be due to higher nutrients content and easy decomposition than FYM. The results are in conformity with Deshmukh *et al.* (1994).

Table 2 **Organic carbon, available nitrogen, phosphorus and potassium in soil after harvest of crops as influenced by organic sources and inorganic fertilizer levels**

Organics	Organic carbon (%)				Available nitrogen (kg/ha)				Available phosphorus (kg/ha)				Available potassium (kg/ha)			
Sunflower + Piginpea	FYM	VMC	PM	Mean	FYM	VMC	PM	Mean	FYM	VMC	PM	Mean	FYM	VMC	PM	Mean
100% RDF + 100% RDF	0.46	0.61	0.66	0.62	165.0	173.0	178.7	172.2	32.1	31.6	33.7	32.4	339.5	315.3	313.8	322.9
100% RDF + 75% RDF	0.60	0.61	0.61	0.61	154.8	165.0	162.8	160.9	28.2	30.8	31.6	30.2	268.2	296.3	304.9	289.8
100% RDF + 50% RDF	0.60	0.61	0.61	0.61	145.4	155.0	155.9	152.1	24.2	29.9	29.1	27.7	288.3	293.5	306.6	296.1
100% RDF + 25% RDF	0.60	0.60	0.61	0.61	139.9	146.8	140.3	142.3	22.0	27.7	26.4	25.4	285.9	290.6	300.4	292.3
100% RDF + no RDF	0.60	0.60	0.60	0.60	120.1	125.2	130.4	125.2	15.1	20.6	23.2	19.5	277.3	287.0	300.0	288.1
Mean	0.61	0.61	0.61	0.61	145.0	153.0	153.6	150.6	24.3	28.0	28.8	27.1	291.8	296.5	305.2	297.8

Comparison of means

Source	Org.	Inorg.	Org. x Inorg.	Org	Inorg	Org. x Inorg	Org.	Inorg	Org. x Inorg	Org.	Inorg	Org. x Inorg
SEm ±	0.015	0.019	0.033	3.71	4.79	8.30	1.14	1.47	2.55	6.42	8.29	14.36
C.D. (P=0.05)	NS	NS	NS	NS	13.88	NS	3.31	4.27	NS	NS	24.02	NS

N.S. = Non - significant
RDF = Recommended dose of fertilizer
FYM = Farmyard manure
VMC = Vermicompost
Pm = Poultry manure

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Short communication

Effect of plastic mulch and fertilizers with foliar spray of Nitrofoska on growth and yield of groundnut

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Groundnut (*Arachis hypogaea* L.) is an important oilseed crop of India. Of the total oil production in the country about 70 % oil is obtained from groundnut alone. Although India ranks first in the world in respect of area and production but ranks 8th in productivity (Anonymous, 1998). The low productivity of groundnut is mainly because of about 90 % of crop is cultivated as a rainfed crop in *kharif*. With the advent of new genotypes of groundnut responsive to fertilizer and irrigation, the area under summer groundnut is increasing mostly in the command areas. For achieving higher productivity with better quality, soil, water and fertilizer management plays significant role. Use of plastic as a mulch is one of the ways for arresting moisture *in situ*. The plastic mulch conserve 25 % more moisture and also creates the congenial temperature between 26.5 to 29.5 °C which was found to be better for pod development (Caichong and Quangjang, 1996). In view of these considerations, the present study was undertaken.

A field experiment was conducted in split plot design with three replications during summer 1998 at Mahatma Phule Krishi Vidyapeeth, Rahuri. The experiment comprised of 16 treatments consisted of white mulch having thickness of 7μ (with plastic mulch and without mulch) and fertilizer levels (100% i.e. 25 kg N + 50 kg P_2O_5 and 75% i.e. 18.75 kg N + 37.5 kg P_2O_5/ha recommended dose of fertilizer) as a main plot treatments and foliar spray of Nitrofoska (12:32:14% NPK, respectively) as a sub plot treatments (Table 1). The soil of experimental plot was low in available nitrogen (118.30 kg/ha), medium in phosphours (20.88 kg/ha) and high in potassium (484.16 kg/ha) and alkaline in reaction (pH-8.3). The crop (var. Koyana) was sown on 22nd Feb., 1998 with spacing of 30 cm between the rows and 10 cm between the plants. The crop was fertilized and mulched as per the treatments.

Table 1 **Mean plant height, plant spread, number of branches and functional leaves and leaf area per plant at harvest as influenced by different treatments**

Treatment	Plant height/plant (cm)	Plant spread/plant (cm)	Number of branches/plant	Number of functional leaves/plant	Leaf area/plant (dm^2)
1. Mulch					
M_1 : With plastic mulch	51.70	53.50	9.07	92.59	31.94
M_2 : Without plastic mulch	44.08	48.57	7.06	87.44	27.43
SEm±	0.53	0.40	0.04	0.26	0.31
CD (P=0.05)	1.83	1.38	0.14	0.91	1.10
II. Fertilizer levels					
F_1 : 100% RDF	47.93	51.08	8.07	90.02	29.71
F_2 : 75% RDF	47.82	50.99	8.06	90.01	29.66
SEm±	0.53	0.40	0.04	0.26	0.31
CD (P=0.05)	NS	NS	NS	NS	NS
III. Foliar spray of Nitrofoska					
S_1 : Control	46.97	50.70	8.11	89.29	29.56
S_2 : 1.0% foliar spray	47.40	51.05	8.11	89.49	29.68
S_3 : 1.5% foliar spray	48.61	51.10	8.15	90.46	29.68
S_4 : 2.0% foliar spray	48.51	51.29	8.16	90.46	30.00
SEm±	0.97	0.73	0.05	0.40	0.64
CD (P=0.05)	NS	NS	NS	NS	NS

The result reported in Table 1 revealed that differences due to application of plastic mulch in respect of growth characters were found significant. The values of mean plant height, plant spread, number of branches, functional leaves and leaf area per plant with plastic mulch were 52 cm, 53.5 cm, 9, 93 and 31.94 dm^2, respectively, which were significantly more than without plastic mulch treatment (Table 2). Consequent upon the favourable effects of mulch on growth characters, the pod and haulm yield improved substantially to non mulch treatment. The pod and haulm yield with plastic mulch were 4770 and 9068 kg/ha, respectively. the same treatment also recorded maximum gross return (Rs. 72,076), cost of cultivation (Rs. 28,593) and net return (Rs. 45,453) per hectare. Patel *et al.* (1985) also reported similar findings.

The differences in growth characters and yield levels did not differ significantly due to fertilizer levels. The values of growth characters (Table 1) *viz.*, mean plant height (48 cm), plant spread (51.08 cm), number of branches (8), functional leaves (90) and leaf area (29.71 dm^2) per plant and pod (4941 kg/ha) and haulm yield (8818 kg/ha) were maximum due to application of 100% recommended dose of fertilizer. Similarly, the maximum values of gross return (Rs. 76,849), cost of cultivation (Rs.28,922) and net return (Rs. 47,927) per hectare recorded due to 100% recommended fertilizer dose (Table 2). Jadhav and Narkhede (1980) and Angadi *et al.* (1990) endorsed the above findings.

The differences in growth characters and yield of groundnut were not significant due to different foliar sprays of Nitrofeska. The maximum values of growth characters were recorded with 2.0% foliar sprays. However, reverse trend was noticed in case of net returns. The interaction effects of factors on growth and yield found to be non significant.

In general, it could be concluded that planting of summer groundnut with plastic mulch and 100 % of recommended fertilizer dose (25 kg N + 50 kg P_2O_5/ha) showed better proposition for achieving higher productivity and net returns.

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Table 2 Pod and haulm yield and economics of summer groundnut as influenced by different treatments

Treatment	Pod yield (Kg/ha)	Haulm yield (kg/ha)	Gross returns (Rs/ha)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)
Mulch					
M_1 : With plastic mulch	4770	9068	72076	28593	45453
M_2 : Without plastic mulch	3680	8536	58388	25037	33351
SEm±	61	33			
CD (P=0.05)	218	114			
Fertilizer levels					
F_1 : 100 RDF	4341	8818	76849	28922	47927
F_2 : 75% RDF	4141	8786	71303	28264	43039
SEm±	61	33			
CD (P=0.05)	NS	NS			
Foliar spray of Nitrofoska					
S_1 : Control	4190	8707	64357	12192	52165
S_2 : 1.0% foliar spray	4194	8761	66190	251.92	40998
S_3 : 1.5% foliar spray	4242	8829	66334	31692	34642
S_4 : 2.0% foliar spray	4288	8912	68046	381.92	29917
SEm±	42	101			
CD (P=0.05)	NS	NS			

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Short communication

Effect of time of harvest on seed quality and seed yield in soybean, *Glycine max* (L.) Merrill. cultivars

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The area under soybean is on increasing in India, yield levels and seed quality are still very poor due to crop subjected to adverse climatic conditions during post maturation/pre-harvest period (Delouche, 1980). Therefore in soybean, harvest time play an important role to conserve the seed quality and to minimize yield loss due to pod shattering. Lin and Severo (1982) stated that the seed quality remains maximum at the time of physiological maturity and it deteriorates progressively with delay in harvest due to seed subjected to weathering in the field. The object of present study was to determine effect of time of harvest on seed quality and yield loss in soybean.

The experiment was conducted at research farm of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The three genotypes of soybean *viz.* PKV-25, JS-335 and JS-80-21 were sown an 10th July 1998. The crop was raised by adopting recommended agronomic management practices. Cultivar PKV - 25 was early variety (75 days) whereas, Cvs. JS-335 and JS-80-21 were mid late varieties matured in about 100 to 110 days. First harvesting in cv. PKV-25 was done 29 days after anthesis (DAA) while first harvesting in JS - 335 and JS - 80 - 21 was done at 49 DAA and 51 DAA respectively. Each harvesting was done with the interval of five days. The harvesting schedule is given as under:

H_1 - Harvesting of pods at 5 days before physiological maturity (P.M.)
H_2 - Harvesting of pods at P.M.
H_3 - Harvesting of pods at 5 days after P.M.
H_4 - Harvesting of pods at 10 days after P.M.
H_5 - Harvesting of pods at 15 days after P.M.
H_6 - Harvesting of pods at 20 days after P.M.

Seed lots thus collected at different harvest times were tested at Seed Technology Research Unit, PDKV, Akola for various seed quality parameters *viz.* 100 seed weight, seed germination by adopting standard procedure as per ISTA, 1986.

Moisture content in three varieties varied significantly (Table 1). Cultivar JS-80-21 had maximum moisture content at harvest than PKV-25 but it was at par with JS-335. Regarding date of harvest, the moisture content went on reducing significantly at every harvest (physiological maturity) was 33.10%. Gore *et al.* (1997) also reported 31 to 33 % seed moisture at physiological maturity, elsewhere 32-38 % moisture content at physiological maturity was observed. The pod shattering was observed in PKV-25, at H_5 and H_6 while in cvs. JS-335 and JS-80-21 it was observed only at sixth harvesting when moisture content reduced to 12.6 %.

Table 1 **Seed quality and yield as influenced by time of harvest in soybean cultivars**

Variety/ Treatment	Moisture (%)	100 seed weight (g)	Germination (%)	Seed yield/ plant (g)
PKV-25	23.00 (28.69)*	10.9	77.24 (8.817)	8.94
JS-335	23.50 (29.00)	12.2	92.22 (9.629)	16.05
JS-80-21	23.80 (29.20)	13.5	82.24 (9.096)	15.58
SEm±	0.03	0.03	0.02	0.14
CD (P=0.05)	0.07	0.09	0.06	0.41
H_1	54.90 (47.79)	10.6	77.43 (8.828)	12.23
H_2	33.10 (35.16)	12.6	85.34 (9.265)	14.60
H_3	18.00 (25.10)	12.5	85.32 (9.264)	14.27
H_4	15.60 (23.26)	12.5	85.16 (9.255)	14.21
H_5	13.60 (21.65)	12.5	84.97(9.245)	13.32
H_6	12.60(20.83)	12.5	84.65 (9.228)	12.50
SEm±	0.04	0.05	0.03	0.02
CD (P=0.05)	0.10	0.13	0.09	0.56

* Figures in parenthesis are arcsine values

The data on seed germination, regarding cultivars indicated that cv. PKV-25 was poor in seed germination as compared other two cultivars due to humid conditions and rainfall between each harvest time after maturity. Seed germination was significantly low at first harvest date (H_1) as compared to further harvest dates. This might be due to incomplete seed development before physiological maturity resulting poor seed quality. In relation to H_2 there was reduction in germination but at every harvest starting from H_3 to H_6 differences were not significant indicating no effect of harvest time on seed germination Arulanthy and Senanyake (1993) also reported no difference in seed germination harvested at physiological maturity and harvestable the maturity.

Cultivar JS-80-21 had maximum and significantly higher as compared to PKV-25 and JS-335. Seed weight was minimum prior to physiological maturity irrespective of varieties while it was on par with other dates of harvest.

Seed yield per plant of the cultivar PKV-25 was poor (8.94g) as compared the JS-335 (16.05 g) and JS-80-21 (15.05 g) which is due to inherent potential of cultivars. However, the difference in yield per plant at various dates of harvest also were significant. Maximum yield was recorded at H_2 (14.6g) i.e. at physiological maturity. These differences in yield shall be attributed to stage of plant growth or weather conditions at the time of harvest. Low yields at first harvest seem to be due to incomplete development of seeds, while low yields at H_5 and H_6 may be due to shattering of pods. This is well obvious from Table 2 showing the grain yield losses in relation to physiological maturity stage (H_2).

Table 2 Grain yield loss (%) at various harvest date in relation to H_2

Treatments	V_1	V_2	V_3	Mean
H_1	21.9	13.7	15.2	16.32
H_3	3.5	1.4	2.4	2.26
H_4	4.0	1.5	3.0	2.67
H_5	29.0	1.0	3.6	8.76
H_6	33.8	16.4	9.1	14.38

The studies revealed that the harvesting of soybean crop should not be delayed beyond 10 days after physiological maturity to avoid the shattering loss while harvesting prior to physiological maturity was also not beneficial, as it was poor in seed quality due to incomplete development of seeds.

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Short communication

A note on granulosis virus infection in *Achaea janata* Linnaeus

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Baculovirus infection in castor semilooper *Achaea janata* L.. Is known to be a mixed infection of Granulosis Virus (GV) and Nuclear Polyhedrosis Virus (NPV) (Battu,1986; Vimala Devi, 1992). However, electron microscopic examinations of viral preparations from infected larvae revealed predominance of GV capsules (Prasad and Vimala Devi-unpubl.). The symptoms of granulosis virus infection in *A. janata* larvae are described in the present endeavour.

As the viral infection proceeds, the larva manifests loss in appetite as the first indication followed by feeding cessation at very advanced stages of infection. Similar loss of appetite followed by cessation of feeding has been reported in granulosis virus infected *Harrisina brillians* (Huger,1963). As multiplication of virus occurs in the infected tissues, changes take place in colour and appearance of integument. The change in colour depends partly on the larval age at the time of infection. The healthy larva appears dorsally smooth and greyish-brown with lateral longitudinal red and black stripes and ventrally dark yellow. In contrast, GV infected larva exhibited patterns of discolouration varying from pale to pinkish (Fig. 1a). Larva showing pinkish discolouration is normally undersized and quite prominent if the larva is infected in early stages. Larva appeared mottled because of inter-segmental discolouration (alternately striped dark and light coloured patches on the integument) (Fig. 1b). Most often this symptom is associated with older larva. Infected older larva appeared wrinkled because of inter-segmental constrictions (Fig.1c) although such appearance of the integument could also occur in young infected larva. In either case, infected larva became fragile and may rupture releasing milky-white haemolymph (Fig. 1a).

Healthy full-grown castor semilooper larva measured about 6.0-7.0 cm in length. Marked reduction in size in advanced stages of the disease is observed with GV infection in semilooper. Our studies on 5 day-old larva infected with different folds of serially diluted *A. janata* virus stocks revealed reduction in larval weight compared with untreated larvae. Reduction in the larval weight at 8 days after infection with the sub -lethal dose (15625-fold) was to the extent of 27%compared to the control larvae, while it was 70% in larvae infected with a 25-fold dilution (Table 1). Larvae infected with the sub-lethal dose failed to pupate even 20 days after hatching. Larval duration in untreated healthy larvae ranged from 13 -18 days and 95% of such larvae entered pupation in 18 days (data not shown).

Haemolymph from healthy larvae appeared clear and colourless while that from infected larvae appeared turbid and milky white. The haemolymph when examined under the microscope revealed enormous number of inclusion bodies showing rapid brownian motion (Phase contrast, 600 x) (Fig. 1d). On Amido black (1% in glacial acetic acid) staining, capsules appeared dark blue against a light blue background under bright field (1500 x).

Rickettsia associated with laboratory colonies' of *A. janata* led to stunting of infected larvae that became stiff after death (Vyas *et al.*, 1989) and can thus be distinguished from granulosis infection.

Table 1 **Weight reduction in semilooper larvae fed with granulosis virus at different concentrations**

Serial dilutions of virus	Mean weight of survivors at 8 days after treatment#		
	Weight/larva (g)*	Number of survivors@	% reduction in weight over control
5 fold	–	0	–
25 fold	0.260a	9	70.3
125 fold	0.366a	14	58.6
625 fold	0.574b	25	34.5
3125 fold	0.546b	19	37.7
15625 fold	0.632b	37	27.9
Control	0.876c	33	--

Treatments were imposed on 5 day old larvae; 5 replications of 10 larvae each/treatment.

* Means followed by the same letter are not significantly different from each other after DMRT.

@ No survivors were left at 8 days in 5-fold treatment; 17 larvae pupated 8 days after treatment in the control.

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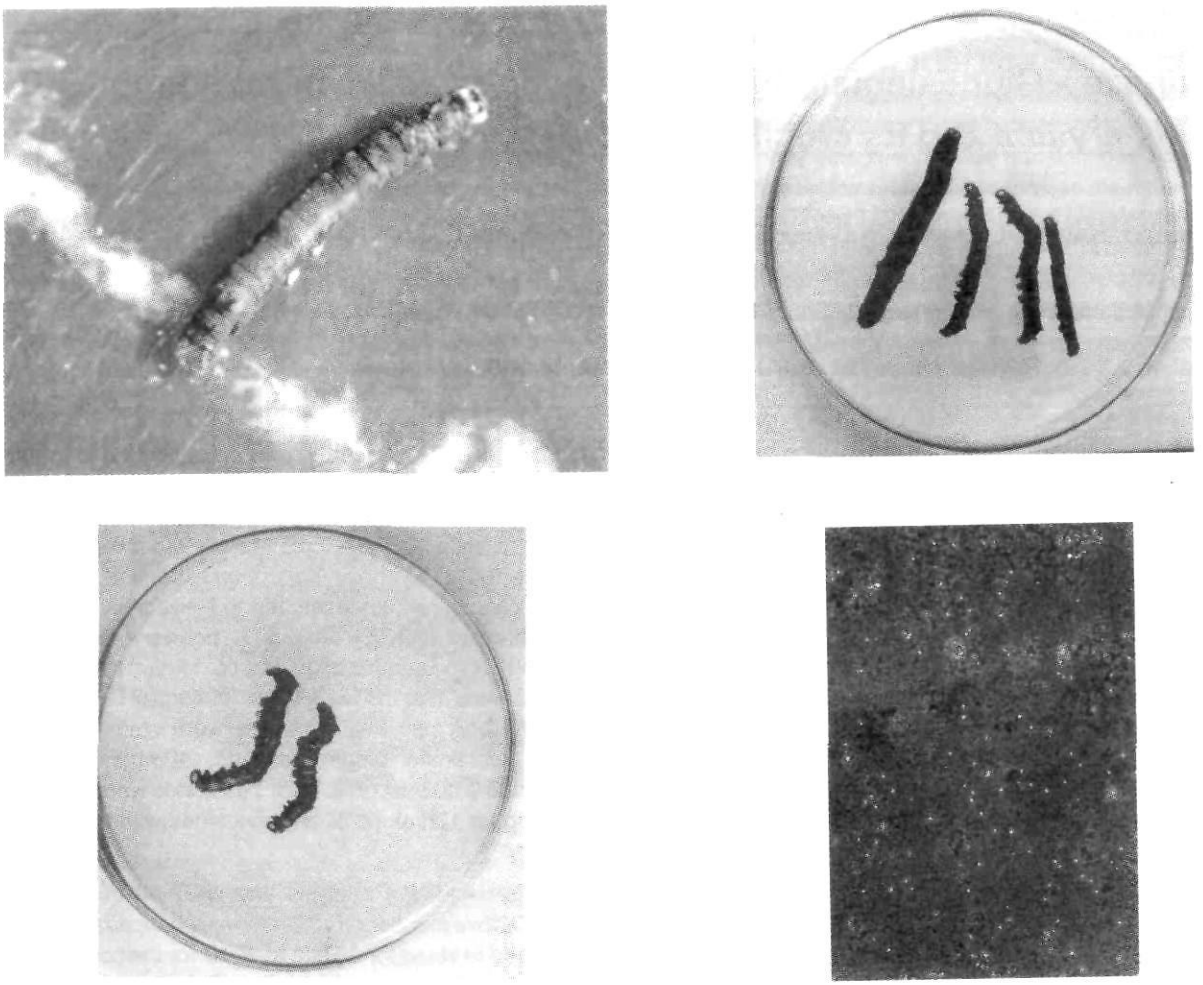

Fig: 1 Symptoms of granulosis virus infection in *A. janata*
(A) Pallid larva with milky-white ooze; (b) Larvae showing inter-segmental discolouration;
(c) Wrinkled larvae and (d) GV inclusion bodies in the haemolymph of infected larva (phase contrast, 600 x).

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Short communication

Myrosinase - Glucosinolate based interactions between mustard aphid, *Lipaphis erysimi* and its cruciferous hosts

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

MacGibbon and Benzenberg (1978) have shown that *L. erysimi* is also known to posses myrosinase enzyme. These myrosinases exhibit electrophoretic mobilities distinct from those of isozymes of their host plants. Thus, an attempt has been made to elucidate host specificity of mustard aphid by studying the myrosinase - glucosinolate based interactions between mustard aphid and its host plant.

Cruciferous cultivars, *viz.*, *Brassica juncea* (RC-199), *B. carinata* (HC-9001, PC-5), *B. campestris* (BSH-1, YSPb-24), *B. napus* (Midas, GSH-1) and *Eruca sativa* (TMH-52) were sown in the plots of 5 x 3m with three replications in a randomized block design as per recommended package of practices (PAU, 1996) on October 25, 1996.

For myrosinase, mustard aphid and leaf samples collected from various cruciferous cultivars were cooled for a few minutes at 10 °C and then leaves were squeezed in the extraction medium containing 0.8g sucrose, 0.05ml of mercaptoethanol in 2ml of Tris HC1 (pH 7.4) buffer. Similarly, a collection of 10 aphids starved for six hours was extracted in the above mentioned extraction medium. The samples were then subjected to Polyacrylamide Gel Electrophoresis (PAGE) on 8.6 % polyacrylamide gel. About 75 % of the sample aliquots were loaded in the wells and gels were run in Tris-glycine buffer (pH 8.3) at a current of 2mA per well. The gels were stained in the solution containing 5mg/ml sinigrin, 10mg/ml barium chloride and 0.003 ascorbic acid. The bands were allowed to develop for 12h at 37 °C and destained with fresh 7 % acetic acid.

For volatile aglucone analysis, the weighed quantity of leaves of above mentioned cultivars was chopped, covered and allowed to stand for 85 min at 30 °C for the conversion of glucosinolates to volatiles. The volatiles were then extracted by steam distillation under reduced pressure and condensate was extracted into ether, which was evaporated at reduced pressure and final volume was made in acetonitrile. The HPCL conditions used were: Column-C18 (250x4.6mm); Solvent system-100% acetonitrile; Flow rate - 1ml/min; Detection wavelength - 235nm at room temperature. Similarly, volatile aglucones from a weighed quantity of aphids were extracted in ether and subsequently into acetonitrile and analyzed by HPCL as mentioned above.

Myrosinase, the glucosinolate degrading enzyme, is known to exist in several different forms which may have different levels of activities (Mithen, 1992). The studies on myrosinase isozyme from various cruciferous cultivars *viz.* *B. napus*, *B. carinata*, *B. campestris*, *B. juncea* and *E. sativa*, varying in susceptibility to mustard aphid attack, demonstrated polymorphism ranging from one to three isozymes. In all, there were four isozymes. First isozyme (Rf = 0.07) was present in *B. napus, B. carinata and B. juncea* while another one (Rf = 0.23) was present in *B. carinata, B. juncea* and *E. sativa*. The isozymes of *B. campestris* (Rf = 0.14) and *B. carinata* (Rf = 0.44) were

distinctly different from all others (Fig. 1a). The volatile aglucone profiles of these cultivars showed qualitative and quantitative variations with respect to isothiocyanates of Ho-butenyl-, allyl-, butenyl- and Ho-indolyl- glucosinolates. Allylisothiocyanate is present in all the species while Ho-indolyl gln is present in *B. juncea* and *B. carinata*. Isothiocyanate of Ho-butenyl gln is absent from *B. juncea* and *B. napus*, while present in *B. carinata*, *B. campestris* and *E. sativa*, though amount was maximum in *E. sativa* (Table 1). The distribution pattern of myrosinase isozyme has been reported to be organ, species, and age specific (Bones and Rossiter, 1996). It has been postulated that the particular isozyme corresponds to endogenous conditions found in that plant or to conditions found in target organism or to a particular glucosinolate that dominates the profile of that tissue. Different aglucone profiles are known to be the result of different isozyme patterns (James and Rossiter, 1991). In our studies, the volatile aglucone profiles (Table 1) and isozymic patterns of various cruciferous cultivars (Fig. 1a) further confirm these observations.

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

Relative Retention Time (R_n)	Glucosinolates	Cultivar				
		B. carinata (HC-9001)	*B. juncea* (RC-199)	*B. napus* (Midas)	*B. campestris* (BSH-1)	*Eruca sativa* (TMH-52)
0.88	Ho-butenyl	11.91	-	-	21.50	26.70
1.00	Allyl	8.82	33.88	20.00	27.20	18.80
1.14	Butenyl	2.38	5.64	-	15.00	-
1.24	Unidentified	4.59	10.16	87.00	5.16	6.77
1.31	Ho-indolyl	3.18	10.84	-	-	-

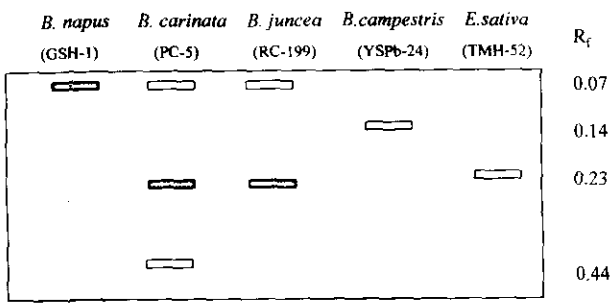

Fig 1a. Zymogram showing the pattern of myrosinase isozymes from different cruciferous cultivars

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

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

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

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

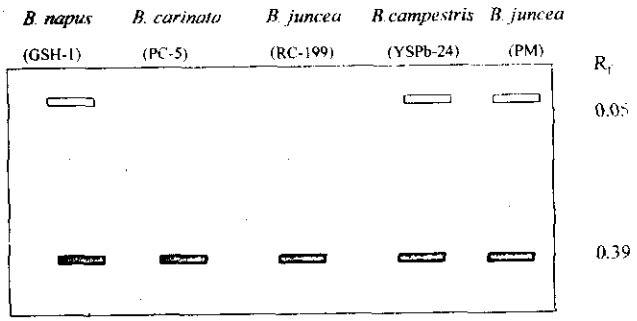

Fig 1b. Zymogram showing the pattern of myrosinase isozymes from mustard aphid feeding on different cruciferous cultivars

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Short communication

Role of *Macrophomina phaseolina* (Tassi) Goid in castor wilt complex

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The castor *(Ricinus communis* L.) is one of the important oil yielding crops in India. Andhra Pradesh has the second largest area cultivated under this crop in India (244.10 lakh ha) with a production of 59.60 m tons and productivity of 244 kg/ha (Oilseeds situation in India, A statistical overview, 1995).

With the introduction of fertilizer responsive and hybrid cultivars, some of the hitherto minor diseases have assumed serious proportion so much so their occurrence has now become a limiting factor in stepping up castor yields. Root rot caused by *Macrophomina phaseolina* (Tassi) Goid was considered as a disease of minor importance, but now it has become a disease of major importance.

Earlier work showed that *M. phaseolina* infection in trees was always associated with other organisms. The most common association reported was with *Fusarium* spp. (Dhingra and Sinclair, 1978). Since little information is available on the interaction between *M. phaseolina* and *F.* oxysporum f. sp. *ricini*, the present investigation was undertaken to delineate the exact role of *M. phaseolina* in castor wilt complex.

Pure culture of *F.* oxysporum f. sp. *ricini* was obtained from Directorate of Oilseeds Research, Rajendranagar. Both *M. phaseolina* and *F. oxysporum* were multiplied on sorghum seed meal medium. Four this, sorghum seed material was soaked in sucrose 2% solution overnight, transferred in 250 ml flasks and sterilised at 15 kg/cm^2 pressure for 20 min. To this, 7 day old culture of *M. phaseolina* and *F. oxysporum* was inoculated separately in different flasks under aseptic conditions. The flasks were incubated at 27 °C for 10 days. To obtain uniform growth of the fungi, sorghum seeds in flasks were shaken periodically. The inocula multiplied were mixed with steam sterilized soil @ 50 g/kg filled in 30 cm diametter earthern pots. Surface sterilized castor seeds were sown in these pots. All the treatments were replicated thrice such that there were 15 plants/replication (Table 1). Observations on pre and post emergence mortality of plants at different ages of plant growth was recorded starting from 25 to 100days.

The infected plants in M_1 F_0 exhibited typical symptoms of root rot such as sudden wilting, hanging/dropping of leaves, blackening at collar region, straw colour discolouration on stems, blackening and disintegration of roots and formation of sclerotial bodies in pith region.

However, infected plants in M_0 F_1 showed typical symptoms of Fusarium wilt. The seedling emergence was poor and slow which were stunted and sickly in appearance. Infection was generally confined to the roots and lower stem portions. The lower part of the tap root and lateral root system was completely sestroyed. At later stages diseased plant leaves turned to bronze or brown colour associated with upward curling. Leaves of affected plants with red and eventually dropped. Wilting of stem and the presence of flaccid leaves were the most common symptoms. Black lesions with pink sporodochia were also observed at later stages of disease development.

Table 1 **Role of *M. phaseolina* and *Fusarium oxysporum* f.sp. *ricini* on the per cent incidence of castor wilt**

Treatment	Pre-emergence	25 DAG	50 DAG	75 DAG	100 DAG	Mean
M_1F_0	6.43 (14.69)	12.00 (20.25)	15.93 (23.52)	36.43 (37.12)	42.60 (40.74)	27.26
M_0F_1	8.80 (17.29)	19.60 (26.27)	23.90 (29.26)	42.50 (40.68)	40.86 (39.73)	30.65
M_1F_2	6.60 (14.92)	14.55 (23.62)	30.80 (33.72)	48.20 (44.00)	54.33 (47.48)	32.74
F_1M_2	8.20 (16.65)	22.00 (27.95)	43.30 (41.16)	64.00 (53.13)	81.60 (63.94)	40.57
M_1F^1	12.73 (20.90)	23.20 (28.88)	60.33 (50.96)	72.66 (58.48)	89.00 (70.71)	45.99

DAG = Days after germination
Figures in parenthesis are the angular transformed values
CD (P=0.05) Treatment : 0.629; Plant age : 0.62; Interaction : 1.400
M_1 = *M. phaseolina* alone 5 gm/100 g soil
M_2 = *M. phaseolina* 25 days after sowing 5 g/100 g soil
F_1 = *F. oxysporum* alone 5 gm/100 g soil
F_2 = *F. oxysporum* 25 days after sowing 5 g/100 g soil
M_1F_1 = Both at the time of sowing (each 5 g/100 g soil)

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The disease severity was more when both the fungus were inoculated together than the symptoms produced by them individually (Table 1). The infected plants at 50 days age showed more conspicuous symptoms of *Fusarium* and when the plants age was 100 days the symptoms that are typical of *M. phaseolina* were noted. Maximum incidence of the disease was observed when the plants were 100 days old. The highest being with M_1F_1 with a plant mortality of 89.0%. With F_1M_2 the mortality was 81.6% followed by M_1 F_2 with 54.33%, M_1 F_0 with 42.6% and M_0 F_1 recording 40.86%, respectively.

This can be attributed to the reason that plants at spike maturation stage are more susceptible to *Macrophomina* infection since the nutrients are translocated to spike from source and *Macrophomina* being a weak pathogen is known to proliferate at lower nutrient levels in plants. Another reason for this type of reaction may be due to the weakening of plants as a result of invasion by *Fusarium*. These results are in conformity with Erzhibov *et al.* (1980).

M. phaseolina and *F. oxysporum* alone took longer time for expressing symptoms and causing death of plants individually, than when both the fungi were added to soil simultaneously. Maximum plant mortality was recorded when both *M. phaseolina* and *Fusarium* were simultaneously added to soil before sowing seed. When both fungi were introduced into soil simultaneously the per cent plants showing mortality symptoms were more at all the growth phases of plant starting from the emergence stage till the crop attained an age of 100 days. This type of interaction might be due to the fact that unlike *M. phaseolina*, *F. oxysporum* is a typical vascular parasite and does not damage cortical cells. The former damages cortical cells and to a certain extent, the different vascular elements. The combination of both the pathogens showed a synergetic effect and led to quick decline of castor plants.

In general, both at pre and post emergence stages, presence of *Fusarium* in soil causes more damage to plants than *Macrophomina* alone. Younger plants were reported to be more susceptible to *Fusarium* wilt than older plants (Grau and Bissonnette, 1974).

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Short communication

In vitro screening of castor genotypes for stress tolerance*

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Castor (*Ricinus communis* L) is an economically important non edible oilseed crop. It is cultivated over an area of 1.71 lakh ha with a production of 0.47 lakh t in Andhra Pradesh. The crop is mostly cultivated in rainfed tracts where it is subjected to moisture stress resulting in low average yield of 275 kg/ha (Damodaram and Hegde, 1999). To identify a suitable castor genotype that would effectively tolerate moisture stress, the screening work was taken up.

Four castor genotypes *viz.*, GCH-4, Bhagya, Aruna and DCH 177 were raised in plastic pots during 1998 *kharif* season. From ten day old seedlings, hypocotyl explants were selected, cut into two cm long pieces, surface sterilized with 0.1% mercuric chloride and inoculated on MS medium (Murashige and Skoog, 1962). To initiate callus, medium was fortified with NAA 0.5 mg/l + BAP 0.5 mg/l which served as control. Graded amounts of PEG were added to the medium to create stress of -3, -6 and -9 bars.

The culture tubes containing the explants were maintained at 25 ± 2 ° C under continuous light. Callus produced from the explants was observed four weeks after inoculation and quantified as small (+), medium (++) and large (+++). The callus obtained was analyzed for proline following the procedure of Bates *et al.*, (1973) and total sugars (Dubois *et al.*, 1956). The data were analyzed in 4 x 4 mixed factorial experiment laid out in completely Randomized block design (Panse and Sukhatme, 1975).

Hypocotyl explants of four castor genotypes produced callus in large amounts in control and also in PEG induced stress treatment of -3 bars. At increased stress of -6 and -9 bars explant growth was effected resulting in small sized callus (Table 1).

The proline content recorded a progressive increase with increase in PEG concentration from -3 bars to -6 bars (373.3 - 713.8 μg/g callus) and declined at -9 bars (606.1 μg/g) as compared to control (244.9 μg/g). Among four castor genotypes, GCH-4 recorded significantly higher proline (582.7 μg/g). Bhagya and Aruna were on par (510.4 - 494.7 μg/g) while DCH 177 recorded the least proline (350.3 μg/g). Genotype x treatment interaction showed significant differences in proline at -6 bars stress (Table 2). GCH-4 recorded the maximum proline content (931.6 μg/g). Enhanced levels of proline in the callus under PEG induced stress was also reported in groundnut (Purushotham *et al.*, 1998). The increased proline content helps in tolerating water stress either by rehydration of the protoplasm or by providing energy for recovery from stress (Khidse *et al.*, 1982).

Table 1 Relative amounts of callus produced from hypocotyl explants of castor genotypes

Genotype	Callus produced (g) at stress level			
	0 bars	-3 bars	-6 bars	-9 bars
GCH-4	+++	+++	+	+
Bhagya	+++	+++	+	+
Aruna	+++	+++	+	+
DCH-177	+++	+++	+	+

Total sugar content, similar to proline, exhibited an increase from -3 to -6 bars (31.0 - 58.7 mg/g callus) and thereafter decreased at -9 bars (39.0 mg/g) as compared to control (14.5 mg/g). The four castor genotypes showed significant variation in total sugar content. GCH-4 recorded the maximum (42.6 mg/g). Bhagya and Aruna were on par (37.2 - 33.9 mg/g), while DCH 177 showed low levels (29.3 mg/g). It was also reported that higher leaf carbohydrates favoured proline accumulation and contributed to enhanced drought tolerance (Hanson and Hitz, 1982).

The study revealed that, it should be possible to screen castor genotypes for stress tolerance by *in vitro* methodology.

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Table 2 Proline and total sugars in callus as influenced by PEG induced stress

Genotype	Proline content (μg/g callus)					Total sugars (mg/g callus)				
	0 bars	-3 bars	-6 bars	-9 bars	Mean	0 bars	-3 bars	-6 bars	-9 bars	Mean
GCH-4	256.1	490.7	931.6	652.3	582.7	20.6	36.5	67.5	45.6	42.6
Mhagya	323.2	423.4	733.2	561.3	510.4	16.3	31.6	60.6	40.1	37.2
Aruna	224.5	356.2	696.3	701.6	494.7	11.5	30.9	57.1	36.5	33.9
DCH-177	175.8	222.8	493.9	508.7	350.3	9.4	25.2	49.5	33.3	29.3
Mean	244.9	373.3	713.8	606.1		14.5	31.0	58.7	39.0	

	SEm ±	CD (P=0.05)	SEm ±	CD (P=0.05)
Genotypes	7.2	21.61	1.30	3.95
Treatments	7.2	21.61	1.30	3.95
Interaction	14.4	43.21	NS	NS

Application for **HARDF Award**

1. Name of the Award : HARDF Award

2. Year :

3. Name & Designation of **Scientist** :
(underline Surname)

4. Date and Place of Birth :

5. *Marital status* : *Married / Unmarried*

6. Complete Postal Address :

7. Telephone : **Office:** **Res:**
Fax :
E-mail :

8. Educati**onal Qualifications:**

Degree	*Year*	*Grade point average*	*Institution*	*Remarks*

9. Employment Record:

Name of the organisation	Designation & *Office Address*	Pay Scale	Period	Type of work done

10. Any other relevant training/experience

11. Details of the research work being presented for the award

i) When, where and how the research work was conceptualised ?

ii) when, where and how it was conducted ?

iii) What are the socio-economic, technological and scientific relevance and priorities of this work?

iv) Who were the principal associate scientists at various stages of research work ?

v) What were the principal milestones reached during the progress of research work ?

vi) What were the principal results obtained and their scientific/technological relevance ?

vii) What is the potential value of these results in increasing production, productivity, profitability and sustainability of agricultural enterprises in the relevant field?

viii) What has been the actual impact of these findings on production, productivity, profitability and sustainability of agricultural enterprises in the relevant field?

ix) Any other impact of results obtained ?

x) A concise statement (about 200 words) highlighting the most significant aspect of the research work done that you would like to see in your citation, if chosen.

12. List of all publications in bibliographic format arising out of the research work.

13. Whether any patents have been taken out or applied for based on results of this research work ? If so, give details.

14. Whether this research work has been submitted for any other award/recognition ? If so, what was the outcome ?

Signature

15. Certificate by the Head of the Institution at which the research work being presented for the award was carried out.

Signature and Seal

16. List of Annexures

IMPORTANT NOTE

ISOR has decided to award the HARDF Awards for outstanding oilseeds research. There are 15 cash awards (each of Rs. 3000/-) and citation in the following disciplines:

i) Four awards in varietal improvement of groundnut, rapeseed-mustard, sesame, safflower, sunflower, soybean, castor, linseed and niger.

ii) Five awards in entomology and four awards in plant pathology for pest management (one each for rapeseed-mustard and groundnut crops) and the rest for remaining crops.

iii) Two awards for chemical weed control in each in groundnut and soybean.

LAST DATE FOR RECEIPT OF APPLICATIONS EXTENDED UPTO

MAY 31, 2002

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