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Excessive Moisture Tolerance in Soybean

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ABSTRACT

*Sixty M_7 generation mutants of soybean [*Glycine max (L.) *Merill] isolated from varieties JS 335, JS 93-05 and NRC 37 treated by 250 and 300 Gy gamma rays along with checks and other varieties were screened for excessive moisture stress tolerance during rainy season of 2007 and 2008 by addressing germination, survival of plant and seed yield. A significant reduction in germination percentage was started after 72 h of flooding in laboratory with large variation after 72 and 96 h of soaking. Genotypes JS 76-205 (black seeded) and JSM 127 were tolerant to excessive moisture before germination. Genotypes JS 97-52, JSM 258, JSM 290, JSM 115, JSM 238 and JSM 175 had high ability to form adventitious roots under excessive moisture stress. Among the stress parameters, stress tolerance index followed by stress susceptibility index were able to distinguish the genotypes under stress. Considering all the traits simultaneously, genotypes JSM 115, JS 97-52, JSM 202, JSM 189 and JSM 248 were considered tolerant to excessive moisture stress. Genotypes JS 97-52, JSM 115 and JSM 202 had minimum deviation for all the observed traits under excessive moisture stress.*

Key word: Adventitious roots, excessive moisture, soybean, stress parameters

Excessive soil moisture, one of the most important constraints for crop production during rainy season, reduces oxygen supply, availability of hormones (to root), nutrients uptake and increases soil and plant toxicity apart from enhanced biotic stresses. In India about 8.5 million hectare of arable soil is prone to this problem, whereas in USA 12 per cent of the agricultural soils is affected (Boyer, 1982). Soybean [*Glycine max* (L.) Merrill] encountered excessive moisture stress from germination that may continue up to pod filling. Yield of soybean is more affected by water logging stress at the reproductive stages than at the vegetative stages (Linkemer *et al*., 1998, Oosterhuis *et al*., 1990 and Scott *et al*., 1989).

Seedling establishment and non-significant alteration in seed yield and seed size are the three important objectives to be achieved under stress condition. The ability to manipulate the influencing factors to achieve these objectives depends on existing variability. This variability can be exploited with the knowledge of genetic control for resistance to excessive moisture that lead

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to greater yield stability in stress environment. Therefore, the present study was undertaken to study the flooding tolerance of soybean genotypes at field and laboratory conditions.

MATERIAL AND METHODS

The experiment was conducted on 60 mutants of M_7 generation developed by applying gamma rays doses of 250 and 300 Gy treatment on varieties JS 335, JS 93-05 and NRC 37 at BARC, Trombay along with checks and seven other varieties (JS 97-52, JS 80-21, JS 76-205, JS 90-41, NRC 7, MACS 13 and MACS 57). Mutants were found fixed from generation M_5 onwards. It was treated to isolate mutant for earliness and resistance to yellow mosaic virus (YMV) in JS 335; better field emergence, non-cracking of seed from JS 93-05; and dwarfness in NRC 7. The initial germination of all the lines was between 80-85 per cent *i.e.,* above seed certification Standard (70 %) under Indian condition. The characteristics of the parental genotypes are as follows.

JS 335 A puberulent variety of 100 days maturity with wide adaptability occupying 85-90 per cent area. The variety is susceptible to YMV.

JS 93-05 A puberulent early duration (90 days) variety with presence of four seeded pod. The drawbacks are susceptibility to YMV, prone to seed coat cracking and poor field emergence.

NRC 37 A pubescent medium late (110 days), tall high yielding variety. The bottlenecks are susceptibility to YMV, late maturity and lodging.

From 250Gy treated population of JS 93-05 (150 plants); JS 335 (200 plants); and NRC 37 (200 plants), whereas from 300 Gy treated JS 93-05 (110 plants); JS 335 (200 plants); and NRC 37 (300 plants) were raised and harvested individually in M_2 generation.

Screening during germination

Randomly selected three hundred seeds (100 seeds/replication) were tested for sensitivity to excessive moisture stress (Hou and Thseng, 1991). Seeds were surface sterilized with 70 per cent ethanol for 30 seconds and soaked in distilled water by complete immersion for 24, 48, 72, 96, 120 and 144 h. After soaking the seeds were left on filter paper to air-dry for 6 h before determination of germination (ISTA, 1999).

Screening in field

Counted seeds (75) of each genotype (>80 % germination) were sown in each row adopting randomized complete block design with two replications under normal and excessive moisture stress in the Seed Breeding Farm, JNKVV, Jabalpur during *kharif* 2007 and 2008 (Plate 1). At V1 stage (fully expanded trifoliate leaf) the field was bunded (barring control) and flooded at two-day interval to create excessive moisture stress at pounding depth of 10.0 ± 5 cm at different growth stages *i.e.,* T_1 Flooding up to V3 (third node stage); T_2 Flooding up to V5 (fifth node stage); T_3 Flooding up to R1 (beginning of blooming). The water was drained off after completion of R1 stage with proper drainage.

Plate 1. Cultivation of soybean genotypes under waterlogged and normal condition

Field emergence index [Germination (%) - Field emergence (%)/ Field emergence (%)]; plant population (at V1 stage), plants with adventitious roots, stress intensity, geometric mean productivity (Singh *et al.,* 2007), mean productivity, tolerance (Rosielle and Hamblin, 1981) and stress susceptibility index = (C-W)/C (C and W indicated the performance under normal and excess moisture conditions, respectively) were observed apart from other yield contributing traits.

RESULTS AND DISCUSSION

The interaction between stage of plant and duration of flooding stress had a significant impact on the germination of the soybean cultivars. There was little difference among the genotypes for germination up to 72 h of flooding (Fig. 1). However, drastic reduction in germination starts after 72 h of flooding. Large variation was observed at 72 and 96 h of soaking. Maximum tolerance was recorded by the genotypes, JS 76-205 and JSM 127 (> 60 % germination after 120 days of flooding). Some sensitive lines *viz.,* JSM 45, JSM 207 and NRC 7 started deterioration even after 42 h of soaking.

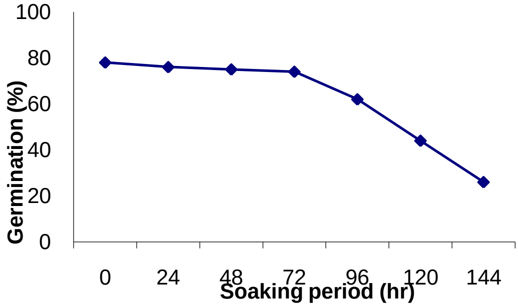

Fig 1. Impact of excessive moisture stress on germination percentage of soybean genotypes

With the increase in duration of excessive moisture stress the minimum and maximum value for germination was reduced. Days to flowering, maturity and grain filling duration were reduced with the increase in duration of excessive moisture stress (Table 1).

Ten percent reduction in plant population over control was observed under excessive moisture stress up to V1 stage, whereas only 51.3 and 42.48 per cent population were recorded up to V3 and V5 under 21 days stress, respectively (Fig 2). Six fold increase was observed in remaining plant population with adventitious roots with the increase in duration of excessive moisture stress. Mean adventitious root formation in controlled condition was zero. Adventitious roots were formed in 9.6 per cent population under excessive moisture stress up to V5 and 58 per cent plants up to R1 stage. Reduction of 20, 41 and 51 per cent in seed yield per plant up to V1, V5 and R1 stage, respectively under excessive moisture stress was observed.

Plate 2. Formation of adventitious roots under waterlogged condition

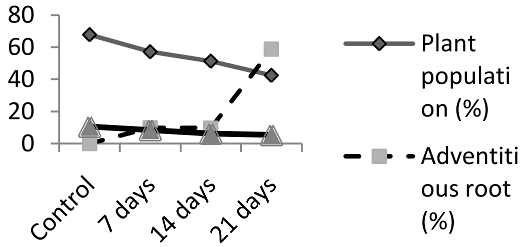

Fig 2. Performance of soybean genotypes under excessive moisture stress

Table 1. Mean performance of observed traits in soybean for ancillary traits under excessive moisture stresses

Observation	Treatment	Mean	Range	SE	CD
Days to flowering (No)	Control	46.00	36-56	0.064	0.18
	T1	45.00	34-55	2.300	6.30
	T2	46.00	32-57	2.300	6.40
	T3	42.00	30-50	3.600	10.20
Days to maturity (No)	Control	89.71	82-96	0.790	2.25
	T1	92.31	84-106	6.400	18.26
	T2	89.91	82-102	0.620	1.73
	T3	82.01	77-98	0.590	1.56
Grain filling duration (days)	Control	43.71	42-48	6.400	18.20
	T1	44.31	38-45	0.129	0.36
	T2	41.91	35-44	0.115	0.32
	T3	38.01	34-40	0.107	0.30
Pod/plant (No)	Control	32.20	16-74	4.100	11.60
	T1	24.60	8-46	4.600	13.00
	T2	20.40	6-38	3.800	10.80
	T3	16.40	5-24	2.500	7.30
Filled pod/plant (No)	Control	28.04	12-46	5.700	16.21
	T1	16.03	6-23	2.360	6.70
	T2	14.30	5-26	2.460	6.75
	T3	11.89	5-38	1.570	4.45
Harvest index (%)	Control	33.64	20.5-47.1	3.440	9.73
	T1	30.68	13.1-38.8	3.830	10.85
	T2	25.62	7.9-32.0	3.750	10.62
	T3	25.71	6.8-28.0	3.860	10.93
100 seed weight (g)	Control	10.18	6.3-10.7	1.419	1.25
	T1	8.90	5.5-9.5	1.417	1.20
	T2	7.80	4.5-8.6	1.400	1.17
	T3	5.76	4.0-7.8	1.390	1.15

T_1 Flooding up to V3); T_2 Flooding up to V5 ; T_3 Flooding up to R1

Table 2. Correlation and direct effect of observed traits on seed yield/plant and their heritability in soybean

	Correlation				Direct effect				Herit-
	Control	**T1**	**T2**	**T3**	**Control**	**T1**	**T2**	**T3**	**ability (%)**
Days to flowering	0.0918	0.4055**	0.3684**	0.2514**	-0.0859	0.1277	0.1519	0.1382	57.05
Days to maturity	0.0397	0.2565**	0.1194	0.2625**	0.1430	0.1457	0.1583	0.2074	55.42
Grain filling duration	0.3140**	-0.0212	-0.1066	0.1091	0.2921	0.2240	0.1923	0.1792	43.13
Pods/ plant	0.3186**	0.4217**	0.1925*	0.0349	0.2685	0.1254	0.1707	0.1745	39.63
Filled pods/ plant	0.5036**	0.3330**	0.3097**	0.1861*	0.2109	0.1722	0.1985	0.2029	42.62
100 seed weight	0.1316	0.2123*	0.3745**	0.4117**	0.0046	0.1797	0.1884	0.1714	40.28
Harvest index	0.7034**	0.5911**	0.6500**	0.5364**	0.5067	0.6050	0.6139	0.4792	36.34
Adventitious roots	-	-0.3083**	-0.1806**	-0.0882	-	-0.119	-0.1305	-0.1203	10.71
Seed yield/plant	-	-	-	-	-	-	-	-	27.14

T_1 Flooding up to V3); T_2 Flooding up to V5 ; T_3 Flooding up to R1

More than 48 per cent plant population was recorded in JSM 202, JS 97-52, JSM 126, JSM 212, JSM 228 and JSM 45 in stress up to R1 stage with formation of adventitious roots in 71 per cent population and range of seed yield from 3 to 11 g per plant. Maximum adventitious roots were formed in genotype, JSM 258 followed by JS 97-52, JSM 290, JSM 115, JSM 238 and JSM 175 that ranged from 80 to 88 per cent under excessive moisture stress up to R1 stage with 4 to 6 g per plant seed yield and 44 to 45 per cent plant population. More than 10 g per plant seed yield was observed in genotypes, JS 335, JSM 3, JSM 45, MACS 57, MACS 13 in excessive moisture stress up to R1 stage, with 30 to 61 per cent adventitious root formation and 39 to 51 per cent plant population (Plate 2).

Number of filled pods per plant, harvest index and seed size were reduced with the increase in duration of excessive moisture stress (Table 1). More than 20 per cent harvest index was recorded in JSM 52, JS 97-52, JSM 200, JSM 3, JSM 152 and MACS 57 and more than 6 g per 100 seed weight in JSM 200, JSM 7, JSM 117, MACS 13 and MACS 57 under excessive moisture stress up to R1 stage.

Among the observed traits, days to flowering and days to maturity had high number of filled pods per plant and unfilled pods per plant had medium; and number of pods per plant, harvest index, adventitious roots and seed yield per plant had low heritability (Table 2). Days to flowering and maturity had positive and significant association with seed yield per plant under stress environment with high positive direct effect (Table 2). Excessive moisture stress during early stage led to delay flowering, whereas, in later stage, it forced the plants to flower earlier than normal condition. Days to maturity was not altered by excessive moisture stress in early stage, but stress in later crop growth stage led to forced maturity. Association of grain filling duration with seed yield was non-significant, but direct effect was positive and higher in magnitude than days to flowering and maturity. It shows that during selection for excessive moisture tolerance preference should be given to the early flowering lines with more grain filling duration to harvest more yield.

Association analysis and direct effect showed that while selection for high yield under excessive moisture stress and optimum condition, preference should be given to the genotypes with more number of pods with main emphasis on more number of filled pods. 100 seed weight had non-significant direct effect on seed yield under control environment However, under different levels of excessive moisture stress and its association and direct effect was high and positive. It showed importance of seed size on seed yield per plant under stress environment.

Under excessive moisture stress, pods per plant along with seed size were more important determinants of grain yield, whereas under normal condition, seed size had a comparatively less important role in determining grain yield. It revealed that genotypes with early flowering may tolerate excessive moisture stress better than genotypes with late flowering. However, days to flowering were not significantly associated with grain yield under control and 21 days of excessive moisture stress. Number of pods per plant, filled pod percentage and harvest index was the significantly important traits for enhancing seed yield per plant under controlled as well as stressed condition.

Selection indices for screening against excessive moisture stress

A selection index summarizes the worth of genotype by making use of information from important secondary traits along with yield. A rainy season crop encountered excessive moisture stress at different critical stages of crop growth from germination to pod filling stage. Based on importance of each stage and expression of plant to encounter excessive moisture stress, selection indices *viz.,* mean productivity (MP), geometric mean productivity (GMP), stress tolerance (ST), stress susceptibility index (SSI), and stress tolerance index (STI) were considered to screen the genotype tolerant against abiotic stress.

Based on mean productivity JSM 202, JSM 3, JS 97-52, JS 335, MACS 13, JSM 45, JS 93-05, JSM 189 and JSM 7 were the best under different duration of excessive moisture stress. JS 97-52, JSM 202, JSM 3, JS 335, MACS-13, JSM 45, JS 93-05 and JSM 189 were the best based on geometric mean productivity. Grain yield had significant and positive correlation with mean productivity and geometric mean productivity under all the three stress environments. However, magnitude of the correlations varies at different stress period. Thus, the higher mean productivity and geometric mean productivity increase the grain yield therefore selection based on these two parameters increases the average performance under stress condition.

Similar findings were reported by Golabadi *et al.* (2006). Rosielle and Hamblin (1981) reported that the mean productivity had very high correlation under high temperature stress environment with grain yield.

Highest value of stress tolerance was recorded by the genotypes, JSM 202, JS 90-41, JSM 189 and JS 97-52 at 21days of excessive moisture stress. Change in magnitude of association between grain yield per plant with stress tolerance from non-significant negative at 7 days stress to non-significant positive at 14 days; and significant and positive association at 21 days stress showed that sensitivity of the trait for tolerance. It shows that selection for excessive moisture tolerance may be made based on stress tolerance at high degree of stress.

The higher the value of stress tolerance index of genotype, indicated better stress tolerance. The genotypes JSM 115, JSM 202, JS 97-52 and JSM 248 had higher STI. Stress tolerance index can be utilized for the selection of genotypes with high yield and higher tolerance for excessive moisture stress as it had significant positive association with grain yield per plant at 14 and 21days of excessive moisture stress.

The smaller the value of stress susceptibility index (SSI) greater will be the stress tolerance. The lowest value for SSI was observed in genotypes JSM 287, JSM 115, JS 97-52, JSM 145, JS 335 and JSM 248. SSI had significant and positive association with grain yield per plant under stress environment. It shows that selection under optimum condition enables the identification of lines with responsiveness to optimum environment, while selecting under stress environment identifies high yielding lines carrying traits for performance under stress condition. Therefore, it can serve as an indicator for selecting genotypes with higher yield and higher tolerance to excessive moisture stress.

The final selection of entries may be done on the basis of their performance across the regimes of moisture availability, in order to assure that the selected genotypes have good yield potential under optimal moisture conditions as well. Considering all the traits simultaneously genotypes are classified in four groups *i.e.,* tolerant (JS 97-52, JSM 115, JSM 202, JSM 189 and JSM 248); moderately tolerant (JSM 3, JSM 287, JSM 45, JS 335), susceptible (JS 93-05, JS 90-41, JSM 7 and MACS 13) and highly susceptible (remaining). It further advocated that considering any one trait at one time may not screen out the tolerant genotype perfectly therefore one should screen the genotypes based on many indices.

Classification of genotypes based on deviation in the performance for important morphological traits under excessive moisture stress from normal cultivation exhibited that genotype JS 97-52, JSM 115 and JSM 202 had minimum deviation for all the observed traits; and JS 248 was sensitive only for 100 seed weight Whereas, JS 93-05 was sensitive for days to flowering along with 100 seed weight. The most typical morphological traits for excessive soil moisture tolerance seem to be the development of adventitious roots followed by maturity duration. From the experimental findings, it could be established that early maturing genotypes by virtue of their fast root growth and plant establishment habit are more tolerant to the excessive soil moisture stress. Over and above the yield potential of a particular genotypes under normal and stress conditions with minimum reduction in yield in stress should be foremost priority in selecting for excess soil moisture tolerance.

Association analysis of grain yield with stress tolerance parameters

Grain yield had significant and positive correlation with mean productivity and geometric mean productivity under all the three stress environments. However, magnitude of the correlations varies at different stress period (Table 3). Thus the higher mean productivity and geometric mean productivity increase the grain yield; therefore, selection based on these two parameters increases the average performance under stress conditions.

Change in magnitude of association between grain yield per plant with stress tolerance from negative non-significant (-0.186) at 7 days stress to non-significant positive (0.199) at 14 days and significant and positive at 21 days stress showed the sensitivity of the trait for tolerance. It shows that selection for excessive moisture tolerance may be made based on stress tolerance at high degree of stress.

STI may be utilized for the selection of genotypes with high yield and higher tolerance for excessive moisture stress. It had significant positive association with grain yield per plant at 14 (0.290) and 21 days (0.628) of excessive moisture stress.

SSI had significant and positive association (7 days 0.264; 14 days 0.289; 21 days 0.580) with grain yield per plant under stress environment. It shows that selection under optimum condition enables the identification of lines with responsiveness to optimum environment, while selecting under stress environment identifies high yielding lines carrying traits for performance under stress condition. Therefore, it can serve as an indication for selecting genotypes with higher yield and higher tolerance to excessive moisture stress.

The investigation revealed that under excessive moisture stress germinability, formation of adventitious root (survival of plant) and stress tolerance indices are the three important components. Among the screened germplasm genotypes, JS 76-205 and JSM 127 had ability to germinate even under very long period of excessive moisture stress, whereas, genotypes, JS 97-52, JSM 258, JSM 290, JSM 115, JSM 238 and JSM 175 had ability to survive under excessive moisture stress by formation of adventitious roots in maximum number of plants. Incorporation of these two traits to maintain the plant population with recommended seed rate in the genotypes JS 97-52, JSM 115 and JSM 202 screened as best based on stress tolerance indices may result in better productivity from per unit area under excessive moisture stress (Fig. 3).

Grain yield, considered as the primary trait of interest, is commonly used as selection criterion in breeding programs for crop improvement.

Table 3. Correlation coefficient of grain yield under stress environment conditions with stress tolerance parameters

Parameters	Excessive moisture Stress (day)		
	7	14	21
Mean Productivity	0.894**	0.725**	0.844**
Geometric Mean Productivity	0.931**	0.816**	0.636**
Stress Tolerance	-0.186	0.199	0.352*
Stress Tolerance Index	0.0144	0.290**	0.628**
Stress Susceptibility Index	0.264*	0.289*	0.580**

**, ** Significant at 0.05 and 0.01 levels, respectively.*

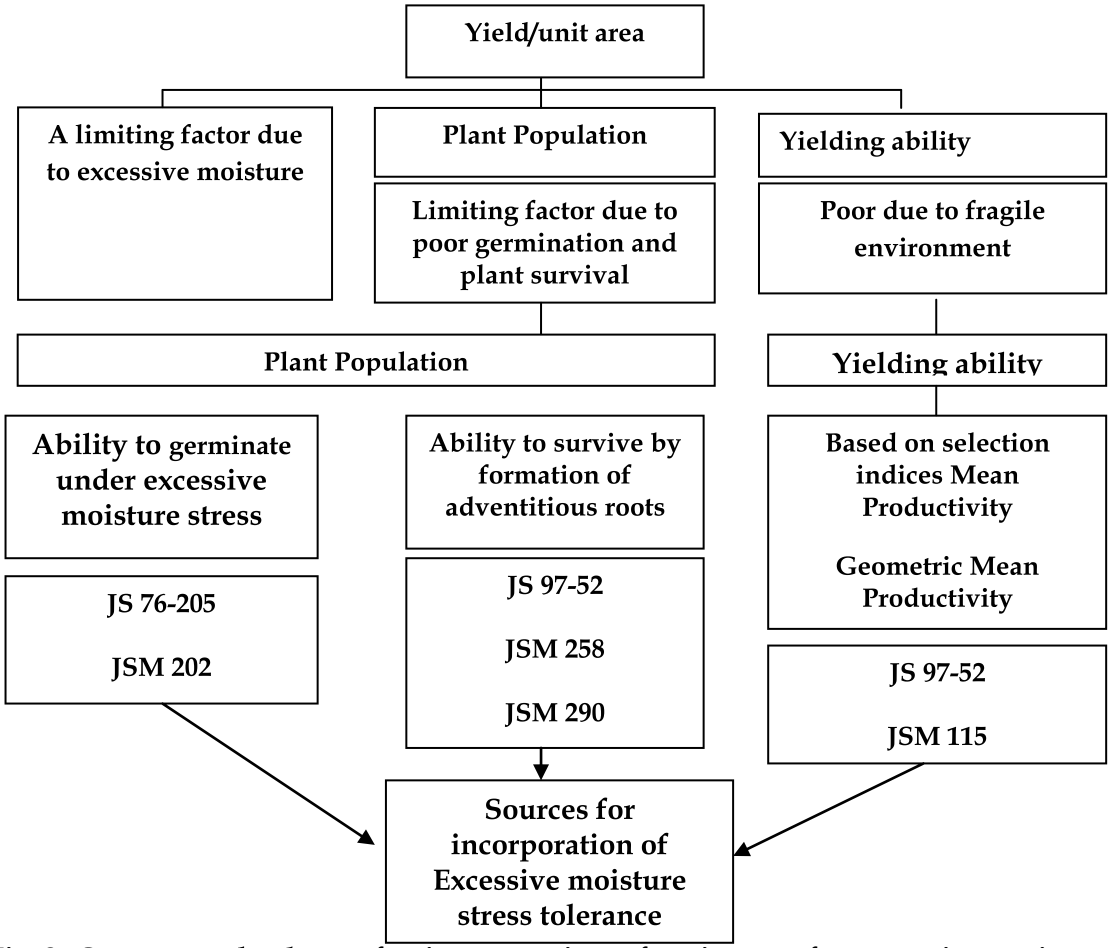

Fig 2. Sources and scheme for incorporation of resistance for excessive moisture tolerance in soybean

However, Selection on the basis of grain yield *per se* for improved performance under abiotic stresses has often been misleading and inefficient as inheritance of yield is complex polygenic trait with decline heritability under stress conditions.

For incorporation of tolerance against excessive moisture, secondary traits *viz.,* field emergence index, crop susceptibility index and the traits of relatively high heritability with positive and significant correlation with grain yield should be considered. The secondary traits like formation of adventitious roots proposed for excessive moisture tolerance are positively related to improved survival or tolerance. But, it is not sufficient to identify secondary traits; therefore the values of such traits should be estimated for using as criteria of selection under excess moisture stress conditions.

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Estimation of Genetic Divergence and Selection of Promising Genotypes for Hybridization in Soybean under Foot Hill Condition of Manipur

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ABSTRACT

The introduction and identification of diverse soybean genotypes with specific utilization in breeding programme is essential for crop improvement in Manipur state. The genetic diversity among 35 genotypes was estimated for yield attributing traits by using D^2 analysis. These 35 genotypes were grouped in to 5 clusters and clustering pattern revealed that genetic diversity may not necessarily be related to geographical diversity. The average inter- cluster distance was maximum between cluster IV and V (35.04) followed by cluster I and IV (29.32), cluster II and V (24.92) and cluster II and IV (24.85) indicating the presence of greater diversity between genotypes belonging to these groups. Days to 50 per cent flowering, plant height, days to maturity and pod breadth together contributed for 87.88 per cent of total divergence. Based on inter-cluster distance values and per se performance, the cross combination between Bragg and Gaurav, JS 80-21 and Bragg, TS 148 and Gaurav, KB 230 and Gaurav, and MAUS 144 and Bragg are expected to give better heterosis and desirable recombinants in order to achieve better yield levels in soybean under agro climatic condition of Manipur.

Key words: D^2 statistic, Genetic diversity, *Glycine max*, soybean

Soybean [*Glycine max* (L.) Merrill] is the world's leading source of oil and protein. It has the highest protein content (40 %) of all food crops and is second only to groundnut in terms of oil content (20 %) among food legumes. The meal is also rich in minerals, particularly calcium, phosphorus and iron. In North-East region, soybean is grown over wider agro-ecologies especially in low to mid altitude areas (1300 to 1700 msl) that have moderate annual rainfall (500 - 1500 mm) but soil acidity and associated infertility and mineral toxicity are major constraints to low production of soybean in this region. For these regions, development of cultivars adapted to the acid soil complex is a promising alternative to exploit the potential of north eastern areas of the country.

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In this regard, evaluation and selection of genetically divergent parents for hybridization programme are essential to obtain desirable recombination in segregating generations. So far, no systematic study on the varietal performance and genetic divergence of soybean under acidic and phosphorus deficient soils of this region has been made. In view of this, the present investigation was taken up to assess the extent of genetic diversity and prediction of potential crosses for soybean improvement under rainfed situation in foot hills of Manipur.

MATERIAL AND METHODS

The experimental materials for the present study comprising of 35 genotypes (Table 1) were evaluated at ICAR Research Farm located at terraced foot hill condition in Manipur at $24^0$45′N latitude and $93^0$56′E longitude with an average altitude of 784.5 meters above mean sea level. The type of the soil of the experimental area was alluvial clayey slightly acidic with pH of 5.5. The experiment was carried out in randomized block design with three replications in plot size of 4.05 x 2.25 m^2 with spacing of 45 cm row to row and 15 cm plant to plant during *kharif* 2004-05. The recommended package of practices was followed with the application of 20:30:40 kg NPK per hectare at the time of field preparation. Observations were recorded on ten competitive plants for ten quantitative characters *viz.,* days to 50 per cent flowering, days to maturity, plant height (cm), primary branches per plant, number of pods per plant, pod breadth (cm), pod length (cm), seeds per pod, 100 seed weight (g) and seed yield per plant (g). To assess the genetic divergence among the genotypes, Mahalanobis D^2 statistic (Singh and Chaudhary, 1985) was estimated. Based on the genetic distance, all the genotypes were grouped into different clusters (Rao, 1952).

RESULTS AND DISCUSSION

The analysis of variance revealed highly significant differences among the genotypes for all the characters studied indicating the existence of wide genetic divergence among them. The mean performance of ten quantitative characters among 35 genotypes is presented in table 1. The coefficient of variation ranged from 1.37 per cent with days to maturity to 25.65 per cent with number of pods per plant. Based on relative magnitude of D^2 values, 35 genotypes were grouped into five clusters (Table 2). The cluster I was the largest containing 16 genotypes followed by cluster II with 12 genotypes and cluster III with 5 genotypes. The clusters IV and V contained one genotype each.

The pattern of distribution of genotypes in different clusters indicated that the genotypes collected/released from different places were often found to occur in the same cluster. Thus, the major cluster I containing the genotypes of heterogeneous origin or region suggested that the pattern of clustering of genotypes was independent of their geographic origin/place of origin and hence, genetic diversity may not necessarily be related to geographical diversity. The present findings are agreement with those of Das

Table 1. Mean performance of ten quantitative characters in 35 soybean genotypes

Genotypes	Days to 50 % flowering	Days to maturity	Plant height (cm)	Primary branches (No/plant)	Pods (No/plant)	Pod breadth (cm)	Pod length (cm)	Seeds (No/pod)	100 seed weight (g)	Seed yield (g/plant)
HIMSO 1597	34.33	125.33	41.87	3.44	20.00	0.85	4.09	2.40	12.18	3.95
VLS 56	43.67	118.67	57.33	3.00	11.60	0.88	3.91	2.60	10.33	2.96
MAUS 144	43.67	120.33	52.83	3.67	41.70	1.00**	3.59	2.00	8.74	9.65**
MACS 754	43.67	123.33	53.73	4.33	35.20	0.91	3.66	2.00	9.12	7.75
KB 165	36.00	125.33	34.80*	2.67	22.77	0.81	3.66	2.00	9.85	4.70
SL 599	43.67	118.67	51.50	3.72	28.86	0.84	4.05	2.00	8.22	7.70
TS 128-5	43.67	115.33	70.30**	3.22	12.47	0.91	3.87	2.00	9.56	2.64
NRC 55	34.33	120.33	42.47	3.11	26.00	0.84	3.60	2.40	9.31	6.69
NRC 56	34.33	121.67	60.57	3.22	21.00	0.81	3.58	2.00	10.36	4.06
VLS 55	36.00	119.00	51.40	3.22	13.53	0.76	3.80	2.27	8.70	3.53
HIMSO 1596	30.67	111.00	46.53	3.11	28.73	0.87	3.73	2.00	8.78	6.54
PK 1308	44.00	112.33	57.17	2.31*	17.87	0.68	3.58	2.00	8.43	4.26
KB 230	34.67	117.00	41.33	2.87	9.87	0.88	3.59	2.00	12.79**	1.55*
TS 148	35.00	120.00	53.70	4.00	47.07**	0.84	3.58	2.00	11.31	5.38
SL 518	33.67	120.67	54.03	3.55	19.40	0.88	3.53	2.13	11.16	3.87
NRC 57	34.67	123.33	57.10	3.55	23.57	0.83	3.48	2.67	10.73	5.62
DSB 3	34.67	121.00	52.30	4.00	30.30	0.86	3.66	2.37	12.77	5.60
MACS 756	43.67	118.67	61.00	2.77	15.27	0.86	3.39	2.00	8.41	3.69
DS 9814	43.67	120.33	58.50	4.11	18.60	0.83	3.77	2.40	7.89	5.70
JS 95-58	44.00	107.33	54.83	4.22	14.97	0.88	3.81	2.07	8.80	3.52
MAUS 145	43.67	122.00	56.87	3.00	11.00*	0.89	3.71	2.00	10.70	2.26
JS(SH)96-3	43.67	119.67	45.77	2.78	24.40	0.92	4.15	2.00	8.97	5.44
MAUS 109	32.33	107.00	54.47	3.22	19.27	0.84	3.65	2.73	9.17	5.74
PK 1314	34.00	118.33	48.23	3.66	19.07	0.83	3.45	2.00	9.94	3.83
JS(SH)96-3	35.00	108.33	63.27	3.44	22.90	0.85	3.33	2.07	12.23	5.52
JS95-60	43.67	111.33	46.00	3.88	31.33	0.89	3.41	2.00	10.05	6.23
RKS 7	44.00	119.33	65.27	3.24	15.87	0.87	4.26**	2.00*	8.85	3.58
MACS 798	35.33	126.00	51.70	2.78	16.57	0.89	3.49	2.13	11.83	2.97
PK 1303	44.00	121.67	47.13	3.89	19.90	0.76	3.51	2.13	10.67	3.97
DS 228	34.33	123.33	36.20	3.89	15.50	0.89	3.53	2.07	10.02	3.09
BRAGG	24.67*	90.33*	56.13	3.11	13.77	0.83	3.25	2.07	10.43	2.70
BIRSA SOY 1	34.67	107.00	51.17	3.44	16.87	0.84	3.31*	2.73	12.00	3.82
NRC-2	44.33**	111.33	56.30	3.44	21.57	0.86	3.52	2.00	7.54*	5.73
JS 80-21	43.67	117.00	53.00	3.77	17.23	0.76*	3.81	2.80**	8.14	5.96
GAURAV	44.00	129.00**	39.03	5.33**	20.93	0.86	3.73	2.73	9.77	5.96
CD (5%)	1.38	2.64	3.34	1.16	8.92	0.04	0.30	0.30	0.96	1.44
CV (%)	2.21	1.37	3.92	20.55	25.65	2.45	4.99	8.20	5.88	18.66

**Lowest; ** Highest value*

et al. (2001), Sood *et al.* (2006) and Tyagi and Sethi (2011), as also revealed that genetic diversity was independent of geographic origin of the genotypes. Thus, the present composition of cluster may be resulted from exchange of breeding materials, genetic drift, spontaneous variation, natural and artificial selection rather than the geographical distribution as suggested by Murty and Arunachalam (1966). Therefore, a hybridization programme may be initiatedinvolving those genotypes belonging to diverse clusters with high means for almost all important component traits and further these divergent parents should also have better combining ability to give results proportionate to heterotic response and wide variability in segregating generations. Arunachalam (1981) also observed that more diverse the parents within its overall limits of fitness, the greater are the chances of heterotic expression of F_1s and a broad spectrum of variability in segregating generations.

Table 2. Clustering pattern of 35 genotypes of soybean based on D^2 statistics

Cluster Number	Number of genotypes	Name of genotypes	Source/Origin
I	16	VLS 56	Almora (UK)
		MAUS 144; MAUS 145	Parbhani (MS)
		MACS 754; MACS 756	Pune (MS)
		SL 599	Ludhiana (PB)
		TS 128-7	BARC, Mumbai (MS)
		HIMSO 1956	Palampur (HP)
		DSB 3	Dharwad (KA)
		DS 9814	New Delhi
		JS 95-98; JS 95-60; JS 80-21	Jabalpur (MP)
		RKS 7	Kota (RJ)
		PK 1303	Pantnagar (UK)
		NRC-2	Indore (MP)
II	12	HIMSO 1596	Palampur (HP)
		KB 165; KB 230	Bangalore (KA)
		PK 1308	Pantnagar (UK)
		NRC 55; NRC 56; NRC 57	Indore (MP)
		TS 148	BARC, Mumbai (MS)
		SL 518	Ludhiana (PB)
		MAUS 109	Parbhani (MS)
		MACS 798	Pune (MS)
		DS 228	New Delhi
III	5	VLS 55	Almora (UK)
		JS (SH) 96-0; JS (SH) 96-3	Sehore (MP)
		PK 1314	Pantnagar (UK)
		BIRSA SOY 1	Ranchi (JH)
IV	1	Bragg	USA
V	1	Gaurav	Jabalpur (MP)

Table 3. Average intra (bold) and inter cluster distance as involving 35 genotypes of soybean

Clusters	I	II	III	IV	V
I	**11.53**	15.96	16.38	29.32	13.84
II		**8.69**	12.63	24.85	24.92
III			**11.07**	18.18	19.99
IV				**0.00**	35.04
V					**0.00**

From the intra and inter cluster distances (Table 3), it can be seen that the genotypes in cluster I had maximum genetic dissimilarity among themselves due to maximum intra cluster distance (11.35) followed by cluster III (11.07) and cluster II (8.65). The intra cluster diversity among genotypes could be due to genetic architecture of the populations, past history of selection in developmental traits and degree of general combining ability (Mahapatra *et al.*, 1993 and Dikshit and Swain, 2000). The highest genetic divergence ($\sqrt{D^2}$) occurred between cluster IV and V (35.04) followed by cluster I and IV (29.32), cluster II and V (24.92) and cluster II and IV (24.85) indicating the presence of greater diversity between genotypes belonging to these groups. Hence, potential genotypes from these clusters may be utilized in crossing programme for isolating desirable segregants for developing high yielding acidic tolerant genetic stock/varieties.

Table 4. Cluster mean values and contribution towards genetic divergence of different yield contributing traits

Characters	Clusters					Contribution (%) towards divergence
	I	II	III	IV	V	
Days to 50% flowering	43.81	34.61	33.73	24.67	44.00	45.37
Days to maturity	118.08	121.86	110.46	90.33	129.00	15.63
Plant height (cm)	54.59	43.5	53.68	56.13	39.03	18.65
Primary branches (No/plant)	3.55	3.39	3.26	3.11	5.33	0.00
Pods (No/plant)	10.57	22.59	20.26	13.77	20.93	1.51
Pod breadth (cm)	0.86	0.85	0.82	0.83	0.86	8.23
Pod length (cm)	3.48	3.60	3.56	3.25	3.73	0.84
Seeds per pod	2.89	2.18	2.36	2.07	2.73	0.84
100 seed weight (g)	9.12	11.02	10.17	10.43	9.77	4.20
Seed yield (g/plant)	5.06	4.26	5.03	2.70	5.96	4.70

The cluster means for various characters (Table 4) revealed that cluster V with one genotype had the highest mean value for number of primary branches per plant, pod length and seed yield per plant along with lower plant height. Similarly, cluster I had genotypes with desirable pod length and number of seeds per pod, whereas the cluster II recorded the highest mean values for pods per plant and 100 seed weight. The earliest days to flowering and maturity was observed in cluster IV.

On the basis of inter cluster distance and per se performance of individual genotype, some of the important cross combinations were suggested for genetic amelioration of higher seed yield and other desirable characters (Table 5). The cross combinations namely, Bragg x Gaurav for higher seed yield, primary branches per plant, pod length in combination of earliness and shorter plant type; JS 80-21 x Bragg for seeds per plant and pod breadth; TS 148 x Gaurav for number of pods per plant and KB 230 x Gaurav for 100 seed weight may be utilized for generating materials suitable for agro climatic condition of Manipur. Further, the ability of D^2 analysis is also enhanced by its also enhanced by its applicability to estimate the relative contribution of the various plant characters to the total divergence. Days to 50 per cent flowering contributed 45.37 per cent to the total divergence followed by plant height (18.65 %), days to maturity (15.63 %) and pod breadth (8.23 %). These traits together accounted for 87.88 per cent contribution to the total divergence, suggesting considering these traits in selection of genetically diverse parents for hybridization programme especially for development of short duration and dwarf varieties.

Table 5. Promising cross combinations based on desirable characters selected from different clusters

Characters	Cluster combination	Promising cross combination
Days to 50% flowering	IV and V	Bragg and Gaurav
Days to maturity	IV and V	Bragg and Gaurav
Plant height (cm)	IV and V	Bragg and Gaurav
Primary branches (No/plant)	IV and V	Bragg and Gaurav
Pods (No/plant)	II and V	TS 148 and Gaurav
Pod breadth (cm)	I and IV	MAUS 144 and Gaurav
Pod length (cm)	IV and V	Bragg and Gaurav
Seeds per pod	I and IV	JS 80-21 and Bragg
100 seed weight (g)	II and V	KB 230 and Gaurav
Seed yield per plant (g)	IV and V	Bragg and Gaurav

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Stability Analysis for Growth and Yield Attributes in Soybean (*Glycine max* (L.) Merrill)

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ABSTRACT

Thirty genotypes of soybean were grown at three sowing dates in randomized block design with three replications during kharif *(2009-10). Analysis of variance for all the ten characters for each environment and on pooled basis indicated substantial amount of variability for most of the yield and yield contributing characters except for days to maturity in environment two and pooled environment. Genotype × environment interactions were found significant for number of primary branches per plant, plant height, number of pods per plant, biological yield per plant, number of seeds per plant, seed yield per plant and 100 seed weight. The genotypes × environment (Linear) mean sums of squares were significant for all the characters except for number of pods per plant. Genotypes TGX 401-54, EC 30967 A, EC 389154, MACS 22 and AGS 11 showed stable performance for all the yield and yield components. Therefore, these genotypes could be recommended for commercial cultivation as well as for inclusion in further breeding programme as donor parents.*

Key words: Mean, regression, seed yield, soybean, stability

Soybean [*Glycine max* (L.) Merrill] is a self pollinated crop with low percentage of natural out-crossing. It belongs to family Leguminose, sub-family Papilonaceae. It is autogamous crop having diploid chromosome number 2n = 40 and with around 20 per cent oil and 40 per cent quality protein. Soybean plays a pivotal role in meeting the ever-increasing demand of the edible oil across the world, contributing nearly 25 per cent to the total edible oil production. In the Madhya Pradesh state, the soybean is grown in 57.30 lakh hectares producing 61.71 lakh tones with the productivity of 1077 kg per ha (SOPA, 2011). The stability analysis has two major objectives in plant breeding programme; (i) to identify the genotypes with greater stability and wider adoptability for yield and its components, and (ii) to identify the potential varieties i.e. genotype with high mean performance under wider range of environments. Such variety can be utilized in hybridization programme. In India, soybean improvement programme initiated in

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1967 led to the development of 103 improved varieties stable for various agro-climatic conditions of the country. Very few varieties have the genetic architecture which have capacity to perform well over wide range of environmental conditions (Verma *et al.*, 2011). Hence, further genetic improvement for development of varieties with high yield, disease resistance and wider adaptability is needed for sustaining higher yield levels. Considering the above points in view, the present investigations have been carried out.

MATERIAL AND METHODS

A field experiment was conducted under All India Coordinated Research Project on Soybean at R A K College of Agriculture, Sehore during the *kharif* 2009. The experiment was laid out in complementary randomized block design with three replications. The thirty genotypes were evaluated under three different environments created by three sowing dates *viz.,* 10 July 2009, 16 July 2009 and 26 July 2009.

Each genotype was sown in two rows pattern of 3 meter length with 45 cm row to row and 3-4 cm plant to plant distance. The fertilizer dose 20:26.6:16.6:20 NPKS kg per ha was applied uniformly and recommended package of practices were adopted for optimum crop growth and plant protection under rainfed condition.

The observation on yield and yield attributes were recorded on 5 competitive plants at the time of harvest from each plot. The stability analysis was carried out as per procedure outlined by Eberhart and Russell (1966)

RESULTS AND DISCUSSION

The pooled analysis of variance for yield and yield contributed traits (Table 1) indicated that the genotypes significantly differed for all the characters taken under study. The interaction of genotype × environment (G×E) mean sum of squares were also found significant for number of primary branches per plant, plant height, number of pods per plant, biological yield per plant, number of seeds per plant, seed yield per plant and 100 seed weight.

The response of genotypes to changing environment was measured by the environmental linear effect, which was significant for all the characters except number of pods per plant.

The stability parameters, *viz*., mean, regression coefficient (b) and deviation from regression $\bar{S}_d^2$ for all characters of each genotype, were computed and are presented (Table 2). The substantial magnitudes of deviation from linearity for all the characters were observed suggesting large fluctuations in the expression of all the characters over environments. Mean sum of squares due to pooled deviation were found significant for most of the characters except days to maturity, biological yield per plant and number of seeds per plant. Stability worked out for all the 30 genotypes for yield and its component traits showed that the genotypes namely TGX 401-54, EC 30967 A, EC 389154, MACS 22 and AGS 11 were stable for all the 10 characters studied. Genotypes TGX 854-28 A, JP 6, EPS 472(B) and B 401 exhibited stability for 9 characters including seed yield per plant. Genotype

Table 1. Stability of different genotypes for different traits

Genotype	Days to 50% flowering	Days to maturity	Primary branches (No/ plant)	Plant height (cm)	Pods/ plant (No/ plant)	Biological yield (g/plant)	Seeds (No/ plant	Seed yield (g/plant)	100 seed weight (g)	Harvest index (%)	Total stable characters
TGX 854-28 A	*	*	*		*	*	*	*	*	*	9
EC 241801	*	*	*		*	*	*		*		7
L 285	*	*	*		*	*	*		*		7
EC 391342	*	*	*	*	*			*	*	*	8
JP 6	*	*	*		*	*	*	*	*	*	9
JS 81-397	*	*	*		*				*	*	6
P 318	*	*	*	*	*		*		*	*	8
VP 1206-9	*	*	*		*			*	*	*	7
EC 34039	*	*	*								3
EC 39743	*	*	*	*		*		*		*	7
EC 389165 B	*		*	*	*					*	5
NKG 33	*	*	*							*	4
TGX 401-54	*	*	*	*	*	*	*	*	*	*	10
EPS 335(B)	*	*	*	*	*	*	*			*	8
EPS 472(B)	*	*	*	*	*	*	*	*	*		9
TGX 1073-30 A	*	*	*	*	*		*	*			7
EC 30967 A	*	*	*	*	*	*	*	*	*	*	10
EC 389150(A)	*	*	*		*	*	*	*		*	8
EC 389154	*	*	*	*	*	*	*	*	*	*	10
TGX854-42D-4	*	*	*	*	*		*	*			7
SL 89	*	*	*		*					*	5
F 79-82	*	*		*	*	*		*		*	7
B 401	*	*	*		*	*	*	*	*	*	9
EC 396058 B		*		*	*	*	*	*		*	7
MACS 22	*	*	*	*	*	*	*	*	*	*	10
EC 37072	*	*		*	*	*	*			*	7
AGS 11	*	*	*	*	*	*	*	*	*	*	10
PLSO 95	*	*	*	*	*		*	*	*		8
EC 95273	*	*	*	*					*	*	6
IC 16829	*	*	*	*					*	*	6
Total stable genotypes	29	29	27	19	25	17	19	18	18	23	

Table 2. Grouping of soybean genotypes based on of regression coefficient and deviation from regression showing suitability for different environmental conditions

Characters	Genotypes stable over environment (gi > mean, bi = 1, s2di = 0)	Genotypes for poor environment (gi > mean, bi < 1, s2di = 0)	Genotypes stable for favourable environment (gi > mean, bi > 1, s2d = 0)
Days to 50 % flowering	EC396058 B,	-	TGX 401-54, EC 30967 A, EC 389154, MACS 22 and AGS 11
Days to maturity	EC389165 B,	-	TGX 401-54, EC 30967 A, EC 389154, MACS 22 and AGS 11
Primary branches (No/plant)	EC396058 B, EC 37072	F 79-82	TGX 401-54, EC 30967 A, EC 389154, MACS 22 and AGS 11
Plant height (cm)	L 285, VP 1206-9, EC 34039, NKG 33, EC 389150(A),B 401	JP 6, JS 81-397, TGX 854-28A, SL 89	TGX 401-54, EC 30967 A, EC 389154, MACS 22 and AGS 11
Pods (No/plant)	EC 34039, EC 39743, NKG 33, EC 95273, IC 16829	-	TGX 401-54, EC 30967 A, EC 389154, MACS 22 and AGS 11
Seeds (No/plant)	VP 1206-9, EC 34039, NKG 33, F 79-82, IC 16829	EC 391342, JS 81-397, EC 39743, EC 389165 B, SL 89, EC 95273	TGX 401-54, EC 30967 A, EC 389154, MACS 22 and AGS 11
Biological yield (g/ plant)	EC 391342, JS 81-397, P 318, EC 389165 B, TGX 854-42D-4, SL 89	VP 1206-9, EC 34039, NKG 33, TGX 1073-30 A, EC 95273, IC 16829, PLSO 95	TGX 401-54, EC 30967 A, EC 389154, MACS 22 and AGS 11
100 Seed weight (g)	EC 389165 B, EPS 335(B)	EC 34039, NKG 33, TGX 1073-30 A, EC 389150(A), EC 396058 B	TGX 401-54, EC 30967 A, EC 389154, MACS 22 and AGS 11
Harvest index	EC 241801, L 285, EC 34039, TGX 854-42D-4	TGX 1073-30 A PLSO 95	TGX 401-54, EC 30967 A, EC 389154, MACS 22 and AGS 11
Seed yield (No/plant)	JS 81-397, P 318, EC 389165 B, EPS 335(B), SL 89, EC 37072, EC 95273	EC 241801, L 285, EC 34039, NKG 33, IC 16829	TGX 401-54, EC 30967 A, EC 389154, MACS 22 and AGS 11

EC 391342, EC 389150(A) and PLSO 95 exhibited stability for 8 characters including seed yield per plant. EC 34039 was found to be least stable showing stability only for 3 characters excluding seed yield per plant.

In respect of stability of different traits it was found that days to 50 per cent flowering and days to maturity were the most stable characters, which remained stable in most of the genotypes (29), followed by number of primary branches per plant (27), number of pods per plant (25) and harvest index (23). Plant height and number of seeds per plant were found stable in 19 genotypes while seed yield per plant and 100 seed weight in 18 genotypes. Biological yield per plant was found least stable character, which was stable only in 17 genotypes.

For the development of improved varieties, genotype × environment interaction had been of great importance to the plant breeder. When genotype are compared over a series of environments relative ranking usually differ which causes difficulty in demonstrating the significant superiority of one genotype over the other. For reducing the impact of genotype × environment interaction, breeder selects stable genotypes, which will interact less with the environment in which they are likely to be grown.

Under present investigation adoptive potential and relative stability of 30 genotypes of soybean for yield and its contributing traits have been determined. The pooled analysis of variance carried out to know the response of different characters to various environmental factors, revealed that genotype × environment interactions were significant for number of primary branches per plant, plant height, number of pods per plant, biological yield per plant, number of seeds per plant, seed yield per plant and 100 seed weight. Thus it indicated that, these characters were highly sensitive to changes in the environmental conditions. Whereas interactions for days to 50 per cent flowering, days to maturity and harvest index were non-significant indicating that these traits were well adopted and exhibited least effect to the changes in the environmental conditions. Rawat *et al.* (2001), Joshi *et al.* (2005), Mahajan *et al.* (2006), Ramana and Satyanarayana (2006), Pan *et al.* (2007) and Ramteke and Husain (2008) also reported significant G x E interaction for most of the yield and yield contributing characters.

Variances due to genotype x environment (linear) was significantly different for days to 50 per cent flowering, days to maturity, number of primary branches per plant, plant height, biological yield per plant, number of seeds per plant, seed yield per plant, 100 seed weight and harvest index indicated the differential response of genotypes to various agro-climatic conditions.

Considering Eberhart and Russell (1966) model state that an ideal genotype is one having high mean ($\bar{X}$), unit regression coefficient (b =1) and least deviation ($\bar{S}_d^2$) around the regression slope i.e. mean deviation square from regression not significantly different from zero. Therefore, it implies that during selection, predicting rate of seed yield in a given environment, mean values, regression slope of the genotypes and deviation from regression should be considered. Genotypes namely, TGX 401-54, EC 30967 A, EC 389154, MACS 22 and AGS 11 showed stable performance for all the yield and yield components together and could be recommended for commercial cultivation inclusion in further breeding programme as donor parents.

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Yield and Soybean Characters under Some Intercropping Patterns with Corn

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ABSTRACT

Two experiments were conducted at Gemmeiza Agricultural Experimental and Research Station, ARC, El-Gharbia Governorate, Egypt, during 2006 and 2007 summer seasons to investigate the possibility of increasing intercropped soybean yield by raising each of soybean plant density and intercepted light on soybean through intercropping patterns. Intercropping patterns comprised alternating and mixed ridges between corn and soybean. Alternating ridges (70 cm/ridge) between corn and soybean were used as 2:2 and 2:4, respectively, soybean was grown in alternating ridges by two rows per ridge (N) in normal plant population density (2:2 and 2:4), in addition to another single row on the other adjacent side of corn ridges (H) to increase the density of the intercropped soybean plants by about 25 per cent than normal density (N) for the two intercropping patterns 2:2 and 2:4. In mixed pattern, four rows of soybean were planted on the wide ridge (140 cm/ridge) by two rows on each side, while, corn was grown on middle of the ridge. Two patterns of solid planting were adopted as those of alternating and mixed patterns. Soybean plants were grown in 2 plants per hill (15 cm apart), while, corn was distributed in two plants per hill (30 cm apart) and four plants per hill (60 cm apart). One corn variety and two soybean varieties were used.

Solid planting patterns had higher values for soybean seed yield and its components as compared with intercropping patterns, whereas, the reverse was true for seed protein content. Growing corn and soybean in 2:4 ridges under high soybean plant density (H) gave higher values for yields of seed, oil and protein as compared with those of normal population of 2:4 (N) and other patterns. The soybean variety Giza 22 had higher values for all the studied parameters, except seed index, than the other variety. All the studied parameters were increased by doubling distance between hills of corn from 30 to 60 cm apart, whereas, the reverse was true for seed protein content.

Key words: Intercropping, light intensity, plant density, seed yield, soybean varieties

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Egypt is facing acute shortage of edible oil. Vegetable oil is imported in large quantities to satisfy the domestic needs of the country. The gap between production and consumption reaches more than 90 per cent. Soybean [*Glycine max* (L.) Merrill) has a great importance as a legume crop cultivated in Egypt and all over the world for protein and oil production. It is one of the most important sources of vegetable protein because it has the highest protein content among the leguminous crops. The nutritional quality of soybean protein is very good as it contains all the essential amino acids. As edible oil, it enters the market as salad oil, cooking oil, margarine and shortening. Oil seed crops represented 1.7 per cent of cultivated land in the Nile Valley and Delta (Noureldin *et al.*, 2002).

In Egypt, soybean was commercially cultivated in 1970 on about 1200 ha with an average seed yield of about 750 kg per hectare. The acreage has increased rapidly, reaching 60, 729 hectares in 1983, with an average seed yield of about 2.50 tons per hectare, then it declined continuously till it reached 14, 575 hectares by 2010 with an average seed yield of about 3.25 tons per hectare. This decline in acreage might be attributed to the competition with other strategic summer crops, as well as, high production costs and lower net returns as compared with other summer crops. Although corn (*Zea mays,* L) is cultivated by around two million acres, Egypt is still importing around 5 million tons from grains yearly. So, it must be using a system to growing soybean plants in the Nile Valley and Delta to avoid the competition with other strategic summer crops such as corn and rice. Intercropping, the practice of producing multiple crops in a given time and space, is used in many parts of the world, especially in regions where the small farmer intensively utilizes a limited land area (Francis, 1986). It is recommended to increase total agriculture products in Egypt (Metwally, 1999). On the other hand, disadvantage of intercropping as compared with sole crops may be occurred (West and Griffith, 1992). Therefore, crop species in an intercropping pattern must be carefully chosen to minimize competition and enhance the efficient use of water, light and nutrients (Sayed Galal *et al.,* 1983). The growth of two crops together in the same field during a growing season may result in inter specific competition or facilitation between the plants (Zhang and Li, 2003).

Amount of light intensity within an intercropping pattern is basic point for any successful intercropping pattern. Consequently, corn canopy architecture (distribution of shoot organs) plays an important role in the amount of sunlight radiation that is intercepted by other crop. Light was proved as a critical competition factor in intercropping sorghum with soybean (Wahua and Miller, 1978). Consequently, environmental conditions prevailing during the growth period, especially intensity and quality of intercepted solar radiation by the canopy, are important determinants of yield components and hence the yield of soybean (Board and Harville, 1992).

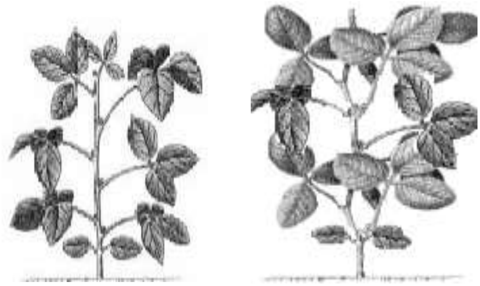
Also, selection of soybean varieties suitable for intercropping has been restricted to introductions from the U.S. (Sayed Galal *et al.*, 1983 and 1984). These introductions are varieties and lines selected for good performance in monoculture pattern. Moreover, row arrangement, in contrast to arrangement of component crops within rows, may also influence the productivity of an intercropping system (Mohta and De, 1980). In another study, Addo- Quaye *et al.* (2011) showed that spatial arrangement of single rows of corn alternating with double rows of soybean recorded the best yields with respect to soybean.

The early research on corn – soybean intercropping in Egypt (Sayed Galal and Abd-El Rasool, 1962) mentioned that soybean could be produced in association with corn grown in widely – spaced multiple hills. Two ridges of corn alternating with two ridges of soybean was the most suitable intercropping pattern for growing the two crops than other patterns. Intercropped yield of corn and soybean plants in an intercropping pattern were decreased as compared to their solid planting (Mohta and De, 1980; Sayed Galal *et al.*, 1983; El-Habbak, 1985; El-Douby *et al.*, 1996, Shafik, 2000 and Metwally *et al.*, 2007).

In view of the above, intercropping patterns and distribution of corn plants have the greatest positive impact on the amount of intercepted sunlight radiation on soybean plants. So, the objective of this study was to investigate the best intercropping pattern with high densities of soybean plants for producing high soybean yield.

MATERIAL AND METHODS

Two field experiments were conducted at Gemmeiza Agricultural Experiments and Research Station, Agricultural Research Center (ARC), El-Gharbia Governorate, during 2006 and 2007 summer seasons. Two intermediate type soybean varieties (Giza 22 and Giza 111) representing narrow and broad leaves (Fig. 1), respectively and belonging to maturity group and corn variety (T.W.C. 310) were provided by Research Departments, F.C.R.I., ARC.



Giza 22 **Giza 111**

Fig. 1. Canopy of the two soybean varieties

Egyptian clover was the preceding winter crop in both seasons. The experimental soil texture was clay. Chemical analysis of the soil (0 – 20 cm), pH value (7.85-7.95), N, total soluble salts (0.08-0.20 %), available N (60-80 ppm), available phosphorus (3.00-5.83 ppm) and available potassium (135-170 ppm), were analyzed by Water and Soil Research Institute, ARC. Chemical analysis of the soil was determined using the methods described by Jackson (1958) and Chapman and Pratt (1961).

Normal cultural practices for growing corn and soybean crops were used as recommended in the area. Soybean seeds were sown on 15 and 25th May at 2006 and 2007 seasons, respectively, while, corn grains were sown ten days later. Soybean was thinned to 2 plants at 15 cm between hills.

The experiment included seven cropping systems (five intercropping and two solid plantings), two soybean varieties and two distributions of corn plants (two plants per hill at 30 cm hill spacing and four plants per hill at 60 cm hill spacing) (Fig. 2).

Cropping systems

Intercropping patterns

- Two corn ridges alternating with another two of soybean. Soybean was grown in two drillings per ridge. This pattern resulted in 50, 000 plants of corn and 200, 000 soybean plants per hectare (designated as 2:2 "N" patterns).
- Two corn ridges alternating with another two of soybean planted as the previous pattern in addition to planting soybean on the other side of corn ridges. This pattern resulted in 50, 000 plants of corn and 300, 000 soybean plants per hectare (designated as 2:2 "H" pattern).
- Two corn ridges alternating with four of soybean grown in two drillings per ridge. This pattern resulted in 33332 plants of corn and 268, 000 soybean plants per hectare (designated as 2:4 {N} pattern).
- Two corn ridges alternating with four of soybean planted as the previous pattern in addition to planting soybean on the other side of corn ridges. This pattern resulted in 33332 plants of corn and 332, 000 soybean plants per hectare (designated as 2:4 {H} pattern).
- Mixed intercropping: Corn was planted in the middle of ridges 140 cm width resulted in 50, 000 plants per hectare, whereas soybean was planted in two drills at each side of ridge (4 drills per ridge) resulted in 400, 000 plants per hectare.

Solid patterns

- *Solid 1:* Pure stand of soybean ridges was conducted by drilling 2 rows per ridge. Soybean was thinned to 2 plants distanced at 15 cm between hills resulted in 400, 000 plants per hectare on ridges 70 cm width. This system is the recommended culture.
- *Solid 2:* Soybean was planted by drilling 4 rows at the two sides of ridge 140 cm width. Soybean was thinned to 2 plants at 15 cm between hills resulted in 400, 000 plants per hectare

Solid plantings of soybean were used to compare the performance of soybean varieties under intercropping patterns.

Distributions of corn plants

- Two plants per hill distanced at 30 cm apart between hills.
- Four plants per hill distanced at 60 cm apart between hills.

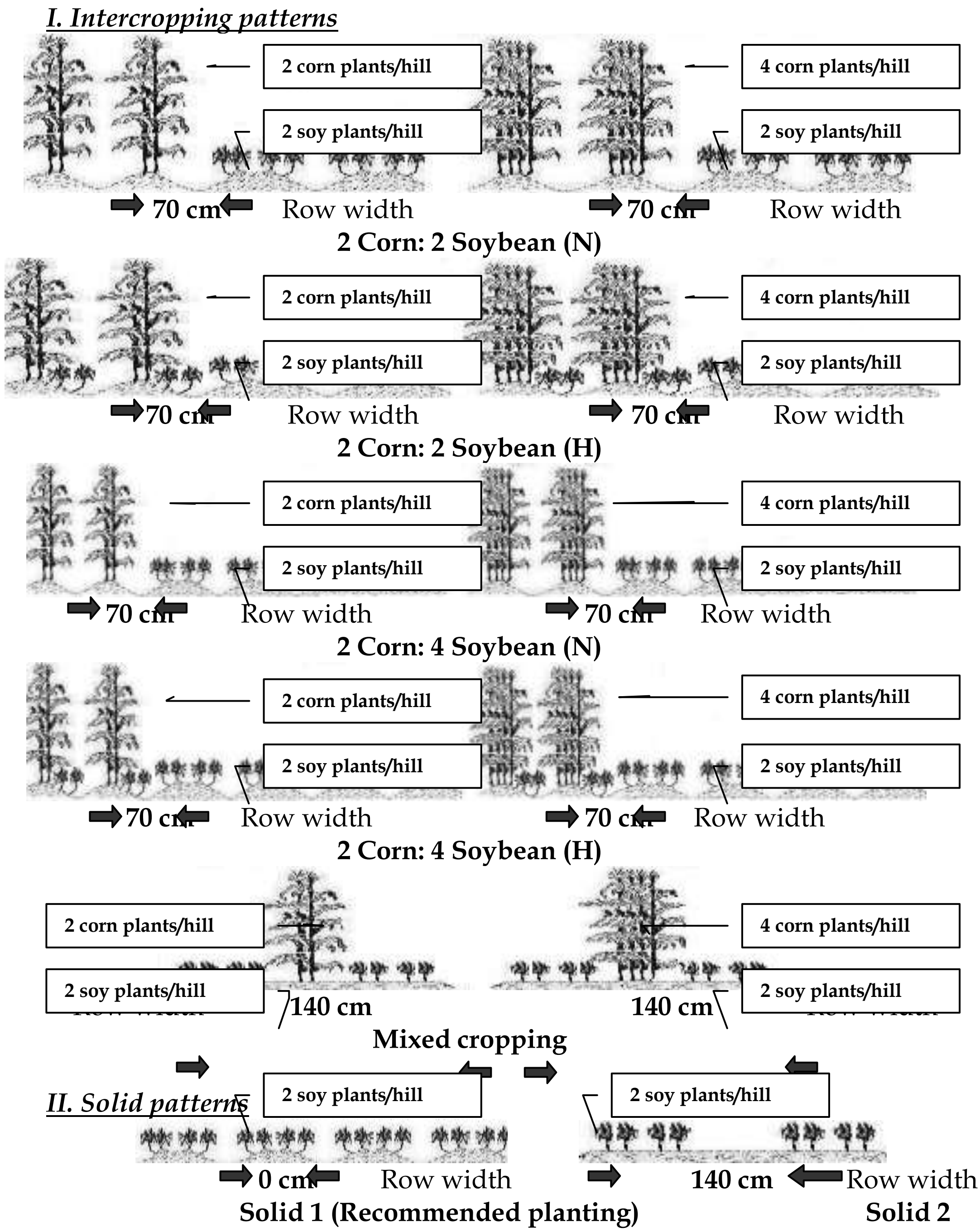


Fig. 2. Cropping patterns of intercropping corn with soybean and solid plantings

A split split plot design in randomized complete block arrangement with three replications was used. Cropping systems (intercropping and solid) were randomly assigned to the main plots, soybean varieties were allotted to sub-plots and the distributions of corn plants were devoted to sub sub-plots. Each sub sub-plot consisted of 12 ridges, each ridge was 6 m long and 0.7 m wide (50.4 m^2).

The characters measured on ten guarded plants from each plot were light intensity (lux) using Lux-meter at 12 h at the middle and bottom (20 cm from soil surface) after 85 days of soybean sowing date and the values obtained were transformed as a percentage of light intensity measured above soybean plants (outside the plant population), plant dry weight (g) after 85 days of soybean sowing date, number of pods per plant, number of seeds per plant, and seed yield per plant (g). Seed yield per plot was recorded at harvest and presented as seed yield per hectare after conversion. Harvest index was calculated as suggested by Clipson *et al.* (1994)

Chemical composition of soybean seeds

For ascertaining chemical composition of seed, 50 g samples of soybean seeds were air dried, then ground and the fine powder stored in brown glass bottles (all the chemical determinations were estimated in ground seeds dried at 70°C till constant weight) for the crude oil and crude protein estimations following procedures described by A.O.A.C. (1995). Crude protein content was calculated by multiplying total nitrogen by 5.71 (Sadasivam and Manickam, 1996). The data analyzed by Chemistry Department, Faculty of Agriculture, Ain Shams University was computed to work out oil and protein yield per hectare and presented.

Statistical analysis

Analysis of variance of the obtained results of each season was performed. The homogeneity test was conducted of error mean squares and accordingly, the combined analysis of the two experimental seasons was carried out. The measured variables were analyzed by ANOVA using MSTATC statistical package (Freed, 1991). Mean comparisons were done using least significant differences (L.S.D) method at 5 per cent level of probability ($P<0.05$) to compare differences between the means.

RESULTS AND DISCUSSION

Light intensity within soybean plants

Light intensity within soybean plants at 85 days from soybean sowing was affected significantly by shading from adjacent corn plants (Table 1). Solid plantings of soybean had higher values for intercepted light intensity as compared with intercropping patterns. Light intensity at middle and bottom of soybean plants were considerably decreased by 33.9 and 48.8 per cent, respectively, as compared with recommended solid planting of soybean (solid 1). This may be due to shading effects of adjacent corn plants. Alternating ridges of patterns 2:4 "N" and 2:4 "H" had the highest values of intercepted light intensity on soybean plants than the other intercropping patterns. The advantage of alternating ridges of these patterns 2:4 "N" and 2:4 "H" in light penetration over alternating ridges 2:2 "N", 2:2 "H" and mixed intercropping patterns may be due to spatial arrangement of these patterns which had the lowest number of corn plants per unit area (67 % of recommended solid planting of corn) as compared to the other intercropping patterns. The four intercropping patterns (2:2 "N", 2:2 "H", 2:4 "N" and 2:4 "H") differed significantly for intercepted light intensity on soybean plants at 85 days age. There were significant differences between 2:2 "N" and 2:2 "H", as well as, 2:4 "N" and 2:4 "H" for intercepted light intensity on soybean plants. These results indicated that intercropping patterns caused significant reduction in light interception through adjacent corn plants. These results are in the same context of those obtained by Chandel *et al.* (1993) who showed that light transmission was decreased by 0.5 – 2.3 per cent and 0.1 – 0.5 per cent after 45 and 60 days from sowing, respectively, under intercropping soybean varieties with corn plants.

Soybean variety Giza 22 at 85 days age had higher values of intercepted light intensity on soybean plants than the other variety (Table 1). This may be due to that canopy structure of soybean variety Giza 22 having narrow leaves that allows passing more solar radiation to the other parts of soybean plant, whereas, soybean variety Giza 111 had broad leaves. These results are in a good line with those obtained by Seversike *et al.* (2009) who indicated that seven-leaflet isolines of soybean had 10 to 21 per cent greater cumulative intercepted photosynthetically active radiation (PAR) at populations 40 m^{-2} as compared to three-leaflet isolines.

Increasing distance between hills of corn plants from 30 to 60 cm, with the same plant population density per unit area, caused a significant increase in intercepted light intensity on soybean plants at 85 days age (Table 1). These data revealed that a wide spaced corn hills formed a good chance for intercroppedsoybean plants to intercept higher percentage of solar radiation than the narrow one. The interactions between each of cropping systems, soybean varieties and corn plant distributions had no significant effects on intercepted light intensity on soybean plant (Table 1).

Plant dry weight (PDW)

Plant dry weight (PDW) at 85 days from soybean sowing was affected significantly by shading of adjacent corn plants (Table 1). Solid plantings of soybean had the highest PDW as compared with intercropping patterns. Alternating ridges of patterns 2:4 "N" and 2:4 "H" had the highest PDW as compared with the other intercropping patterns. The advantage of alternating ridges of these patterns 2:4 "N" and 2:4 "H" in PDW over alternating ridges 2:2 "N", 2:2 "H" and mixed intercropping patterns was due to spatial arrangement of 2:4 "N" and 2:4 "H" patterns which had the lowest ratio of occupied area by corn plants (67 % of recommended solid planting of corn), whereas, it was about 100 per cent of the unit area under 2:2 "N", 2:2 "H" and mixed intercropping patterns. The four intercropping patterns (2:2 "N", 2:2 "H", 2:4 "N" and 2:4 "H") affected significantly

PDW at 85 days age. There were significant differences between 2:2 "N" and 2:2 "H", as well as, 2:4 "N" and 2:4 "H" for PDW. The results were parallel with amount of solar radiation. These results are in accordance with those obtained by Tetiokagho (1988) who mentioned that dry matter (DM) accumulation of soybean varieties "Cobb and Davis" were reduced significantly by intercropping with corn plants. Similar results were obtained by Metwally *et al.* (2007).

The two soybean varieties differed significantly for PDW at 85 days age (Table 2). In general, soybean variety Giza 22 had the highest PDW than Giza 111 variety. These results revealed that soybean variety Giza 22 was more efficient in utilizing photosynthates and consequently had higher dry matter (DM) accumulation than Giza 111 variety. These results are in a good line with those obtained by Metwally *et al.* (2007).

PDW at 85 days age was affected significantly by the distribution of corn plants (Table 2). PDW was increased by increasing distance between hills of corn plants from 30 to 60 cm with the same plant population density per unit area. Increasing distance between hills of corn led to decrease in competition between soybean plants on solar radiation at 60 cm than the other distribution, especially solar radiation which penetrated within corn plants. The interactions between each of cropping systems, soybean varieties and corn plant distributions had no significant effects on PDW at 85 days age (Table 1).

Number of pods per plant

Number of pods per plant was affected significantly by shading of adjacent corn plants (Table 2). Solid plantings of soybean had the highest number of pods per plant as compared with intercropping patterns. Alternating ridges of patterns 2:4 "N" and 2:4 "H" had the highest number of pods per plant than the other intercropping patterns, because it had the lowest shading effects of adjacent corn plants on intercropped soybean plants as compared with the other intercropping patterns (Table 1). Number of pods per plant is depended on number of branches per plant that is formed during the early stages. Hence, intercropping corn with soybean plants led to significant decrease in number of pods per plant as a result of reduction of number of branches per plant under intercropping cultures. The four intercropping patterns (2:2 "N", 2:2 "H", 2:4 "N" and 2:4 "H") affected significantly number of pods per plant without significant differences between 2:2 "N" and 2:2 "H", as well as, 2:4 "N" and 2:4 "H". These results are in the same context of those obtained by Metwally *et al.* (2007).

Overall different intercropping systems, the two soybean varieties did not differ significantly for number of pods per plant (Table 2). Number of pods per plant was affected significantly by the distribution of intercropped corn plants (Table 2). It was increased significantly by increasing number of corn plants from two to four per hill. Wide distance between hills of corn caused significant increase in number of pods of adjacent soybean plants under the intercropping patterns than the narrow one. The interactions between each of cropping systems, soybean varieties and corn plant distributions had no significant effects on number of pods per plant (Table 2).

Number of seeds per plant

Number of seeds per plant was affected significantly by shading of adjacent corn plants (Table 2). Solid plantings of soybean had the highest number of seeds per plant as compared with intercropping patterns. Alternating ridges of patterns 2:4 "N" and 2:4 "H" had the highest number of seeds per plant than the other intercropping patterns (2:2 "N", 2:2 "H" and mixed intercropping patterns). The four intercropping patterns (2:2 "N", 2:2 "H", 2:4 "N" and 2:4 "H") affected significantly number of seeds per plant without significant differences between 2:2 "N" and 2:2 "H", as well as, 2:4 "N" and 2:4 "H". These results agreed with number of pods per plant. They are in the same context of those obtained by Metwally (1973) and Metwally *et al.* (2007) who demonstrated that seed yield per plant was decreased significantly by intercropping soybean with corn.

The two soybean varieties differed significantly for number of seeds per plant (Table 2). Variety Giza 22 produced the highest number of seeds per plant than the other variety. These results are in a good line with those obtained by Metwally *et al.* (2007). Number of seeds per plant was affected significantly by the distribution of intercropped corn plants (Table 2). There is significant increment in number of seeds per plant by increasing distance between hills of corn plants from 30 to 60 cm. These results are parallel with the trend of number of pods per plant. The interactions between each of cropping systems, soybean varieties and corn plant distributions had no significant effects on number of seeds per plant (Table 2).

Seed index

Seed index was affected significantly by shading of adjacent corn plants (Table 2). Solid plantings of soybean had the highest weight of 100 seeds as compared with intercropping cultures. This may be due to shading effects of adjacent corn plants. There were significant differences among all intercropping patterns for seed index. Similar results were obtained by Metwally (1973). The two soybean varieties did not differ significantly for seed index (Table 2). Doubling distance between hills of corn plants from 30 to 60 cm led to increase in weight of 100 seeds. These data were parallel with the trend of amount of light intensity on soybean plants (Table 1). The interactions between each of cropping systems, soybean varieties and corn plant distributions had no significant effects on weight of 100 seeds (Table 2).

Seed yield per plant

Seed yield per plant was affected significantly by shading of adjacent corn plants (Table 3). Solid plantings of soybean had the highest seed yield per plant as compared with intercropping patterns. Intercropping cultures decreased seed yield per plant by 17.6 per cent as compared with recommended solid planting of soybean (solid 1). It is

Table 1. Effect of cropping systems, soybean varieties, corn plant distribution and their interactions on intercepted light intensity on soybean plants and plant dry weight at 85 days (combined data across 2006 and 2007 seasons)

Cropping system	Distribution of corn plants	Per cent of light intensity at						PDW (g)		
		Middle of the plant			Bottom of the plant					
		Giza 22	Giza 111	Mean	Giza 22	Giza 111	Mean	Giza 22	Giza 111	Mean
I. Intercropping patterns										
	2 plants/hill	6.17	4.75	5.46	2.17	1.80	1.98	28.55	34.14	31.34
2 corn:2 soybean (N)	4 plants/hill	7.35	6.26	6.80	2.94	2.42	2.68	28.91	34.47	31.69
	Mean	6.76	5.50	6.13	2.55	2.11	2.33	28.73	34.30	31.51
2 corn:2 soybean (H)	2 plants/hill	5.75	4.47	5.11	1.68	1.41	1.54	25.28	30.94	28.11
	4 plants/hill	6.63	5.91	6.27	2.52	2.04	2.28	25.62	31.29	28.45
	Mean	6.19	5.19	5.69	2.10	1.72	1.91	25.45	31.11	28.28
2 corn:4 soybean (N)	2 plants/hill	7.04	6.27	6.65	2.55	2.34	2.44	30.12	35.69	32.90
	4 plants/hill	8.57	7.72	8.14	3.43	3.12	3.27	30.44	36.06	33.25
	Mean	7.80	6.99	7.39	2.99	2.73	2.86	30.28	35.87	33.07
2 corn:4 soybean (H)	2 plants/hill	6.42	5.37	5.89	2.31	1.93	2.12	28.83	34.38	31.60
	4 plants/hill	7.96	6.67	7.31	2.99	2.62	2.80	29.18	34.77	31.97
	Mean	7.19	6.03	6.60	2.65	2.27	2.46	29.00	34.57	31.78
Mixed cropping	2 plants/hill	5.07	3.73	4.40	1.32	1.16	1.24	23.22	28.81	26.01
	4 plants/hill	6.29	5.17	5.73	2.14	1.65	1.89	23.51	29.15	26.33
	Mean	5.68	4.45	5.06	1.73	1.40	1.56	23.36	28.98	26.17
Average of intercropping	2 plants/hill	6.09	4.91	5.50	2.00	1.72	1.86	28.60	34.19	31.39
	4 plants/hill	7.36	6.34	6.85	2.80	2.37	2.58	28.93	34.54	31.73
	Mean	6.72	5.62	6.17	2.40	2.04	2.22	28.76	34.36	31.56
II. Solid patterns										
Solid 1	Mean	9.52	9.16	9.34	4.62	4.07	4.34	30.53	36.18	33.35
Solid 2	Mean	9.06	8.65	8.85	4.24	3.63	3.93	30.52	36.09	33.30
General mean of soybean varieties	Mean	7.45	6.56	7.00	2.98	2.56	2.77	28.26	33.87	31.06
LSD (0.05%)										
Cropping systems (S)				**0.39**						**1.24**
Soybean varieties (V)				**0.21**						**0.90**
Distribution of corn plants (D)				**0.13**						**0.31**

Table 2. Effect of cropping systems, soybean varieties, corn plant distribution and their interactions on number of pods/plant, seeds/plant and seed index (combined data across 2006 and 2007 seasons)

Cropping system	Distribution of corn plants	Pods (No/plant)			Seeds (No/plant)			Seed index (g)		
		Giza 22	Giza 111	Mean	Giza 22	Giza 111	Mean	Giza 22	Giza 111	Mean
I. Intercropping patterns										
	2 plants/hill	32.95	32.83	32.89	88.65	87.80	88.22	17.80	17.63	17.71
2 corn:2 soybean (N)	4 plants/hill	34.33	34.00	34.16	89.40	88.63	89.01	18.63	18.35	18.49
	Mean	33.64	33.41	33.52	89.02	88.21	88.61	18.21	17.99	18.10
2 corn:2 soybean (H)	2 plants/hill	32.31	32.13	32.22	88.01	87.10	87.55	17.16	16.93	17.04
	4 plants/hill	33.76	33.58	33.67	88.96	88.15	88.55	18.03	17.93	17.98
	Mean	33.03	32.85	32.94	88.48	87.62	88.05	17.59	17.43	17.51
2 corn:4 soybean (N)	2 plants/hill	34.58	34.36	34.47	90.21	89.63	89.921	19.43	19.16	19.29
	4 plants/hill	36.06	35.80	35.93	91.66	90.46	91.06	20.36	20.15	20.25
	Mean	35.32	35.08	35.20	90.93	90.04	90.48	19.89	19.65	17.77
2 corn:4 soybean (H)	2 plants/hill	33.98	33.58	33.78	89.30	88.96	89.13	18.75	18.16	18.45
	4 plants/hill	35.28	35.00	35.14	90.46	89.90	90.18	19.58	19.35	19.46
	Mean	34.63	34.29	34.46	89.88	89.43	89.65	19.16	18.75	18.95
Mixed cropping	2 plants/hill	32.21	31.65	31.93	87.88	86.63	87.25	17.06	16.53	16.79
	4 plants/hill	33.61	32.61	33.11	88.83	87.11	87.97	17.88	17.00	17.44
	Mean	32.91	32.13	32.52	88.35	86.87	87.61	17.47	16.76	17.11
Average of intercropping	2 plants/hill	33.20	32.91	33.05	88.81	88.02	88.41	18.04	17.68	17.86
	4 plants/hill	34.60	34.19	34.39	89.86	88.85	89.35	18.89	18.55	18.72
	Mean	33.90	33.55	33.72	89.33	88.343	88.88	18.46	18.11	18.28
II. Solid patterns										
Solid 1	Mean	37.51	37.16	37.33	92.08	91.70	91.89	21.86	21.51	21.68
Solid 2	Mean	37.13	36.83	36.98	91.81	91.23	91.52	21.365	21.18	21.41
General mean of soybean varieties	Mean	34.88	34.53	34.70	90.07	89.30	89.68	19.40	19.03	19.21
LSD (0.05%)										
Cropping systems (S)				**1.47**			**0.94**			**2.98**
Soybean varieties (V)				**N.S.**			**0.68**			**N.S.**
Distribution of corn plants (D)				**1.15**			**0.52**			**0.62**

Table 3. Effect of cropping systems, soybean varieties, corn plant distribution and their interactions on seed yield and harvest index (combined data across 2006 and 2007 seasons)

Cropping system	Distribution of corn plants	Seed yield (g/plant)			Seed yield (kg/hectare)			Harvest index (%)		
		Giza 22	Giza 111	Mean	Giza 22	Giza 111	Mean	Giza 22	Giza 111	Mean
I. Intercropping patterns										
	2 plants/hill	7.94	6.83	7.38	1433.2	1174.5	1303.7	21.36	17.40	19.33
2 corn:2 soybean (N)	4 plants/hill	8.52	7.74	8.13	1575.7	1353.7	1464.7	22.14	18.75	20.44
	Mean	8.23	7.28	7.75	754.5	1264.0	1384.2	21.70	18.07	19.88
2 corn:2 soybean (H)	2 plants/hill	6.47	6.05	6.26	1707.2	1487.2	1597.2	20.45	16.92	18.68
	4 plants/hill	7.42	6.68	7.05	1995.0	1747.7	1871.5	21.51	18.43	19.97
	Mean	6.94	6.36	6.65	1851.0	1617.5	1734.2	20.98	17.67	19.32
2 corn:4 soybean (N)	2 plants/hill	8.77	8.21	8.49	2269.0	2105.0	2187.0	23.64	20.11	21.87
	4 plants/hill	9.40	8.87	9.13	2448.2	2304.7	2376.5	24.83	21.39	23.11
	Mean	9.08	8.54	8.81	2358.5	2204.7	2281.7	24.23	20.75	22.49
2 corn:4 soybean (H)	2 plants/hill	8.37	7.76	8.06	2605.2	2218.2	2411.7	23.11	19.59	21.35
	4 plants/hill	8.96	8.41	8.68	2786.7	2572.2	2679.5	24.13	21.76	22.94
	Mean	8.66	8.08	8.37	2696.0	2395.2	2545.5	23.62	20.67	22.14
Mixed cropping	2 plants/hill	6.11	5.72	5.91	2281.2	2036.5	2158.7	18.54	15.11	16.82
	4 plants/hill	6.50	6.10	6.30	2418.7	2220.0	2319.2	19.11	15.389	17.50
	Mean	6.30	5.91	6.10	2350.0	2128.2	2239.0	18.82	15.50	17.16
Average of intercropping	2 plants/hill	7.53	6.91	7.22	2059.2	1804.2	1931.7	21.40	17.82	19.61
	4 plants/hill	8.16	7.56	7.86	2244.7	2039.7	2142.2	22.34	19.24	20.79
	Mean	7.84	7.23	7.54	2152.0	1922.0	2037.0	21.87	18.53	20.20
II. Solid patterns										
Solid 1	Mean	9.39	8.94	9.16	3414.5	3239.5	3327.0	26.36	23.16	24.76
Solid 2	Mean	9.24	8.74	8.99	3312.5	3147.7	3230.0	26.15	22.83	24.49
General mean of soybean varieties	Mean	8.26	7.69	7.97	2498.0	2285.2	2391.5	23.12	19.80	21.46
LSD (0.05%)										
Cropping systems (S)				**0.43**			**260.75**			**2.32**
Soybean varieties (V)				**0.22**			**106.50**			**1.16**
Distribution of corn plants (D)				**0.19**			**94.50**			**0.64**

Table 4. Effect of cropping systems, soybean varieties, corn plant distribution and their interactions on seed yield and harvest index (combined data across 2006 and 2007 seasons)

Cropping system	Distribution of corn plants	Seed oil (%)			Seed protein (%)			Oil yield (kg/hectare)			Protein yield (kg/hectare)		
		Giza 22	Giza 111	Mean	Giza 22	Giza 111	Mean	Giza 22	Giza 111	Mean	Giza 22	Giza 111	Mean
I. Intercropping patterns													
	2 plants/hill	21.78	21.21	21.49	39.20	39.81	39.50	312.0	249.0	280.5	561.7	467.5	514.5
2 corn:2 soybean (N)	4 plants/hill	22.18	21.56	21.87	38.85	39.41	39.13	349.5	291.7	320.5	612.0	533.5	572.7
	Mean	21.98	21.38	21.68	39.02	39.61	39.31	330.7	270.2	300.5	586.7	500.5	543.5
2 corn:2 soybean (H)	2 plants/hill	21.51	20.83	21.17	39.98	40.38	40.18	367.0	309.7	338.2	682.5	600.5	641.5
	4 plants/hill	21.96	21.40	21.68	39.46	40.10	39.78	438.0	374.0	406.0	787.0	700.7	743.7
	Mean	21.73	21.11	21.42	39.72	40.24	39.98	402.5	341.7	372.0	734.7	650.5	692.5
2 corn:4 soybean (N)	2 plants/hill	22.31	21.96	22.13	38.43	38.81	38.62	506.0	462.2	484.0	871.7	816.7	844.2
	4 plants/hill	22.85	22.46	22.65	37.76	38.28	38.02	559.2	517.5	538.2	924.2	882.2	903.2
	Mean	22.58	22.21	22.39	38.09	38.54	38.31	532.5	489.7	511.0	898.0	849.5	873.7
2 corn:4 soybean (H)	2 plants/hill	22.15	21.78	21.96	38.60	38.86	38.73	577.0	483.0	530.0	1005.5	862.0	933.7
	4 plants/hill	22.56	22.30	22.43	38.08	38.45	38.26	628.5	573.5	601.0	1061.0	989.0	1025.0
	Mean	22.35	22.04	22.19	38.34	38.65	38.49	602.7	528.2	565.5	1033.2	925.5	979.2
Mixed cropping	2 plants/hill	20.73	20.16	20.44	44.18	44.48	44.33	472.7	410.5	441.5	1007.7	905.7	956.7
	4 plants/hill	21.41	20.96	21.18	43.33	43.81	43.57	517.7	465.2	491.5	1048.0	972.5	1010.2
	Mean	21.07	20.56	20.81	43.75	44.14	43.94	495.2	437.7	466.5	1027.7	939.0	983.2
Average of intercropping	2 plants/hill	21.69	21.18	21.43	40.07	40.46	40.26	446.5	382.0	414.2	825.0	729.7	777.2
	4 plants/hill	22.19	21.73	21.96	39.49	40.01	39.75	498.0	443.0	470.5	886.2	816.0	851.0
	Mean	21.94	21.45	21.69	39.78	40.23	40.00	472.2	412.5	442.2	855.5	772.7	814.0
II. Solid patterns													
Solid 1	Mean	23.23	22.86	23.04	36.38	36.58	36.48	793.0	740.5	766.7	1242.0	1185.0	1213.5
Solid 2	Mean	23.13	22.78	22.95	36.53	37.00	36.76	766.0	717.0	741.5	1210.0	1164.5	1187.2
General mean of soybean varieties	Mean	22.29	21.84	22.06	38.83	39.25	39.04	560.2	503.5	531.7	961.7	887.7	369.9
LSD (0.05%)													
Cropping systems (S)				**1.47**			**4.63**			**51.05**			**95.70**
Soybean varieties (V)				**0.35**			**0.36**			**31.72**			**45.60**
Distribution of corn plants (D)				**0.23**			**0.26**			**28.60**			**41.95**

clear that shading of intercropped corn plants played a major role in reducing productivity of seed yield per plant by negative effect on number of pods per plant and weight of 100 seeds. Alternating ridges of patterns 2:4 "N" and 2:4 “H" had the highest seed yield per plant than the other intercropping patterns, because the ratio of corn plants per unit area was the lowest under these patterns and consequently low shading effects on intercropped soybean plants. Mixed intercropping pattern had the lowest seed yield per plant as compared with alternating ridges and solid plantings. The four intercropping patterns (2:2 "N", 2:2 "H", 2:4 "N" and 2:4 "H") affected significantly seed yield per plant. Also, there were significant differences between 2:2 "N" and 2:2 "H", as well as, 2:4 "N" and 2:4 "H" for seed yield per plant. It is clear that effect of shading of corn on adjacent soybean plants on the other side of corn ridges in alternating ridges was higher as compared with normal alternating ridges (2:2 "N" and 2:4 "N") and mixed ones. These results are in the same context of those obtained by Sayed Galal *et al.* (1984) who showed that the intercropping pattern reduced soybean yield to almost 60 per cent in comparison with solid planting. Three ridges of corn alternating with three ridges of soybean gave higher significantly in individual plant characters and yield of soybean. Similar results were obtained by Metwally *et al*. (2005 and 2007)

Seed yield per plant was affected significantly by soybean varieties (Table 3). Soybean variety Giza 22, fixing high amount of solar energy and converting it to chemical energy per unit area during the early stages and transferring to produce higher yield than the other variety. However, the differences between these varieties in this trait may be due to their genetic makeup. These results are in a good line with those obtained by Shafik (2000) who demonstrated that soybean genotypes differed significantly in yielding ability under solid and intercropping cultures. Also, Adeniyan and Ayoola (2006) mentioned that there were variations among improved soybean varieties, corn and cassava for intercropping, location, year and their interactions. Similar variability indicating considerable diversity for seed yield per plant was observed by Bharadwaj *et al.* (2007) while evaluating 87 accessions of soybean.

Seed yield per plant was affected significantly by the distribution of intercropped corn plants (Table 3). There is significant increment in seed yield per plant by increasing distance between hills of corn plants from 30 to 60 cm. These results were in agreement with the trend of number of seeds per plant and seed index. They are in agreement with those obtained by Metwally *et al*. (2005) who concluded that higher value of 100-seed weight of soybean plants was achieved by increasing corn plant density from 25, 000 to 50, 000 plants per hectare. The interactions between each of cropping systems, soybean varieties and corn plant distributions had no significant effects on seed yield per plant (Table 3).

Seed yield per hectare

Seed yield per hectare was affected significantly by shading of adjacent corn plants (Table 3). Solid plantings of soybean had the highest seed per ha as compared with intercropping patterns. Intercropping cultures decreased seed yield per hectare by 38.7 per cent as compared with recommended solid planting of soybean (solid 1). The intercropping pattern 2:4 "H" had the highest seed yield per hectare as compared with the other intercropping patterns, whereas, intercropping pattern 2:2 "N" had the lowest seed yield per hectare. This may be due to lower number of soybean plants per unit area (50 % of unit area) and shading effects of adjacent corn plants. There was a significant increase in soybean yield by using the high population density of soybean under alternating pattern 2:4 (H) than that obtained by mixed intercropping pattern by 13.6 per cent. The four intercropping patterns (2:2 "N", 2:2 "H", 2:4 "N" and 2:4 "H") affected significantly seed yield per hectare. Also, there were significant differences between 2:2 "N" and 2:2 "H", as well as, 2:4 "N" and 2:4 "H" for seed yield per hectare. It is clear that effect of shading of corn on adjacent soybean plants on the other side of corn ridges in alternating ridges was higher as compared with normal alternating ridges (2:2 "N" and 2:4 "N") and mixed ones. It could be concluded that number of soybean plants per unit area and seed yield per plant were integrated together for producing intercropped seed yield per acre under different intercropping patterns. These results are in the same context of those obtained by Fisher (1977) who studied corn/bean intercrop systems at varying densities and reported significant increase in intercrop bean yield with a rise in bean density. The seed yields of beans were 320, 650 and 940 kg per hectare from the lowest to the highest density. Also, Metwally *et al.* (2005) reported that alternating pattern produced the lowest soybean yield per hectare as compared with those obtained from mixed intercropping and solid patterns.

Two soybean varieties differed significantly for seed yield per hectare (Table 3). Soybean variety Giza 22 out yielded the other variety. It gave an increment in seed yield, over all solid and intercropping patterns, by 9.3 per cent than Giza 111 variety. The differences between the two soybean varieties may be due to the inherent varietal characters. These data suggest that the soybean variety Giza 22 would perform well under narrow ridges or intercropping patterns. Similar results were obtained by Sayed Galal *et al.* (1983) who showed that some soybean varieties were relatively more tolerant to intercropping conditions than others.

Seed yield per hectare was affected significantly by the distribution of intercropped corn plants (Table 3). Increasing distance between hills of corn plants from 30 to 60 cm led to increase in seed yield per acre by 10.8 per cent as compared with the narrow distance. This may be due to more intercepted light from wide distance than narrow distance (Table 1). These results are in agreement with those obtained by Metwally *et al.* (2005) who concluded that higher value of seed yield per hectare of soybean plants was achieved by increasing corn plant density from 24, 700 to 49, 400 plants per hectare. The interactions between each of cropping systems, soybean varieties and corn plant distributions had no significant effects on seed yield per hectare (Table 3).

Harvest index (HI)

HI was affected significantly by shading of adjacent corn plants (Table 3). Solid plantings of soybean had the highest HI as compared with intercropping patterns. Alternating ridges of intercropped patterns 2:4 "N" and 2:4 "H" had the highest HI than the other intercropping patterns. This may be due to lower shading effects of intercropped corn plants, because the ratio of intercropped corn plants was the lowest in these patterns. It is clear that shading of corn plants on adjacent soybean plants under intercropping cultures caused significant reduction in HI. The four intercropping patterns (2:2 "N", 2:2 "H", 2:4 "N" and 2:4 "H") affected significantly HI without significant differences between 2:2 "N" and 2:2 "H", as well as, 2:4 "N" and 2:4 "H". These results are in the same context of those obtained by Metwally *et al.* (2007).

Soybean variety Giza 22 had significantly higher HI than Giza 111 variety. This may be partially due to higher seed yield per hectare than Giza 111 variety. These results were agreed with those obtained by Metwally *et al.* (2007) who showed that HI was affected by soybean varieties. HI was affected significantly by the distribution of intercropped corn plants (Table 3). Increasing distance between hills of corn plants from 30 to 60 cm led to increase in HI. These results were parallel with the trend of seed yield per hectare. The interactions between each of cropping systems, soybean varieties and corn plant distributions had no significant effects on HI (Table 3).

Seed oil and protein percentages

Seed oil and protein percentages were affected significantly by shading effects of intercropped corn plants (Table 4). Solid plantings of soybean had the highest seed oil percentage as compared with intercropping patterns, whereas, the reverse was true for seed protein percentage. Mixed intercropping pattern had the lowest seed oil percentage as compared with the other intercropping patterns, whereas, the reverse was true for seed protein percentage. Similar results were obtained by Metwally (1978). Two soybean varieties differed significantly for seed oil and protein percentages (Table 4). Soybean variety Giza 22 had the highest seed oil percentage than Giza 111 variety, whereas, Giza 111 variety had the highest seed protein percentage than Giza 22 variety. These results are in a good line with those obtained by Abdel – Wahab (2002) who found that there were significant differences among the tested soybean genotypes. Seed oil and protein percentages were affected significantly by doubling distance between hills of corn plants from 30 to 60 cm (Table 4). Seed oil percentage was parallel with the trend of amount of light intensity on soybean plants (Table 1). Seed protein percentage was decreased significantly by doubling distance between hills of corn plants from 30 to 60 cm, this result refers to dilution effect to the content of soybean seeds from protein due to the significant increase in seed yield per hectare when corn plants were spaced at 60 cm than 30 cm. The interactions between each of cropping systems, soybean varieties and corn plant distributions had no significant effects on seed oil and protein percentages (Table 4).

Oil and protein yields per hectare

Oil and protein yields per hectare were affected significantly by shading effects of adjacent corn plants (Table 4). Solid plantings of soybean had higher values for oil and protein yields per hectare as compared with intercropping patterns. With respect to intercropping patterns, 2:4 "H" intercropping pattern had the highest oil yield per hectare, whereas, mixed intercropping pattern recorded the highest protein yield per hectare as compared with the other intercropping patterns. This may be due to shading effects of adjacent corn plants. The four intercropping patterns (2:2 "N", 2:2 "H", 2:4 "N" and 2:4 "H") affected significantly oil and protein yields per hectare. Also, there were significant differences between 2:2 "N" and 2:2 "H", as well as, between 2:4 "N" and 2:4 "H" for oil and protein yields per hectare. It is clear that possibility of increasing of oil and protein yields per hectare under common intercropping patterns between corn and soybean 2:2 "N" and 2:4 "N" by increasing soybean plant density by 25 per cent under these patterns. Oil yield per hectare was increased by 23.7 and 10.6 per cent under intercropping patterns 2:2 "H" and 2:4 "H" as compared with the common intercropping patterns (2:2 "N" and 2:4 "N"), respectively. Also, protein yield per hectare was increased by 27.4 and 12.0 per cent under intercropping patterns 2:2 "H" and 2:4 "H" as compared with the common intercropping patterns 2:2 "N" and 2:4 "N", respectively.

Oil and protein yields per hectare were affected significantly by soybean varieties (Table 4). Soybean variety Giza 22 had higher values for oil and protein yields per hectare than the other variety. These results are in a good line with those obtained by Abdel – Wahab (2002). Oil and protein yields per hectare were affected significantly by doubling distance between hills of corn plants from 30 to 60 cm with the same plant population density per unit area (Table 4).

The interactions between each of cropping systems, soybean varieties and corn plant distributions had no significant effects on oil and protein yields per hectare (Table 4).

It is concluded that increasing soybean plant density by 25 per cent under common patterns between corn and soybean increased seed, oil and protein yields without any adverse effects on intercropped corn yield.

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Effect of Graded Levels of Major Nutrients on Productivity, Energy Budgeting and Economic Viability of Soybean in India

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ABSTRACT

Field experiments were conducted at thirteen locations situated under diverse agro-climatic regions of India viz., north eastern, north plain, central and southern zone. Application of nitrogen, phosphorus and potassium nutrients increased the productivity of soybean across the zones by 17.0-5.30, 19.15-73.82, 20.79-57.94 per cent, respectively over control. Irrespective of type of nutrient, the sustainability yield indices were noted minimum in southern zone and maximum in north eastern zone. It varied from 0.229 to 0.705, 0.302 to 0.787 and 0.305 to 0.700 due to application of nitrogen, phosphorus and potassium, respectively. The stability parameter for all the three nutrients indicated that the application of nitrogen in north eastern and southern zone performed better under favourable environmental conditions (b > 1) while remaining two zone did well under unfavourable conditions (b < 1). The agronomic efficiency of all the three nutrients drastically declined as the levels of nutrients increased. The energy and economic indices followed the similar trend as it was observed in yield.

Keywords: Agronomic efficiency, energy, nitrogen, phosphorus, potassium, stability, sustainable yield index

Intensive cultivation coupled with growing of exhaustive crops in the past has rendered soil deficient in macro- as well as micro-nutrients. The success of any crop indiviually or in a cropping system depends upon the appropriate management of resources, particularly balanced use of fertilizers employing integrated approach. The cultivation of legumes has made radical improvement in the farming community. These are considered to be exhaustive crops demanding more nutrition when grown either with low nitrogen and phosphorus or with lesser quantities of organic sources in soil. This has resulted in deterioration in soil health and productivity. Use of organic manures may prove a viable option for sustaining the productivity of legumes and adds life to the soil.

Nutrient requirement for optimum growth of soybean is site-specific. Any restriction in root growth, decline in the rate of photosynthesis, or serious nutrient

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shortage can hamper the full expression of genetic potential of crops including soybean. To overcome the shortage of nutrient requirement, the goal should be to supply each plant with its specific needs throughout the season. The present investigation therefore was initiated to study the effect of graded levels of nitrogen, phosphorus and potassium on sustainable and stable soybean productivity in India.

MATERIAL AND METHODS

A field study was carried out during 2003 and 2004 at location belonging to four agro-climatic zones *viz*., north eastern (Raipur), north plain (Pantnagar, Ludhiana and Hisar), central (Indore, Sehore, Parbhani and Kota) and southern (Bangalore, Pune, Lam, Coimbatore and Dharwad) as defined under All India Coordinated Research Project on Soybean. The experiment conducted on these locations included thirteen treatment combinations—two levels of nitrogen and potassium each (20 and 40 kg/ha), three levels of phosphorus (40, 60 and 80 kg/ha) and one control (without nutrients) which were replicated thrice in randomized block design. The data from different centres of the respective zone were pooled and further indices were worked out. The treatment-wise sustainable yield index (SYI) and stability (b) were determined by using data from the specified centers. The yield stability was computed following simple regression coefficient and mean over the years (Finlay and Wilkinson, 1963). The sustainable yield index was computed as suggested by Singh *et al*. (1990).

The prevailing prices of inputs and outputs were utilized to work out economics. The energy budget of treatments was determined by using the conversion factors for inputs, outputs and cultural activities as suggested by Mittal and Dhawan (1988). Energy intensiveness (EI) and energy productivity (EP) were worked out as per Burnett (1982) and Fluck (1979). The treatment-wise economics was worked out by the using of prevailing market price of inputs and output.

RESULTS AND DISCUSSION

North Eastern zone

Soybean yield was substantially increased by the nitrogen levels at Raipur centre as compared to control; the differences in yield between 20 and 40 kg N per ha being non-significant (Table 1). However, the magnitude of response was approximately 55 per cent over control. The agronomic efficiency drastically declined as the levels of nitrogen increased. The basal application of 20 kg N per ha showed higher sustainable yield index and also exhibited stable performance over 40 kg N/ha. Stability index indicated that the application of nitrogen did well under favourable environmental conditions. The energy input appreciably increased as the levels of nitrogen increased but a reverse trend was noted in case of energy output. The maximum energy use efficiency and productivity were associated with 20 kg N per ha. The Net returns and B:C ratio differed non-significantly between 20 and 40 kg N per ha.

Application of different levels of phosphorus caused an appreciable improvement in seed yield of soybean (Table 1). It increased significantly as the levels of phosphorus increased. Application of 40, 60 and 80 kg phosphorus per hectare increased the yield by 35.28, 55.47 and 73.82 per cent, respectively over control. Agronomic efficiency of phosphorus remained unchanged due to different levels of phosphorus. The highest sustainable yield index was recorded with 80 kg P_2O_5 per ha while, 40 kg P_2O_5 per ha showed stable performance. All the energy and economical indices were appreciably improved as the levels of phosphorus increased.

Soybean yield was also significantly improved by application of potassium, though the difference between 20 and 40 kg K_2O per ha was non-significant (Table 1). Yield increment was to the tune of 51.63 and57.94 per cent due to 20 and 40 kg K_2O per ha, respectively as compared to control. The agronomic efficiency being highest with 20 kg K_2O per ha and decreased with further increased level of potassium. The highest sustainable yield index was noted with 40 kg K_2O per ha while the stable performance was with 20 kg K_2O per ha. All the energy and economical indices were marginally higher with 40 kg K_2O per ha.

North plain zone

The significant variation in soybean yield was observed due to nitrogen levels (Table 2). The yield enhancement was to the tune of 14.64 to 24.98 per cent as compared to control. The application of 20 kg N per ha produced maximum yield and was sustainable and stable. Both the levels of nitrogen performed better under unfavourable environmental conditions. The agronomic efficiency decreased as the levels of nitrogen increases. All the energy and economical indices were significantly higher with 20 kg N per ha.

Soybean yield was significantly influenced by the applied phosphorus levels (Table 2), while the difference between 40 and 60 kg P_2O_5 per ha was found to be non-significant. The magnitude of response was 19.15 to 24.41 per cent over control. Agronomic efficiency declined as the levels of phosphorus increased. Application of 80 kg P_2O_5 per ha brought out sustainable and stable performance of soybean. The maximum energy indices and net returns were with 80 kg P_2O_5 per ha while the highest B:C ratio was with 40 kg P_2O_5 per ha.

Application of potassium significantly influenced soybean yield (Table 2). The difference between 20 and 40 kg K_2O per ha was found to be non-significant. The extent of yield increase was about 21 per cent over control. Agronomic efficiency drastically reduced with the increased levels of potassium. The sustainability yield index and stability indicated that both the levels were more or less similar. All the energy and economical indices were marginally higher with 20 kg K_2O per ha.

Central zone

A significant increase in soybean yield was recorded with increased nitrogen levels (Table 3). The magnitude

Table 1. Effect of major nutrients on productivity of soybean under north eastern zone

Treatment	Seed yield (kg/ha)	SYI	b	Agronomic efficiency (kg seed /kg)	Energy input (MJ/ha)	Net energy output (MJ/ha)	EUE	Energy productivity (g/MJ)	Cost of cultivation (`/ha)	Net returns (`/ha)	B:C ratio
Nitrogen level (kg/ha)											
20	1946	0.705	1.201	34.65	11327	17270	2.52	172	8597	16260	2.89
40	1934	0.672	1.447	17.03	12539	15886	2.27	154	8880	16251	2.83
SEm (+/-)	44.63	-	-	-	78.41	567.33	0.04	2.99	42.96	471.94	0.04
CD (P=0.05)	**NS**	**-**	**-**	**-**	**215.45**	**1515.20**	**0.12**	**8.51**	**119.68**	**1343.61**	**0.12**
Phosphorus level (kg/ha)											
40	1695	0.598	1.251	11.05	11711	13191	2.13	145	8416	13597	2.62
60	1948	0.682	1.356	11.58	11933	16689	2.41	164	8739	16573	2.90
80	2178	0.787	1.365	11.56	12155	19855	2.64	180	9062	18596	3.06
SEm (+/-)	54.66	-	-	-	96.03	694.84	0.05	3.66	52.61	578.00	0.05
CD (P=0.05)	**155.63**	**-**	**-**	**-**	**267.55**	**1978.20**	**0.15**	**10.43**	**146.58**	**1645.58**	**0.14**
Potassium level (kg/ha)											
20	1900	0.678	1.309	32.35	11866	16062	2.36	161	8674	16024	2.84
40	1979	0.700	1.338	18.15	12000	17094	2.43	164	8803	16486	2.87
SEm (+/-)	44.63	-	-	-	78.41	567.33	0.04	2.99	42.96	471.94	0.04
CD (P=0.05)	**127.06**	**-**	**-**	**-**	**215.45**	**1515.20**	**0.12**	**8.51**	**119.68**	**1343.61**	**0.12**
Control	1253	-	-	-	9248	9171	1.99	135	7150	9139	2.28
SEm+/-for Control vs treatment	109.33	-	-	-	192.07	1389.68	0.11	7.32	105.22	1156.01	0.10
CD (P=0.05) for Control vs treatment	**311.26**	**-**	**-**	**-**	**535.10**	**3956.41**	**0.31**	**20.85**	**293.15**	**3291.17**	**0.29**

Table 2. Effect of major nutrients on productivity of soybean under north plain zone

Treatment	Seed yield (kg/ha)	SYI	b	Agronomic efficiency (kg seed /kg)	Energy input (MJ/ha)	Net energy output (MJ/ha)	EUE	Energy produc-tivity (g/MJ)	Cost of cultiva-tion (Rs/ha)	Net returns (Rs/ha)	B:C ratio
Nitrogen level (kg/ha)											
20	2897	0.530	0.845	28.95	11327	31259	3.76	256	8597	29065	4.37
40	2717	0.498	0.801	9.98	12539	27401	3.19	217	8880	26441	3.98
SEm+/-	29.50	-	-	-	78.41	413.74	0.05	3.34	42.96	338.70	0.04
CD (P=0.05)	**83.29**	**-**	**-**	**-**	**218.45**	**1167.99**	**0.14**	**9.43**	**119.68**	**956.14**	**0.11**
Phosphorus level (kg/ha)											
40	2762	0.505	0.819	11.10	11711	28880	3.49	237	8416	27481	4.25
60	2776	0.516	0.771	7.63	11933	28871	3.44	234	8739	27347	4.14
80	2884	0.521	0.879	7.08	12155	30241	3.51	239	9062	28431	4.14
SEm+/-	36.13	-	-	-	96.03	506.73	0.06	4.09	52.61	414.82	0.05
CD (P=0.05)	**102.00**	**-**	**-**	**-**	**267.55**	**1430.50**	**0.17**	**11.55**	**146.58**	**1171.03**	**0.13**
Potassium level (kg/ha)											
20	2815	0.501	0.842	24.85	11866	29507	3.50	238	8674	25915	4.21
40	2800	0.518	0.789	12.05	12000	29153	3.44	234	8803	27591	4.14
SEm+/-	29.50	-	-	-	78.41	413.74	0.05	3.34	42.96	338.70	0.04
CD (P=0.05)	**83.29**	**-**	**-**	**-**	**218.45**	**1167.99**	**0.14**	**9.43**	**119.68**	**956.14**	**0.11**
Control	2318	-	-	-	9248	24827	3.68	251	7150	22984	4.21
SEm+/-for Control vs treatment	72.27	-	-	-	192.07	1013.46	0.12	8.18	105.22	829.63	0.09
CD (P=0.05) for Control vs treatment	**204.01**	**-**	**-**	**-**	**535.10**	**2860.99**	**0.34**	**23.10**	**293.15**	**2342.16**	**0.26**

Table 3. Effect of major nutrients on productivity of soybean under central zone situation

Treatment	Seed yield (kg/ha)	SYI	b	Agronomic efficiecncy (kg seed /kg)	Energy input (MJ/ha)	Net energy output (MJ/ha)	EUE	Energy productivity (g/MJ)	Cost of cultivation (Rs/ha)	Net returns (Rs/ha)	B:C ratio
Nitrogen level (kg/ha)											
20	1597	0.548	0.808	20.55	11327	12152	2.08	141	8597	12617	2.42
40	1701	0.583	0.873	12.88	12539	12456	1.99	136	8803	13224	2.49
SEm+/-	23.73	-	-	-	78.41	266.33	0.02	1.14	42.96	247.64	0.02
CD (P=0.05)	**74.46**	**-**	**-**	**-**	**218.45**	**742.00**	**0.05**	**3.18**	**119.68**	**689.91**	**0.05**
Phosphorus level (kg/ha)											
40	1525	0.534	0.713	8.48	11711	10858	1.92	131	8416	12078	2.36
60	1693	0.565	0.960	8.45	11933	13267	2.09	142	8739	13261	2.52
80	1730	0.596	0.850	6.80	12155	13244	2.10	143	9062	13423	2.48
SEm+/-	32.73	-	-	-	96.03	326.19	0.02	1.40	52.61	303.29	0.02
CD (P=0.05)	91.21	-	-	-	267.55	908.77	0.06	3.89	146.58	844.97	0.06
Potassium level (kg/ha)											
20	1629	0.560	0.823	22.15	11866	12083	2.02	137	8674	12955	2.44
40	1668	0.571	0.858	12.05	12000	12525	2.05	140	8803	12885	2.47
SEm+/-	23.73	-	-	-	78.41	266.33	0.02	1.14	42.96	247.64	0.02
CD (P=0.05)	**74.46**	**-**	**-**	**-**	**218.45**	**742.00**	**0.05**	**3.18**	**119.68**	**689.91**	**0.05**
Control	1186	-	-	-	9248	8186	1.89	128	7150	8268	2.16
SEm+/-for Control vs treatment	65.48	-	-	-	192.07	652.38	0.04	1.67	105.22	606.58	0.05
CD (P=0.05) for Control vs treatment	**182.42**	**-**	**-**	**-**	**535.10**	**1817.53**	**0.12**	**4.72**	**293.15**	**1689.93**	**0.13**

Table 4. Effect of major nutrients on productivity of soybean under southern zone situations

Treatment	Seed yield (kg/ha)	SYI	b	Agronomic efficiency (kg seed /kg)	Energy input (MJ/ha)	Net energy output (MJ/ha)	EUE	Energy produc-tivity (g/MJ)	Cost of cultiva-tion (Rs/ha)	Net returns (Rs/ha)	B:C ratio
Nitrogen level (kg/ha)											
20	1848	0.299	1.108	19.20	11327	15841	2.40	163	8597	15430	2.80
40	1868	0.317	1.055	10.01	12539	14914	2.19	149	8880	15397	2.74
SEm+/-	18.41	-	-	-	78.41	166.99	0.02	1.45	42.96	161.99	0.01
CD (P=0.05)	**51.28**	**-**	**-**	**-**	**218.45**	**465.25**	**0.05**	**3.23**	**119.68**	**461.21**	**0.03**
Phosphorus level (kg/ha)											
40	1818	0.302	1.052	8.85	11711	15003	2.29	156	8416	15209	2.81
60	1863	0.307	1.091	6.65	11933	15454	2.31	157	8739	15481	2.78
80	1894	0.314	1.102	5.38	12155	15676	2.30	156	9062	15551	2.72
SEm+/-	22.55	-	-	-	96.03	204.52	0.02	1.40	52.61	198.41	0.01
CD (P=0.05)	**62.82**	**-**	**-**	**-**	**267.55**	**569.81**	**0.06**	**3.91**	**146.58**	**552.76**	**0.04**
Potassium level (kg/ha)											
20	1859	0.305	1.098	19.75	11866	15459	2.31	157	8674	15491	2.79
40	1857	0.311	1.056	9.83	12000	15296	2.28	155	8803	15336	2.74
SEm+/-	18.41	-	-	-	78.41	166.99	0.02	1.45	42.96	161.99	0.01
CD (P=0.05)	**51.28**	**-**	**-**	**-**	**218.45**	**465.25**	**0.05**	**3.23**	**119.68**	**461.21**	**0.03**
Control	1464	-	-	-	9248	12273	2.33	158	7150	11882	2.66
SEm+/-for Control vs treatment	45.09	-	-	-	192.07	652.38	0.04	1.67	105.22	396.81	0.03
CD (P=0.05) for Control vs treatment	**125.62**	**-**	**-**	**-**	**535.10**	**1817.53**	**0.12**	**4.73**	**293.15**	**1105.52**	**0.07**

of response was to the tune of 34.65 to 43.42 per cent for 20 and 40 kg N per ha over control. However, the agronomic efficiency declined significantly with the increment in nitrogen levels. The higher level of nitrogen showed the sustainable as well as stable performance of soybean than lower level and also performed better under unfavourable environmental conditions, The net energy output, net returns and B:C ratio were higher with 40 kg N per ha while the remaining indices were higher with 20 kg N per ha.

Phosphorus application caused an appreciable enhancement in soybean yield which was to the extent of 28.58 to 45.87 per cent as compared to control (Table 3).

The agronomic efficiency declined from 8.48 to 6.80 with increasing levels of phosphorus. The highest sustainable yield index was with 80 kg P_2O_5 per ha while the stable performance was noticed with 60 kg P_2O_5 per ha and all the levels of phosphorus did well under unfavourable environmental conditions. With respect to energy and economical indices, the difference between 60 and 80 kg P_2O_5 per ha were marginal and better than lower level.

Application of potassium increased the soybean yield by 37.35 and 40.64 percent over control (Table 3). Agronomic efficiency drastically decreased as the levels of potassium increased. The higher sustainability and stability were associated with 40 kg K_2O per ha and both the levels performed better under unfavourable environmental conditions. All the energy and economical indices were more or less similar for both the levels of potassium.

Southern zone

A perceptible enhancement (about 27 %) in soybean yield was observed due to nitrogen application over control, though both the levels of nitrogen differed non-significantly (Table 4). Agronomic efficiency decreased as the levels of nitrogen increased. Application of 40 kg N per ha proved to be better with reference to sustainable yield index and stability, while the energy and economical indices indicated that 20 kg N per ha was found to be better. A significant increase in soybean yield by 24.18 to 29.37 per cent over control was noticed with the applied phosphorus (Table 4). Agronomic efficiency declined as the levels of phosphorus increased. The highest sustainable yield index was with 80 kg P_2O_5 per ha and 40 kg P_2O_5 per ha showed stable performance. The energy and economical indices showed non-significant variations due to phosphorus levels.

Application of potassium significantly enhanced the soybean yield by about 27 per cent over control (Table 4). The difference between 20 and 40 kg K_2O per ha was found to be non-significant. Agronomic efficiency also declined as the levels of potassium increases. Both the levels of potassium were found to be sustainable and stable. All the energy and economical indices followed the more or less similar trend as was observed in yield.

On the basis of foregoing results, it could be concluded that the application of 20 kg N: 80 kg P_2O_5: 20 kg K_2O per hectare in north eastern, 20 kg N:60 kg P_2O_5:20 kg K_2O per hectare in north plain, 40 kg N:60 kg P_2O_5:20 kg K_2O per hectare in central and 20 kg N:40 kg P_2O_5:20 kg K_2O per hectare in southern zone were found to be the most productive, remunerative and energy efficient for soybean.

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Broad- bed Furrow and Ridge and Furrow Method of Sowing under Different Seed Rates of Soybean (*Glycine Max* L.) for High Rainfall Areas of Chhattisgarh Plains

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ABSTRACT

An investigation was carried out during kharif season of 2006 -2008 at Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, India to find out the best combination of sowing on different land configuration systems and seed rates of soybean under high rainfall conditions of Chhattisgarh. Results revealed that growth parameters, yield attributes and seed yield of soybean were the highest under ridge and furrow sowing. Seed yield of soybean was unaffected due to different seed rates. Sowing on ridge and furrow (2248 kg/ha) and seed rate of 62.5 kg per ha (2071 kg/ha) was found to be the best yielder than rest of treatments. The economic returns (net returns- ₹22, 880 and CB ratio – 2.57) were maximum under ridge and furrow planting. Alternatively, broad-bed planting with 4 rows with seed yield of (2214 kg/ha) offering net returns of ₹ 33, 520 with B:C ratio of 3.50 should be the preferred method over other methods. Planting on flat land led to lowest seed yield (1690 kg/ha) and economic benefits (net returns – ₹15, 640 and B: C ratio - 1.84).

Keywords Broad bed, Ridge and furrow, Sowing Method, Seed rate, *Vertisols*

Chhattisgarh has emerged as one of the important soybean growing states of India in recent years. The present estimated area in the state under the soybean is 1.50 lakh hectares with productivity of 1025 kg per ha (http:\\www.sopa.org/ REK2011. pdf). Major area under this rainfed crop in Chhattishgarh lies on *Vertisols* and associated soils of this state coupled with high mean rainfall of 1400 mm, suffers from water stagnation leading to poor crop stand and consequent lower yield. To overcome this problem and enhancing the yield, planting on appropriate land configuration using optimum seed rate can be of help. This is likely to provide the crop with required plant stand and utilization of incoming light radiation, water, nutrient and space to a maximum extent. In view of above, an attempt has been made to evaluate crop performance on altered land configuration and varying seed rate at Indira Gandhi Krishi

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MATERIAL AND METHODS

An experiment was carried out for three consecutive years (2006, 2007 and 2008) during *kharif* season at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur involving four sowing methods namely- broad-bed (67.5 cm) planting with 2 rows per bed, broad-bed (135 cm) planting with 4 rows per bed, ridge and furrow (60 cm) planting and flat planting at 45 cm with three seed rates (50, 62.5 and 75 kg/ha). The experiment was laid out in split plot design assuming main plots to planting on different land configuration and sub-plot to seed rate. The treatments were replicated thrice. The soil of the experimental field was clayey in texture (*Vertisols*) with low nitrogen (228.8 kg N/ha), medium phosphorus (13.6 kg P_2O_5/ha) and high potassium (372.6 kg K_2O/ha) content. Recommended fertilizer dose of 20:60:40:20 kg N:P_2O_5:K_2O:S per ha was applied to the experimental plots. Variety used was 'JS 335'. Except treatments, standard package of practices were followed to raise the crop. The crop received 1055, 658 and 537 mm of rainfall during *kharif* 2006, 2007 and 2008, respectively. Sowing was performed on 28.06.2006, 11.07.2007 and 26.06.2008 and harvesting on 15.10.2006, 23.10.2007 and 18.10.2008, respectively during the course of experiment. The observation on plant height, number of branches per plant, leaf area at 60 days after sowing (DAS), dry matter accumulation, number and dry weight of nodules, number of pods per plant, number of seeds per plant, 100 seed weight, seed and stover yield and bulk density were recorded and statistically analyzed by using the method of analysis of variance for split plot deign and significance was tested by 'F' test (Gomez and Gomez, 1984). The computations were done for CGR, RGR, production efficiency, energy output-input ratio, energy efficiency and economics and presented. Production efficiency and energy use efficiency (Mittal *et al.,* 1985) was calculated with the help of following formula-

$$\text{Production efficiency (kg/ha/day)} = \frac{\text{Seed yield (kg/ha)}}{\text{Duration of the crop (days)}}$$

$$\text{Energy use efficiency (MJ x } 10^{-3}\text{ /ha)} = \frac{\text{Biological yield (q/ha)}}{\text{Energy input (MJ x } 10^{-3}\text{)}}$$

RESULTS AND DISCUSSION

Growth and yield attributes

Ridge and furrow method of sowing produced significantly higher plant height and branches per plant at harvest over flat planting and was on par with broad-bed plantings. The maximum value of leaf area at 60 DAS was associated with ridge and furrow method was significantly superior (957 cm^2) than broad-bed plantings (808-879 cm^2) and flat planting (772 cm^2). Maximum dry matter accumulation was observed under broad-bed planting with 4 rows (33.3 g/plant) followed by ridge and furrow planting (33.1 g/plant), which were significantly higher than broad-bed planting with 2 rows (29.3 g/plant) and planting on flat land (25.3 g/plant). Ridge and furrow planting revealed its superiority in production of nodules (112.3/plant) and their dry weight at 60 DAS (247.0 mg/plant) followed by broad-bed planting with 4 rows (97.1mg/plant), broad-bed planting with 2 rows (91.9 g/plant) and flat planting (75.67 g/plant) of soybean. Number of seeds produced per plant were maximum in broad-bed planting with 4 rows (241 seeds/plant), but was significantly higher than broad-bed planting with 2 rows (170 seeds/plant). In case of 100 seed weight, the maximum value (11.71 g) was associated with ridge and furrow, which was significantly superior over flat planting (10.48 g) and broad-bed planting with 2 rows (11.14 g) (Table 1). The favourable growth responses may be accounted for reduced oxygen stress, better nutrient acquisition and favourable physical environment for crop growth. The results also confirm the findings of Ralli and Dingra (2003).

Varying seed rate influenced plant height, leaf area at 60 DAS, dry matter per plant and pods per plant at 60 DAS significantly. Plant height increased regularly from 38.64 cm with increase in seed rate reaching maximum (42.16 cm) with 75 kg per ha. Remaining growth parameters as well showed similar trend, but the differences between 65.5 kg per ha and 75 kg per ha were non-significant. Higher plant population due to increasing seed rate might have led to increased plant height due to plant-to-plant competition for light. Rajput and Shrivastava (1999) and Hamid *et al.* (2002) also noted similar results. Higher dry matter production per plant with increasing seed rate appears to be related to increasing leaf area per plant facilitating higher photosynthesis and rapid crop growth rate. Similar results were also noted by Hamid *et al.* (2002) and Kumar and Badiyala (2004). Seed rate of 75 kg per ha showed maximum number of seeds per plant, whereas 100 seed weight was maximum in case of 62.5 kg/ha. Number and dry weight of nodules revealed non-significant increase with increasing seed rate (Table 1).

Although numerically higher values for dry matter accumulation, CGR and RGR during crop growth period were noticed in ridge and furrow and bed planting as compared to flat planting of soybean, the values differed significantly in dry matter observation at 60 DAS and CGR between 45 and 60 DAS.Maximum values for these growth parameters were associated with ridge and furrow system (Table 2). The dry matter accumulation is directly related to the higher number of leaves and LAI at different crop growth stages, which indicates higher photosynthesis and better plant growth rate as revealed by CGR and RGR values. Ralli and Dingra (2003) also noted similar results. The reason for higher growth rates in case of ridge and furrow can be accounted for less stagnation of water due to furrow and proper aeration due to ridges leading to satisfactory physical environment for plant growth. On the contrary, flat sowing of soybean causes stagnation of water and saturated conditions in soil which ultimately affects plant population and lead to poor plant growth as compared to crop sown on ridge and furrow and bed configuration. The bulk density of soil was estimated minimum in ridge and furrow method (1.32 g/cc) as compared to broad-bed plantings (1.36-1.37 g/cc) and flat planting (1.48 g/cc).

Table 1. Effect of planting methods and seed rate on growth and yield attributes of soybean (Mean data over 3 years)

Treatment	Plant height at harvest (cm)	Branches (No/plant)	Leaf area at 60 DAS (cm^2/ plant)	Dry matter production (g/plant)	At 60 DAS			Seeds (No / plant)	Seed index (g/100 seeds)
					Nodule (No/ plant)	Nodule dry weight (mg/plant)	Pods (No /plant)		
Sowing Method									
Broad-bed planting (2 rows/bed)	41.59	7.78	808	29.3	91.9	130.7	56.47	170	11.14
Broad-bed planting (4 rows/bed)	41.55	8.19	879	33.3	97.1	181.7	63.63	241	11.54
Ridge and furrow planting	43.74	8.74	957	33.1	112.3	247.0	67.67	237	11.71
Flat planting	35.18	7.02	772	25.3	75.67	109.8	47.87	214	10.48
SEm (+)	0.834	0.227	17.10	0.569	4.29	9.45	1.14	10.54	0.107
CD (P=0.05)	**2.42**	**0.66**	**49.61**	**1.65**	**12.46**	**27.42**	**3.33**	**30.59**	**0.31**
Seed rate (kg/ha)									
50.0	38.64	7.79	826	29.3	89.1	149.6	56.56	196	11.14
62.5	40.75	7.99	849	30.1	94.8	169.4	59.00	212	11.29
75.0	42.16	8.01	887	31.4	98.9	182.9	60.90	237	11.19
SEm (+)	0.289	0.195	15.42	0.462	3.13	12.71	0.848	7.94	0.089
CD (P=0.05)	**0.84**	**NS**	**44.72**	**1.34**	**NS**	**NS**	**2.46**	**23.02**	**NS**

Table 2. Dry matter, CGR and RGR as influenced by different methods of sowing and seed rate

Treatment	Dry matter (g)			CGR (g/cm2/day)		RGR (g/g/day) at	
	30 DAS	45 DAS	60 DAS	30 -45 DAS	45-60 DAS	30 -45 DAS	45-60 DAS
Sowing method							
Broad-bed planting (2 rows/bed)	1.17	2.78	7.18	0.107	0.293	0.057	0.063
Broad-bed planting (4 rows/bed)	1.11	2.91	7.65	0.120	0.316	0.064	0.064
Ridge and furrow planting	1.24	3.21	8.58	0.131	0.358	0.063	0.065
Flat planting	1.04	2.15	6.17	0.074	0.268	0.048	0.070
SEm (±)	0.12	0.39	0.26	0.023	0.016	0.008	0.007
CD (P=0.05)	**NS**	**NS**	**0.76**	**NS**	**0.048**	**NS**	**NS**
Seed rate (kg/ha)							
50.0	1.10	2.95	7.73	0.123	0.318	0.065	0.064
62.5	1.17	2.76	7.51	0.106	0.317	0.057	0.067
75.0	1.15	2.58	6.94	0.095	0.291	0.054	0.066
SEm (±)	0.11	0.27	0.106	0.017	0.009	0.005	0.004
CD (P=0.05)	**NS**	**NS**	**0.31**	**NS**	**0.027**	**NS**	**NS**

Table 3. Yield and production efficiency of soybean as influenced by planting methods and seed rate

Treatment	Seed yield (kg/ha)				Stover yield (kg/ha)	Production efficiency (kg/ha/day)
	2006	2007	2008	Mean		
Sowing Method						
Bed planting (2 rows per bed)	1413	2150	2100	1887	2611	20.67
Bed planting (4 rows per bed)	1673	2452	2518	2214	2895	23.58
Ridge and furrow	1477	2532	2735	2248	2934	24.35
Flat planting	1133	1943	1995	1690	2331	18.69
SEm (±)	25.51	60	60.01	10.96	53.65	0.579
CD (P=0.05)	**74**	**174**	**176.95**	**31.8**	**155.3**	**1.68**
Seed rate (kg/ha)						
50.0	1323	2167	2228	1906	2530	20.84
62.5	1523	2303	2396	2071	2777	22.15
75.0	1426	2337	2386	2050	2771	22.47
SEm (±)	5.03	58	57	28.70	43.13	0.567
CD(P=0.05)	**14.6**	**NS**	**NS**	**NS**	**125.1**	**NS**

Dry matter at 60 DAS and CGR between 45 and 60 DAS showed significant differences for varying seed rate; the values for 50 and 62.5 kg per ha were at par. (Table 2)

Yield

Mean seed yield over three years of experimentation was maximum with ridge and furrow planting (2248 kg/ha) followed by broad-bed furrow planting with 4 rows (2214 kg/ha), which was significantly superior over broad-bed planting with 2 rows (1887 kg/ha) and flat planting (1690 kg/ha). During first year (2006), the yield levels were not satisfactory as there was a limited rain during 2nd fortnight of June and 1st week of July affecting the plant population.

he higher yield in altered land configuration, particularly in ridge and furrow system, can be accounted for the cumulative effect of yield attributing traits like- number of branches per plant, number of pods per plant, number of seeds per plant and 100-seed weight and rapid growth rates. Similar results were also noted by Raut *et al.* (2000) and Tomar *et al.* (2007). Similarly, these yield attributing traits were cumulatively responsible for numerically higher seed yield levels at seed rates of 62.5 kg per ha followed by 75 kg per ha. Stover yield as well showed a trend similar to seed yield. These results are in conformity to those reported by Kumar and Badiyala (2005). The production efficiency also showed a similar trend to seed and stover yield. Ridge and furrow showed production efficiency at par with broad- bed planting with 4 rows and were significantly higher broad-bed planting with 2 rows and flat planting (Table 3).

Economics and energetic

Total dry matter production in a plant often reflects its potentiality for its biomass production, whereas, mobilization towards the seed development is an important factor for realization of economic yield and serves as the yard stick for the acceptance and rejection of treatment hypothesis. Economics of the present study revealed that among the sowing method of ridge and furrow planting gave the highest net returns (₹ 22, 880/ha) and B: C ratio (2.57), however, the net returns and B: C ratio was found comparable with bed planting with 4 rows (₹ 20, 330/ha and 2.52, respectively). Similar results were also noted by Tomar *et al.* (1996) and Jain and Dubey (1998). Among the seed rates, 62.5 kg per ha gave maximum net returns (₹ 20, 150/ha) and B: C ratio (2.19), however differences among seed rate were non-significant. Similar results were also noted by Kumar and Badiyala (2005). Soybean sown on ridge and furrow gave significantly the highest energy output-input ratio (34.38) and energy use efficiency (3.59 MJ x 10^3/ha). The lowest value was recorded under flat planting (28.02 and 2.90 MJ x 10^3/ha, respectively) (Table 4).

Considering higher seed yield, production efficiency, net returns, B: C ratio, energy output: input ratio and energy use efficiency ridge and furrow planting followed broad-bed-planting with 4 rows were superior among different sowing methods. Seed rate of 62.5 kg per ha emerge out to be adequate for JS 335 to draw maximum advantage on these land configurations.

Table 4. Economic evaluation and energetic of soybean as influenced by planting method and seed rate

Treatment	Net returns ('000 ₹/ha)	B:C ratio	Energy output: input ratio	Energy use efficiency (MJ x 10^{-3} /ha)
Sowing method				
Broad-bed planting (2 rows/bed)	17.83	2.01	29.83	3.10
Broad-bed planting (4 rows/bed)	20.33	2.52	33.52	3.50
Ridge and furrow planting	22.88	2.57	34.38	3.59
Flat planting	15.64	1.84	28.02	2.90
SEm (±)	1.94	0048	-	-
CD (P=0.05)	**5.65**	**0.14**	**-**	**-**
Seed rate (kg/ha)				
50.0	18.06	2.01	28.57	3.18
62.5	20.15	2.19	28.61	2.98
75.0	19.70	2.08	27.31	2.84
SEm (±)	1.48	0.04	-	-
CD (P=0.05)	**NS**	**NS**	**-**	**-**

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Effect of FYM, Vermicompost, Vermiwash and NPK on Growth, Microbial Biomass and Yield of Soybean

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ABSTRACT

A field experiment was conducted during kharif *2006 and 2007 to study the effect of FYM, vermicompost (VC), vermiwash (VW) and NPK nutrients on nodulation, growth, microbial biomass and yield of soybean [*Glycine max. (L.) *Merrill] var. PS- 1347 on Tarai Mollisols*. Twelve treatments consisting *50 per cent NPK, 100 per cent NPK, FYM @ 10 t per ha, VM @ 5 t per ha, foliar spray of 10 per cent VW at 30 and 45 days, and their combinations were included in the study. The treatments having FYM @ 10 t per ha, VC @ 5 t per ha and VW @ 10 per cent gave significantly more number of nodules per plant than 100 per cent NPK in 2006 and in 2007 the treatment with FYM @ 10 t per ha was significantly better than 50 per cent NPK. The nodule dry weight was significantly higher with VC @ 5 t per ha and VW @ 10 per cent than 100 per cent NPK in 2006, all the treatments showed significantly higher microbial biomass carbon than 100 per cent NPK while significant increase (23.1 %) was recorded with VC @ 5 t per ha over VW @ 10 per cent in the grain yield. The combined applications of treatments performed significantly better than their alone applications for most of the parameters. The treatment having FYM @ 5 t per ha + VC @ 2.5 t per ha + V W @ 10 per cent + 50 per cent NPK gave maximum nodule number (49 and 53 /plant), highest nodule dry weight (384 and 372 mg/ plant) and plant dry weights (30.33 and 40.33 g /plant) at 60 DAS, soil microbial biomass carbon (308 and 292 µg/ soil), grain yields (3210 and 3231 kg/ ha) and seed protein (42.6 and 38.9 %), respectively in the year 2006 and 2007.*

Key words: FYM, vermiwash, vermicompost, nodulation, soybean, microbial biomass C, yield

Soybean [*Glycine max* (L.) Merrill] is one of the most important oil seed crops of the world. It requires high amount of nutrients due to its high yield potential. The crop removes a large quantity of nitrogen, phosphorus and potash. A good crop producing 6, 720 kg per ha biomass removes about 514 kg nitrogen, 480 kg phosphorus and 485 kg potash per ha (Nelson, 1989). Its full nitrogen requirement often is not met by symbiosis only and depends upon the ability of soybean plant for nitrogen fixation with rhizobia, about 240 - 250 kg per ha (Chandel

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et al., 1989), but it also gets reduced at seed development stage when requirement of nitrogen is maximum. N, P and K fertilization of soybean during pod filling is known to increase the yield up to 27 to 31 per cent (Gracia and Hanway, 1976, Paradkar and Deshmukh, 2004). At higher rate of nitrogen, more protein has been synthesized and lipid metabolism favored which significantly improved dry matter accumulation in soybean – sorghum intercropping (Ramesh *et al.*, 2003). There still exists a wide gap between potential productivity and present level of productivity of soybean in India. Balanced plant nutrition through conjoint use of organics and chemical fertilizers may help enhance productivity (Behera *et al.*, 2007) of the crop. Therefore, there is necessity to asses the judicious combinations of organic and inorganic fertilizers for soybean. Considering the above, the present investigation was undertaken to study the effect of various organic sources of nutrients on the growth and yield of soybean.

MATERIAL AND METHODS

The field experiment was conducted at N. E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar, to study the effect of organic and inorganic sources of nutrients on soybean var. PS 1347 during rainy season (*kharif*) of 2006 and 2007. The experimental soil was well drained silty clay loam with pH 7.4, high in organic carbon (0.86%), medium in available phosphorus (19.19 kg/ ha) and low in available potassium (130.71 kg/ ha) and nitrogen (240.17 kg/ ha) contents. There were twelve treatments, *viz*. NPK 100 per cent, NPK 50 per cent, FYM @ 10 t per ha, vermicompost (VC) @ 5 t per ha, Vermiwash (VW) @ 10 per cent spray at 30 and 45 days after sowing (DAS), FYM @ 5 t per ha + VC @ 2.5 t per ha, FYM @ 5 t per ha + VW @ 10 per cent, VC 2.5 t per ha + VW @ 10 per cent, FYM @ 10 t per ha + NPK 50 per cent, VC @ 5 t per ha + NPK 50 per cent, VW 10 per cent + NPK 50 per cent, and FYM @ 5 t per ha + VC @ 2.5 t per ha + VW 10 per cent + NPK 50 per cent, which were replicated thrice in randomized block design (RBD). Basal N, P_2O_5 and K_2O (20:60:40) were applied through urea, graded doses of SSP and murate of potash. The FYM, VC and VW were obtained from the Instructional Dairy Farm of Pantnagar University. FYM, VC and VW contained 0.67 per cent, 1.55 per cent and 17.73 ppm N, 0.27 per cent, 0.42 per cent and 17.73 ppm P, and 0.98 per cent, 1.87 per cent and 55.3 ppm K, respectively. FYM and VC were applied at sowing time and two sprays of VW were done at 30 and 45 DAS. The microbial biomass C was estimated by Vance *et al.* (1987) method. For recording the observations on various growth parameters, five plants were randomly selected and uprooted from each plot. Nodules were carefully detached from the washed roots and counted, then nodules from each replication were dried in open glass petri dishes at 65 ± 2°C for 48 h in an oven till constant weight and dry weight of plants was also recorded in the same manner. After threshing and proper cleaning the grain yield of individual plot was recorded.

RESULTS AND DISCUSSION

The treatments consisting 100 per cent and 50 per cent NPK did not differ significantly in between themselves with respect to nodule number and their dry weight per plant (Table 1) in both the years. Alone applications of all the organic sources significantly increased nodule number than 100 per cent NPK in first year with numerical increases in the second year. Combined application of FYM @ 5 t per ha + VC @ 2.5 t per ha gave significantly more (36.0 and 29.4 %) number of nodules per plant, respectively than FYM @10 t per ha and VC @ 5 t per ha in the first year. Similarly, addition of FYM @ 10 t per ha along with 50 per cent NPK significantly increased nodule number than their lone applications but spray of VW @ 10 per cent either with FYM @ 5 t per ha or VC @ 2.5 t per ha did not show significant effect on the nodule number in comparison to FYM @ 10 t per ha and VC @ 5 t per ha in both the years. Combined application of VC @ 5 t per ha + 50 per cent NPK was significantly better than their lone applications in the first year and 50 per cent NPK in the second year. Maximum nodule number (49 and 53, respectively) per plant in both the years was noticed in combined application of FYM @ 10 t per ha + 50 per cent NPK.

Application of VC @ 5 t per ha and VW @ 10 per cent recorded significantly higher nodule dry weight than 50 per cent NPK, 100 per cent NPK and FYM 10 t per ha in the first year (Table 1), however, in second year the increases were not significant. All the combined treatments performed significantly better than individual treatments in first year, however, in the second year, combined treatments having FYM @ 5 t per ha + VC @ 2.5 t per ha, VC @ 2.5 t per ha + VW 10 per cent, VC @ 5 t per ha + 50 per cent NPK and VW @ 10 per cent + 50 per cent NPK recorded significantly higher nodule dry weight than 50 per cent and 100 per cent NPK alone. The highest nodule dry weights of 384 and 372 mg per plant, respectively in the first and second years were given by FYM @ 10 t per ha + 50 per cent NPK and VC @ 5 t per ha + 50 per cent NPK treatments. The findings corroborate with the findings of Mahto and Yadav (2005), who reported that application of VC (2500 kg /ha equivalence) and DAP (100 kg/ha equivalence) + foliar spray of VW (10 %) at 30 DAS increased nodule number per plant in vegetable pea by 23.6 per cent over the control.

The treatments did not differ significantly with each other for the dry weight of plant during 2006 (Table 1). However, highest plant dry weights of 30.33 and 40.33 g were given by combined application of FYM @ 5 t per ha + VC @ 2.5 t per ha + VW @ 10 per cent + 50 per cent NPK in 2006 and 2007, respectively. In 2007, lone applications of FYM @ 10 t per ha, VC @ 5 t per ha and VW @ 10 per cent were at par with 50 per cent and 100 per cent NPK. The treatments having VC @ 2.5 t per ha + VW @ 10 per cent, VW @ 10 per cent + 50 per cent NPK and FYM @ 5 t per ha + VC @ 2.5 t per ha + 50 per cent NPK were significantly better than 50 per cent and 100 per cent NPK treatments. The highest dry weight of plant obtained from the application of FYM @ 5 t per ha + VC @

Table 1. Effect of different treatments on nodule number, nodule dry weight, plant dry weight, soil microbial biomass carbon, seed yield and protein content of soybean var. PS 1347

Treatment	At 60 DAS								Seed yield (kg/ha)		Seed protein content (%)	
	Nodule (No/plant)		Nodule dry weight (mg/plant)		Dry weight (g/plant)		Microbial biomass C (µg g^{-1} soil)					
	2006	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
NPK 100 %	25.0	36.6	182.0	282.0	25.20	30.33	255.5	256.3	2716	2213	35.44	36.56
NPK 50 %	30.0	33.0	206.5	273.1	24.66	29.33	283.8	267.2	2870	2938	37.69	37.44
FYM @ 10 t/ha	33.3	41.0	200.1	330.1	27.66	33.00	289.2	274.4	2840	2868	40.00	36.63
VC @ 5 t/ha	35.0	37.0	253.8	320.5	28.00	32.33	282.9	265.7	2963	2758	37.63	38.25
VW @ 10 %	36.0	38.6	240.5	307.2	29.33	34.00	281.3	268.9	2406	2878	38.00	37.19
FYM @ 5 t/ha + VC @ 2.5 t/ha	45.3	39.0	370.5	370.5	29.33	34.00	308.1	271.5	2870	2811	39.00	38.06
FYM @ 5 t/ha + VW @ 10 %	37.3	40.6	303.5	303.5	28.16	35.33	278.1	278.2	2642	2572	36.88	38.88
VC @ 2.5t /ha + VW @ 10 %	32.0	40.6	363.8	363.8	26.00	40.33	304.0	283.3	2994	2533	36.94	37.31
FYM @ 10t / ha + NPK 50 %	49.0	53.0	384.0	324.8	29.00	36.33	305.4	273.2	2747	2815	39.44	36.69
VC @ 5t /ha + NPK 50 %	48.6	40.3	372.2	372.2	27.53	36.66	283.5	273.5	2963	2859	39.63	36.94
VW @ 10% + NPK 50 %	41.0	49.0	342.0	342.0	25.83	38.66	291.4	265.2	2685	2858	38.00	36.63
FYM @ 5t/ ha + VC @ 2.5t /ha + VW @ 10% + NPK 50 %	39.3	49.3	269.6	319.6	30.33	40.33	308.2	292.0	3210	3231	43.63	38.94
C.D. (P = 0.05)	**7.7**	**6.4**	**26.5**	**59.8**	**NS**	**7.13**	**22.9**	**NS**	**470.7**	**486.3**	**NS**	**NS**

NPK 100 % - 20:60:40::N:P_2O_5:K_2O: FYM- Farmyard manure; VM – Vermicompost; VW – Vermiwash folier spray at 30 and 45 days after sowing (DAS)

2.5 t per ha + 50 per cent NPK, might be due to the improvement in the soil structure and more availability of nutrients to the plant which has resulted in the synthesis of more plant tissues. Khutate *et al.* (2005) also observed that application of 75 per cent NPK + 25 per cent VC (576 kg/ha) or FYM (50 %) recorded highest shoot dry weight per plant over the control.

All the treatments showed significantly higher soil microbial biomass carbon than 100 per cent NPK in the first year (Table 1), however, in second year the increases were not significant. Combined application of FYM @ 5 t per ha + VC @ 2.5 t per ha showed significantly higher (8.9 %) microbial biomass C than VC @ 5 t per ha in the first year. Similarly, the treatment having FYM @ 5 t per ha + VC @ 2.5 t per ha + VW @ 10 per cent + 50 per cent NPK showed significant increases in soil microbial biomass C than alone applications of 50 per cent NPK, 100 per cent NPK, VC @ 5 t per ha and VW @ 10 per cent in 2006, and recorded highest microbial biomass carbon (Table 1) in both the years (2006 and 2007). It might be due to the improvement in the soil physical properties like soil structure, aeration, porosity and more availability of nutrients to the plant with addition of FYM, VC, VW and NPK which favorably affected on the growth of soil microorganisms. Manna *et al.* (2001) and Ghosh *et al.* (2002) have also reported that application of enriched compost significantly increased soil microbial biomass C which might be due to positive effect of FYM and vermicompost on soil microbial number and activity. The results also corroborate with those of Wang Yan *et al.* (1998) who reported that soil microbial biomass increased greatly after application of organic manures.

The seed yield was not affected significantly with 50 per cent and 100 per cent NPK treatments in first year however, in second year, 50 per cent NPK showed significant increase (725 kg/ha) in grain yield over 100 per cent NPK treatment. This increase in seed yield remains un-explainable. The treatment having VC @ 5 t per ha gave significant increase (23.1 %) in seed yield over VW @ 10 per cent (Table 1). Application of VC @ 2.5 t per ha + VW @ 10 per cent recorded significantly higher seed yield (24.4 %) than VW @ 10 per cent alone. Highest seed yields of 3, 209.8 and 3, 230.8 kg per ha, respectively in the first and second years were obtained by combined application of FYM @ 5 t per ha + VC @ 2.5 t per ha + VW @ 10 per cent + 50 per cent NPK. This was significantly higher than treatments namely 100 per cent NPK, VW @ 10 per cent, FYM @ 5 t per ha + VW @ 10 per cent and VW @ 10 per cent + 50 per cent NPK in 2006. In the second year, this treatment was significantly better than 100 per cent NPK, FYM @ 5 t per ha + VW @ 10 per cent and VC @ 2.5 t per ha + VW @ 10 per cent. This might be due to the cumulative effect of organic and inorganic on physical and biological properties of soil and more supply of plant nutrients which resulted in higher seed yield. These findings are in line with those reported by Behera (2006) and Behera *et al.* (2007), who reported significant increase in the yield of *durum* wheat with integrated use of organic sources and 50 per cent or 100 per cent recommended NPK over the sole application inorganics, indicating that NPK fertilizers alone did not provide adequate and balanced nutrition to realize the potential yield of the crop.

The applied treatments did not have significant effect on the seed protein in both the years which ranged from 35.44 to 43.63 per cent (Table 1). The combined application of FYM @ 5 t per ha + VC @ 2.5 t per ha + VW @ 10 per cent + 50 per cent NPK in both the years showed highest grain protein of 42.63 and 38.94 per cent, respectively. This was possibly due to translocation of more nitrogen in seed during seed formation which was converted into protein.

It can be concluded that the productivity of soybean can be enhanced with the integrated use of organic and inorganic nutrient sources.

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Optimization of Sulphur Levels for Soybean Production under Different Agro-climatic Regions of India

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ABSTRACT

A multilocation trial was conducted in diverse agro-climatic zones of India to optimize the sulphur requirement of soybean crop. The substantial soybean yield improvement was observed due to sulphur application at all the centres except Raipur, Pune and Lam. The region-wise pooled results revealed that the highest soybean yield was recorded with 20 kg S per ha in north plain (1, 644 kg/ha), 35 kg S per ha in north eastern (1, 873 kg/ha) and 30 kg S per ha in central (2 064 kg/ha) and southern zone (2, 500 kg/ha). The highest sustainability yield index was associated with 35 and 40 kg S per ha in north plain and north eastern zones while it was maximum with 30 kg S per ha in central and southern zones. The agronomic efficiency indicated that as the levels of sulphur increased, the efficiency decreased in all the zones except north plain zone where there was no definite trend. The relationship between soybean yield and sulphur levels was found to be curvilinear. The economic optimum level of sulphur was worked out for soybean to be 24.39, 51.27, 33.83 and 32.28 kg S per ha for north plain, north eastern, central and southern zones, respectively.

Keywords: Agronomic efficiency, sulphur, sustainable yield index

The poor productivity of soybean may be on account of imbalanced nutrient management and being a rainfed crop in India. Soybean is a sulphur loving plant like other oilseeds and leguminous crops and its sulphur requirement is much more than any other crops for better growth and development. Hence, the optimal use of this element is essentially required to bridge the vast gap between present level of national productivity (above 1.2 t/ha) and potential productivity (>2.5 t/ha) of soybean. Sulphur represents the ninth and least abundant essential secondary nutrient in plants, preceded by C, O, H, N, K, Ca, Mg and P. The dry matter of sulphur in plants is only about one-fifteen of that of nitrogen. S is best known for its role in the formation of amino acids methionine (21 % S) and cysteine (27 % S); synthesis of proteins and chlorophyll; oil content of the seeds and nutritive quality of forages (Tandon, 1986; Jamal *et al.*, 2005, 2006, 2009).

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Now areas of sulphur deficiency are becoming widespread throughout the world (Irwin *et al.*, 2002; Scherer, 2001). Sulphur is one of the limiting plant nutrients threatening the sustainability of crop production in semi-arid tropical regions of India. Sulphur as a fertilizer or as a constituent of other fertilizers is generally not applied by Indian farmers. As a result, large areas of S deficiency are reported from different agro- ecological region of India (Ganeshmurthy and Saha, 1999). Therefore, the present investigation was initiated to optimize the sulphur level for soybean in different agro-climatic zones as defined by All India Coordinated Project for Soyeban in India.

MATERIALS AND METHODS

A field experiment was conducted at different locations situated under four diverse agro-climatic regions of India viz., north plain zone (Pantnagar, Ludhiana and Delhi); north eastern zone (Raipur, Ranchi and Biswanathchariali); central zone (Indore, Sehore, Kota, Parbhani, and Amravati); and southern zone (Dharwad, Pune, Lam, and Coimbatore) during *kharif* 2005 under rainfed conditions. Nine treatments of sulphur levels (0, 5, 10, 15, 20, 25, 30, 35 and 40 kg S/ha) were arranged in three randomized blocks. Nitrogen, phosphorus, potassium and sulphur were applied through di-ammonium phosphate, muriate of potash and gypsum, respectively as per treatment. All the treatments had uniform component of recommended nitrogen (20 kg/ha), phosphorus (60 kg P_2O_5/ha) and potassium (20 kg K_2O/ha). Soybean was sown on onset of the monsoon and harvested in the month of October.

The relationship between soybean yield and levels of sulphur was worked out zone-wise using the quadratic equation $Y=a + bx - cx^2$. The yield data pooled over the centres and zone-wise agronomic efficiency of sulphur, additional returns and incremental cost benefit ratio (IBCR) were worked out by using the standard procedures. The sustainable yield index (SYI) and stability of the treatments were determined by using the centre-wise data of the respective zone. The sustainable yield index was also computed (Singh *et al.*, 1990). For the computing of economics of the treatments, the prevailing market price of inputs was considered.

RESULTS AND DISCUSSION

North plain zone

The application of sulphur to soybean crop brought an appreciable improvement in soybean yield at all the three centres of North plain zone (Table 1). The highest soybean yield was observed at Pantnagar followed by Delhi and Ludhiana centre. The highest soybean yield was observed with 20 kg S per ha at Pantnagar and Ludhiana centres where as it was maximum with 35 kg S per ha at Delhi centre. On the basis of zonal mean, the soybean yield increased to the tune of 1.89 to 15.61per cent due to sulphur application. The maximum soybean yield as well as agronomic efficiency were recorded when 20 kg S per ha was applied while the highest sustainable yield index was associated with 35 kg S per ha. The higher yield in control over 20 kg S per ha at Pantnagar and lower yield at 15 kg S per ha than 10 and 20 kg S per ha at Ludhiana is difficult to explain. The relationship between soybean yield and sulphur levels was found to be quadratic in nature at Pantnagar ($Y= 2067.06 + 1.728x - 0.154x^2$) and Ludhiana ($Y= 1109.62 + 3.897x - 0.0179x^2$) as well as in pooled data ($Y= 1418.20 + 4.678x - 0.0831x^2$) while it was linear relationship at Delhi Centre ($Y= 1087.39 + 5.97x + 0.0062x^2$). The physical and economic optimum level of sulphur was found to be 5.61 and 3.58 kg S per ha with corresponding yield of 2, 070 and 2, 071 kg per ha at Pantnagar; 108.30 and 90.84 kg S per ha with the yield of 1, 320 and 1, 314 kg per ha at Ludhiana and 28.15 and 24.39 kg S per ha with the yield of 1, 484 and 1, 483 kg per ha on zonal basis. The maximum additional yield and returns were recorded with 35 kg S per ha while the highest IBCR was with 20 kg S per ha (Table 2).

North eastern zone

Soybean yield was significantly influenced by the applied sulphur only at Ranchi, and Biswanathchariali centres and on the zonal basis (Table 1). The marginally higher yield was associated with 35 kg S per ha at Raipur and significantly higher yield was noted with 40 kg S per ha which remained at par up to 20 and 15 kg S per ha at Biswanathchariali and Ranchi Centre. On the basis of pooled data, the maximum soybean yield was recorded due to 35 kg S per ha which was statistically at par with 25, 30 and 40 kg S per ha. The mean values across the zone indicated that the soybean yield enhanced to the extent of 6.37 to 24.45 per cent in north eastern zone. The highest agronomic efficiency was noted with 25 kg S per ha while, the maximum SYI was with 40 kg S per ha.

The relationship between soybean yield and sulphur level was found to be curvilinear at all the centres. The equation were $Y= 2353.63 + 2.168x - 0.003x^2$ for Raipur, $Y= 1121.86 + 1.62x - 0.031x^2$ for Ranchi, $Y= 1077.14 + 23.80x - 0.36x^2$) for Biswanathchariali Centre and $Y= 1517.63 + 14.06x - 0.131x^2$ for the zone.

The physical and economic optimum level of sulphur for soybean was found to be 37.38 and 26.60 kg S per ha with the yield of 2, 394 and 2, 391 kg per ha for Raipur, 26.45 and 16.04 kg S per ha with the yield of 1, 143 and 1, 140 kg per ha for Ranchi, 33.05 and 32.19 kg S per ha with yield of 1, 471 and 1, 470 kg per ha for Biswanathchariali centres and 53.66 and 51.27 kg S per ha with yield of 1, 895 and 1, 894 kg per ha for the zone. The maximum additional yield and returns were associated with 35 kg S per ha and the maximum IBCR was with 25 kg S per ha (Table 2).

Central zone

The maximum soybean yield was recorded with 15 kg S per ha at Indore, 40 kg S per ha at Sehore and Kota, 30 kg S per ha at Amravati and in zone as a whole (Table 3). The magnitude of yield enhancement was to the tune of 7.14 to 25.94 per cent as compared to control. The maximum SYI was associated with 30 kg S per ha while the highest agronomic efficiency was with 25 kg S per ha.

The relationship between soybean yield and sulphur levels was quadratic in nature at all the Centres except at Kota

Table 1. Response of sulphur to soybean in north plain and north eastern zone of India

Sulphur level (kg/ha)	North plain zone						North eastern zone					
	Pantnagar	**Ludhiana**	**Delhi**	**Mean**	**SYI**	**AE**	**Raipur**	**B. char-iali**	**Ranchi**	**Mean**	**SYI**	**AE**
0	2180	1019	1068	1422	0.38	-	2339	1158	1018	1505	0.37	-
5	1973	1222	1152	1449	0.46	5.40	2319	1214	1270	1601	0.44	19.20
10	1957	1290	1157	1468	0.48	4.60	2499	1223	1289	1670	0.43	16.50
15	1957	951	1170	1359	0.40	-	2369	1292	1346	1669	0.47	10.93
20	2338	1426	1168	1644	0.49	11.10	2372	1432	1383	1729	0.51	11.20
25	1960	883	1230	1358	0.39	-	2361	1592	1452	1802	0.56	11.88
30	1960	1222	1312	1498	0.50	2.53	2388	1601	1454	1814	0.56	10.30
35	1916	1426	1320	1554	0.55	3.77	2497	1666	1455	1873	0.57	10.51
40	1888	1087	1316	1430	0.47	0.20	2417	1677	1474	1856	0.58	8.78
CD (P=0.05)	**160**	**285**	**137**	**118**			**NS**	**250**	**194**	**138**		

Table 2. Effect of sulphur on soybean additional yield and economic returns*

Sulphur level (kg/ha)	**North plain zone**				**North eastern zone**			
	Additional yield (kg/ha)	**Additional returns (₹/ha)**	**Additional cost (₹/ha)**	**IBCR**	**Additional yield (kg/ha)**	**Additional returns (₹/ha)**	**Additional cost (₹/ha)**	**IBCR**
0	-	-	-	-	-	-	-	-
5	7	84	38	2.21	96	1152	38	30.32
10	26	312	76	4.10	165	1980	76	26.05
15	-	-	114	-	164	1968	114	17.26
20	202	2424	152	15.94	224	2688	152	17.68
25	-	-	190	-	297	3564	190	18.75
30	56	672	228	2.95	309	3708	228	16.26
35	112	1344	266	5.05	368	4416	266	16.60
40	-	-	304	-	351	4212	304	13.86

**Prevailing market price: soybean @ ` 20/kg; sulphur @ ` 23/kg (gypsum @ ` 3/kg)* where it was linear (Y= 1782.52 + 12.67x + 0.008x^2). The relationship arrived at Y= 1255.23 + 18.55x – 0.501x^2 at Indore, (Y= 2129.66 + 17.75x – 0.187x^2 at Sehore, Y= 1941.53 + 24.57x – 0.297x^2) at Parbhani, (Y= 998.05 + 38.96x – 0.639x^2 at Amaravati centres and Y= 1633.89 + 22.48x – 0.323x^2 for the zone. The physical and economic optimum level of sulphur for soybean was worked out to be 18.51 and 17.89 kg S per ha with yield of 1, 427 and 1, 427 kg per ha for Indore, 47.46 and 45.77 kg S per ha with yield of 2, 551 and 2, 550 kg per ha for Sehore, 41.36 and 40.31 kg S per ha with yield of 2, 450 and 2, 449 kg per ha for Parbhani, 30.49 and 29.99 kg S per ha with yield of 1, 592 and 1, 592 kg per ha for Amravati and 34.80 and 33.83 kg S per ha with the corresponding yield of 2, 025 and 2, 024 kg per ha for the central zone. The maximum additional yield and returns were observed due to 30 kg S per ha while the highest IBCR was with 25 kg S per ha (Table 4).

Southern zone

Soybean yield was substantially improved by the sulphur application at Dharwad, Bangalore and Coimbatore centres while there was non-significant increase at Pune and Lam centres (Table 3). The highest soybean yield was recorded with 30 kg S per ha at Dharwad, 40 kg S per ha at Bangalore and Coimbatore. However, the marginally higher yield was recorded due to 35 and 30 kg S per ha at Pune and Lam, respectively. Over all yield improvement was in the range of 6.36 to 12.10 per cent due to sulphur in southern zone. On the basis of pooled data, the significantly highest yield was associated with 30 kg S per ha as compared to control. The maximum SYI and agronomic efficiency was associated with 30-35 kg S per ha and 5 kg S per ha, respectively.

There existed quadratic relationship between soybean yield and sulphur levels was found to be quadratic in nature at Pune (Y= 3516.24 + 14.05x – 0.229x^2), Lam (Y= 2680.71 + 13.46x – 0.381x^2), Bangalore (Y= 1791.25 + 12.10x – 0.159x^2) and Dharwad (Y= 2395.86 + 20.99x – 0.174x^2) as well as in pooled data (Y= 2252.97 + 12.70x – 0.187x^2) while it was linear in nature at Coimbatore centre (Y= 880.58 + 2.547x + 0.010x^2). The physical and economic optimum level of sulphur was found to be 30.67 and 29.31 kg S per ha with corresponding yield levels of 3, 732 and 3, 731 kg per ha at Pune; 17.66 and 16.84 kg S per ha with the yield of 2, 800 and 2, 799 kg per ha at Lam, 38.05 and 36.08 kg S per ha with yield of 2, 021 and 2, 021 kg per ha at Bangalore, 60.31 and 58.52 kg S per ha with yield of 3, 029 and 3, 028 kg per ha at Dharwad and 33.95 and 32.28 kg S per ha with the yield of 2, 469 and 2, 468 kg per ha on zonal basis. The highest additional yield and returns were recorded with 30 kg S per ha and the maximum IBCR was with 25 kg S per ha (Table 4).

The synergistic effect of S may be attributed due to utilization of high quantities of nutrients through their well developed root system and nodules and thereby resulting in better growth and yield. Similar results have been reported earlier by Sharma and Gupta (1992); Vyas *et al.* (2006). Nasreen and Farid (2006) also concluded that the economic optimum level of sulphur varied from 49 to 52 kg S per ha which

Table3. Response of sulphur to soybean in central and southern zone of India

Sulphur level (kg/ha)	Central zone								Southern zone							
	Indore	Sehore	Par-bhani	Kota	Amra-vati	Mean	SYI	AE	Dhar-wad	Pune	Bang-alore	Lam	Coimb-atore	Mean	SYI	AE
0	1227	2222	1935	1727	1083	1639	0.47	-	2469	3530	1713	2560	878	2230	0.35	-
5	1343	2245	2085	1928	1181	1756	0.52	23.40	2428	3625	1956	2950	900	2372	0.38	28.40
10	1394	2334	2153	1931	1212	1805	0.53	16.60	2569	3527	1922	2772	908	2340	0.38	11.00
15	1505	2402	2195	1966	1363	1886	0.57	16.47	2627	3729	1928	2734	916	2387	0.38	10.47
20	1407	2492	2318	1976	1406	1920	0.57	14.05	2715	3665	1910	2767	933	2398	0.39	8.40
25	1366	2536	2414	2087	1714	2023	0.61	15.36	2895	3715	1985	2700	943	2448	0.40	8.72
30	1338	2559	2398	2192	1835	2064	0.63	14.17	2933	3760	2023	2806	977	2500	0.41	9.00
35	1267	2581	2439	2274	1476	2007	0.57	10.51	2899	3818	2024	2745	988	2495	0.41	7.57
40	1236	2593	2443	2279	1469	2004	0.56	9.13	2920	3640	2028	2571	992	2430	0.40	5.00
CD (P=0.05)	**286**	**191**	**172**	**113**	**176**	**88**			**318**	**NS**	**169**	**NS**	**87**	**155**		

Table 4. Effect of sulphur on soybean additional yield and economic returns

Sulphur level (kg/ha)	Central zone				Southern zone			
	Additional yield (kg/ha)	Additional returns (₹/ha)	Additional cost (₹/ha)	IBC R	Additional yield (kg/ha)	Additional returns (₹/ha)	Additional cost (₹/ha)	IBC R
0	-	-	-	-	-	-	-	-
5	117	1404	38	36.85	142	1704	38	44.84
10	166	1992	76	26.21	110	1320	76	17.37
15	247	2964	114	29.58	157	1884	114	16.53
20	281	3372	152	22.18	168	2016	152	13.26
25	384	4608	190	24.25	218	2616	190	13.77
30	425	5100	228	22.37	270	3240	228	14.21
35	368	4416	266	16.60	265	3180	266	11.95
40	365	4380	304	14.40	200	2400	304	7.89

depended on soybean genotypes and sulphur utilization was higher with lower doses of sulphur. Similar results were also reported by Joshi and Billore (1998).

On the basis of above results, it could be concluded that the application of sulphur become inevitable for realizing sustainable soybean production. The economic optimum dose of sulphur was assessed to be 24.39, 51.27, 33.83 and 32.28 kg S per ha for north plain, north eastern, central and southern zone of India, respectively.

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Evaluation of Weed Control Efficiencies of Herbicides and their Mixture under Various Fertility Levels in Soybean

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ABSTRACT

The field experiment was conducted at Agricultural Research Station, Kota to evaluate the weed control efficiencies of different herbicides and their mixtures along with different fertility levels during 2002-2003. The herbicides quizalofop ethyl (50 g/ ha) and fenoxaprop-p-ethyl (70 g/ ha) were effective against graminiceous weeds whereas chlorimuron ethyl (9 g /ha) reduced the density and biomass of broad leaved weeds effectively. Tank mixtures of chlorimuron ethyl + fenoxaprop-p-ethyl (9 g +70 g and 6 g +50 g/ha) as post-emergence gave very effective control of both the categories of weeds and also resulted in highest seed yield (2, 252 kg/ha) of soybean which was on par with alachlor 2 kg per ha + one hand weeding at 30 days after sowing (2, 207 kg/ha) and proved significantly superior to sole application of these herbicides and weedy check. The highest net returns (Rs.22, 885/ha) and benefit in terms of rupees per rupee invested (₹ 2.71/ rupee) were associated with post-emergence application of tank mixture of chlorimuron ethyl (6 g/ha) + fenoxaprop-p-ethyl at (50 g/ha). The yield attributing characters viz. pod/plant, 100 seed weight and seed yield (1, 837 kg/ha) showed an improvement at the fertility level of 125 per cent (N+P_2O_5+K_2O ::25:50:50 kg/ha) recommended dose (1, 793 kg/ha) of fertilizers but was on par with the 100 per cent recommended dose of fertilizers (N+P_2O_5+K_2O::20:40:40 kg/ha).The recommended dose of fertilizers (N+P_2O_5+K_2O::20:40:40 kg/ha) was economically better than the rest of the fertility levels.

Key words : Fertility levels, herbicides mixture, soybean, weed control efficiency

Stress created by severe weed competition is one of the major constraints for low productivity of soybean in India. A reduction in seed yield of soybean to an extent of 25-77 per cent was reported (Kurchania *et al*., 2001). The production potential of soybean cannot be realized fully if weeds are not managed timely and the crop is not fertilized adequately. Most of the post-emergence herbicides have selectivity to control either graminiceous or broad-leaved weeds. The tank- mix application of different herbicides having different mode of action may limit a broad

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spectrum of weeds in a single application depending on their extent of compatibility. Weeds exploits the habitat more efficiently particularly nutrients and reduce their availability to the crop. Hence, an experiment was taken up to test the bio-efficacy of herbicide mixtures under different fertility management and their effect on the productivity of soybean.

MATERIAL AND METHODS

A field experiment was conducted during *kharif* 2002 and 2003 at Agricultural Research Station, Kota. The soil was clay loam (typic chromustert, Vertisols) in texture having pH 7.7, organic carbon 0.56 per cent, available N, P_2O_5, K_2O : 367, 23.5, 310 kg per ha, respectively. The experiment was conducted in split plot design comprising of twelve weed management treatments in main plots viz. two hand weeding at 30 and 45 days after sowing (DAS), alachlor @ 2.0 kg a.i. per ha as pre-emergence (PE), alachlor @ 2.0 kg per ha (PE) + one hand weeding (HW) at 30 DAS, one hand weeding at 30 DAS, chlorimuron ethyl as post –emergence (POE) @ 9 g a.i. per ha, fenoxaprop-p-ethyl @ 70 g per ha(POE), quizalofop ethyl @ 50 g per ha (POE), two levels (9 g + 70 g and 6g + 50 g a.i./ha) of chlorimuron ethyl + fenoxaprop-p-ethyl (POE), two levels (9 g + 50 g and 6 g + 37.5 g a.i./ha) of chlorimuron ethyl + quizalofop ethyl (POE) at 10-25 days after sowing. The herbicides were sprayed by hand sprayer fitted with flat fan nozzle using 600 liters of water per hectare. Three fertility levels namely 75 per cent, 100 per cent and 125 per cent of recommended dose of fertilizers (RDF-20:40:40::N:P_2O_5:K_2O/ha) were taken in sub-plots. Soybean cv. "Pratap Soya 1" was sown on 21 July, 2002 and 7 July, 2003 and harvested on 20 October 2002 and 12 October 2003, respectively. The total rainfall received during the soybean crop season of the year 2002 was 344.6 mm while 378.7 mm was received during 2003. The plot size was 5 m x 4.5 m. The observations on weed density and weed dry matter were recorded using quadrate at 50 days. The height and dry matter of five randomly tagged plants from each plot was measured from the ground to the tip of the main shoot at 50 DAS and average was calculated. Yield attributes viz., pods per plant and 100 seed weight and yield was recorded at the time of harvesting. The leaves of five randomly selected plants at 60 DAS were detached after plant removal from the plot and categorized as small, medium, large and extra large and counted. The representative leaf of each category was directly fed to the leaf area meter to workout the total leaf area of five plants used for calculating leaf area index (LAI) by the formula given by Watson (1947).

$$Leaf\ area\ index\ (LAI) = \frac{Leaf\ area\ per\ plant\ (cm^2)}{Ground\ area\ occupied\ by\ each\ plant\ (cm^2)}$$

RESULTS AND DISCUSSION

Weed flora

The pre-dominant grassy weeds uncounted in soybean at 50 DAS were *Echinochloa colonum* (L.) Link,. *crusgalli, Cyperus rotundus* (L.), *Cynodon dactylon* (L.) Pears and *Dinebra arabica* Jacq among the grassy weeds (53.1 %). Among broad leaved weeds (56.6 %) *Celosia argentea* (L.), *Digera arvensis* Forsk, *Commelina*

Table 1. Effect of weed control and fertility levels on weed density and weed control efficiency in soybean at 50 DAS (Pooled of 2002 and 2003)

Treatment	Weed density (No/ m²)		Weed dry matter (kg/ha)		Weed control efficiency (%)
	Monocots	Dicots	Monocots	Dicots	
Weed control					
Weedy check	11.36* (128.52)	10.66* (113.33)	612.58	799.23	-
One Hand weeding 30 DAS	9.32 (86.46)	8.31 (68.88)	155.91	332.23	65.60
Two Hand weedings 30 & 45 DAS	0.71 (0.00)	0.71 (0.00)	0	0	99.99
Alachlor 2 kg/ha (PE)	7.10 (50.21)	9.83 (96.14)	243.28	785.54	27.16
Alachlor 2 kg/ha (PE) + one hand weeding 30 DAS	3.18 (9.62)	5.48 (29.98)	52.39	56.17	92.33
Chlorimuron ethyl 9 g / ha (POE)	10.50 (109.69)	5.78 (33.12)	371.67	51.36	70.02
Fenoxaprop-p-ethyl 70 g / ha (POE)	6.27 (38.82)	10.58 (111.79)	154.08	770.47	34.68
Quizalofop ethyl 50 g / ha (POE)	6.02 (35.97)	10.41 (107.97)	150.85	767.00	35.12
Chlorimuron ethyl + Fenoxaprop-p-ethyl 9+70 g / ha (POE)	4.21 (17.31)	2.61 (6.41)	63.85	22.03	93.96
Chlorimuron ethyl + Fenoxaprop-p-ethyl 6+50 g / ha (POE)	4.45 (19.37)	3.17 (9.82)	69.25	27.09	93.24
Chlorimuron ethyl + Quizalofop ethyl 9+50 g / ha (POE)	4.85 (22.99)	5.50 (29.85)	80.88	64.30	89.76
Chlorimuron ethyl + Quizalofop ethyl 6+37.5 g / ha (POE)	5.01 (24.58)	6.07 (36.42)	88.45	74.54	88.49
CD (P=0.05)	0.35	0.30	11.21	20.34	-
Fertility levels (% of recommended level)					
75	6.04 (35.98)	6.16 (37.51)	159.33	296.61	67.76
100	6.08 (36.48)	6.18 (37.88)	173.56	316.34	65.35
125	6.13 (37.09)	6.25 (38.62)	177.91	324.53	64.47
CD (P=0.05)	**NS**	**NS**	**5.31**	**8.17**	**-**

* *Values are* $\sqrt{x+0.5}$ *transformed and actual values are in parentheses*

Table 2. Effect of weed control and fertility levels on growth, yield attributes and seed yield of soybean (Pooled of 2002 and 2003)

Treatment	Plant height(cm) 50 DAS	Crop biomass (g/ plant) 50 DAS	Leaf area index (LAI)	Pods/ plant (No)	100 seed weight (g)	Seed yield (kg/ ha)	Net returns (₹./ ha)	Returns per Rupee invested
Weed control								
Weedy check	63.2	5.80	1.83	21.50	8.98	854	5368	0.78
One Hand weeding 30 DAS	55.2	10.80	2.66	40.84	10.81	1438	11011	1.15
Two Hand weedings 30 & 45 DAS	59.7	13.18	3.21	63.31	13.14	2314	21653	1.89
Alachlor 2 kg/ha (PE)	55.6	8.10	2.52	38.03	10.43	1278	10038	1.24
Alachlor 2 kg/ha (PE) + one hand weeding 30 DAS	58.4	10.04	3.16	61.81	13.07	2207	21398	2.18
Chlorimuron ethyl 9 g / ha (POE)	52.1	10.88	3.02	52.03	11.28	1598	14689	1.82
Fenoxaprop-p-ethyl 70 g / ha (POE)	56.6	9.43	2.65	46.97	11.10	1408	12006	1.49
Quizalofop ethyl 50 g / ha (POE)	56.6	9.26	2.79	49.64	11.12	1490	12873	1.52
Chlorimuron ethyl + Fenoxaprop-p-ethyl 9+70 g / ha (POE)	58.0	12.79	3.10	60.36	12.90	2252	22734	2.53
Chlorimuron ethyl + Fenoxaprop-p-ethyl 6+50 g / ha (POE)	59.1	12.35	3.07	58.89	12.82	2221	22885	2.71
Chlorimuron ethyl + Quizalofop ethyl 9+50 g / ha (POE)	54.8	11.51	3.06	52.45	12.71	1882	17311	1.84
Chlorimuron ethyl + Quizalofop ethyl 6+37.5 g / ha (POE)	53.1	10.37	1.83	50.25	12.58	1854	17545	2.00
CD (P=0.05)	**3.83**	**0.75**	**0.217**	**3.84**	**0.43**	**1.31**	**1665**	**0.19**
Fertility levels (% of recommended level)								
75	54.2	8.79	2.70	45.23	11.52	1569	13860	1.60
100	57.1	11.04	2.89	50.75	11.83	1793	16584	1.85
125	59.3	11.28	2.93	53.04	11.89	1837	16933	1.83
CD (P=0.05)	**1.65**	**0.35**	**0.04**	**1.76**	**0.18**	**0.56**	**705**	**0.08**

benghalensis L., *Trianthema portulacastrum* L *dominated*. Although, grassy weeds dominated during the initial growth phase of soybean, the crop growth was suppressed most on account of shift over to excessive growth of broad leaved weeds during the later phase.

Weed biomass and weed control efficiency

All the herbicidal treatments significantly reduced the weed dry biomass. Lowest weed dry biomass and highest weed control efficiency at 50 DAS was recorded with two hand weedings. Among the herbicides, tank mixture of chlorimuron ethyl + fenoxaprop-p-ethyl (9g + 70 g a.i. /ha) recorded highest weed control efficiency (93.96 %) being at par with chlorimuron ethyl + fenoxaprop-p-ethyl @ 6 g + 50 g a.i. per ha (93.24 %). The different fertility levels could not influence weed density but marginal increase in dry matter of weeds was observed with increasing fertility level at 50 DAS of crop growth (Table 1).

Effect on crop

Growth attributes: The differences in plant height under weedy check (63.2 cm) had significantly taller plants than rest of the treatments at 50 DAS. Greater accumulation of dry matter by crop plants under various weed control treatments was the direct effect of lower weed competition as compared to weedy check. Leaf area index (LAI) was significantly increased by weed control treatments compared to weedy check.Better crop growth was registered in two hand weedings followed by alachlor + one hand weeding and chlorimuron ethyl + fenoxaprop-p-ethyl mixture. The sole application of post-emergence herbicides registered less crop dry biomass and leaf area index compared to their mixtures but were superior to alachlor @ 2.0 kg a.i. per ha, one hand weeding and weedy check (Table 2).

Different fertility levels significantly influenced the crop growth as evidenced from higher crop dry biomass and leaf area index. Application of 125 per cent RDF recorded the highest values of crop biomass (10.7 g/plant) and leaf area index (11.9) at 60 days being at par with 100 per cent RDF (10.3 g/plant and 11.8),respectively and both were significantly higher than 75 per cent RDF.

Yield attributes and yield: Application of tank mixture of chemicals produced more number of pods per plant (50-60) and higher 100 seed weight (12.58-12.90 g) obviously due to favorable environment as a result of effective management of both mono- and di-cot weeds. Herbicidal treatments have better effect on yield attributes and yield over weedy check (Table 2). Among the herbicides, application of chlorimuron ethyl + fenoxaprop-p-ethyl (9 g + 70 g a.i./ha) posses highest pooled yield (2, 252 kg/ha) which was on par with chlorimuron ethyl + fenoxaprop-p-ethyl (6g + 50 g a.i. /ha) (2221 kg/ha), alachlor @ 2 kg a.i. per ha + one hand weeding (2, 207 kg/ha). Application of post-emergence herbicides (1, 408-1, 598 kg/ha) individually were also better than alachlor (1, 278 kg/ha), one hand weeding (1, 438kg/ha) and weedy check (854 kg/ha) in terms of yield. These results are in close conformity with Tiwari and Mathew (2002). The yield of soybean was significantly influenced by different fertility levels. Application of 125 per cent RDF gave the highest (pooled) yield (1, 837 kg/ha) being at par with 100 per cent RDF (1, 793 kg/ha) but both were significantly higher than 75 per cent RDF (Table 2). Joshi *et al*. (1998) and Vyas *et al*. (2004) also reported similar findings. The highest monetary returns (Rs.22, 885/ha) were obtained with the application of chlorimuron ethyl + fenoxaprop-p-ethyl (6 g + 50 g a.i./ha) where as 100 per cent recommended dose of fertilizers was found most economical by giving Rs.1.85 per rupee invested, among the fertility levels (Table 2).

On the basis of pooled results of two years, it may be concluded that broad and narrow leaved weeds were effectively controlled and higher soybean yield and monetary returns could be obtained by post-emergence application of chlorimuron ethyl + fenoxaprop-p-ethyl (6 g + 50 g a.i. /ha) mixture, whereas 100 per cent recommended dose of fertilizers was found most economical among different fertility levels.

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Performance of Promising Genotypes of Soybean [*Glycine max* (L.) Merrill] for Quality in Punjab

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ABSTRACT

Four genotypes of soybean namely SL 744, SL 752, SL 768 and SL 790 along with one check that is SL 525 were evaluated for their physico-chemical and cooking characteristics grown at two locations viz., Ludhiana and Abohar in the years 2006 and 2007. No kokroos were found in any genotype at any locations in both the years. Cooking time was found lowest for grains at Abohar. Average protein content of all the genotypes was highest at Ludhiana followed by Abohar. Similarly, oil content was high at Abohar. Protein content was also found highest in SL 768 at Abohar and Ludhiana in both the years. No genotype registered higher oil content than check (SL 525) at Abohar in both years; however, SL 744 exhibited higher oil content than SL 525 at Ludhiana in both the years. Water absorption after cooking (%) was found maximum in SL 744 at Abohar and in SL 790 at Ludhiana. Volume expansion after cooking (%) was highest in SL 790 at Ludhiana and Abohar. Water absorption after cooking (%) was recorded highest at Abohar in year 2006. The genotype SL 744, SL 768 and SL 790 were found to be most promising with respect to different quality parameters studied.

Key words: Cooking quality, correlation, location, oil, protein, soybean, year

Today soybean occupies a vital place in agriculture and oil economy of India. It has emerged as number one oilseed crop. Soybean is generally processed for its oil (20 %), quality protein (40 %) and lecithin (0.4 %) and other nutrients. Soybean seeds vary in color, shape, size and composition. These attributes are important in determining the acceptance and end use. Soybean proteins are of high nutritive value containing the highest content of amino acid lysine of all legumes. Grain quality is an important parameter for marketing and processing and can affect the commodity value. Alencar *et al.* (2006) reported the factors for deteriorating the quality of grain as physical, chemical and biological. Based on this, the objective of this study was to evaluate genotypic and environmental effects on the physico-chemical and cooking quality of different

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genotypes of soybean and also the relationship among quality traits.

MATERIAL AND METHODS

Four genotypes of soybean namely SL 744, SL 752, SL 768 and SL 790 along with check SL 525 from Ludhiana and Abohar were evaluated for physico-chemical and cooking quality attributes in 2006 and 2007. The field experiments were conducted in a randomized block design in the experimental area of Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana and Regional Research Station, Abohar during 2006 and 2007. Each genotype was grown in six rows of five-meter length with row-to-row spacing of 45 cm with three replications in each environment. All recommended package of practices (3-4 irrigations and manure/fertilizer application @ 10 tonnes FYM; 70 kg urea and 500 kg super phosphate per hectare) were followed to raise the crop in loamy soil at both the location. Pooled sample of grains of each genotype from both the environments were analyzed for different quality characters in the Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana. The grain samples were cleaned and kept in plastic jars at room temperature for further analysis. Protein and oil content were estimated by non-destructive method on whole grain analyser NIT 1241. Soaking in distilled water was done for 24 hours to estimate the soaking quality parameters and the cooking quality was determined by following the method of Sharma *et al* (2004). Correlations among various traits were worked out.

RESULTS AND DISCUSSIONS

Variation in physico-chemical characters

All the genotypes recorded higher 100 grain weight at Abohar (average 13.18 g) as compared to that at Ludhiana (11.37 g) (Table 1). On the contrary, 100 grain volume was higher (14.60 ml) at Ludhiana than Abohar (13.68 ml). No genotype at Abohar had higher volume than check (SL 525), however, SL 744 and SL 768 showed higher volume than check at Ludhiana. Density of grains at Ludhiana was higher than at Abohar and it varied from 1.05-1.10 g per ml whereas at Abohar from 0.96-1.03 g per ml. The average density of grain at Ludhiana (1.07 g/ml) was higher than that of Abohar (0.99 g/ml). The varieties as well differed significantly in these characters. The average value of water absorption after soaking and volume expansion after sowing was as well higher at Ludhiana (117.20 and 125.75 %, respectively) as compared to Abohar (83.79 and 79.85 %, respectively). Water absorption and volume expansion in case of SL 768 was found to be highest among varieties at both the locations. The similar variation in water absorption has earlier been reported by Greater *et al.* (2000). The average protein content recorded was higher at Ludhiana (39.87 %) than at Abohar (32.14 %). All the genotypes showed higher protein content at Ludhiana. A large variation in protein content in genotypes at Abohar (SL 790- 30.80% to SL 768 – 33.58%) and Ludhiana (SL 790 – 37.39% to SL 768 – 41.91%) was observed. This is in conformity with variation in protein contents reported by Maier *et al.* (1998). Oil content shown reverse trend (Ludhiana- 20.15 % and

Abohar – 24.26 %) confirming strong negative correlation between oil and protein contents (Clemente and Cahoon, 2009). All the genotypes had lower amount of oil than check at both the locations except SL 744 at Ludhiana (Table 1).

Variations in physico-chemical attributes of genotypes were recorded during the two years of experimentation (Table 2). Significant differences were observed among genotypes for one hundred grain weight and volume and density during 2006 and 2007. The value of hundred grain weight varied from 10.00 to 12.89 g in 2006 and from 11.72-14.19 g in 2007 with mean values of 11.32 and 12.89 g, respectively. In general, SL 752, SL 768 and SL 790 performed better than check SL 525 in both the years with respect to water absorption after soaking and volume expansion after soaking. Hard shelled grains after soaking were found higher at Abohar than at Ludhiana (data not shown). As in case of locations, water absorption and volume expansion after soaking were observed highest in SL 768 during both the years. Protein content was significantly higher in SL 768 in 2007 than other genotypes including check SL 525. None of the genotype had higher oil content than check in both the years.

Variation in cooking quality characters

All the genotypes performed better in 2007 as compared to 2006 irrespective of two locations with respect to water absorption after cooking and volume expansion after cooking and solid dispersion after cooking (Tables 3 and 4). The grains took less time to cook at Abohar in both the years. The minimum cooking time was observed in SL 744 at Abohar (68.5 minutes) and at Ludhiana (76.0 minutes). *Kokroos* (hard grains) left after cooking were not found in any genotype at any location and in any year. Water absorption after cooking (132.49 %), volume expansion after cooking (135.97 %) and solid dispersion after cooking (25.84 %) were recorded higher at Abohar (Table 3). All the genotypes showed higher water absorption after cooking than check; however, at Abohar it was exhibited higher than check in SL 744 and SL 790. Volume expansion after cooking was observed higher than check in SL 790 at both the locations and also in 2007. It was recorded higher at Abohar (135.97 %) than at Ludhiana (118.57 %). All the genotypes had higher solid dispersion after cooking than check at both the locations. SL 790 exhibited maximum value of solid dispersion after cooking followed by SL 752.

The correlations between attributes (Table 5) revealed that density, water absorption and volume expansion after soaking, cooking time, solid dispersion after cooking were negatively correlated with 100 grain volume at both the locations. Oil was negatively correlated with density, volume expansion after soaking, cooking time, solid dispersion and water absorption after cooking at both the locations. At Ludhiana, solid dispersion after cooking was significantly negatively correlated with volume expansion after cooking (r = -0.92). Negative correlation was observed for water absorption after soaking and water absorption after cooking at both the locations, however it was significant at Ludhiana (r = - 0.96);

Table 1. Variation in physico- chemical attributes over two locations (mean of 2006 and 2007)

Genotypes	100 grain weight (g)		100 grain volume (ml)		Density (g/ml)		Water absorption after soaking (%)		Volume expansion after soaking (%)		Protein (%)		Oil (%)	
	Abo.	**Lud.**	**Abo.**	**Lud.**	**Abo.**	**Lud.**	**Abo.**	**Lud.**	**Abo.**	**Lud.**	**Abo.**	**Lud.**	**Abo.**	**Lud.**
SL 744	13.21	11.41	12.90	16.50	1.03	1.06	44.94	116.28	53.85	115.00	32.66	41.24	24.36	21.74
SL 752	13.15	11.41	13.50	13.50	0.97	1.07	111.84	115.36	110.71	118.33	31.13	38.76	24.95	20.32
SL 768	13.00	11.39	13.50	15.00	0.96	1.10	134.22	117.22	107.14	142.98	33.58	41.91	23.96	19.11
SL 790	13.31	10.87	13.00	14.00	1.02	1.05	68.31	114.33	69.23	119.44	30.80	37.39	23.30	18.04
SL 525	13.23	11.77	15.50	14.00	0.98	1.07	59.67	122.83	58.33	133.03	32.53	40.06	25.76	21.55
Mean	13.18	11.37	13.68	14.60	0.99	1.07	83.79	117.20	79.85	125.75	32.14	39.87	24.46	20.15
LSD (5 %)														
Genotype(G)	**0.015**	**0.018**	**0.015**	**0.014**	**0.008**	**0.017**	**0.108**	**NS**	**NS**	**0.143**	**0.082**	**NS**	**NS**	**0.012**
Location (L)	**0.04**	**0.31**	**3.33**	**4.27**	**0.003**	**0.001**	**4245.2**	**33.13**	**2211.74**	**420.22**	**3.98**	**10.09**	**8.78**	**7.53**
G x L	**0.14**		**2.27**		**0.005**		**2059.42**		**1639.28**		**13.16**		**15.66**	

Abo- Abohar; Lud: Ludhiana

Table 2. Variation in physico- chemical attributes over two years (mean of two locations; Abohar and Ludhiana)

Genotypes	100 grain weight (g)		100 grain volume (ml)		Density (g/ml)		Water absorption after soaking (%)		Volume expansion after soaking (%)		Protein (%)		Oil (%)	
	2006	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
SL 744	12.89	11.72	16.50	12.90	1.12	0.96	73.19	88.03	91.92	76.92	38.97	34.92	21.97	24.13
SL 752	11.44	13.13	15.00	12.00	1.06	0.98	114.33	112.87	135.71	93.33	33.05	36.83	22.26	23.00
SL 768	11.51	12.86	15.50	13.00	1.06	1.00	127.93	123.52	142.44	107.69	37.37	38.12	21.23	21.84
SL 790	10.00	12.52	18.00	11.50	1.11	1.01	103.07	96.95	122.22	92.95	32.22	36.68	17.83	20.78
SL 525	10.80	14.19	16.50	13.00	1.06	0.99	81.25	101.24	92.64	98.72	36.05	36.54	23.17	24.14
Mean	11.32	12.88	16.30	12.48	1.08	0.98	99.95	104.52	116.98	93.92	35.53	36.61	21.29	22.77
LSD (5 %)														
Genotype (G)	**0.085**	**0.013**	**0.102**	**0.083**	**0.016**	**0.016**	**NS**	**NS**	**0.061**	**NS**	**NS**	**0.022**	**0.022**	**0.029**
Year (Y)	**3.39**	**2.42**	**3.97**	**1.43**	**0.003**	**0.001**	**1548.89**	**578.04**	**1697.85**	**377.21**	**24.44**	**3.89**	**12.68**	**6.45**
G x Y	**1.42**		**1.75**		**0.0015**		**1911.48**		**1523.67**		**11.28**		**17.57**	

Table 3. Variation in cooking quality attributes over two locations (mean of 2006 and 2007)

Genotype	Cooking time (min)		Water absorption after cooking (%)		Volume expansion after cooking (%)		Solid dispersion after cooking (%)	
	Abohar	Ludhiana	Abohar	Ludhiana	Abohar	Ludhiana	Abohar	Ludhiana
SL 744	68.5	76.0	151.62	121.91	117.18	123.07	24.23	12.4
SL 752	80.5	82.0	101.73	121.56	126.49	106.67	27.49	17.59
SL 768	81.5	81.5	118.77	118.62	140.38	114.07	23.64	18.15
SL 790	84.0	82.0	150.83	137.08	161.54	125.00	32.95	11.73
SL 525	73.5	74.5	139.52	96.22	134.28	124.06	20.88	11.40
Mean	77.6	79.1	132.49	119.07	135.97	118.57	25.84	14.18
LSD (5 %)								
Genotype G)	**NS**	**0.037**	**NS**	**1.947**	**0.139**	**0.128**	**0.028**	**NS**
Location (L)	**123.15**	**39.98**	**1414.62**	**692.51**	**839.29**	**190.19**	**63.98**	**33.19**
G X L	**144.11**		**1161.72**		**637.39**		**45.68**	

Table 4. Variation in cooking quality attributes over two locations (mean of two locations; Abohar and Ludhiana)

Genotype	Cooking time (min)		Water absorption after cooking (%)		Volume expansion after cooking (%)		Solid dispersion after cooking (%)	
	2006	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
SL 744	77.5	67.0	126.07	147.46	100.00	140.26	14.14	22.49
SL 752	73.5	89.0	101.4	121.89	111.11	122.05	17.48	27.60
SL 768	75.0	88.0	114.67	122.72	131.38	123.05	18.70	23.09
SL 790	80.0	84.0	119.96	152.51	100.00	155.77	12.42	22.00
SL 525	75.0	73.0	100.98	134.75	120.16	138.18	14.91	17.38
Mean	74.25	80.2	112.54	125.87	112.53	135.87	15.53	22.51
LSD (5 %)								
Genotypes (G)	**0.120**	**NS**	**NS**	**NS**	**0.037**	**0.105**	**NS**	**NS**
Year (Y)	**19.72**	**284.10**	**375.28**	**585.72**	**547.16**	**581.97**	**19.38**	**39.62**
G x Y	**131.52**		**796.26**		**183.01**		**41.92**	

Table 5. Correlation among different quality parameters at different locations in 2006 and 2007

	Locations	100 grain weight (g)	100 grain volume (ml)	Density (g/ml)	Hard shelled grains after soaking (%)	Water absorption after soaking (%)	Volume expansion after soaking (%)	Cooking time (min)	Water absorption after cooking (%)	Volume expansion after cooking (%)	Solid dispersion after cooking (%)	Pro-tein (%)
100 grain volume (ml)	Abohar	0.05										
	Ludhiana	0.06										
Density (g/ml)	Abohar	0.73	-0.44									
	Ludhiana	-0.13	-0.03									
Hard shelled grains after soaking (%)	Abohar	0.36	0.20	0.61								
	Ludhiana	0.09	0.33	-0.90*								
Water absorption after soaking (%)	Abohar	-0.82	-0.11	-0.83	-0.78							
	Ludhiana	0.83	-0.09	-0.20	0.28							
Volume expansion after soaking (%)	Abohar	-0.72	-0.19	-0.77	-0.90*	0.96**						
	Ludhiana	0.36	-0.11	0.70	-0.52	0.53						
Cooking time (min)	Abohar	-0.15	-0.22	-0.40	-0.71	0.65	0.65					
	Ludhiana	-0.69	-0.41	0.61	-0.75	-0.76	0.01					
Water absorption after cooking (%)	Abohar	0.65	-0.07	0.84	0.87	-0.84	-0.92*	-0.41				
	Ludhiana	-0.95*	0.08	0.16	-0.30	-0.96**	-0.48	0.72				
Volume expansion after cooking (%)	Abohar	0.27	-0.07	0.03	-0.16	0.13	0.04	0.77	0.23			
	Ludhiana	-0.15	0.33	-0.52	0.88*	0.28	-0.10	-0.57	-0.05			
Solid dispersion after cooking (%)	Abohar	0.45	-0.64	0.39	-0.07	0.01	0.128	0.65	0.11	0.63		
	Ludhiana	0.07	-0.15	0.80	-0.77	-0.30	0.37	0.63	0.11	-0.92*		
Protein (%)	Abohar	-0.69	0.24	-0.32	-0.17	0.20	0.004	-0.41	-0.01	-0.37	-0.81	
	Ludhiana	0.58	0.69	0.40	0.36	0.37	0.53	-0.40	-0.45	-0.08	0.30	
Oil (%)	Abohar	-0.01	0.82	-0.38	0.21	-0.15	-0.11	-0.51	-0.27	-0.58	-0.73	0.18
	Ludhiana	0.82	0.38	-0.54	0.80	0.58	-0.17	-0.84	-0.69	0.08	-0.24	0.46

* $r_{5\%} = 0.88$; ** $r_{1\%} = 0.96$

hard shelled grains and volume expansion after soaking and was significant at Abohar (r = - 0.90). Protein and oil were not significantly correlated with any physical and cooking quality attributes at both the locations.

It can be concluded that average protein content of all the genotypes was highest at Ludhiana followed by Abohar. Similarly, oil content was high at Abohar. Protein content was also found highest in SL 768 at Abohar and Ludhiana in both the years. No genotype registered higher oil content than check (SL 525) at Abohar in both years; however, SL 744 exhibited higher oil content than SL 525 at Ludhiana. No *kokroos* were found in any genotype at any locations in both the years. The genotype SL 744, SL 768 and SL 790 were found to be more promising with respect to different quality parameters studied.

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Tractor Operated Furrow Irrigated Raised Bed System (FIRBS) Seed Drill for Rainfed Soybean in Vertisols

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ABSTRACT

The study comprised two treatments with ten replications. The treatments consisted of sowing by the tractor operated FIRBS seed drill and flat sowing. A tractor operated FIRBS seed drill was fabricated suiting to Vertisols and farm validated for facilitating development of raised beds along with sowing operations on the raised bed. Planting of soybean using FIRBS seed drill resulted in 20.48 per cent increase in plant population and resultant seed yield by 21.93 per cent. The additional cost of FIRBS (₹ 14, 000) over normal seed drill (₹ 44, 000) can be recovered in 2.3 years. The FIRBS made by the machine is capable of mitigating the effect of dry spells as well as water logging conditions. A significant higher seed yield was observed when used FIRBS machine over flat sowing. The recorded yield ranged between 1251 to 1350 kg per ha on FIRBS plots as compared to 1035 to 1082 kg per ha on flat plots.

Key words: Moisture, raised bed, tractor operated FIRBS seed drill, water

The soybean is ranked first among major oil crops in the world (Chung and Singh, 2008) and has acquired a premier position among oilseeds in India. The increase in crop production brought by the green revolution in India is now shadowed by new challenges related to soil degradation and scarcity of water resources (Duboc *et al.*, 2011). Soybean is highly photosensitive short day plant and its yield is sensitive to planting time (Johnsen *et al.*, 1960; Sahoo *et al.*, 1991). Planting of soybean after 25th of June reduces its productivity linearly by 188.77 kg per ha for every 5 days delay in sowing (Billore *et al.*, 2000) and sharp yield decline was observed after 10th July (Bhatia *et al.*, 1999). However soybean is mostly grown as a rainfed crop and depends upon the on-set of monsoon which is highly erratic over the years.

Being grown under rainfed environment, to sustain the productivity level of crop at higher level, curtail the cost of production and conserve the rainwater to make it available during crop growth

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period, mechanisation to plant crop on changed land configuration appears to be a sound proposition.

Appropriate farm mechanisation is one of the most important aspects that offer good opportunity in this effort, not only in case of soybean but other crops as well. In addition to limiting the expenditure on manual labour, it helps in planting of the crop in one go on altered land configuration to optimise productivity of crops, particularly of soybean on Vertisols and associated soils, which are inherently characterised to exhibit substantial runoff. Quanqi *et al.* (2008), while working on wheat in north China, suggested that with proper variety the yield from bed planting can surpass that of planting on the flat.

In rainfed crops like soybean grown on Vertisols and associated soils, sowing on raised beds appears to be crucial for better performance under inadequate or excess and non-uniformly distributed rainfall. Keeping these facts in view, a furrow irrigated raised bed seed drill suitable to function on Vertisols and associated soils, was developed and farm validated for three consecutive years and results obtained are presented in the present manuscript.

MATERIAL AND METHODS

The tractor operated FIRBS seed drill (Fig. 1) was devised at the Directorate of Soybean Research can easily be fitted and detached to and from the 3 point links of the tractor. Furrow openers of this FIRBS seed drill have been made of high carbon steel to prevent faster wearing in Vertisols. This machine can be attached to suitably powered tractor to sow the crop on furrow irrigated raised bed system (FIRBS) in one go (Fig. 2) and saves time and labour in the planting process. The cost of fabrication worked out to ₹ 58, 035. This developed FIRBS seed drill also has provision to change the row to row spacing while sowing. The machine has facility to adjust the depth of the ridge former and also the width of the ridge former. The FIRBS seed drill also has seed covering device to cover the dropped seeds.

The developed FIRBS seed drill was validated for its efficiency for three consecutive soybean cropping seasons (*kharif* 2007-09) in soybean at research farm of Directorate of Soybean Research, Indore. Deep tillage was done with the help of mechanically reversible mould board plough followed by planking 25 days prior to sowing with tractor operated FIRBS seed drill. The soybean crop was sown using 40 PTO hp tractor attached with FIRBS seed drill to ensure row planting at 45 cm row to row distance. Height of the shoe of the furrow opener was adjusted so that the soybean seed is not placed deep. The experiment was conducted on randomized block design. The plant population per square meter was recorded from ten replicated plots measuring 50 m x 2.25 m for each of the above two treatments. Soybean variety JS 335 was sown on 25th June, 26th June, and 1st July in 2007, 2008 and 2009, respectively and crop was managed as per recommended management practices. The yield data from each plot was recorded and expressed as kg per ha. The variable rainfall received during the cropping season (June

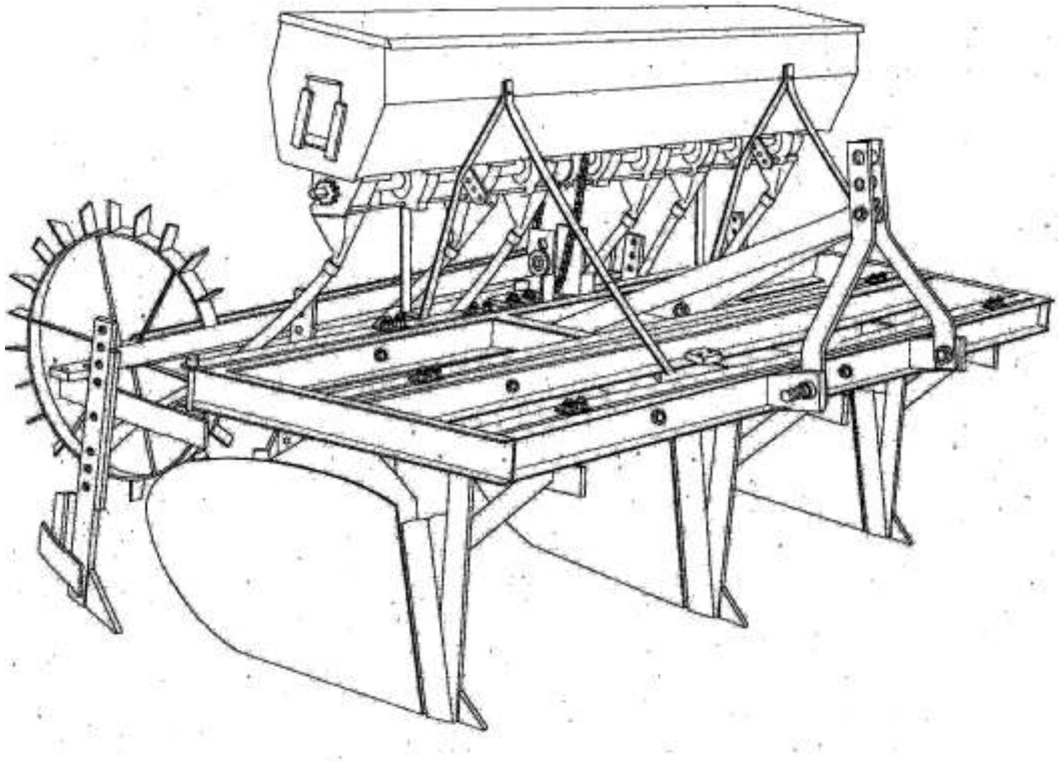

Fig. 1. FIRBS seed drill

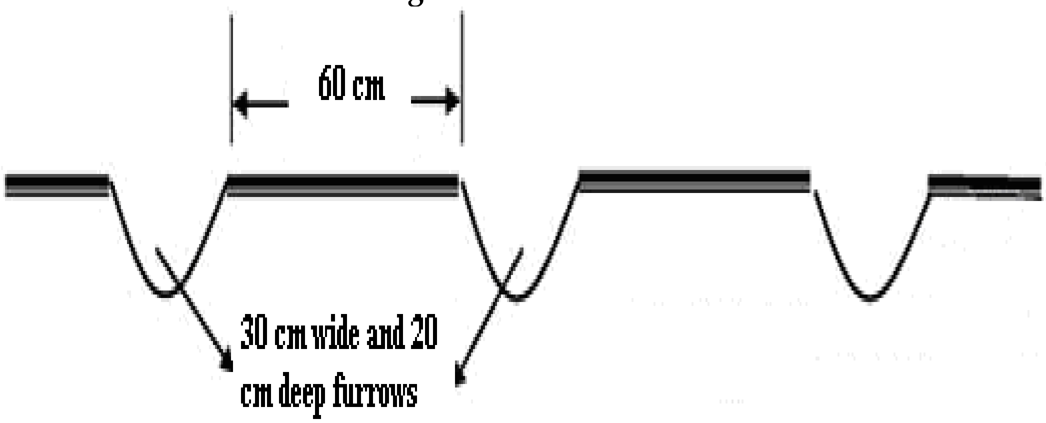

Fig. 2. Furrow and bed formation with FIRBS seed drill

to October) was 873.78 mm, 549.39 mm and 859.59 mm during 2007, 2008 and 2009, respectively. The data was statistically analysed (Panse and Sukhatame, 1978)

RESULTS AND DISCUSSION

During all the three years, the planting on FIRBS resulted in significantly higher plant population than on normally adopted flat bed. The increase population in crop planted on FIRBS was 24, 22 and 16 per cent higher than flat sowing during 2007, 2008 and 2009, respectively. On the mean basis, the increase in plant population by planting on FIRBS was 20.48 per cent higher over flat (Table 1).

In our experiment the resultant seed yield in all the three years was significantly higher in plots planted using FIRBS seed drill as compared to flat planting. The recorded yield ranged between 1251 and 1350 kg per ha on FIRBS plot as compared to 1035 to 1082 kg per ha on flat plots during the evaluated period (Table 2). The yield increase ranged between 20 and 25 per cent with an average increase in three years by 21.93 per cent. Similar yield enhancements by planting on raised bed were reported in wheat (Sepat *et al.*, 2010; Hobs and Gupta, 2003) and maize (Singh *et al.*, 2007). On account of water conservation, improved grain filling and grain quality, avoiding water logging and associated adverse effects on crop, Rai (2009) and Gupta and Malik (2009) stated that the FIRBS systems opened new vistas for growing a number of crops with enhanced productivity.

Table 1. Resultant plant population (no/m^2) under FIRBS and flat sowing

Sowing method	Year			Mean
	2007	2008	2009	
FIRBS	47.6	50.6	48.8	49.0
Flat	38.4	41.6	42.0	40.7
CD (p = 0.05)	**2.36**	**1.54**	**1.08**	**1.66**

Table 2. Resultant seed yield (kg/ha) under FIRBS and flat sowing

Sowing method	Year			Mean
	2007	2008	2009	
FIRBS	1350	1252	1251	1284
Flat	1082	1043	1035	1053
CD (p=0.05)	**12.71**	**11.27**	**20.77**	**7.88**

It can be seen that on an average an increase in seed yield per hectare by the use of FIRBS machine amounts to about 230 kg per ha, which can generate about Rs 6000 as an additional returns considering the average price of soybean. The normal seed drill of reasonable quality costs nearly Rs 44, 000 as compared to Rs 58, 035 of FIRBS Seed drill. Logically the additional cost on FIRBS machine can be recovered in 2.3 years.

It can be seen that the use of FIRBS machine for sowing could consistently give better crop establishment with higher seed yield of soybean by way of mitigating soil moisture stress as a result of water conservation in furrows or draining of excess water through them, creating better soil physical environment and better nutrient utilization (Ramesh *et al.*, 2008). Hence it is suggested that the FIRBS seed drill should be popularised among farmers for cultivation of soybean and other crops free from natural vagaries of monsoon.

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An Analytical Study of Seed Scenario at Farmers' Level in Major Soybean Growing States

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ABSTRACT

A study was conducted in major soybean growing states of the country involving 300 farmers of Madhya Pradesh, Maharashtra and Rajasthan with the basic objective to study various issues pertaining to utilization of soybean seed by the farmers. Majority of the surveyed farmers from Madhya Pradesh (99 %) Maharashtra (59 %) and Rajasthan (77 %) preferred to grow soybean as a kharif crop. The farmers of Madhya Pradesh and Rajasthan were found using comparatively higher seed rate than recommended and that too farm saved seed from previous season without carrying out recommended practices to maintain genetic purity, seed processing and storage. Further, while using their own produce as seed, majority of farmers (90 %) do not test its germination before sowing. Furthermore, the threshing done at lower rpm (350 to 400) was observed to be causing reduction in germination percentage culminating in use of increased seed rate against the recommendations. The survey also revealed majority of farmers were not aware of precautions taken to preserve seed viability. Over 60 per cent farmers do not maintain proper storage conditions. Very few farmers were found to carry seed treatment with carbendazim in storage conditions.

Key words: Farmers, germination, seed, soybean, states, storage

Soybean has occupied premier position in the oilseed scenario of the country. As an exceptional crop among oilseeds, soybean has attained an unparallel glory of its horizontal expansion in a very short span of nearly four decades. Starting from mere 3, 000 ha during seventies, the country has crossed the magic figure of 9.95 million ha and is expected to produce nearly 12.57 million tons (DAC, GOI, 2011) of soybean leaving other oilseeds far behind. Because of its versatile characteristics like short maturity duration, suitability for diverse climatic situations and varied soil types, high profit margins from minimum input, care and cost of cultivation, export potentials of soy meal and above all its suitability for different cropping systems, it fascinated not only majority of farmers belonging to small land holding but also by the industrialists, traders, researchers and development officials who have contributed significantly to the success of this relatively new crop in the country.

The upward productivity trends of soybean in recent past has exhibited slow down at about 1 ton per ha against the productivity potential of nearly 2.5 ton per ha which is amply demonstrated

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through frontline demonstrations conducted across the country. Beside vagaries of monsoon, in the last decade which is experienced normally to be more erratic, scanty and early withdrawn, unavailability of quality seed is reported to be a major problem in soybean resulting in less productivity (Dupare *et al.,* 2010). Out of nearly 100 soybean varieties released since 1967 through All India Coordinated Research Project, only 10 odd varieties are being maintained in formal seed chain (Anonymous, 2011). Out of total coverage in the country, nearly 93 per cent of area comes under three major soybean growing states viz. Madhya Pradesh, Maharashtra and Rajasthan. The farmers, most of them are found to be using different formal and informal channels to meet their seed requirement (Dupare, *et al.,* 2011). Like other crops, farm saved seed of soybean is reportedly used by the farmers for sowing in the ensuing season. The present study was, therefore, undertaken to study the soybean seed scenario at farmers' level and issues involved therein.

MATERIAL AND METHODS

The present study was conducted involving 300 farmers belonging to three major soybean growing states of the country i. e, Madhya Pradesh, Maharashtra and Rajasthan with the proportionate sample of 160 farmers from Madhya Pradesh (Indore, Ujjain, Dhar, Dewas, Khargone, Badwani, Shajapur, Hoshangabad, Betul, Chhindwara), 110 farmers from Maharashta (Nagpur, Wardha, Amaravti, Akola, Buldhana, Aurangabad, Parbhani, Beed, Nanded, Latur, Satara, Sangli, Kolhapur and Pune) and 30 farmers from Rajasthan (Kota, Jhalawad and Bundi). The data were collected from the farmers belonging to major soybean growing districts representing different agro-ecological zones of the concerned state. A semi-structured interview schedule consisting on questions seeking information on seed related aspects was formulated and used to collect relevant data from the respondents. The collected information was coded, collated, scored and analyzed using simple statistical tools like frequency and percentages after undertaking content analysis.

RESULTS AND DISCUSSION

Profile of soybean growers

Out of 300 respondents representing three major soybean growing states which contribute about 93 per cent of crop coverage in the country, majority of them had an average age of about 45 years. Madhya Pradesh being the epi-center of soybean cultivation wherein commercial cultivation of soybean was initiated way back during the seventies , it appears that knowledge of its cultivation has penetrated to younger farmers on account of their continuous association with the crop and elder farmers. Hence, the average age of the soybean growers is relatively less (41 years). The average age of farmers from Maharashtra and Rajasthan was 48 years.

Further, the average annual income for the respondents of the three states was ₹2, 12, 374. Madhya Pradesh farmers had least income of ₹ 1, 65, 897 and was 29 per cent and 37 per cent lower than farmers of Rajasthan and Maharashtra, respectively. Since the number of respondents is limited, it will not be very appropriate to comment on observed land holding in each state. Of the farmers surveyed in the three states, majority of them (99 %) from Madhya Pradesh are inclined to grow soybean as *kharif* crop, may be on account of introduction of soybean as commercial crop in the state occupied the monsoon fallows (Bhatnagar and Joshi, 1999). In Maharashtra and Rajasthan, only59 per cent and 77 per cent farmers were growing soybean as *kharif* crop. In latter two states the soybean, by and large, has been replacing the existing non-remunerative crops. Overall 70 per cent farmers in the three states were found to cultivate soybean.

Table 1. Profile of soybean growers

State	Maharashtra (n=110)	Madhya Pradesh (n=160)	Rajasthan (n=30)	Total (N= 300)
Age (yrs)	48.03	40.91	48.72	44.63
Annual Income (₹)	2,63,900	1,65,897	2,33,965	2,12,374
Land Holdings (ha)	3.74	4.64	4.48	3.85
Area under soybean (ha)	2.21	4.15	3.43	2.70

Seed rate applied by soybean growers

Seed is the most expensive and important input in cultivation of crops, particularly in soybean. It has been considered as one of the major constraints in enhancing the productivity of soybean. There appears to be marked difference in the quantity of seed used by the farmers of the three states (Table 2). On an average, 37.00 per cent and 46.33 per cent of the farmers were found to use 75 kg and 100 kg per ha against general recommendation of 75 kg per ha (Bhatnagar and Tiwari, 1995). About 12.00 per cent and 4.67 per cent farmers used the seed rate of 87.5 and 62.5 kg per ha. An important information emerging out from state-wise data that farmers of Maharashtra restricted the use of seed between 62.5 and 75.0 kg per ha, which corresponds to comparatively higher average productivity (1, 230 kg/ha) of the state. On the contrary, farmers of Madhya Pradesh used seed rate from 87.5 to 100 kg per ha, and state productivity average of the states is 1, 045kg/ha and 990 kg/ha (Anonymous, 2007). The other astonishing picture about Maharashtra farmers is that they are purchasing the certified seed every year either from the State owned Maharashtra State Seed Corporation or seed companies in convenient packs of 30 kg sufficient to cover 1 acre land. In contrast, the farmers of Madhya Pradesh and Rajasthan use comparatively higher seed rate than recommended and that too farm saved seed from previous season, which normally is multiplied with-little care on maintenance of genetic purity, seed processing and storage. Such poor quality seed with lower viability culminates in poor plant population and lower yields. The farmers of these two states are with false notion that increasing the number of plants would result in higher yields. Some farmers have also conceptualized that higher the plant population and closure spacing, higher will be the smothering of weeds. Others use higher seed rate with fear that the seed sown may not emerge to give required population.

Table 2. Seed rate practiced by the respondent farmers in the states of Maharashtra, Madhya Pradesh and Rajasthan

Seed rate (kg/ha)	Maharashtra (n=110)	Madhya Pradesh (n=160)	Rajasthan (n=30)	Total (N= 300)
62.5	9 (08.18)	5(3.12)	0 (0.00)	14 (04.67)
75.0	101 (91.81)	10 (6.25)	0 (0.00)	111 (37.00)
87.5	0 (0.00)	26 (16.25)	10 (33.33)	36 (12.00)
100	0 (0.00)	119 (74.38)	20 (66.66)	139 (46.33)

Figures in parentheses indicate percentages

Testing the germination percentage

Soybean seed constitute a poor germinating unit. It is invariably recommended that it will be appropriate to test the germination/emergence of seed to be used for planting, a fortnight prior to sowing. To understand the adoption of this recommendation, the query from farmers using farm saved seed revealed that majority of farmers (90%) does not resort to germination test before sowing. As per recommendation, at specified seed rate the germination of soybean seed to be sown should be minimum 70 per cent Above 70 per cent farmers, irrespective of the state they belonged, were ignorant about this aspect. The progressive farmers only had knowledge on minimum germination percent and utility of germination test.

Maintenance of purity and viability

Utmost care is needed in the process of seed production and subsequent processing and storage to retain quality of seed of soybean varieties. The off plants not to the true type of variety and diseased plants are to be roughed out when the seed crop is in the fields. Furthermore, the threshing of the seed is to be done at lower rpm (350 to 400) of the drum of the thresher and seed so obtained to be sundried to bring the moisture at 10 per cent or below. The survey revealed that the majority of farmers are not aware to these precautions and do not resort to them. Only a small fraction of respondents had knowledge on these aspects (Table 4).

Storage is one of the major aspects that affect the quality seed. Of late, the farmers are learnt to stock their produce and wait for higher prices in the market in order to get more returns. It was decided further to explore farmers' efforts to maintain germination and viability during storage. It was observed that around 60 per cent farmers do not

Table 3. Carrying out germination test

Germination test	Maharashtra (n=110)	Madhya Pradesh (n=160)	Rajasthan (n=30)	Total (N= 300)
Carrying out germination test before sowing				
Adoption	12(10.90)	16(10.00)	2(6.66)	30(10.00)
Non-adoption	98(89.09)	144(90.00)	28(93.34)	270(90.00)
Knowledge about germination % of soybean				
70%	9(8.18)	31(19.37)	5(16.66)	45(15.00)
80%	19(17.27)	18(11.25)	3(10.00)	40(13.33)
Don't Know	82(74.54)	111(69.37)	22(73.33)	215(71.66)

Figures in parentheses indicate percentages

Table 4. Precautions in seed production

Seed production technique	Maharashtra (n=110)	Madhya Pradesh (n=160)	Rajasthan (n=30)	Total (N= 300)
Roughing for seed purity				
Adoption	9(8.18)	12(7.50)	2(6.66)	23(7.66)
Non-adoption	101(91.82)	148(92.50)	28(93.33)	277(92.33)
Threshing at low rpm				
Adoption	12(10.90)	20(12.50)	2(6.66)	34(11.33)
Non-adoption	108(98.18)	140(87.50)	28(93.33)	266(88.66)
Sun drying				
Adoption	17(15.45)	31(19.37)	2(6.66)	56(18.66)
Non-adoption	93(84.54)	129(80.62)	28(93.33)	244(81.33)

Figures in parentheses indicate percentages

maintain proper storage conditions. On asked about storage material/facility used, only 40 per cent of the farmers are maintaining proper storage conditions most of them using gunny bags /Jute bags followed by indigenous structure i.e. Kothi. Very few farmers are found to have seed treatment with carbendazim in storage conditions.

The study brings out that only farmers of Maharashtra are sowing their soybean crop replacing the seed on annual basis with seed rate recommended by the R and D system as compared to that of Madhya Pradesh and Rajasthan who sow their crop using harvested produce of previous year without paying much attention on its viability and purity which

Table 5. Precaution in seed storage

Seed storage	Maharashtra (n=110)	Madhya Pradesh (n=160)	Rajasthan (n=30)	Total (N= 300)
No Storage/with no precaution	92(83.63)	62(38.75)	25(83.33)	179(59.66)
Proper storage technique	18(16.36)	98(61.25)	5(16.67)	121(40.33)
a. Jute bags/Gunny bags	18(100.00)	90(91.83)	5(100.00)	113(93.38)
b. *Kothi*	0(0.00)	6(6.12)	0(0.00)	6(4.95)
c. Warehouse	0(0.00)	2(2.04)	0(0.00)	2(1.65)
Treatment with Fungicides				
Yes (Bavistin/Trichoderma)	2(1.81)	6(3.75)	0(0.00)	8(2.66)
No	108(98.19)	154(96.25)	30(100.00)	292(97.33)

Figures in parentheses indicate percentages

prompted them to increase the seed rate to considerable extent. Hence, it is recommended that the capacity building programme should be carried out more extensively in order to provide them knowledge and skills of seed production. The state owned seed supply agencies are also required to increase their capabilities in order to provide quality seed of preferred variety to their famers in required quantity in order to increase the seed replacement rate which definitely will add to increased national average productivity.

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Impact of Improved Technology on Soybean Productivity in South Eastern Rajasthan

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ABSTRACT

The frontline demonstration were conducted during 2005-06 to 2010-11 on farmers' field in the Zone V to evaluate the performance of improved soybean production technology recommended by Maharana Pratap University of Agriculture and Technology. The results revealed that the improved technology was more useful and remunerative as compared to farmers' practices. With the adoption of improved technology, the productivity of soybean increased by 20.56 per cent over farmers practice. In term of net returns, 23.32 per cent increase was observed over farmers' practice. Similarly improved technologies exhibited higher value of Sustainable Yield Index and Sustainable Value Index in most of the years.

Key words: Farmer's practices, frontline demonstration, improved technology, soybean, sustainability value index, sustainability yield index

Soybean [*Glycine max* (L.) Merrill] belongs to the legume family, is recognized as golden or miracle bean due to its high nutritive value and various uses viz., for feed, oil and soy food products. It is rich in protein (38-42 %) and contains 18-22 per cent edible oil. Soybean ranked first in the world in oil production (57%) and in the international trade markets among the major oilseed crops. Soybean continues to be number one oilseed crop in India, currently (*kharif* 2010-11) occupying 9.55 million ha with production of 12.57 million tonnes. During 2009-10, Rajasthan ranked third in area (7.8 lakh ha) and production (of 9.1 lakh tones) after Madhya Pradesh and Maharashtra (Anonymous, 2011).

The crop also plays an important role in the oil economy and foreign earnings as among nine major oilseed crops, during 2009-10; it contributed 40 and 23 per cent to the total oilseeds and edible oil production of the country and earned valuable foreign worth (₹ 4, 258 corers) by exporting soya meal. During 2009-10, the export of soybean meal was reduced as compared to previous year (₹ 7, 485 corers) on account of several reasons. Although, the soybean research

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and development system in the country has generated viable production technology to raise the present average productivity of 1 ton per ha by 80 per cent, it appears that there are impediments in reaching it to end users creating a technological gap (Bhatnagar, 2009). In Rajasthan state the average productivity of soybean is very low in comparison to the potential realization. The reason may be that most of the research emanated technologies have not yet reached to the farmer's field. The prevailing climatic conditions (precipitation between 500 and 700 mm during last week of June to September) and soil conditions (heavy black with medium nitrogen and phosphorus, and high potassium contents) supports soybean cultivation in humid South East Rajasthan (Zone-V), concerted efforts are needed to take the production technology to farmers. Keeping this in view, the front line demonstrations were organized under AICRP on Soybean (ICAR) with financial assistance from Ministry of Agriculture and Cooperation, Government of India to demonstrate the impact of improved technologies on soybean productivity and income generation in South East Rajasthan under real farm conditions.

MATERIAL AND METHODS

A total of 105 frontline demonstrations were carried out during the last six year (2005-06 to 2010-11) during *kharif* season at Kota, Bundi, Baran and Jhalawar districts. Every demonstration was laid out in an area of 0.4 ha with improved package of practices involving high yielding varieties (Pratap soya 1, NRC 37 , JS 335, JS 95-60 , JS 93-05 and RKS 24), seed treatment with Thiram (2.0 g) plus Carbendazim (1.0 g) per kg seed, rhizobium culture @ 5 g per kg seed and PSB culture @ 5 g per kg seed, recommended dose of fertilizers (N:P:K:S 20:40:40:30 kg/ha), weed management (hand weeding, imazeythpyr 0.750 kg per ha as post-emergence spray and chlorimuron ethyl 9.37 g per ha as post emergence spray) , plant protection (one spray of monocrotophos @ 1000 ml per ha followed by one spray of quinalphos @ 700 ml per ha), crop geometry (30 cm x 10 cm), seed rate (60-80 kg /ha). The results for 105 demonstrations carried over for six years (2005-06 to 2010-11) were analyzed and compared with farmers'practice. Farmers were allowed to follow their own technology which involved traditional practices (use their own seed of local variety, no seed treatments and NPK application, hand weeding only, no prophylactic control measures for pest and diseases, chemical plant protection after the appearance of insect pest, improper spacing and higher seed rate 100 kg/ha).

Data recorded on seed yield and net returns were statistically analyzed for calculation of parameters like standard deviation and coefficient of variation as per standard procedure (Panse and Sukhatme, 1978). Sustainability indices (Sustainability Yield Index, Sustainability Value Index) were worked out using following formula:

$$SYI / SVI = Y/V\text{-}SD / Y\ max.$$

Where, Y/V is estimated average yield/net return of practice over year (study period), SD is standard deviation and Y max is observed maximum yield/maximum net return during the study period (Singh *et al.*, 1990)

RESULTS AND DISCUSSION

Average yield obtained in demonstration field by using given package of improved technologies of soybean cultivation was 1637 kg per ha, whereas, it was 1360 kg per ha from farmers' practices (Table 1). This result revealed that the adoption of improved production technologies of soybean cultivation enhanced the productivity by 20.56 per cent over farmers' practice. Bhatnagar (2001) reported that the research emanated production technologies were capable of increasing the productivity of soybean by 32.26 per cent through frontline demonstration. Similarly, Raghuwanshi *et al*. (2009) also observed a 34.33 per cent enhancement in the productivity of soybean by adoption of improved technology over farmers' practices. Similar yield enhancement in frontline demonstrations conducted in other crops has been documented (Kumar *et al*., 2010; Dhaka *et al*., 2010).

In an economic evaluation, per hectare net return of ₹ 14, 148 per ha was obtained in demonstration plots, while ₹ 11, 483 per ha were obtained in farmers' practice. The data clearly indicated that additional net return of ₹ 4241 per ha over farmers' practice was obtained in demonstrations. Though the cost of cultivation was more (₹ 1, 279) in demonstrations over farmers' practices, but there was an increase in net returns to the tune of 23.32 per cent. Per rupee return obtained through improved technologies was 1.34 which was 8.06 per cent higher than the farmers' practices. The integration of different components of soybean production technology in improved cultivation practices though increase the cost of cultivation by 14.29 per cent (Table 2) but due to this, additional increase over net returns of Rs. 2678 per ha was also obtained. Similarly Raghuwanshi *et al*. (2010) also observed 20.01 per cent higher net returns our farmers practice in soybean front line demonstrations.

Further, improved technologies exhibited higher value of sustainability indices (SYI and SVI) for all the years except 2008, wherein a heavy infestation of the crop with yellow mosaic virus followed by charcoal rot, which ultimately reduced production potential and resulted in lower SYI and SVI. However, overall mean of 6 years study period for sustainability parameter was also of higher magnitude with improved technologies as compared to farmers' practices because of higher standard deviation values due to variation in crop conditions, response to inputs and also depended upon varying situation of cultivation. Similar observation was also observed by Dubey and Ali (1999) and Kumar and Ali (2002) in linseed front line demonstrations.

It is concluded that cultivation of soybean with improved technology adopted in frontline demonstrations at farmer field was more profitable compared to the crops grown by using farmer's practices. Sustainability parameter like SYI and SVI were also higher in improved technologies during the study period.

Thus, the study proved that improved technology of soybean cultivation offered higher yield and profit as compared to farmers practice. The sustainability parameters like SYI and SVI were higher with improved methods during most of the years under study. Soybean productivity can be enhanced by adopting improved production technology.

Table 1. Performance of improved technologies of soybean production through frontline demonstrations

Particulars	Years						Mean
	2005	2006	2007	2008	2009	2010	
Number of demonstration	15	26	24	20	10	10	-
Mean seed yield (kg/ha) IT	1592	1815	2060	1168	1312	1873	1637
Mean seed yield (kg/ha) FP	1259	1538	1655	0978	1096	1631	1360
Increase in seed yield over FP (%)	26.45	18.25	24.49	19.56	19.74	14.87	20.56
Mean net return IT (₹/ha)	9490	14401	12374	4151	12882	31670	14148
Mean net return FP (₹/ha)	7166	11204	9541	3160	10400	27429	11483
Additional return over FP	2324	3197	2833	0991	2482	4241	2678
ICBR ratio	2.72	2.98	2.87	1.67	2.68	5.27	3.03

IT: Improved technology, FP: Farmers practice & ICBR: Incremental cost benefit ratio

Table 2. Variability in seed yield and net return in soybean front line demonstration

Particulars	Kharif 2005		Kharif 2006		Kharif 2007		Kharif 2008		Kharif 2009		Kharif 2010		Mean	
	IT	FP	IT	FP	IT	FP	IT	FP	IT	FP	IT	FP	IT	FP
Seed Yield Range (kg/ha)	1277-1782	1000-1495	1250-2125	1125-1850	1780-2440	1420-1980	1025-1540	1000-1250	1180-1425	1000-1200	1710-2010	1530-1750	1025-2440	1000-1980
Mean	1592	1259	1815	1538	2060	1655	1168	0978	1312	1096	1873	1631	1637	1359
Standard Deviation	178.3	162.7	251.5	223.6	196.4	162.5	112.0	91.3	93.4	77.4	106.3	82.7	344.7	289.1
CV (%)	11.20	12.92	13.85	14.54	9.53	9.81	9.59	9.34	7.12	7.60	5.67	5.07	21.05	21.28
Net Return Range (₹/ha)	6091-11529	4395-9410	5693-17068	5125-14650	8500-15520	6136-12184	1402-8509	811-6500	10672-15572	8850-12650	24045-35818	20165-31765	1402-35818	811-31765
Mean	9490	7166	14401	11204	12374	9541	4151	3160	12882	10400	31670	27429	14148	11483
Standard Deviation	1874.5	1644.8	3170.1	2736.0	2482.4	2110.2	1775.1	1491.4	1868.7	1510.6	4284.8	4644.9	9285.1	8333.1
CV (%)	19.79	22.95	23.31	24.42	20.06	22.12	42.76	47.20	14.05	14.25	14.77	18.44	65.62	72.57
SYI	0.793	0.733	0.736	0.710	0.763	0.753	0.709	0.685	0.855	0.848	0.884	0.878	0.540	0.529
SVI	0.660	0.586	0.658	0.578	0.637	0.609	0.279	0.256	0.707	0.702	0.764	0.717	0.136	0.099

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DSb 21 – A promising Soybean Rust Resistant Genotype in India

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Soybean rust caused by *Phakopsora pachyrhizi* Syd., a disease that causes serious crop losses in many parts of the world is of serious concern in India (Feng *et al.,* 2005). It is a major problem especially in southern parts of India causing significant yield losses ranging from 30 to 100 per cent (Sarbhoy and Pal, 1997). Heavily infected plants have reduced seed weight, fewer pods and seeds. The spread of disease is very fast and has become a major threat for production and expansion of soybean cultivation in Southern parts of India.

Most of the popular cultivars *viz.,* JS 335, JS 93-05, DSb 1, MACS 450 etc., are highly susceptible to rust and as such use of fungicides has been proved to be not economical besides their environmental concerns if encouraged to use. Keeping this in view, a long-term breeding programme has been initiated at University of Agricultural Sciences, Dharwad, India to develop rust resistant genotypes.

Two germplasm lines *viz.,* EC 241778 and EC 241780 have been identified as rust resistant during rainy seasons of

Rust resistant 'DSb 21' Rust resistant 'DSb 21' Rust susceptible JS 335

Fig 1. Rust resistant and susceptible varieties

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Table 1. Reaction of DSb 21 to rust at hot spots

Variety	Artificially inoculated condition	Natural epiphytotic condition (0-9 scale)			
	2008 (Dharwad)	2008 (Ugarkhurd)	2009 (Ugarkhurd)	2010 (Ugarkhurd)	2011 (Ugarkhurd and Dharwad)
DSb 21	R	1 (HR)	1 (HR)	1 (HR)	1 (HR)
JS 335 (C)	S	9 (HS)	9 (HS)	9 (HS)	9 (HS)

R: Resistant; HR: Highly Resistant; S: Susceptible; HS: Highly Susceptible

2002 and 2003 (Patil *et al.*, 2004). These lines were utilized in hybridization with agronomically superior but rust susceptible cultivars *viz.*, JS 335, JS 93-05 and DSb 1. More than 500 advanced breeding lines developed from the above crosses were screened under natural epiphytotic condition as well as artificially inoculated glass house condition.

The scoring of the disease was done by employing 0-9 scale (Mayee and Datar, 1986), where 0 denotes no disease and 9 denotes > 90 per cent area covered due to rust infection. Among them, one line *viz.*, DSb 21 a cross derivative of JS 335 x EC 241778 exhibited highly resistant reaction to rust consistently for four years (2008 to 2011) at hot spots for rust *viz.*, Dharwad and Ugarkhurd (Fig 1; Table 1).

Under rust prone conditions, it has recorded seed yield of 2, 080 kg per ha compared to the best check JS 335 the most popular cultivar in India which recorded 599 kg per ha across three environments during 2010 and 2011 (Table 2). Further, there was no reduction in seed index of DSb 21 (14.02 g) but in case of JS 335 it was reduced to 6.42 g due to rust severity. It has also recorded 13 to 20 per cent yield superiority over JS 335 in various trials *viz.*, station trials, coordinated trials, multilocation trials, on farm trials and large scale demonstrations conducted during 2009 to 2011 (Table 3). In one of the large scale demonstrations, it has recorded highest seed yield of 5, 250 kg per ha revealing its maximum genetic potentiality.

Thus, this study clearly indicated that DSb 21 is highly resistant to rust with high yield potentiality and it will be a boon to the soybean growing farmers in southern parts of India.

Table 2. Performance of DSb 21 under rust prone conditions

Variety	Seed yield (kg/ha)				Seed index (g/100 seeds)
	2010	2011		Mean	
	Ugarkhurd (9)	Dharwad (11)	Ugarkhurd (17)		
DSb 21	1898*	2156*	2187*	2080	14.02
JS 335 (C)	214	1042	540	599	6.42
CD (5%)	163	385	366		
CV (%)	9.5	11.0	16.8		

Figures in the parenthesis indicate the number of entries

Table 3. Performance of DSb 21 in various trials

Trial	Seed yield (kg/ha)		% increase over JS 335
	DSb 21	JS 335 (C)	
Station trials (2009 to 2011)	2811	2469	13.8
Co-ordinated trial (IVT-2011, Southern zone)	3069	2549	20.4
Agronomy trial (2011)	2178	1850	17.7
Multilocation trial (UAS, Dharwad)	2975	2628	13.2
Onfarm trials	1874	1706	15.3
Large Scale Demonstrations	2958	2459	20.3

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On Farm Assessment of Integrated Nutrient Management in Soybean for Enhancing Productivity

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Intensive cultivation, growing of exhaustive crops, use of unbalanced and inadequate fertilizers accompanied by restricted use of organic manures and bio- fertilizers have made the soils not only deficient in the nutrients, but also deteriorated the soil health resulting in poor crop yields in the region. Under such a situation, integrated nutrient management system has assumed a great importance and has vital role in the maintenance of soil productivity. Organic manures, particularly vermicompost, not only supply macronutrients, but also improve soil health. Boosting yield, reducing production cost and improving soil health are three inter-linked components of the sustainability triangle. Therefore, in view of development of suitable combination of chemical fertilizers, organic manures and microbial cultures, the present investigation was undertaken to generate integrated nutrient management module for soybean for enhanced production on Vertisol and to convince the farmers for adoption of integrated nutrient management (INM) practices to enhance the productivity of soybean at their farms.

An on-farm trial was conducted for two consecutive years (2008 and 2009) in *kharif* seasons in village Chokhala (Bagidora block) of Banswara district of Rajasthan which comes under the southern sub-humid plain zone IV B of Rajasthan. The soil of the experimental site was clayey and analysed: pH (1:2.5) - 7.92, EC (1:2.5) - 0.32 dS/m, organic carbon - 0.38 per cent, available phosphorus 22 kg per ha and available potassium — 438 kg per ha. The soybean variety JS 335 was grown as a test crop. Three treatments *viz*, farmers practice (12: 30 :0 kg :: N: P_2O_5: K_2O/ha), general recommended doses of fertilizers as per the package of practices of Zone IVB of Rajasthan (40:40:0 :: kg N:P_2O_5:K_2O/ha) and INM based on soil test value (25:40:10 kg :: N:P_2O_5: K_2O/ha, in which 50 per cent N through vermicompost and remaining NPK was given by chemical fertilizers

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along with seed treatment with use of *Bradyrhizobium japonicum* and PSB cultures) were tested in a randomized block design with 4 replications. The trial was conducted at four farmers' field and each farmers' field was considered as a replication accommodating all the three treatments. In the treatment with farmer's practice, only di-ammonium phosphate was applied as basal. In case of the treatments general recommended doses of fertilizers and integrated nutrient management, entire amount of vermicompost, nitrogen, phosphorus and potassium were applied at sowing. Fertilizers used were urea, single super phosphate and urea, single super phosphate and muriate of potash, respectively in these two treatments. The seed was treated with *Bradyrhizobium japanicum* and PSB culture 2 h before the sowing time. The rainfall received during 2008 and 2009 was 499 mm and 632 mm, respectively. Soil samples collected after harvest of crop were air dried, ground, passed through a 2 mm sieve and analysed for pH, EC, organic carbon, available phosphorus and potassium contents using standard procedures (Jackson, 1967).

The highest seed yield of soybean (950 kg/ha) was recorded when crop was grown with INM based on soil test value while the lowest seed yield of 600 kg per ha was obtained with farmers' practice of nutrient management (Table 1). Use of integrated nutrient management on soil test basis enhanced the soybean yield to the tune of 32.5 and 58.33 per cent over general recommended practice and farmers existing practice of nutrient management, respectively. These results get support from earlier observations of Sahoo and Panda (2000) and Singh *et al.* (2008). The B:C ratio (1.44) and net returns (₹ 22 000/ha) were also higher with INM as compared to farmer's practice (1.04 and ₹ 13 800/ha). Superiority of the use of organic manures along with mineral fertilizers arrests the declining trend in soil productivity associated with the continuous application of fertilizers alone. The beneficial influence of organic inputs and chemical fertilizers could be related to increased biological activity in the soil, leading to better soil aggregation and nutrient availability (Palaniappan and Natarajan, 1993).

A reduction in soil pH and conductivity was noted in the treatment with INM as compared to sole application of chemical fertilizers (Table 2). Acids produced during decomposition of organic matter and released by the microbes were probably responsible for the reduction in soil pH. Increase in water holding capacity of soil due to improvement in soil aggregation (Duhan and Singh, 2002) probably remained responsible for the reduction in salt concentration as is evident from the facts that plot treated with INM remained moist for longer period as compared to the untreated ones. Organic carbon content of surface soil (Table 2) increased with the adoption of INM practice. Application of only chemical fertilizers showed negative impact and lowered the organic content of soil during studied period. The increase in organic carbon content in INM is attributed to the direct incorporation of organic matter in the soil. The subsequent

Table 1. Effect of balanced integrated nutrient management on seed yield and net profit of soybean cultivation

Treatment	Seed yield (kg/ha)			Net returns (₹/ha)	B:C ratio
	2008*	2009	Average		
Farmers practice[1]	210	990	600	13 800	1.04
General recommended doses of fertilizers[2]	300	1290	795	18 300	1.33
INM based on soil test[3]	450	1450	950	22 000	1.44
SEm (±)	28	44			
CD (p = 0.05)	**97**	**153**			

** Low yield during 2008 due to low rainfall (499 mm) in experimental area;[1](12:30:0 kg N, P_2O_5 and K_2O/ ha), [2] (40:40:0 kg N, P_2O_5 and K_2O/ ha); [3](25:40:10 kg N, P_2O_5 and K_2O/ha in which 50 % N through vermicompost and remaining NPK given by chemical fertilizers with seed treatment with rhizobium and PSB cultures)*

Table 2. Effect of treatment on fertility status of soil of studied area

Treatment	Fertility status of soil after 2 years				
	pH	EC (dS/m)	Organic carbon (%)	Available P (P_2O_5 kg/ha)	Available K (K_2O kg/ha)
Farmers practice [1]	8.05	0.26	0.23	19.32	398
General recommended doses of fertilizers[2]	8.02	0.23	0.28	20.05	411
INM based on soil test value[3]	7.77	0.19	0.67	26.81	485
SEm (±)	0.026	0.019	0.013	1.22	4.06
CD (p = 0.05)	0.090	0.065	0.046	4.22	14.05
	Pre-experimental fertility status				
	7.92	0.32	0.38	22.00	438

[1](12:30:0 kg N, P_2O_5 and K_2O/ ha), [2] (40:40:0 kg N, P_2O_5 and K_2O/ ha); [3](25:40:10 kg N, P_2O_5 and K_2O/ha in which 50 % N through vermicompost and remaining NPK given by chemical fertilizers with seed treatment with rhizobium and PSB cultures)

decomposition of these materials might have resulted in the enhanced organic carbon content of the soil (Singh *et al.*, 2008).

Available phosphorus and potassium content of surface soil (Table 2) increased with the INM treatment as compared to general recommended fertilizers and farmers' practice of nutrient management. The increase in available phosphorus content of soil might be due to release of CO_2 and organic acids during decomposition, which helps in solubilising the native soil P. Application of PSB significantly contributed towards the phosphate nutrition of soybean. The beneficial effect of vermicompost on available potassium may be ascribed to the reduction of K fixation, solubilization and release of K due to the interaction of organic matter with clay, besides the direct potassium addition to the potassium pool of the soil (Tandan, 1987).

On the basis of results of this on farm trial it can be concluded that balanced integrated nutrient management practice based on soil test value should be adopted in order to improve soil fertility and for enhancing productivity of soybean in farmer's field.

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Effect of Herbicides on Microbial population in Soil under Soybean Cropping

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Herbicide application for weed management is an integral part of plant protection in agriculture through chemicals. Herbicides (5 to 40 % of applied amount) are used partially for weed destruction and the rest of the amount remains in the environment due to high stability of these chemicals (Kozhuro *et al.*, 2005). Being a factor of man's impact on the environment, herbicides can play a role of toxicants under certain conditions, with manifestation of their effect on different living organisms.

Microorganisms involved in a number of biochemical processes that contribute plant nutrition. These include mineralization, nitrogen fixation, nitrification/denitrification, phosphate solubilization, antibiosis, siderophores production, plant growth regulation and induced resistance. Several groups of organisms act both competitively and synergistically to mediate the above processes (Alexander, 1971). Microbes also play an important role in soil structure maintenance, soil borne disease control and plant growth. In a cropping field study, paraquat increased populations of bacteria, fungi and actinomycetes at normal application rates but at higher application rates was toxic to fungi (Camper *et al.*, 1973). Both stimulating and inhibitory effects on microbial populations were observed, depending on concentration of the herbicide and the period of incubation (Pampulha et *al.*, 2007).

This study investigated the effects of herbicide application on the population of fungi, *Trichoderma* spp. (antagonist), bacteria and actinomycetes

Six commonly used herbicides in soybean cultivation were used to study the impact on soil microorganisms. There were eight treatments with three replications, which include two controls i.e. hand weeding (HWC) and no-hand weeding (UWC) for comparison. Populations of microorganisms were also estimated before sowing soybean.

Three groups of herbicides; pre plant incorporation (PPI), pre-emergence (PE) and post-emergence (PoE) were used (Table 1).

Three soil samples (10 cm deep, 60 mm diameter); one from each treatment

[1]*Principal Scientist*

were collected before sowing and 10 days after application of herbicides and bulked.

The bulked soil samples of each treatment were dried at room temperature in shade, vortex mixed and stored at room temperature. Culturable bacteria, actinomycetes, fungi and *Trichoderma* were then isolated by dilution plating (with three plate/replicates) on semi-selective medium used for specific organisms as described below.

Table 1. Herbicides and their doses

Chemical Name	Common name	Type of use	Dose (ai/ha)
Fluchloralin	Basalin	PPI	1.00 kg
Trifluralin	Treflan	PPI	1.00 kg
Pendimethalin	Stomp	PE	1.00 kg
Clomazone	Command	PE	1.00 kg
Imazethapyr	Pursuit	PoE	100 g
Quizalfop ethyl	Targa super	PoE	50 g

From the bulked samples of each treatment, 10 g soil was taken and mixed thoroughly in 100 ml sterile distilled water. From this 10 ml solution was aseptically drawn with sterile pipette, mixed in 90 ml sterile distilled water and simultaneously three successive dilutions were made. Mostly, third dilution was used for plating to assess the population of soil microorganisms.

Bacterial population in the soil was enumerated before sowing and after application of herbicides. Nutrient agar (NA)–medium was employed (American Public Health Association, 1920). From the third dilution 100 µL soil suspension was spread on NA plates, and plates were incubated for 48-72 h, the total number of bacteria was counted and expressed as population per g of soil.

The fungal population in the soil was also enumerated before sowing and after application of herbicides. A selective medium, Martin-Rose Bengal–Streptomycin-Agar medium (Martin's medium) was used (Martin, 1950). From third dilution 100 µL soil suspension was spread on the medium and plates were incubated for 6-7 days and the total number of fungi was counted and expressed as population per g of soil.

Actinomycetes population in the soil was enumerated before sowing and after application of herbicides using selective medium Arginine-glycerol-salt (AGS) medium (Moustafa and Lechevalier, 1963). From third dilution 100 µL soil suspension spread on the AGS medium and plates were incubated up to 10 days and the total number of actinomycetes was counted and expressed as population per g of soil.

The population of *Trichoderma* species in the soil was enumerated before sowing and after application of herbicides. A trichoderma selective medium (TSM), which contains chloramphenicol and streptocycline was employed (Elad *et al.*, 1981). From third dilution 100 µL was spread on TSM plates and plates were incubated for 6-7 days and the total numbers of *Trichoderma* colonies were counted and expressed as population per g of soil.

The pooled data of both the years revealed that as compared to HWC, the population of total soil microorganisms increased in herbicides applications irrespective of their nature and mode of application. In comparison to the UWC, the microorganisms reduced both in herbicide and hand weeded treatments with few exceptions. This may be attributed to the diversity of flora present in the UWC and nutrients provided by plant roots to the microorganisms (Smit *et al.,* 2001). Among herbicides, Targa super application increased the bacteria and actinomycetes, and Treflan and Command increased the trichoderma and fungi populations (Fig. 1- 4).

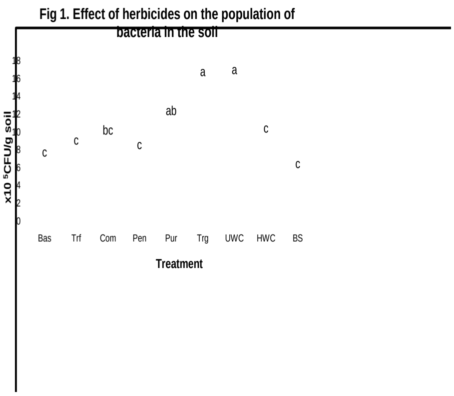
Bacterial population before sowing was 5.0x10^5 CFU per g soil and it increased in all the treatments after sowing of soybean. Among herbicides, the maximum population was recorded in Targa super (15.30x10^5 CFU/g soil) followed by Pursuit (10.94x10^5 CFU/g soil). Shukla (1997) has reported increase in bacterial population in rice soil with use of herbicides. The impact of herbicides on soil bacterial populations was found varying both between and within the groups. In soil applied with PPI herbicides, the bacterial population was lowest, whereas in case of PoE it was highest. In case of PE, the herbicide, Command application resulted in more bacterial populations (8.74x10^5 CFU/g soil), than pendimethalin (7.11x10^5 CFU/g soil). In UWC maximum population (15.58 x10^5 CFU/g soil) was recorded (Fig 1). The lowest population before the sowing was due to less soil moisture as the non-spore forming bacteria are less resilient to moisture stress (Labeda *et al.,* 1976). The bacterial population increased in presence of the crop as most of the bacteria are generally R-strategists (adapted to grow and multiply in high nutrient environments) so they are usually much more numerous on plant roots rather than in bulk soil (Smit *et al.,* 2001). Reasons for less population in soils applied with PPI herbicides may be that the compounds are detrimental to the bacteria and more over by that time there were no root or nutrient to support the growth of bacteria.

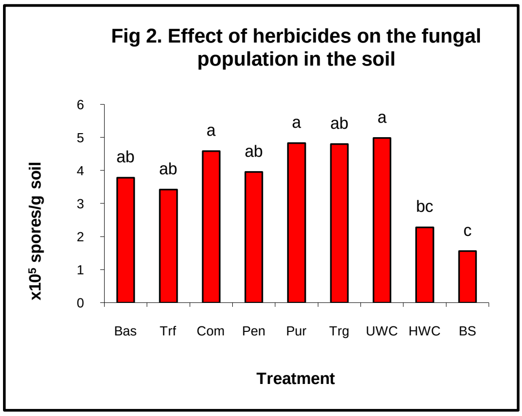
Before sowing the fungal population was less (1.56x10^5 CFU/g soil), which increased after sowing in all the treatments, however, their population was still lower as compared to the UWC, which has the maximum number of spores (4.98x10^5 CFU /g soil). It showed that the roots of some weeds may be encouraging more fungal populations. Among the herbicides treatment there were not much differences, however, Pursuit and Targa super (PoE) had the more population i.e. 4.8x10^5CFU/g soil, which is at par to the UWC (Fig 2). Treflan application had lower fungal population (3.42 x10^5 CFU/g soil), but more than HWC (2.28 x10^5 CFU/g soil). These findings are in agreement with Breazeale and Camper (1970), who found increased fungal population in trifluralin application than control. The lower fungal population in the trifluralin applied soil may be result of a combination of factors. This could result in severe competition for nutrients, in which the fungi are unsuccessful.

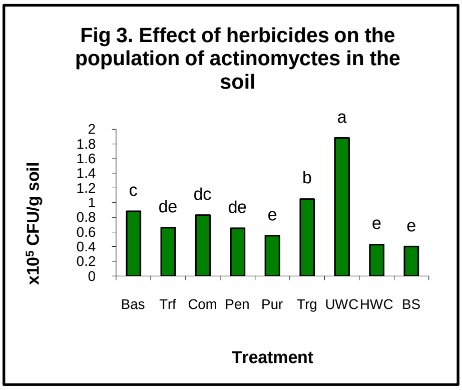
The results revealed that in all the treatments the population of actinomycetes was more after sowing as compared to before sowing of soybean (0.40x10^5 CFU/g soils). In HWC the population was minimum (0.43x10^5 CFU/g soil) and was maximum in UWC (1.88x10^5 CFU/g soil). Among the herbicides Targa super application had 1.05x10^5 CFU per g soils, which has an edge over other treatments. There was not much difference in the actinomycetes populations among the treatments. Different compounds behaved differently. PE herbicides application had less actinomycetes population than PPI and PoE. Pendimethalin and clomazone as PE had 0.88×10^5 CFU per g soils, while Targa super (quizolfop ethyl) as PoE had 1.05×10^5 CFU per g soil (Fig. 3). Nada and Govedarica (2002) have reported that the clomazone application stimulate the development of actinomycetes in the soil.

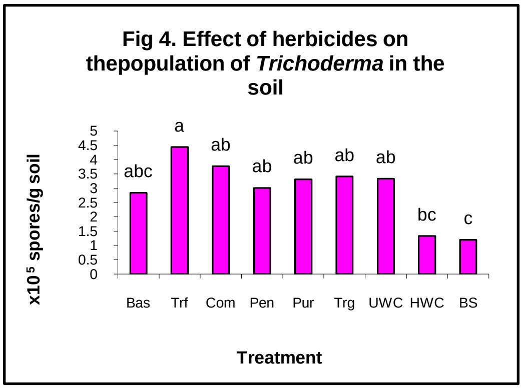
Data presented in Fig. 4 revealed that before sowing the population of *Trichoderma* was minimum (1.2×10^5 CFU/g soil), which increased after sowing in all the treatments and the highest value was recorded in Treflan-treated soil (4.44×10^5 CFU/g soil). Breazeale and Camper (1970) also reported similar findings. Among the herbicides the minimum population was recorded in Basalin (2.48×10^5 CFU/g soil) and maximum in Treflan (4.44×10^5 CFU/g soil). There was not much difference in the population of *Trichoderma* in the soil among different herbicide application. The less population before sowing may be due to moisture scarcity in the soil.

Glyphosate, a widely used broad spectrum, non-selective, post-emergence herbicide in Australian viticulture, has been shown to reduce soil bacterial populations in peach orchard and soybean field soils (Araujo *et al.,* 2003) and in wheat field soils (Mekwatanakarn and Sivasithamparam, 1987) and to reduce bacterial, actinomycete and fungal populations in forest soil (Gorlach-Lira *et al.,* 1997) and vineyard soil (Encheva and Rankov, 1990). On the other hand, some studies reported increased populations of bacteria in rice soil with butachlor, fluchloralin,2,4-D and oxyfluorfen (Shukla, 1997), soil actinomycetes and fungi with glyphosate (Araujo *et al.,* 2003), increased soil microbial biomass (Haney *et al.*, 2002) or no long-term change in microbial populations (Busse *et al.,* 2001). Glyphosate and paraquat were reported to cause activation in soil urease and invertase soil enzymes but suppression of phosphatase enzymes (Sannino and Gianfreda, 2001) whilst Diquat and Paraquat increased fungal populations, decreased the population of some fungal antagonists to take-all and increased the take-all incidence in wheat soil (Mekwatanakarn and Sivasithamparam, 1987). Different workers have reported different results; actinomycetes and fungal colonies increased due to trifluralin (Breazeale and Camper, 1970), metachlor caused reduction in bacteria, Alachlor was toxic to both bacteria and fungi (Ismail and Shamsuddin, 2005), Atrazine and metolachlor decreased microbial counts (Ayansina and Oso, 2006) and imazethapyr stimulated the growth of actinomycetes (Nada and Govedarica, 2002). Robert (2003) and Nada and Govedarica (2002) have demonstrated that many microorganisms utilize these compounds as a food source, initially reduce and then increase in population. This phenomenon is more common in warm and humid climate than cold climate. The persistence of herbicides is dependent on many factors such as temperature, soil moisture, and pH and nutrient levels (Taiwo and Oso, 1997).









Bas – Basalin; Trf – Trifluarin; Com – Command; Pen – Pendimethalin; Pur – Pursuit; Trd – Turga super; UMC – Un weeded control; HWC – Hand weeded control; BS – Bare soil

Note: Means followed by same alphabet are significantly not different, Tukey's test (P=0.05)

Except bacteria the other soil microorganisms were less in herbicides-treated soil, may be the effect of herbicides which had reduced the population of microorganisms or lethal to the organisms. Ayansina and Oso (2006) also observed that the soil treated with herbicides had much lower microbial counts compared to soils with untreated or low dose treated herbicides. Among herbicides Targasuper was found to encourage the population of bacteria and actinomycetes more and less so the population of fungi and *Trichoderma*, may be the chemical present in utilized by these organisms.

From the results obtained, it is evident that the microfloral populations in herbicide-applied soil were altered. A change in the normal soil microflora may be either beneficial or harmful to soil fertility. Loss of microbial biodiversity can affect the functional stability of the soil microbial community. Significant populations of microorganisms with the ability to attack or suppress plant pathogenic fungi. Thus a more critical evaluation of the effects of soil applied herbicides on microbial populations is needed.

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NRC 107– AN EARLY MUTANT OF SOYBEAN VARIETY 'NRC 37'

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The soybean variety NRC 37, released and notified in 2001 for cultivation in the Central zone in India, has high yield potential with very good germination, resistance to collar rot, bacterial pustule, pod blight, stem fly and leaf minor. Despite its high yield potential and very good seed longevity, its adoption by farmers had been limited mainly due to its late maturity. Gamma irradiation has been used as a successful tool to develop early flowering and early maturity mutants in pearl millet, mung bean, rice etc. which could escape the adverse environmental conditions and fit well into double cropping system (Hanna and Burton, 1985; Rutger *et al*., 2004; Khan and Goyal, 2009, Shehzad *et al.*, 2011). Neto *et al.* (1997) in Brazil could reduce the duration of soybean *cv.* 'Parana' by 10 days using gamma ray mutation breeding. Song (2010) developed a new soybean variety 'Josaengseori' by shortening the maturity period of black soybean 'Seoritae' by 10 days using gamma irradiation.

Fig. 1. Plants of NRC 107 bearing fully formed pods (Left) and NRC 37 with flower initiation (Right) at 45 days after sowing

To reduce the maturity of *cv.* NRC 37, 500 g seeds were treated with gamma irradiation at a dose of 250 Gy at Bhabha Atomic Research Centre, Mumbai and M_1 plants were raised in the fields at Directorate of Soybean Research, Indore

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Fig. 2. Fully matured NRC 107 (Right) and NRC 37 at $R_{6\text{-}7}$ stage (Left) at 85 days after sowing

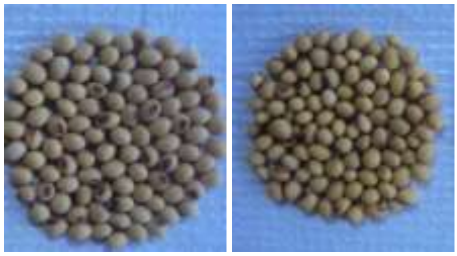

Fig. 3. Freshly harvested seeds of NRC 107 **(Right) and NRC 37 (Left)**

in cropping season 2007. M_2 plants were screened for early flowering and early maturity traits. One mutant plant flowering in 28 days and maturing in 85 days was advanced to M_5 generation and designated as NRC 107 (Fig. 1).

The early flowering and early maturity traits of this new genotype were found to be stable. The plant of NRC 107 bears white flowers at 28 days as compared to 45 days of NRC 37, and matures in 85 days (20 days earlier than NRC 37) with 5-6 clusters of 4-6 brown pods on the main stem, and produces seeds with yellow coat and brown hilum similar to the parent variety NRC 37 but was found to be resistant to lodging. NRC 107 has shorter plant height (67 cm) and larger seed size with seed index of 13.0 g compared to 75 cm plant height and 11.0 g seed index of NRC 37 (Fig. 2 and 3), with yield levels of 3.0 tonnes per ha. Thus, NRC 107, an early maturing mutant of NRC 37 having higher seed index, resistance to lodging maintaining the high yield potential of NRC 37 will prove to be promising alternative varietal diversification of soybean.

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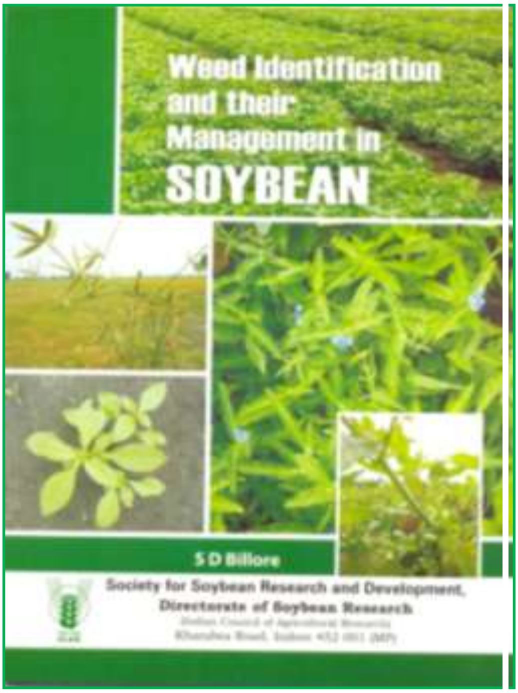
A new book - "Weed identification and their management in soybean" published



A book encompassing the details on identification and management of weeds in soybean has jointly been published by Society for Soybean Research and Development and Directorate of Soybean Research, Indore, Madhya Pradesh. The book, authored by Dr S D Billore, Sr. Scientist (Agronomy), DSR, comprehensively deals with the general weed scenario in soybean, possible yield losses, preventive along with cultural, mechanical and chemical methods of weed management, mode of action of herbicides in usage and 250 coloured photographs of weeds with common and botanical nomenclature for easy identification. The publication is expected to meet the requirement of farmers, students, teachers, researchers and extension workers associated with soybean crop.

This publication is available for sale at a price of Rs. 250/-. Interested persons can procure it from the office of Soybean Research and Development, Directorate of Soybean Research, Khandwa Road, Indore 452 001, M P on cash payment. One can also opt for receiving it by post by sending the cost (Rs 250/-) of book plus Rs 50/- as postal charges by remitting the amount through DD in favour **Society for Soybean Research and Development**".