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CONTENTS

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Morphological Characterization and Genetic Divergence Study in Soybean

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ABSTRACT

Present investigation was carried out to study the genetic divergence and morphological characterization in 57 promising genotypes of soybean at G B Pant University of Agriculture and Technology in kharif *2004. These genotypes were evaluated for sixteen morphological and yield contributing traits. On the basis of character association analysis, it is evident that number of pods per plant, hundred seed weight, harvest index and dry matter weight per plant had major contribution in determining seed yield per plant in soybean. As per D^2 statistic, these genotypes were grouped in ten clusters, whereas maximum number of genotypes represented by cluster I (34 genotypes) followed by cluster II (7 genotypes) and cluster III (6 genotypes). Clusters VII, VIII, IX and X comprised of only one genotype each. Maximum genetic divergence was observed between clusters IX and X, whereas lowest genetic divergence was between clusters IV and VII. The genotypes included in the cluster with maximum inter-cluster distance were genetically more divergent therefore; these breeding lines with high mean value can be utilized for future breeding programmes to get heterotic segregants. Number of pods per plant contributed maximum (22.05 %) towards the genetic divergence followed by plant height (20.73 %), 100 seed weight (17.98 %), dry matter weight per plant (14.22 %) and days to 50 per cent flowering (12.40 %). Based on this study, the genotypes, namely* Glycine soja*, PK 327, PK 308, PS 1029, UPSM 534, Bhatt, MACS 450, Alankar and Kalitur were identified as important donors for important characters. Whereas, potential parental combination, specifically* Glycine soja *derived pre-breeding lines, namely T-49 x* Glycine soja*, PS 1029 x* Glycine soja*, Pusa 40 x* Glycine soja*, PK 564 x* Glycine soja *and MACS 450 x* Glycine soja*, may be expected as better recombinant for economically important traits.*

Key words: Cluster, genetic divergence, heterotic segregants, recombinant

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Soybean (*Glycine max* (L.) Merrill) is often designated as a miracle crop, which is being used as a potential source of edible oil, protein and nutritious food. *Glycine soja* Seib and Zucc are reported to be the probable progenitor of cultivated soybean (2n = 40). The major thrust in soybean breeding has been on the development of high yielding varieties. In India yield potential of the existing soybean varieties is 2,500-3,500 kg per ha and this need to be stepped up to 4,000 kg per ha in the near future. Improvement in any crop is possible only when sufficient genetic variability exists in the population of that species. Especially the hereditary variation is of major interest to the plant breeders without which no heritable plant improvement is possible. Genetic divergence among parents is of paramount importance in selecting parental genotypes for crossing programme. More diverse the parents, greater are the chances of achieving heterotic F_{1s} and a broad spectrum variability in segregating generations. Yield is the function of various traits and their interaction with the environment. Genetic diversity and the diverse gene pool are the basis of plant breeding and genetic engineering. A planned utilization of genetic diversity for any of the economically important traits present in land races, cultivars and wild relatives aims at pyramiding of genes for higher productivity, better quality and resistance to biotic and abiotic stresses, ultimately to evolve the higher yielding varieties. In case of Indian soybean varieties, a narrow genetic base has been of great concern so there is a need to divert major attention for broadening the genetic base of future varieties.

To meet the requirement of the Plant breeders and Farmers Rights Act 2001, it is imperative to identify a set of morphological traits, which can be used for DUS (Distinctness, Uniformity and Stability) testing. In view of this, the present investigation was taken up to assess the extent of the genetic divergence in Indian soybean varieties and identify genetically most diverse soybean varieties.

MATERIAL AND METHODS

The present investigation was comprised of the 57 genotypes encompassing the varieties released from different agro-climatic zones of India. These genotypes were evaluated at N E Borlaug, Crop Research Centre Pantnagar, India during *kharif* 2004. Pantnagar is situated at 29^{o}N latitude, 79.30 ^{o}E longitudes and an altitude of 248.84 m above the mean sea level. The type of the soil of the experimental area was sandy loam. The genotypes selected for the investigation were genetically diverse and exhibited a wide range of variation for all the characters studied. The experiment was carried out in randomized block design with two replications. Each plot consisted of 2 rows of 4 meter length with spacing of 60 cm row to row and 5-6 cm for plant to plant. The recommended package of practices was followed to raise a healthy crop. Observations were recorded on five random competitive plants for eight quantitative characters, namely days to flowering, days to maturity, plant height (cm), number of pods per plants, 100-seed weight (g), seed yield per plant (g), dry matter weight per plant (g) and harvest index. To assess the divergence among the genotypes, Mahalanobis D^2 statistic (Singh and Chaudhary, 1979) was employed. Based on the genetic distance, all the genotypes were grouped into different clusters. D^2 being treated as the square of generalized distance, according to the method described by Tocher (Rao, 1952).

RESULTS AND DISCUSSION

The analysis of variance showed highly significant differences among the genotypes for all the eight characters studied (Table 1). The coefficient of variation ranged from 4.58 per cent for days to maturity to 8.56 per cent with seed yield per plant (g). The analysis of variance revealed existence of sufficient genetic diversity between the genotypes. On the basis of Mahalanobis D^2 statistics 57 soybean genotypes were grouped into ten clusters (Table 2). The cluster I was the largest containing 34 genotypes followed by cluster II with 7 genotypes and cluster III with 6 genotypes. Cluster IV, V and VI were comprised of two genotypes each, whereas cluster VII, VIII, IX and X of one genotype each.

The pattern of distribution of genotypes in different clusters indicated that the genotypes collected from different locations were often found to occur in the same cluster. As per "plant descriptor of soybean" important morphological characters namely, hypocotyle colour, leaf shape, flower colour, pubescence colour, pod colour, seed coat colour and hilum colour were considered important and appears in different frequencies in different clusters. Investigation revealed that varieties developed from different agro- ecological zones showed different morphological characteristic and the genotype within the cluster were not following a definite clustering pattern. Even varieties

Table 1. Analysis of Variance for yield and yield contributing characters in 57 genotypes of soybean

Source of variation	DF	Mean squares							
		Days to 50% flowering	Days to maturity	Plant height (cm)	Number of pods per plant	100 seed weight	Seed yield (g/ plant)	Dry matter weight per plant (g)	Harvest index
Block	1	2.66	3.40	96.50	50.58	1.55	0.38	12.06	0.12
Treatments	56	33.26**	14.90**	515.30**	586.08**	8.12**	38.07**	295.59**	0.23**
Error	56	12.74	31.30	26.4	26.59	0.57	1.80	15.48	0.37

DF: Degree of freedom

Table 2. Clustering pattern of 57 genotypes of soybean based on D^2 statistics

Cluster number	Name of genotypes	Number of genotypes
I	Ankur, Bragg, Birsa soya 1, Co 1, Co 2, Hara Soya, Improved Pelican, JS 335, JS 72-280, JS 72-44, JS 76-205, JS 79-81, Lee, MACS 124, MACS 57, Monetta, NRC 2, NRC 12, NRC 37, NRC 7, PS 1024, PK 308, PK 416, PK 472, Pb 1, Pusa 20, Pusa 22, Shilajeet, Shivalik, SL 295, PK 1225, PK 515, PK 1337, PS 1337	34
II	Alankar, Hardee, MAUS 47, PS 1029, PK 262, PK 471, VLS 47	7
III	Kalitur, MACS 13, MACS 450, MACS 58, PS 1241, Bhatt	6
IV	PK 327, PK 564	2
V	GS 1, Pusa 40	2
VI	JS 80-21, KHSb 2	2
VII	Pusa 16	1
VIII	T 49	1
IX	UPSM 534	1
X	*Glycine soja*	1

included in PK and PS series developed at Pantnagar were represented in different clusters. Thus, the major cluster I containing the genotypes of heterogeneous origin suggested that the pattern of clustering of genotypes was independent of their geographic origin and hence, genetic diversity may not necessarily be related to geographical diversity. The present findings are in agreement with those of Das *et al.* (2000), Ganesamurthy and Seshadri (2002), Kumar and Nandrajan (1994) and Tyagi and Sethi (2011). The clustering of genotypes from different eco-geographic locations into one cluster could be attributed to the free exchange of breeding materials from one place to another (Raut *et al.*, 2001).

Intra and inter-cluster average D^2 values (Table 3) and genetic distance (D values) (Table 4) revealed that intra-cluster average D values (genetic distance) ranged from 0.00 to 2.71. The inter-cluster distances were higher than the average intra-cluster distances, which indicated wide distance between the clusters. Cluster V comprised maximum intra-cluster average D value (2.71) with 2 genotypes followed by cluster III (2.58) with 6 genotypes, cluster VI (2.51) with 2 genotypes, cluster II (2.17) with 7 genotypes, cluster I (2.16) with 34 genotypes and cluster IV (1.95) with 6 genotypes. Cluster VII, VIII, IX and X comprised one genotype each, hence the intra-cluster distance in these clusters was zero. The inter-cluster average D values (genetic distance) was maximum

Table 3. Average intra and inter-cluster D^2 Value of 57 genotypes of soybean

Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X
I	4.68	7.72	10.56	11.19	11.25	9.15	9.89	23.25	14.64	48.90
II		4.73	9.15	10.99	13.69	11.63	13.81	27.44	12.17	55.30
III			6.70	15.71	14.57	10.92	11.30	23.86	12.52	52.46
IV				3.83	10.12	21.78	6.78	27.73	25.78	54.90
V					7.35	26.62	13.94	11.14	21.40	55.05
VI						6.23	25.64	35.55	10.27	45.52
VII							0.00	28.90	28.78	53.03
VIII								0.00	24.39	63.08
IX									0.00	65.48
X										0.00

Table 4. Average intra and inter-cluster distance (D) of 57 genotypes of soybean

Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X
I	2.16	2.78	3.25	3.34	3.35	3.02	3.14	4.82	3.82	6.99
II		2.17	3.02	3.31	3.70	3.41	3.71	5.23	3.48	7.43
III			2.58	3.96	3.81	3.30	3.36	4.88	3.53	7.24
IV				1.95	3.18	4.97	2.60	5.26	5.07	7.40
V					2.71	5.15	3.73	3.33	4.62	7.41
VI						2.51	5.06	5.96	3.20	6.74
VII							0.00	5.37	5.36	7.28
VIII								0.00	4.93	7.94
IX									0.00	8.00
X										0.00

between cluster IX and cluster X (8.00) with one genotype each cluster followed by cluster VIII and cluster X (7.94) with one genotype in each cluster and cluster II and X (7.43) with 7 genotypes in cluster II and one genotype in cluster X. The minimum inter-cluster average D value (2.60) was found between cluster IV with 2 genotypes and cluster VII with one genotype followed by between cluster I with 34 genotypes and cluster II with 7 genotypes (2.78) and cluster I and cluster VI (3.02) and cluster II and cluster III (3.02) with 34 genotypes in cluster I, 2 genotypes in cluster VI, 7 genotypes in cluster II and 6 genotypes in cluster III, respectively. It indicated that the varieties of these clusters are very close to each other. Thus hybridization between genotypes, UPSM 534 and *Glycine soja* falling in the most distant clusters (IX and X) should result in highest number of useful segregants and better recombinant (Shwe *et al.*, 1972). Hybridization between genotypes from highly divergent groups could produce new and heterotic

Table 5. Cluster mean values and contribution towards genetic divergence of different yield contributing traits

Characters	I	II	III	IV	V	VI	VII	VIII	IX	X	Contri-bution (%) towards divergence
Days to 50 % flowering	58.59	56.50	59.00	60.75	60.75	55.00	60.00	64.00	65.00	75.00	12.40
Days to maturity	120.53	120.85	124.12	118.50	122.00	122.75	122.00	126.00	122.00	130.00	4.88
Plant height (cm)	70.47	62.34	89.26	51.66	77.52	91.37	73.50	112.00	81.00	133.56	20.73
Number of pods/plants	64.54	78.74	95.45	78.75	61.54	71.50	107.50	57.00	74.40	135.00	22.05
100-seed weight (g)	10.75	13.09	11.81	9.75	10.54	11.16	9.53	11.18	15.30	0.36	17.98
Seed yield/ plant	13.90	20.21	22.04	15.85	13.12	15.25	20.50	12.50	23.25	1.50	4.07
Dry matter weight/plant (g)	40.93	55.10	63.9	57.50	49.75	39.50	71.00	50.50	61.00	7.50	14.22
Harvest index	0.33	0.34	0.34	0.27	0.25	0.38	0.28	0.25	0.36	0.19	3.63

Table 6. Identification of donors for important yield contributing characters

Characters	Donors		
Days to 50 % flowering	KHSb 2	PK 515	Bhatt
Days to maturity	PK 327	Co 1	PK 308
Plant height (cm)	PK 471	Birsa soya 1	PK 262
Number of pods/plants	*Glycine soja*	Pusa 16	Kalitur
100-seed weight (g)	UPSM 534	PS 1029	Alankar
Seed yield/plant	MACS 450	Alankar	PS 1241
Dry matter weight/plant (g)	MACS 450	Pusa 16	Bhatt
Harvest index	Birsa soya 1	JS 80-21	UPSM 534

unknown gene combinations.

On the basis of cluster mean (Table 5), cluster IX emerged important for 100-seed weight and seed yield per plant. Cluster X had highest mean value for number of pods per plant, plant height, days to maturity and days to 50 per cent flowering along with lower 100-seed weight, seed yield per plant, dry matter weight per plant and harvest index. Cluster VII had highest mean value for dry matter weight per plant, while cluster VI had highest mean value for harvest index and lowest for days to 50 per cent flowering. Cluster IV had lowest mean value for plant height and days to maturity, while cluster VIII had lowest mean value for number of pods per plant. Thus, indicating that PK 327 and PK 564 are early maturity type and *Glycine soja* and T 49 are late maturity type.

The contribution of characters towards diversity of the genotypes revealed maximum contribution (22.05 %) by number of pods per plants followed by plant height (20.73 %) and 100-seed weight (17.98 %) and minimum contribution by harvest index (3.63 %) followed by seed yield per plant (4.07 %) and days to maturity (4.88 %). Over 60.76 per cent of the diversity among the genotypes was accounted by number of pods per plants, plant height and 100-seed weight, suggesting the scope for yield improvement by exploiting variability for these traits.

Based on the genetic divergence analysis, it would be possible to point out some potential combinations, subject to the condition that environment maintain the relative expression of characters with regard to the genotypes. Thus, the varieties which show maximum value of cluster mean can be used as a donor parent in future breeding programme for different important characters (Table 6). To a great extent, it may be possible to obtain largely identical clustering pattern (Murty *et al.*, 1973 and Chaudhary, 1975), but it is a safe strategy to expect non-repeatability pattern afresh before taking out a useful breeding programme. A compromise may, however, be possible if for instance hybridization between varieties belonging to clusters having the maximum inter-cluster divergence is only to be attempted. Since the top and the bottom clusters are likely to be largely repeatable unless environment causes a major change in the trend of D^2 values (Arunchalam, 1981).

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Response of Soybean [*Glycine max* (L.) Merrill] Varieties to Fertility Levels in Vertisols of Vindhyan Plateau of Madhya Pradesh

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ABSTRACT

A field experiment was conducted during kharif *2009, 2010 and 2011 under All India Co-ordinated Research Project on soybean at R A K College of Agriculture, Sehore to assess the optimum nutrient level for soybean varieties in Vertisols of Vindhyan plateau of Madhya Pradesh. The growth and yield attributes, seed and straw yield, total uptake and balance of nitrogen, phosphorus and potassium in soil were significantly higher with the application of 125 per cent recommended dose of fertilizers (RDF - 20:60:20:20:: N:P_2O_5:K_2O:S kg/ha) with FYM @ 5 t per ha than other fertilizer schedules except 100 per cent RDF with FYM @ 5 t per ha. Soybean variety JS 95-60 recorded significantly higher growth, yield attributes (except pods/plant and straw yield), seed yield and total uptake and balance of nitrogen, phosphorus and potassium in soil over soybean variety JS 97-52. The treatment comprised of 125 per cent RDF with FYM @ 5 t per ha and variety JS 95-60 fetched highest net returns and B: C ratio.*

Key words: Fertility levels, soybean, varieties

Soybean [*Glycine max* (L.) Merrill] has emerged as a potential oilseed crop and has brought perceptible change in the economy of the farmers in the state of Madhya Pradesh. It is cultivated over an area of 5.81 million ha with production of 6.68 million tons in this soya state of the country (Anonymous, 2012). This crop is also a richest and cheapest source of best quality protein (40 %) and fat (20 %). Since 1980 onward, many varieties were developed in different parts of the country, which have different maturity and yield potentials. These varieties having different maturity and canopy characteristics being cultivated with the same recommended levels of nutrients. Superior performance of newly developed varieties has been reported earlier (Rajput and Shrivastava, 1999, Billore *et al*., 2000, and Pandya *et al*., 2005). Therefore, to know the nutrient

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requirement of newly released varieties having different maturity duration, the present investigation was undertaken in *Vindhayan* Plateau agro-climatic zone of Madhya Pradesh.

MATERIALS AND METHODS

A field experiment was conducted for consecutive 3 years (*kharif* 2009-12) under AICRP on soybean at College of Agriculture, Sehore to assess the optimum fertility levels for currently cultivated varieties of soybean under *Vindhyan* plateau of Madhya Pradesh. Sehore is situated in the eastern part of Vindhyan plateau in sub-tropical zone at the 27^0 12′ North latitude and 77^0 05′ East longitudes at an altitude of 498.77 m above mean sea level in Madhya Pradesh. The soil was clay loam in texture, having pH 7.6, organic carbon 0.46 per cent and 245.25, 17.8 and 425.24 kg per ha of available N, P_2O_5 and K_2O, respectively. The experiment was laid out in factorial randomized block design with 3 replications encompassing two soybean varieties (JS 95-60 and JS 97-52), 8 fertility levels (75 % RDF without FYM, 75 % RDF with FYM @ 5 t/ha, 100 % RDF without FYM, 100 % RDF with FYM @ 5 t/ha, 125 % RDF without FYM, 125 % RDF with FYM 5 t/ha, FYM @ 5 t/ha) and an absolute control. Crop was sown in the month of July (on 03rd July, 2009, 06th July, 2010 and 2nd July, 2011) and harvested in September-October each year according to the maturity of varieties (*cv* JS 95-60 on 28th September, 2009, 30th September, 2010 and 13th October, 2010 and JS 97-52 on 13th October, 2009, 15th October, 2010 and 12th October, 2010).

The RDF was 20 kg N + 60 kg P_2O_5 + 20 kg K_2O + 20 kg S per ha. Nutrients were applied in the form of urea, single super phosphate and muriate of potash. Crop was raised following the recommended package of practices. Representative samples of soil, seed and straw were analyzed for ascertaining the nutrient content (N, P and K). Observations were recorded on growth and yield attributes namely, dry weight per plant, crop growth rate, relative growth rate, pods per plant and 100 seed weight.

RESULTS AND DISCUSSION

Growth and yield attributes

Fertility levels had significant impact on growth and yield attributes, namely dry matter accumulation, crop growth rate (CGR), nodule weight and pods per plant (Table 1 and 2). Whereas, relative growth rate (RGR) and seed index were not influenced due to fertility levels. Fertility levels resulted in significant improvement in dry matter accumulation and CGR gradually up to 100 per cent RDF. Significantly more number of pods per plant at harvest was obtained on application of 125 per cent RDF. The better nutritional environment for plant growth at active vegetative stage as a result improvement in root growth, which ultimately increased the dry matter and CGR. The increase in the rate of biosynthesis of various plant metabolites and physiological processes in the plant system might have led to increase the rate of pod formation and the results confirm the findings of Kumrawat *et al*. (1997), Sharma and Dixit (1987) and Prasad and Sanoria (1981).Variety JS 95-60 recorded higher values for all growth and yield attributes except pods per plant, which were higher in variety JS 97-52.

Yield and quality

Soybean variety JS 95-60 recorded significantly higher yield (2,141 kg/ha) than JS 97-52 (1,424 kg/ha). Similarly, the higher protein content in seed was obtained in JS 95-60 (40.26 %) than JS 97-52 (39.26 %). But the JS 97-52 gave significantly higher straw yield (3,348 kg/ha) than JS 95-60 (1,379 kg/ha). Fertility levels caused significant impact on seed yield (Table 2). Significantly higher seed yield was obtained with successive increase in fertility levels up to 125 per cent RDF + FYM @ 5t per ha. Deshmukh *et al.* (2005) have also reported similar results. Varying fertility levels did not cause significant variation in straw yield and harvest index. Protein content in seed was higher at higher levels of nutrition may be because of increased availability of nitrogen followed by higher N uptake by the crop. Increase in protein content with increasing fertility levels was also reported by Kacha *et al.* (1990) and Lone *et al*. (2009)

Nutrient uptake

Nitrogen, phosphorus and potassium uptake was significantly influenced by the different fertility levels and varieties. Application of 125 per cent RDF + FYM @ 5 t per ha significantly increased the N and K uptake, which was at par with 100 per cent RDF + FYM @ 5 t per ha (Table 1). However, P uptake was increased with each successive increase in fertility level. The increase in nutrient uptake by integrating of FYM with inorganic fertilizers may be due to increased availability of nutrients to the plants. It also improves the soil environment, which enhances profuse root system resulting in better absorption of moisture and nutrients. Thus, it resulted in higher biomass production. Application of 125 per cent RDF alone and with FYM @ 5 t per ha increased the N, P and K uptake by 78.52, 22.00 115.48, 66.66 9.42 and 95.79 per cent, respectively as compared to unfertilized control. These results corroborated the findings of Meena *et al.* (2006) and Sharma and Dixit (1987). Prasad and Sanoria (1981) reported that applied phosphorous improved the nutrient uptake because of its significant role in regulating the photosynthesis, root development and enhanced microbial activities. The high level of phosphorous resulted in the maximum uptake of NPK due to close association of N and P in the process of metabolism in plant cells. Variety JS 95-60 recorded significantly higher uptake of nitrogen, phosphorous and potassium than JS 97-52.

Post harvest N status and N balance

Available N status in post-harvest soil increased significantly with successive the post-harvest N fertility in soil. Application of FYM temporary enhanced the biological immobilization and continuous mineralization of FYM on surface layer of the nutrient to soybean in adequate amount and remained in soil in

Table 1. Effect of fertility levels and varieties on dry matter, CGR, RGR, nodule dry weight, total uptake of nitrogen, phosphorus and potassium at harvest (Pooled data of 03 years)

Treatment	Dry matter (g/plant)			Crop Growth rate (g/day)		Relative growth rate (g/g/day)		Nodule dry weight (g/plant)	Total uptake (kg/ha) of macro-nutrient at harvest		
	30 DAS	45 DAS	60 DAS	30-45 DAS	45-60 DAS	30-45 DAS	45-60 DAS		Nitrogen	Phosphorus	Potassium
Fertility levels											
75 % RDF	1.44	4.36	7.25	5.37	5.51	0.077	0.034	0.638	125.66	15.35	73.62
75 % RDF + FYM @ 5t/ha	1.39	5.06	7.75	6.99	5.07	0.088	0.028	0.634	131.27	16.84	80.38
100 % RDF	1.50	5.17	8.73	7.02	6.39	0.083	0.035	0.684	135.12	17.00	80.65
100 % RDF + FYM @ 5t/ha	1.44	5.39	9.05	7.48	6.42	0.090	0.035	0.718	143.47	19.50	91.02
125 % RDF	1.50	5.75	9.39	8.04	6.38	0.091	0.033	0.747	137.06	18.00	86.82
125 % RDF + FYM @ 5t/ha	1.34	5.97	9.92	8.84	6.96	0.102	0.034	0.768	146.80	20.58	92.98
FYM @ 5t/ha	1.28	4.47	7.00	6.16	4.68	0.086	0.030	0.628	89.38	10.49	58.32
Absolute control	1.06	3.93	6.34	5.38	4.56	0.093	0.032	0.449	82.23	9.27	55.76
SEm (±)	0.17	0.18	0.32	0.44	0.82	0.007	0.004	0.028	2.39	0.29	1.49
CD (P=0.05)	**NS**	**0.55**	**0.98**	**1.32**	**NS**	**NS**	**NS**	**0.085**	**7.18**	**0.88**	**4.29**
Varieties											
JS 95-60	1.63	5.48	8.34	9.25	6.88	0.082	0.028	0.668	162.67	21.97	93.28
JS 97-52	1.10	4.54	8.01	4.57	4.62	0.096	0.037	0.658	85.08	9.78	61.60
SEm (±)	0.06	0.09	0.21	0.23	0.41	0.003	0.002	0.012	1.18	0.15	0.74
CD (P = 0.05)	**0.17**	**0.28**	**NS**	**0.66**	**1.19**	**0.009**	**0.006**	**NS**	**3.59**	**0.44**	**2.15**

Table 2. Effect of fertility levels and varieties on yield attributes, seed and straw yields, harvest index, protein content and economics of soybean (Pooled data of 03 years)

Treatment	Pods (No/ plant)	Seed index (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Protein content (%)	Net returns (Rs/ha)	B:C ratio
Fertility levels								
75 % RDF	34.39	8.75	1736	2460	43.44	39.71	27090	3.44
75 % RDF + FYM @ 5t/ha	36.11	8.92	1830	2431	44.52	40.01	29153	3.63
100 % RDF	39.83	8.50	1926	2493	45.67	40.02	31271	3.82
100 % RDF + FYM @ 5t/ha	44.78	8.83	1974	2515	45.19	40.31	32341	3.91
125 % RDF	46.50	8.50	1985	2510	45.90	40.25	32573	3.94
125 % RDF + FYM @ 5t/ha	48.67	8.83	2073	2482	47.64	40.67	34511	4.11
FYM @ 5t/ha	32.17	8.75	1442	2114	41.59	39.34	20619	2.86
Absolute control	30.11	8.67	1293	1960	40.33	37.78	17344	2.56
SEm (±)	1.11	0.15	16	83	1.35	0.17	353	0.03
CD (P=0.05)	3.19	NS	48	250	4.05	0.50	1060	0.10
Varieties								
JS 95-60	24.08	10.96	2141	1382	56.26	40.26	36003	4.24
JS 97-52	54.06	6.48	1424	3351	32.37	39.26	20222	2.82
SEm (±)	0.55	0.07	31	37	0.67	0.86	707	0.06
CD (P=0.05)	1.59	0.22	96	110	2.02	NS	2121	0.19

Table 3. Effect of fertilizers levels and varieties on available nitrogen, phosphorus and potassium and balance of nitrogen, phosphorus and potassium (Pooled data of 03 years)

Treatments	Initial (kg/ha)			Added through fertilizers (kg/ha)			Calculated availability (kg/ha)			Expected balance (kg/ha)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1	2	3	4	5	6	7	8	9	10	11	12	13
Fertilizer levels												
75 % RDF	245.25	17.8	425.24	15	45	15	260.25	62.8	440.24	134.59	47.45	366.62
75 % RDF + FYM @ 5t/ha	245.25	17.8	425.24	40	55	40	285.25	72.8	465.24	153.98	55.96	384.85
100 % RDF	245.25	17.8	425.24	20	60	20	265.25	77.8	445.24	130.13	60.80	364.58
100 % RDF + FYM @ 5t/ha	245.25	17.8	425.24	45	70	45	290.25	87.8	470.24	146.78	68.30	379.21
125 % RDF	245.25	17.8	425.24	25	75	25	270.25	92.8	450.24	133.20	74.79	363.42
125 % RDF + FYM @ 5t/ha	245.25	17.8	425.24	50	85	50	295.25	102.8	475.24	148.45	82.22	382.26
FYM @ 5t/ha	245.25	17.8	425.24	25	10	25	270.25	27.8	450.24	180.87	17.32	391.92
Absolute control	245.25	17.8	425.24	-	-	-	245.25	17.8	425.24	163.02	8.53	369.48
Varieties												
JS 95-60	245.25	17.8	425.24	27.5	50.0	27.5	272.75	67.8	452.74	110.08	45.83	359.45
JS 97-52	245.25	17.8	425.24	27.5	50.5	27.5	272.75	67.8	452.74	187.67	58.01	386.64

Table 3. contd.

Treatments	Actual balance (kg/ha)			Net loss/ gain (kg/ha)			Crop removal (kg/ha)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
	14	15	16	17	18	19	20	21	22
Fertilizer levels									
75 % RDF	253.20	14.24	292.28	7.94	-3.56	-32.95	125.66	15.35	73.62
75 % RDF + FYM @ 5t/ha	257.08	14.55	401.72	11.83	-3.25	-23.52	131.26	16.84	80.38
100 % RDF	255.00	15.58	394.48	9.75	-2.21	-30.75	135.12	17.00	80.65
100 % RDF + FYM @ 5t/ha	258.62	15.84	405.28	13.37	-1.95	-19.96	143.47	19.54	91.02
125 % RDF	256.45	16.23	396.20	11.20	-1.57	-29.06	137.06	18.00	86.82
125 % RDF + FYM @ 5t/ha	261.36	17.05	408.07	16.11	-0.75	-17.17	146.80	20.58	92.98
FYM @ 5t/ha	256.15	15.52	395.61	10.90	-3.80	-29.63	89.37	10.48	58.32
Absolute control	245.86	8.85	383.98	0.62	-8.95	-41.26	82.23	9.27	55.76
Varieties									
JS 95-60	252.35	14.58	394.99	7.32	-3.59	-30.24	162.66	21.97	93.28
JS 97-52	258.58	14.89	399.41	13.32	-2.90	-25.83	85.08	9.79	61.60

considerable quantity after meeting the nitrogen requirement of soybean, that eventually improved the post harvest N fertility in soil. Application of FYM temporarily enhanced the biological immobilisation and continuous mineralisation of FYM on surface layer of soil was responsible for higher post harvest N availability. A net gain of 16.11 kg N per ha was recorded under 125 per cent RDF + FYM @ 5t per ha that was 20.49 and 36.18 per cent higher than 100 per cent RDF + FYM @ 5t per ha and 75 per cent RDF + FYM @ 5t per ha (Table 3).

Post-harvest P status and P balance

The post-harvest available P content of the soil indicated a significant and progressive increase with corresponding increase in levels of fertilizer (Table 3). The highest available P of 17.05 kg per ha was recorded at 125 per cent RDF with FYM @ 5 t per ha and minimum 8.85 kg per ha when no fertilizer was added. It was due to addition of adequate amount of P through higher level of fertilizer, besides supplying proportionate amount to soybean, considerable amount of unutilized P left in the soil. The net gain over initial P status was negative indicating the significance of balanced nutrition for soil health sustainability. Appreciable variation in post-harvest P availability was also observed in FYM added treatments. This was owing to the improvement in soil health due to application of FYM which increased availability of native phosphorus. Moreover, the capacity of FYM to form a cover of sesquioxide which reduce the phosphorus fixation leading to higher availability in post- harvest soil. Results corroborate the findings of Govindan and Thrimurugan (2005).

Post harvest K status and K balance

The availability of K in post-harvest soil increased progressively up to the highest level of fertilizer application (Table 3). Maximum K status of 408.07 kg per ha in post-harvest soil was observed under 125 per cent RDF + FYM @ 5.0 t per ha and minimum 292.28 kg per ha was observed when no fertilizer was applied. Increased levels of fertilizer assured the availability of K to the soybean in adequate amount and left out in the soil after crop uptake to fulfil the requirement. In turn that ultimately enhanced the post-harvest status of K nutrient in soil. The net gain over initial K status was observed to be negative, indicating that application of balanced nutrients is essential to sustain soil health. Appreciable variation in post-harvest K availability was also noticed in FYM added treatments. This might be due to increased availability of native K owing to improved physical and biological properties of soil.

Economics

Soybean varieties JS 95-60 and JS 97-52 recorded absolute higher net returns of Rs. 42,120 kg per ha and Rs. 26,901 per ha with the application of treatments (125 % RDF with FYM @ 5 t/ha) followed by JS 95-60 with (100 % RDF with FYM @ 5 t/ha) and JS 97-52 with (125 % RDF without FYM). Among the various nutrient levels, the treatment 125 per cent RDF with FYM @ 5 t per ha gave highest net returns (Rs. 34,511/ha) and B: C ratio (4.11) followed by 125 per cent RDF without FYM (Table 2). Results corroborate with the findings reported by Deshmukh *et al.* (2005) and Ramesh *et al.* (2009). Similarly, Chaturvedi *et al.* (2009) also reported maximum net returns with the application of RDF with 10 t FYM per ha.

This performance of certain nutrient level is highly related with the varietal characteristic of the crop. An appropriate combination of variety with optimum dose of nutrient can give maximum seed yield as well as economic returns. In the present investigation both the varieties (JS 95-60 and JS 97-52) did well with the 125 per cent RDF with FYM @ 5 t per ha, however JS 97-52 gave second higher net returns with 125 per cent RDF without FYM and JS 95-60 with 100 per cent RDF with FYM @ 5 t per ha.

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Assessment of Customized Fertilizer for Soybean [*Glycine max* (L.) Merrill] in Chhattisgarh Plains under Rainfed Condition

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ABSTRACT

Field experiments were conducted at research farm, IGKV, Raipur during zaid *and* kharif *season of 2012 on Vertisols, which was low in nitrogen, medium in phosphorus and high in potassium content. The maximum plant height and dry matter per plant were recorded under the application of 150 per cent dose of customized fertilizer (CF). Whereas, application of 100 per cent recommended dose of fertilizers (RDF) was found to be significantly superior over other treatments in producing higher number pods per plant, seeds per pod, higher test weight, higher seed and stover yields. Application of 100 per cent RDF and 100 per cent CF were at par in respect to net returns and B: C ratio and they were significantly higher than that of other treatments.*

Key words: Customized fertilizer, growth, nutrient content, soybean, yield

Globally legumes play a vital role in human nutrition as these are rich sources of protein, calories, certain minerals and vitamins. Among legumes, soybean is the largest source of protein and vegetable oil with poly-unsaturated fatty acids specially Omega 6 and Omega 3 (Chauhan *et al*., 1988). Effective and judicious use of fertilizer in rainfed crops depends on the application of appropriate amount of fertilizer in balanced form. Therefore, nutrient management is of utmost importance in increasing the productivity of soybean. The term customized fertilizer (CF) is new to Indian farmers. India's first customized fertilizer was launched in 2010. It is formulated to meet out the requirement of a crop in a specific location. Customized fertilizer provides the plant nutrients in the right proportion required at different growth stages of crop and may lead to enhanced growth. The price escalation and restricted availability of straight fertilizers do not allow the small landholders to provide

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balanced nutrition to a crop. Thus, customized fertilizer may work out to be a suitable/appropriate option to provide it. In view of this the present study to evaluate different levels of CF in comparison with recommended dose of fertilizer (RDF) for soybean was undertaken.

MATERIAL AND METHODS

Field experiments on soybean were carried out for two seasons (*zaid* and *kharif*) of 2012 at research farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur at a fixed site. The soil of experimental field belonged to Vertisols with neutral pH, low in available nitrogen (225 kg/ha), medium in available phosphorus (22 kg P_2O_5/ha) and high in available potassium (367 kg K_2O/ha). Seven treatments were comprised of five doses of CF along with 100 per cent RDF and a control (non-application of fertilizer) (Table 1). The experiment was laid out in randomized block design with three replications. The RDF was applied in the form of urea, single super phosphate and muriate of potash at the time of sowing as basal application. The soybean variety JS 93-05 was used as a test crop. The seeds were treated with thiram @ 3 g per kg seed followed by inoculation with *Bradyrhizobium japonicum* @ 5 g per kg seed prior to sowing. The seeds were sown @ 75 kg per ha.

The plant height was recorded from tagged five plants at harvest. Five plants were uprooted, washed and dried in oven at 60^{o}C till constant weight for determination of dry matter accumulation. Number of branches, pods and seeds were counted from randomly selected five plants and average value was worked out. Randomly seed samples were taken from each net plot thereafter 100 seeds were counted and same were oven dried at 60^{o}C to get constant weight and represented as seed index. The weighed bundles were threshed, winnowed and cleaned separately. Treatment wise moisture content of threshed seed samples was recorded and then seed yield was recorded. The harvested produce from each net plot was tied in bundles separately. Stover yield of plot was calculated after subtraction of seed yield from bundle weight. Five soil samples were collected from 20 cm depth from each plot. Composite soil samples were dried under shade and grinded and passed through 2 mm sieve. The analysis of available N, P_2O_5, K_2O and Zn were determined by alkaline permanganate method (Subbiah and Asija, 1956), Olsen's method (Olsen *et al*., 1954), Flame photometric method (Jackson, 1967) and atomic absorption spectrophotometer method (Lindasay and Norvell, 1978), respectively. Nitrogen, phosphorus and potassium content in seed and stover were determined by Kjeldahl method (Jackson, 1967), vanado molybdate acid yellow colour method (Jackson, 1967) and Flame photometric method using tri-acid digestion system (Chapman and Patra, 1967).

RESULTS AND DISCUSSION

Growth/yield attributes and yield

Maximum plant height as well as

Table 1. Details of nutrients supplied through fertilizer to different treatments

Treatments	Nutrient supplied (kg/ha)			
	N	P_2O_5	K_2O	Zn
50% recommended dose (RD) of customized fertilizer (CF)	18.75	21.25	13.75	0.50
75% RD of CF	28.13	31.88	20.63	0.75
100% RD of CF	37.50	42.50	27.50	1.00
125% RD of CF	46.88	53.12	34.38	1.25
150% RD of CF	56.25	63.75	41.25	1.50
Recommended dose of fertilizer (RDF)	20	60	40	0
Control (non- application of fertilizer)	0	0	0	0

dry matter were recorded under the application of 150 per cent recommended dose (RD) of customized fertilizer (CF) and significantly higher than rest of the treatments, except 125 per cent RD of CF, 100 per cent RD of CF and 100 per cent RDF in case of plant height (Table 2). This may be ascribed to application of higher amounts of nutrients in these treatments. The results are in the accordance with the findings of Shivakumar and Ahlawat (2008), Umeh *et al*. (2011) and Undie *et al*. (2012).

Most of the yield attributes in treatments recorded higher values than control establishing the impact of balanced nutrition to the crop (Table 2). Although, number of branches per plant recorded significantly higher values in 125 and 150 per cent RD of CF, number of pods per plant, seeds per pod and seed index were much higher in RDF and significantly superior over all other treatments (Table 2). The cumulative effect of yield attributing traits was visualised in maximum and significantly superior seed and stover yields of soybean in RDF treatment. This exhibited the impact of balanced application of nutrients through research emanated RDF. These results are in conformity with the findings of Khutate *et al*. (2005) and Shafii *et al*. (2011).

As far as the CF treatments is concerned, its higher doses enhanced the vegetative growth for extended time, which failed to culminate in higher number of pods per plant and seeds per pod, increase in seed index and seed and stover yields in comparison to RDF.

Economics

The maximum net returns were obtained under the application of 100 per cent RDF followed by 100 per cent RD of CF, 75 per cent RD of CF, 50 per cent RD of CF and 150 per cent RD of CF in descending order. The benefit: cost (B: C) ratio followed a similar trend to that of net returns (Table 2). Less input cost

Table 2. Influence of customized fertilizer on growth, yield attributes, yield, quality and economics of soybean (mean value of two seasons)

Treatment	Plant height (cm)	Plant dry matter (g/plant)	Branches (No/ plant)	Pods (No/ plant)	Seed index (g)	Seeds (No/ pod)	Seed yield (kg/ha)	Stover yield (kg/ha)	Net returns (Rs/ha)	B:C ratio
50% RD of CF	32.01	17.90	3.90	32.20	11.80	3.10	976	2035	11084	1.01
75% RD of CF	34.00	19.00	3.90	45.60	12.20	3.20	1228	2365	16213	1.42
100% RD of CF	37.85	23.12	4.00	47.30	12.40	3.30	1307	2485	17232	1.43
125% RD of CF	38.97	25.37	4.70	37.40	12.00	3.10	1016	2090	10030	0.79
150% RD of CF	39.76	27.81	5.00	36.90	11.90	3.20	1008	2065	9201	0.69
RDF	37.53	22.54	4.20	54.40	13.50	3.80	1581	2765	22070	1.65
Control	30.17	13.53	3.10	25.00	10.80	3.00	694.5	1690	6078	0.64
SEm (±)	0.82	0.45	0.20	1.80	0.30	0.20	74.9	43.6	1678	0.13
CD (P = 0.05)	**2.52**	**1.40**	**0.50**	**5.40**	**0.90**	**0.50**	**230.9**	**134.4**	**5173**	**0.41**

RD- Recommended dose; CF - Customized fertilizer; RDF – Recommended dose of fertilizer

Table 3. Influence of customized fertilizer on nutrient content in soil, seed and stover of soybean (mean value of two seasons)

Treatment	Soil available nutrient at harvest (kg/ha)			Zn in soil at harvest (ppm/ha)	N content (%)		P content (%)		K content (%)	
	N	P	K		Seed	Stover	Seed	Stover	Seed	Stover
50% RD of CF	220.00	15.35	411.22	0.18	4.02	2.22	0.36	0.11	2.12	1.45
75% RD of CF	222.50	16.07	418.64	0.20	4.17	2.37	0.40	0.16	2.54	1.56
100% RD of CF	229.50	17.78	421.69	0.35	4.31	2.38	0.41	0.18	2.61	1.53
125% RD of CF	249.00	20.36	432.73	0.50	4.08	2.18	0.37	0.12	2.08	1.43
150% RD of CF	273.00	23.20	448.63	0.58	4.12	2.16	0.36	0.13	2.01	1.42
RDF	225.00	18.18	439.03	0.29	4.77	2.66	0.42	0.22	2.67	1.58
Control	198.50	10.98	355.19	0.12	3.23	2.09	0.29	0.07	1.69	1.10
SEm (±)	4.49	0.69	32.00	0.03	0.07	0.24	0.009	0.01	0.10	0.06
CD (P=0.05)	**13.84**	**2.13**	**NS**	**0.09**	**0.22**	**NS**	**0.03**	**0.04**	**0.30**	**0.19**

RD- Recommended dose; CF - Customized fertilizer; RDF – Recommended dose of fertilizer and higher economical yield may be result in increase the B: C ratio. Similar results were also reported by Vyas *et al*. (2006) and Shivakumar *et al*. (2008).

Nutrient status

The available N and P content in soil were significantly higher under the application of 150 per cent RD of CF than that of other treatments. Whereas, Zn in soil was also higher under the application 150 per cent RD of CF, but it was at par with the application of 125 per cent RD of CF. The nutrient content might have increased due to application of higher doses of these nutrients. The lowest N and P contents were observed under the control (Table 3). The effect of treatments on K content in soil was not found significant. This is in accordance with the findings of Arbad and Ismail (2011) and Shivakumar *et al*. (2008).

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Nitrogen content is seed was increased due to the application of 100 per cent RDF. Although P and K content in seed were also higher under the application of RDF, it was remained comparable with the application of 100 per cent RD of CF and 75 per cent RD of CF. Lowest N, P and K content in seed were observed under the control (Table 3). The efficient use of balanced fertilizer might have increased the nutrient content in seed. Similar findings have also been reported by Morshed *et al*. (2008) and Wasmatkar *et al*. (2002).

It is concluded that application of 100 per cent RDF (20:60:40 kg N: P: K/ha) followed by 100 per cent RD of CF (250 kg/ha) found to be more effective than other doses of CF with respect to net returns and B: C ratio.

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Integrated Nutrient Management in Soybean Varieties Grown Under Different Agro-climatic Conditions of India

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ABSTRACT

Field experiments at different locations across four agro-climatic regions of India were conducted for three years (2009-11) under All India Coordinated Research Project on Soybean to study the effect of integrated nutrient schedule on the newly released soybean varieties. Application of nutrients either through inorganic or organic sources substantially improved the seed yield of soybean over control. Application of FYM @ 10 t per ha increased the seed yield by 10.9, 21.2, 23.3 and 38.2 per cent, respectively in North Plain, North Eastern, Central and Southern zones, while corresponding mean increase in yield due to inorganic fertilizers was 11.7, 52.9, 47.3 and 40.6 per cent, respectively. Integration of inorganic fertilizers with FYM further increased the seed yield over control by 10.9, 7.5, 5.5 and 9.8 per cent in North Plain, North Eastern, Central and Southern zones, respectively. Integration of nutrient carriers led to reduction in chemical fertilizer component between 10 and 20 per cent. The physical optimum dose of fertilizers without or with FYM showed little differences and the values were 107.4 and 118.8 per cent for North Plain, 143.1 and 129.5 per cent for North Eastern, 124.7and 118.4 per cent for Central and 107.7 and 108.2 per cent for Southern zones. Application of 125 per cent recommended dose of fertilizers (RDF) + FYM @ 5 t per ha brought in the sustainability and stability with minimum yield variability over years. Soybean varieties namely PS 1347 in North Plain, JS 97-52 in North Eastern and Central, and RKS 18 in Southern zones were found to be more responsive to applied nutrients and were economically viable than other evaluated varieties of respective zones and also showed differences in their physical optimum levels of nutrients. These high yielding varieties showed higher sustainability yield index and lower stability coefficient as compared to low yielding soybean varieties in respective zones. The highest net returns in all the four zones were achieved with application of 125 per cent RDF. The incremental benefit cost ratio showed a declining trend as the levels of nutrients increased.

Key words: Integrated nutrient management, soybean, sustainable yield index, stability

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Soils of the arid and semi-arid sub-tropical regions are inherently poor in soil organic matter and fertility. Furthermore, intensive cropping under irrigated conditions to meet the food and fiber needs of fast growing population, and the common practice of removal or burning of crop residue after crop harvest cause losses of organic matter and nutrients from agricultural soils (Aulakh and Garg, 2007; Singh *et al*., 2009). Small farm-holders in countries such as India encounter a soil fertility crisis. Soil surveys in semi-arid regions have consistently shown multi-nutrient (N, P, K, S, and Zn) deficiencies due to continuous cropping with limited use of nutrient inputs (Reddy *et al.,* 2005). There are indications that the highly productive fertilizer and seed technologies introduced over the past three decades may be reaching a point of diminishing returns (Bouis 1993; Cassman *et al*., 1995).

Excess application of fertilizers, while inexpensive for some farmers in developed countries induces neither substantially greater crop nutrient uptake nor significantly higher yields (Smaling and Braun 1996). Rather, excessive nutrient applications are economically wasteful and can damage the environment. Under application, on the other hand, can retard crop growth and lower yields in the short-term, and in the long-term jeopardize sustainability through soil mining and erosion. The inadequate / imbalance of nutrient application can be wasteful as well. The correction of nutrient imbalances can have a dramatic effect on crop yields.

Soybean has significantly less water requirement and it could meet most of its needed N through biologically fixed N. Recently, Aulakh *et al*. (2010) have demonstrated that soybean could biologically fix N ranging from 81 to 125 kg N per ha, equivalent to 68–85 per cent of total N uptake, depending upon tillage and crop management. Current fertilizer NP recommendation of 20 kg N and 26 kg P per ha for soybean is not adequate and either application of 25 per cent higher NP rate (25 kg N and 33 kg P/ha) or additional 10 t FYM per ha is required for optimum crop production of 2,500 kg per ha (Aulakh *et al*., 2012).

Concerns are also growing about the long-term sustainability of agriculture. Both the over- and under application of fertilizer and the poor management of resources have damaged the environment. Moreover, the sustainability of crop production could not be possible either solely dependence on synthetic fertilizers which is based on non-renewable energy or organic manures, which is not available in adequate quantity to meet out the total requirement. The overall strategy for increasing crop yields and sustaining them at a high level must include an integrated approach to manage nutrients in soil, along with other complementary measures. An integrated nutrient management approach recognizes that soils are the storehouse of most of the plant nutrients essential for plant growth and agricultural sustainability. Keeping the sustainability in view, the present investigation was under taken to study the impact of integrated nutrient management on soybean under different agro-climatic regions of India.

MATERIAL AND METHODS

The field experiments were conducted at 12 locations during 2009-2011 at four agro-climatic zones namely, North Plain (Pantnagar and Hisar), North Eastern (Ranchi, Imphal, Medziphema and Raipur), Central (Sehore, Kota, Amravati and Ujjain) and Southern (Dharwad, Coimbatore and Adilabad), identified for soybean under All India Coordinated Research Project on Soybean. In all eight treatments of nutrient management schedule [75 % recommended dose of fertilizers (RDF), 100 % RDF and 125 % RDF, with and without FYM @ 5 t per ha, FYM @ 10 t per ha and control) and two soybean varieties each in North Plain (PS 1347 and SL 525), Central (JS 95-60 and JS 97- 52) and Southern (RKS 18 and MAUS 61) zones, and three varieties in North Eastern zone (RKS 18, MAUS 61 and JS 93- 05). All the treatment combinations were laid out in randomized block design under factorial arrangements with three replications at each centre. The recommended dose of fertilizers was 20 N: 60 P_2O_5:20 K_2O:30 S kg per ha for North Plain, 20 N: 80 P_2O_5:40 K_2O:40 S kg per ha for North Eastern, 20 N: 60 P_2O_5:40 K_2O:20 S kg per ha for Central and 20 N: 80 P_2O_5:20 K_2O:30 S kg per ha for Southern zones was applied as basal application. Soybean yield data were collected from all the locations and grouped under different zones and were statistically analyzed taking years as replications. Based on the three years data, the sustainability yield index (SYI; Singh *et al*., 1990) and stability coefficient (Finlay and Wilkinson, 1963) were computed. Treatment-wise coefficient was also worked out. The economical and physical optimum levels of nutrients for each zone and varieties were determined by using the quadratic equation, *i. e*. $Y= a + bx - Cx^2$. The incremental benefit cost ratio (IBCR) was calculated using the additional returns and additional cost over control.

RESULTS AND DISCUSSION

Nutrient schedule

Application of nutrients either through inorganic or organic sources substantially enhanced the yield of soybean in all the four zones.

Under the conditions of North plain zone, significantly highest soybean yield was recorded with 125 per cent RDF + FYM @ 5 t per ha and 125 per cent RDF as compared to control (Table 1), though the differences among the nutrient management schedules were non-significant. The lone application of FYM increased the soybean yield to the tune of 10.9 per cent over control. However, the integration of FYM with inorganic fertilizers behaved more or less identical with respect to yield levels indicating that it had very little effect on yield. Inorganic fertilization led to hike the yield levels from 8.5 (75 % RDF) to 14.8 per cent (125 % RDF) as compared to control, while the corresponding values were 8.0 to 14.8 per cent when the FYM @ 5 t per ha was integrated with inorganic fertilization. The relationship between yield and nutrient management schedule was found to be curvilinear in both the cases namely, inorganic fertilization with and without FYM (Table 7). The physical optimum level for inorganic and integrated nutrient schedules was 107.4 and 108.0 per cent of RDF, which was indicative of the nutrient levels of 21 N: 64 P_2O_5:21 K_2O:32 S and 22 N: 65 P_2O_5:22 K_2O:32 S kg per ha, respectively.

The application of 125 per cent RDF + FYM @ 5 t per ha showed highest SYI (0.76), which was closely followed by 100 per cent RDF + FYM @ 5 t per ha (0.75). The variation in yield levels over the years was similar to that of SYI. In general, the integrated nutrient management schedule showed values less than one of stability parameter (regression coefficient), while inorganic fertilization showed more than one, which indicated that the former performed better under unfavourable environmental conditions and later one performed under favourable conditions.

In case of North Eastern zone, the maximum seed yield was recorded with the application of 125 per cent RDF + FYM @ 5 t per ha, which remained at par with 100 per cent RDF + FYM @ 5 t per ha (Table 2). Soybean yield increased by 31.7 to 78.8 per cent with the mean of 68.6 per cent due to the different nutrient schedules over control. Nutrients supplied through organic and inorganic sources enhanced the yield to the extent of 23.3 and 47.3 per cent, respectively over control while, the integration of inorganic fertilizers and FYM further increased the seed yield by 5.5 per cent over inorganic fertilizers only. The relationship between soybean yield and nutrient management schedule was found to be quadratic in nature (Table 7). The physical optimum level of nutrients for only inorganic and with organic sources was worked out to be 143.1 per cent (29 N: 114 P_2O_5:57 K_2O:57 S kg/ha) and 129.52 per cent (26 N: 104 P_2O_5:52 K_2O:52 S kg/ha), respectively.

The application of 125 per cent RDF + FYM @ 5 t per ha or 100 per cent RDF showed highest SYI with lower yield variations over the years. However, the 75 or 100 per cent RDF with or without FYM performed very well under unfavourable environmental conditions as compared to 125 per cent RDF.

Under Central zone situations, significantly maximum yield was observed with 125 per cent RDF + FYM @ 5 t per ha and remained at par with 100 per cent RDF + FYM @ 5 t per ha (Table 4). Soybean yield increased by 23.30 and 47.30 per cent, when nutrients were supplied through FYM and inorganic fertilizers, respectively as compared to control. On an average, the yield enhancement varied from 31.10 to 63.75 per cent due to different treatments over control. The yield improvement (5.53 %) was further observed when inorganic fertilizers were integrated with FYM @ 5 t per ha. The relation between yield and nutrient level was found to be quadratic (Table 7) and the physical optimum level was worked out to be 124.7 per cent (25 N: 75 P_2O_5:50 K_2O:25 S kg/ha) and 118.4 per cent (24 N: 71 P_2O_5:47 K_2O:24 S kg/ha) without and with FYM @ 5 t per ha, respectively.

The maximum SYI was associated with 125 per cent RDF + FYM @ 5 t per ha, which closely followed by 125 per cent

RDF. While the least variation in yield over the years was recorded in 125 per cent RDF followed by 75 per cent RDF and FYM @ 10 t per ha. The application of 75 or 125 per cent RDF and FYM @ 10 t per ha did well under unfavourable climatic environment, while remaining treatments performed better under favourable environmental conditions.

In Southern zone, significantly higher yield was noted with 125 per cent RDF + FYM @ 5 t per ha over 75 per cent RDF, FYM @ 10 t per ha and control. The yield improvement varied from 36.91 to 61.36 per cent over control (Table 5). Application of FYM alone increased the yield to the extent of 38.21 per cent over control, while the corresponding increase was 41.22 per cent due to inorganic fertilization. The integration of nutrients further enhanced the yield to the tune of 9.81 per cent over inorganic fertilization. The relation between yield and nutrient schedule was found to be quadratic (Table 7) and the physical optimum levels was 107.69 per cent (22 N: 86 P_2O_5:22 K_2O:32 S kg/ha) and 108.17 per cent (22 N: 87 P_2O_5:22 K_2O:32 S kg/ha) for inorganic fertilization and integration of fertilizers with FYM, respectively.

The highest SYI (0.91) was associated with 125 per cent RDF + FYM @ 5 t per ha followed by 100 per cent RDF + FYM @ 5 t per ha (0.86). The lowest yield variation over the years was recorded with 75 % RDF + FYM @ 5 t per ha and followed by 125 per cent RDF + FYM @ 5 t per ha. The application of 75 per cent RDF with or without FYM, 125 per cent RDF + FYM @ 5 t per ha and FYM @ 10 t per ha performed very well under unfavourable environmental conditions, while remaining treatments did well under favourable environment. Application of 75 per cent RDF + FYM @ 5 t per ha was found to be the most stable.

Application of nutrient either through organic (FYM) or inorganic fertilizers brought in perceptible change in soybean yield in each zone. The increase in yield might be due adequate supply of nutrients, boosted plant growth, enhanced physiological processes, improved yield attributes and better utilization of nutrients by the crop plants. Thus, these favourable effects on yield components are ultimately manifested by the increased seed yield. This is in conformity with the findings of Billore *et al*. (2005) and Billore and Vyas (2012). Further improvement in soybean yields was observed on integration of inorganic fertilizers with FYM @ 5 t per ha. The increase in yield due to integrated nutrient management might be due to regulated supply of nutrients including that of micronutrients and creation of favourable environment for plant growth in the presence of organic manures. Moreover, the organic manures also improve the physical, chemical and biological properties of soil which resulted in better nutrient use efficiency. These results are in accordance of (Singh and Rai, 2004; Ghosh *et al*., 2004; Jadhav *et al.,* 2007; Bhattacharyya *et al*., 2008; Narayan *et al*., 2009; and Arbad and Syed, 2011). Further the organic sources unlike inorganic ones have substantial residual effect on succeeding crops (Duraisami and Mani, 2001; Shivakumar and Ahlawat, 2008).

Table 1. Impact of integrated nutrient management schedule on yield, sustainability yield index, stability and coefficient of variation of soybean varieties in North plain zone (2009-11)

Treatment	PS 1347				SL 525				Mean			
	Yield (kg/ha)	**SYI**	**b**	**CV (%)**	**Yield (kg/ha)**	**SYI**	**b**	**CV (%)**	**Yield (kg/ha)**	**SYI**	**b**	**CV (%)**
75 % RDF	2135	0.61	0.970	362.18	2130	0.57	1.148	473.13	2163	0.66	1.078	411.74
75 % RDF+FYM @ 5 t/ha	2127	0.59	1.032	387.12	2072	0.59	0.780	330.35	2153	0.69	0.805	315.36
100 % RDF	2124	0.61	0.859	336.50	2196	0.57	1.293	537.53	2231	0.69	1.016	393.22
100 % RDF+ FYM @ 5 t/ha	2148	0.65	0.640	248.12	2169	0.65	0.674	278.85	2226	0.75	0.575	235.34
125 % RDF	2266	0.66	0.884	327.36	2192	0.61	0.935	392.10	2290	0.72	0.900	357.45
125 % RDF + FYM @ 5 t/ha	2306	0.71	0.559	218.66	2158	0.66	0.335	231.73	2291	0.76	0.437	261.65
FYM @10 t/ha	2239	0.63	1.059	392.91	2139	0.57	1.153	477.92	2212	0.67	1.110	427.91
Control	1892	0.53	0.887	337.78	1971	0.39	1.750	835.42	1994	0.55	1.339	525.45
Mean	2155	0.63	0.861	318.49	2145	0.59	1.000	412.29	2197	0.69	0.912	353.53
	FL	Var	Intr.	Y								
SEm (±)	79.00	39.54	111.85	48.43								
CD (P = 0.05)	**227.91**	**114.07**	**322.68**	**139.72**								

FL- Fertility level, Var- Variety, Intr- Interaction of FL and Var, Y- Year

Table 2. Impact of integrated nutrient management schedule on yield, sustainability yield index, stability and coefficient of variation of soybean varieties in North eastern zone (2009-11)

Treatment	JS 97-52				RKS 18				JS 93-05				Mean			
	Yield (kg/ha)	SYI	b	CV (%)	Yield (kg/ha)	SYI	b	CV (%)	Yield (kg/ha)	SYI	b	CV (%)	Yield (kg/ha)	SYI	b	CV (%)
75% RDF	1567	0.72	1.231	75.80	1222	0.43	1.036	178.84	1440	0.40	1.131	476.79	1410	0.64	1.047	126.30
75% RDF+FYM @ 5 t/ha	1707	0.77	1.814	112.07	1387	0.49	1.044	212.14	1620	0.47	1.149	481.76	1571	0.73	0.833	105.43
100% RDF	1849	0.86	0.886	62.16	1509	0.53	1.497	241.98	1725	0.53	1.053	444.10	1694	0.88	-0.485	48.88
100% RDF+ FYM @ 5 t/ha	1961	0.90	0.570	101.65	1641	0.65	0.499	87.39	1773	0.57	0.920	389.51	1792	0.84	0.721	91.13
125% RDF	1965	0.92	0.398	49.56	1514	0.48	1.732	353.64	1938	0.66	0.855	359.25	1806	0.79	1.820	217.23
125% RDF + FYM @ 5 t/ha	2052	0.97	0.494	46.69	1617	0.58	1.075	215.62	2077	0.73	0.726	307.85	1915	0.88	1.150	140.61
FYM 10 t/ha	1357	0.62	0.649	69.87	1233	0.47	0.276	92.38	1305	0.36	1.057	444.60	1298	0.58	1.083	130.09
Control	1081	0.48	-1.005	81.10	948	0.33	0.840	150.64	1183	0.30	1.073	451.15	1071	0.45	1.325	158.66
Mean	1693	0.79	0.633	48.01	1384	0.51	1.000	160.31	1633	0.50	0.995	417.67	1570	0.71	-0.632	141.71
	FL	Var	Intr.	Y												
SEm (±)	80.61	49.36	139.62	49.36												
CD (P=0.05)	**229.59**	**140.58**	**397.66**	**140.59**												

FL- Fertility level, Var- Variety, Intr- Interaction of FL and Var, Y- Year

Table 3. Impact of integrated nutrient management schedule on economics of variation of soybean varieties in North plain and North eastern zone (2009-11)

Treatment	North plain zone						North Eastern zone							
	PS 1347		SL 525		Mean		JS 97-52		RKS 18		JS 93-05		Mean	
	Net returns (Rs/ha)	IBCR	Net returns (Rs/ha)	IBCR	Net returns (Rs/ha)	IBCR	Net returns (Rs/ha)	IBCR	Net returns (Rs/ha)	IBCR	Net returns (Rs/ha)	IBCR	Net returns (Rs/ha)	IBCR
75% RDF	45582	33.84	45472	33.76	46198	34.28	32599	18.39	25009	14.34	29805	16.90	29145	16.54
75% RDF + FYM @ 5 t/ha	40906	7.95	39696	7.74	41478	8.04	31179	5.89	24139	4.79	29265	5.59	28187	5.42
100% RDF	44878	25.26	46462	26.11	47232	26.53	38178	16.27	30698	13.28	35450	15.18	34768	14.91
100% RDF+ FYM @ 5 t/ha	40906	7.44	41368	7.51	42622	7.71	36142	6.16	29102	5.16	32006	5.57	32424	5.63
125% RDF	47539	21.55	45911	20.85	48067	21.78	40105	13.83	30183	10.66	39511	13.64	36607	12.71
125% RDF + FYM @ 5 t/ha	43919	7.45	40663	6.97	43589	7.40	37519	5.92	27949	4.67	38069	5.99	34505	5.53
FYM 10 t/ha	44758	10.95	42558	10.46	44164	10.81	25354	6.63	22626	6.03	24210	6.38	24056	6.35
Control	41624	-	43362	-			23782	-	20856	-	26026	-	23562	-
Mean	**43764**	**16**	**43187**	**16**	**44764**	**17**	**33107**	**10**	**26320**	**8**	**31793**	**10**	**30407**	**10**

Table 4. Impact of integrated nutrient management schedule on yield, sustainability yield index, stability and coefficient of variation of soybean varieties in Central zone (2009-11)

Treatment	JS 95-60				JS 97-52				Mean			
	Yield (kg/ha)	SYI	b	CV (%)	Yield (kg/ha)	SYI	b	CV (%)	Yield (kg/ha)	SYI	b	CV (%)
75% RDF	1603	0.69	1.153	184.19	1457	0.64	0.538	94.00	1530	0.72	0.810	83.52
75% RDF+FYM @ 5 t/ha	1659	0.70	1.294	206.21	1660	0.61	1.421	200.44	1660	0.74	1.577	168.63
100% RDF	1811	0.79	1.137	183.78	1784	0.72	1.326	183.53	1798	0.83	1.201	126.46
100% RDF+ FYM @ 5 t/ha	1922	0.79	1.878	299.62	1818	0.70	1.294	190.62	1870	0.82	1.910	210.30
125% RDF	1852	0.81	1.122	178.61	1807	0.77	0.729	115.22	1830	0.87	0.752	76.22
125% RDF + FYM @ 5 t/ha	1927	0.85	1.155	182.77	1894	0.78	1.107	159.35	1911	0.88	1.286	136.87
FYM @ 10 t/ha	1479	0.68	0.385	72.34	1399	0.61	0.936	129.94	1439	0.67	0.733	91.34
Control	1232	0.59	0.127	18.77	1102	0.54	0.661	98.49	1167	0.56	0.242	43.49
Mean	1685	0.74	1.032	162.66	1615	0.67	1.000	138.01	1650	0.76	1.066	111.63
	FL	Var	Intr.	Y								
SEm (±)	53.45	26.72	75.58	32.73								
CD (P=0.05)	**154.20**	**77.09**	**218.05**	**94.42**								

FL- Fertility level, Var- Variety, Intr- Interaction of FL and Var, Y- Year

Table 5. Impact of integrated nutrient management schedule on yield, sustainability yield index, stability and coefficient of variation of soybean varieties in Southern zone (2009-11)

Treatment	RKS 18				MAUS 61				Mean			
	Yield (kg/ha)	SYI	b	CV (%)	Yield (kg/ha)	SYI	b	CV (%)	Yield (kg/ha)	SYI	b	CV (%)
75% RDF	1857	0.67	-0.226	342.16	1457	0.55	0.667	199.26	1591	0.74	0.889	158.77
75% RDF+FYM @ 5 t/ha	2000	0.83	0.294	115.21	1558	0.61	0.370	162.54	1722	0.84	0.926	86.47
100% RDF	1923	0.76	0.501	187.95	1489	0.53	0.919	272.02	1639	0.73	2.508	219.68
100% RDF+ FYM @ 5 t/ha	2035	0.77	0.877	276.93	1594	0.62	0.608	180.48	1808	0.86	1.402	126.03
125% RDF	1909	0.73	0.821	258.28	1508	0.57	0.703	207.61	1694	0.80	1.560	136.31
125% RDF + FYM @ 5 t/ha	2114	0.88	0.464	110.15	1637	0.60	0.698	274.19	1875	0.91	0.238	108.51
FYM @ 10 t/ha	1854	0.75	-0.330	147.76	1468	0.54	0.630	241.90	1606	0.76	0.368	136.27
Control	1373	0.53	-0.737	162.50	1126	0.41	0.422	200.03	1162	0.58	0.144	41.96
Mean	1995	0.78	0.978	212.15	1559	0.56	1.000	293.87				
	FL	Var	Intr.	Y								
SEm (±)	89.12	44.56	126.04	54.58								
CD (P=0.05)	**257.11**	**128.55**	**363.62**	**157.46**								

FL- Fertility level, Var- Variety, Intr- Interaction of FL and Var, Y- Year

Table 6. Impact of integrated nutrient management schedule on economics of soybean varieties in Central and Southern zone (2009-11)

Treatment	Central zone						Southern zone					
	JS 95-60		JS 97-52		Mean		RKS 18		MAUS 61		Mean	
	Net returns (Rs/ha)	IBCR	Net returns (Rs/ha)	IBCR	Net returns (Rs/ha)	IBCR	Net returns (Rs/ha)	IBCR	Net returns (Rs/ha)	IBCR	Net returns (Rs/ha)	IBCR
75% RDF	33841	24.75	30629	22.49	32235	23.62	39166	24.20	30366	18.99	33314	20.74
75% RDF+FYM @ 5 t/ha	30573	6.16	30595	6.16	30595	6.16	37812	7.11	28088	5.54	31696	6.12
100% RDF	37942	20.97	37348	20.66	37656	20.82	40056	18.80	30508	14.56	33808	16.03
100% RDF+ FYM @ 5 t/ha	35884	6.61	33596	6.25	34740	6.43	38020	6.63	28318	5.20	33026	5.89
125% RDF	38369	17.16	37379	16.74	37885	16.95	39185	14.93	30363	11.79	34455	13.25
125% RDF + FYM @ 5 t/ha	35519	6.17	34793	6.06	35167	6.12	39195	6.36	28701	4.92	33937	5.64
FYM @ 10 t/ha	28038	7.23	26278	6.84	27158	7.04	36288	9.06	27796	7.18	30832	7.85
Control	27104	-	24244	-	25674		30206	-	24772	-	25564	-
Mean	**33409**	**13**	**31858**	**12**	**32639**	**12**	**37491**	**12**	**28614**	**10**	**32079**	**11**

Table 7. Relationship between soybean yield and nutritional schedule and economic optimum level

Zone/ variety	Without FYM	Physical optimum level (%)	With FYM	Physical optimum level (%)
North Plain	***20:60:20:30 NPKS-RDF***			
PS 1347	Y= 478.73 + 409.41x -18.500x^2	11.057/110.57 (22:66:22:33)	Y= 474.79 + 411.39 x -18.460x^2	11.143/111.43 (22:67:22:33)
SL 525	Y= 493.54 + 436.01x -21.013x^2	10.375/103.75 (21:62:21:31)	Y= 494.03 + 423.50 x -20.189x^2	10.488/104.88 (21:63:21:31)
Mean	Y= 500.30 + 432.41x -20.139x^2	10.735/107.36 (21:64:21:32)	Y= 499.83 + 429.09 x -19.866x^2	10.799/107.99 (22:65:22:32)
North Eastern	***20:80:40:40 NPKS-RDF***			
JS 97 52	Y= 270.59 + 288.52x -10.477x^2	13.769/137.69 (28:110:55:55)	Y= 270.02 + 322.99x -12.704x^2	12.713/127.13 (25:102:51:51)
RKS 18	Y= 235.84 + 235.29x -8.991x^2	13.083/130.83 (26:105:52:52)	Y= 236.03 + 275.84x -11.608x^2	11.882/118.82 (24:95:48:48)
JS 93 05	Y= 296.35 + 246.33x -7.319x^2	16.827/168.27 (34:135:67:67)	Y= 296.95 + 275.80x -8.991x^2	15.337/153.37 (31:123:61:61)
BSS 2	Y= -266.14 + 418.06x -15.790x^2	13.238/132.38 (26:106:53:53)	Y= 265.61 + 474.97x -20.261x^2	11.721/117.21 (23:94:47:47)
Mean	Y= 270.70 + 271.75x -9.496x^2	14.309/143.09 (29:114:57:57)	Y= 271.71 +308.25 x -11.899x^2	12.952/129.52 (26:104:52:52)
Central	***20:60:40:20 NPKS-RDF***			
JS 95 60	Y= 227.59 + 312.26x -13.154x^2	11.869/118.69 (24:71:47:24)	Y= 302.49 + 326.67x -13.728x^2	11.898/118.98 (24:71:48:24)
JS 97 52	Y= 276.11 + 276.45x -10.387x^2	13.307/133.07(27:80:53:27)	Y= 276.51 + 321.03x -13.635x^2	11.772/117.72(24:71:47:24)
Mean	Y= 291.04 + 295.39x -11.846x^2	12.468/124.68(25:75:50:25)	Y= 2291.73 + 323.89x - 13.682x^2	11.836/118.36(24:71:47:24)
Southern	***20:80:20:30 NPKS -RDF***			
RKS 18	Y= 344.53 + 381.38x -18.418x^2	10.354/103.54(21:83:21:31)	Y= 345.28 + 397.36x -18.489x^2	10.745/107.45(22:89:22:33)
MAUS 61	Y= 282.41 + 295.18x -14.119x^2	10.462/104.62(21:84:21:31)	Y= 282.06 + 312.09x -14.640x^2	10.659/106.59(21:85:21:32)
Mean	**Y= 292.66 + 310.55x -14.423x^2**	**10.769/107.69(22:86:22:32)**	**Y= 293.04 +332.747x -15.381x^2**	**10.817/108.17(22:87:22:32)**

Varietal performance

Yield performance of PS 1347 and SL 525 was similar under North Plain zone. Nutrition through farmyard manure alone increased the yield of PS 1347 and SL 525 to the extent of 18.3 and 8.5 per cent over control (Table 1). The yield enhancement pattern in both the varieties was unaltered irrespective supplementation of nutrition through inorganic fertilization or integration of inorganics with organics. However, the yield increment observed was 12.8 to 21.9 per cent in PS 1347 and 5.1 to 11.4 per cent SL 525 over their respective controls, indicating that the later variety was less responsive to applied nutrition. The relationship between yield and nutrient schedule was quadratic (Table 7). The physical optimum level worked out for PS 1347 under inorganic fertilization and integrated nutrition was 110.6 per cent (equivalent to 22 N: 66 P_2O_5:22 K_2O:33 S) and 111.4 per cent and 22 N: 67 P_2O_5:22 K_2O:33 S), respectively. The corresponding physical optimum for SL 525 was 103 per cent (21 N: 62 P_2O_5:21 K_2O:31 S) and 104.9 per cent (21 N: 63 P_2O_5:21 K_2O:31 S), respectively.

Soybean variety PS 1347 was found to be more sustainable (0.63) with less variation in yield over years than SL 525, while the just reverse was the case with respect to stability. The maximum and identical SYI was noted with 125 and 100 per cent RDF + FYM @ 5 t per ha. The lowest yield variation over the years was found to be with 100 per cent RDF with or without FYM. Application of 75 per cent RDF, 125 per cent RDF with and without FYM did well under favourable environmental conditions indicating the b values to be more than unity. The yield variations over the years were higher with SL 525. The integration of both the sources of nutrients showed lower values of stability parameter (b) as compared to inorganic source of nutrients directing that the integration of nutrient insured the crop against unfavourable environmental conditions.

In North Eastern zone, significantly higher yield was recorded with variety JS 97-52 (3.7 % over JS 93-05 and 23.3 % over RKS 18) and remained at par with JS 93-05 (18.0 %) as compared to RKS 18 (Table 2). The yield enhancement varied from 45.0 to 89.9 per cent in JS 97-52, 28.9 to 73.1 per cent in RKS 18 and 21.7 to 75.6 per cent in JS 93-05. The highest response (30.1 %) was recorded with RKS 18 followed by JS 97-52 (25.5 %) and JS 93 05 (10.3 %) when only FYM @ 10 t per ha was applied as compared to control. The corresponding increase in yield due to inorganic fertilization was 66.0 per cent in JS 97-52, 49.3 per cent in RKS 18 and 43.8 per cent in JS 93-05 over control. The integration of nutrients brought out the further hike in yield to the tune of 6.3, 7.2 and 9.4 per cent in JS 97-52, JS 93-05 and RKS 18, respectively. The relationship between yield and nutrient management schedules was found to be quadratic in nature (Table 7) and the physical optimum level of nutrients was determined to be 137.7 per cent (28 N:110 P_2O_5:55 K_2O:55 S kg/ha) and 127.1 per cent (25 N:102 P_2O_5:51 K_2O:51 S kg/ha) for JS 97-52, 130.8 per cent (26 N:105 P_2O_5:52 K_2O:52 S kg/ha) and 118.8 per cent (24 N:95 P_2O_5:48 K_2O:48 S kg/ha) for RKS 18 and 168.3 per cent (34

N:135 P_2O_5:67 K_2O:67 S kg/ha) and 153.4 per cent (31 N:123 P_2O_5:61 K_2O:61 S kg/ha) for JS 93-05 for without and with FYM application which indicated that the integration of nutrients could be able to reduce the dependency on synthetic fertilizer by 10 to 15 per cent.

Among soybean varieties, JS 97-52 showed maximum SYI with least variation yield over years as compared to RKS 18 and JS 93-05. However, the most stable performance was recorded with RKS 18 followed by JS 93-05 and JS 97-52. The highest SYI with least variation in yield was observed with JS 97-52 and JS 93-05 + 125 per cent RDF + FYM @ 5 t per ha, RKS 18 + 100 per cent RDF + FYM @ 5 t per ha. The application of 75 per cent RDF with or without FYM performed better under favourable environmental conditions in JS 97-52. While in case of RKS 18, 100 per cent RDF + FYM @ 5 t per ha and FYM @ 10 t per ha did well under unfavourable conditions. The application of 100 or 125 per cent RDF + FYM @ 5 t per ha and 125 per cent RDF also performed well under unfavourable condition in JS 93-05.

In case of Central zone, the yielding ability of JS 95-60 (11.80 %) was found to be higher along with higher SYI (0.74) and variation in yield over years (162.66 %) as compared to JS 97-52 (Table 4). However, JS 97-52 was found to be more stable than JS 95-60. The physical optimum level of nutrients was 118.7 per cent (24 N:71 P_2O_5:47 K_2O:24 S kg/ha) and 119.0 per cent (24 N:71 P_2O_5:48 K_2O:24 S kg/ha) for JS 95-60 and 133.0 per cent (27 N:80 P_2O_5:53 K_2O:27 S kg/ha) and 117.7 per cent (24 N:71 P_2O_5:47 K_2O:24 S) for JS 97-52 under inorganic fertilization and integration of fertilization and FYM, respectively (Table 7). All the treatments except FYM @ 10 t per ha in JS 95-60 and 75 or 125 per cent RDF and FYM 10 t per ha in JS 97-52 performed better under favourable conditions indicating 'b' values more than unity.

Under the conditions of Southern zone, soybean variety RKS 18 showed its superiority over MAUS 61 in terms of yield (27.97 %), SYI (0.78) and lower variation in yield over years. However, the stable performance of the variety was just reverse. Variety RKS 18 responded better (35.3 to 54.0 %) to applied nutrients than MAUS 61 (29.4 to 45.4 %). A similar trend was also observed in case of application of FYM only. The integration of nutrients further increased the yield levels of soybean to the tune of 8.1 and 7.5 per cent in RKS 18 and MAUS 61 as compared inorganic fertilization. The relationship between yield and nutrient schedule was found to be curvilinear (Table 1). The physical optimum levels was 103.5 per cent (21 N: 83 P_2O_5:21 K_2O:31 S kg/ha) and 107.5 per cent (22 N: 89 P_2O_5:22 K_2O:33 S kg/ha) for RKS 18 and 104.6 per cent (21 N: 84 P_2O_5:21 K_2O:31 S kg/ha) and 106.6 per cent (21 N: 85 P_2O_5:21 K_2O:32 S kg/ha) for MAUS 61 without and with FYM, respectively.

Soybean variety RKS 18 was found to be more sustainable and revealed least variation in yield over the years. Both the varieties were more or less equally stable in their performance.

The variation in yielding potential of different soybean varieties might be due their genetic variability and the yield being genetically controlled trait (Tony *et al*., 2013; Ikeogu and Nwofia, 2013; Reni and Rao, 2013). This genetic variation also caused differentiation in nutrient uptake which is resulted in higher yield. The observed differential genotypic responses can be traceable to differences in inherent genetic composition higher fertility levels. Such responses had been recorded by Nwoko and Sanginga (1999) and Sanginga *et al*. (2000).

Economic evaluation

The supplementation of nutrients through fertilizer sources was found to be most economical than their integration with FYM (Table 3 and 6). The maximum net returns were associated with the application of 125 per cent RDF in all the four zones. The IBCR significantly reduced as the levels of nutrients increased (Table 3 and 6). The maximum IBCR was associated with 75 per cent RDF. The trend of economical parameters with reference to soybean varieties was similar as was observed in yield. The difference in economical parameters is the function of the yield levels achieved and the respective cost of cultivation incurred. The lower dose of nutrients/ fertilizer is more effective to enhance the yield per unit nutrients/ fertilizers. It will not be fair to compare the integration of fertilization with FYM and only fertilization on the basis of economics only, as the organic sources had long-term residual effect and positive influence on soil properties, which do not get reflected directly in terms of economics.

On the basis of foregoing results it could be concluded that the present levels of recommended fertilizer levels are not sufficient to meet out the nutritional requirement of soybean varieties. The optimum level of nutritional schedule was 107 per cent RDF with or without FYM for North plain zone, 130 per cent RDF with FYM and 143 per cent RDF without FYM for North eastern zone, 125 per cent RDF and 118 per cent RDF without and with FYM for Central zone and 108 per cent without and with FYM. Soybean variety PS 1347 in North plain, JS 97-52 in North Eastern zone, JS 95-60 in Central zone and RKS 18 in Southern zone responded very well to applied nutrients.

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Productivity, Energy and Economics as Influenced by the Different Fertility Levels in Soybean + Pigeonpea Intercropping System

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ABSTRACT

Field experiments were conducted during two consecutive kharif *seasons of 2013 and 2014 at the research farm of College of Agriculture, Lembucherra, Tripura to find out the productivity and economics of soybean [*Glycine max *(l.) Merrill] + pigeonpea [*Cajanus cajan *(L.) Millsp.] intercropping system as influenced by the different fertility levels. The treatments comprised of seven fertility levels in intercropping system besides sole soybean and sole pigeonpea with 100 per cent RDF for comparison purpose. From the investigation, it could be concluded that to produce 1 kg seed of soybean and pigeonpea we need to expend 0.08 and 2.21 Mj of energy, respectively. In intercropping system, integrated nutrient management practices comprising of 75 per cent RDF + vermicompost + Zn can be adopted as best nutrient management practice to obtain maximum economic returns and to sustain the system productivity.*

Keywords: Energy use efficiency, intercropping system, pigeonpea, soybean, soybean equivalent yield

Intercropping of soybean with pigeonpea offers improved production than its sole cropping (Billore and Joshi, 2004). Intercropping can play a significant role in enhancing the productivity and profitability per unit area and time through more efficient use of land, water and solar energy besides assuring insurance against crop failure due to vagaries of weather and/or pest and disease epidemics in rainfed agriculture. It also confirms adequate yield of one of the crops under aberrant weather conditions (Rao and Willey, 1980). Soybean, being a short duration crop with moderate inputs requirement, has substituted many *kharif* crops requiring larger investments (Hazari, 2014). In view of insufficient information on nutrient management in soybean+ pigeonpea intercropping, the present investigation was undertaken to evaluate

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the productivity, energy and economics advantage as influenced by the different fertility levels in this cropping system.

MATERIAL AND METHODS

Field experiments were conducted during *kharif* seasons of 2013 and 2014 at the research farm of College of Agriculture, Lembucherra, Tripura situated between 22°57′ N latitude and 91°09′ E longitude. The soil of the experimental site was sandy loam having pH of 5.5, organic carbon 0.47 per cent, available nitrogen 260.0 kg N per ha, available phosphorus 8.30 kg P_2O_5 per ha, available potash 176.0 kg K_2O per ha and available sulphur 12.0 kg S per ha. The climate of hilly zone is sub-tropical in nature with distinctive characteristics of high rainfall, high humidity and a prolonged winter. The bulk density of soil was 1.36 mg per m^3 and pore space was 34.9 per cent. The fertility treatments imparted to soybean (JS 335) + pigeonpea (AL 2021) intercropping system involved combinations of 100 (20:30:20 kg $N:P_2O_5:K_2O$/ha), 75 and 50 per cent recommended dose of fertilizers of base crop (soybean) with vermicompost @ 2.5 t per ha or/and 5 kg Zn per ha and 100 per cent RDF (Table 2). Sole soybean with RDF (20:30:20 kg $N:P_2O_5:K_2O$) and sole pigeonpea with RDF (30:40:20 kg $N:P_2O_5:K_2O$) were also taken for comparison purpose. The treatments were laid out in randomized complete block design and replicated thrice. Growth parameters like plant height and pod per plant were observed at harvest by taking average data of ten randomly selected plants in each treatment.

Manual energy (Em) expended was determined using formula: Em = 1.96 NmTmMJ, where Nm = number of labour spent on a farm activity; Tm = useful time spent by a labour on a farm activity (h) (Chaudhary *et al.,* 2006). Mechanical energy input was evaluated by quantifying the amount of diesel fuel consumed (Umar, 2003). The diesel fuel energy input was determined by; Ef = 56.31D MJ, where 56.31 = unit

Table 1. Energy expended on different cultural operation for soybean + pigeonpea intercropping

Cultural Practices	Energy expanded (Mj)		
	Soybean	Pigeonpea	Soybean + pigeonpea
Tillage	1280		1280
Seed	1120	646	1765
Layout and sowing	581	453	847
Intercultural operation	706		706
Harvesting	721	564	1286
Threshing	690	533	1223
Total	4261	3198	7107

Table 2. Energy of primary inputs involved in the soybean + pigeonpea intercropping system

Primary Inputs	Primary Energy (Mj)	References
100 % RDF (Control)	8785.35	
100 % RDF + Vermicompost + Zn	12785.35	
100 % RDF + Vermicompost	12410.35	
75 % RDF + Vermicompost + Zn	12365.60	Chaudhary *et al.* (2006)
75 % RDF + Vermicompost	11990.60	
50 % RDF + Vermicompost + Zn	11945.85	
50 % RDF + Vermicompost	11570.85	
Soybean seed energy (100 g)	1.866	USDA (2010) Nutrient Database
Pigeonpea seed energy (100 g)	1.435	

RDF- recommended dose of fertilizers; VC- Vermicompost @ 2.5 t/ha; Zn- Zinc @ 5 kg/ha

energy value of diesel, MJ per L, D = amount of diesel consumed. The calculations for operation-wise energy consumption for soybean and pigeonpea sole with intercropping system (Table 1) and primary inputs (Table 2) were done.

RESULTS AND DISCUSSION

Among the different treatments, application of 100 per cent RDF + vermicompost + Zn led to maximum number of pods per plant (38.77) and plant height (36.95 cm), which were significantly varied from most of the treatments except 75 per cent RDF+ vermicompost + Zn (Table 3). This showed the significant effect of RDF + vermicompost + Zn in enhancing growth and yield parameters. This increase was mainly due to zinc application, which is having important role in iron absorption by the plants. The iron is an essential constituent of structural component of nitrogenase enzyme, nitrate reductase activity and carbohydrate metabolism in all the legume crops. These results are in confirmation with the observations made by earlier workers (Verma and Yadav, 2004; Vyas *et al.,* 2006; Sharma *et al.,* 2010).

The pooled data for two years revealed that similar to the growth parameters, application of 100 per cent RDF + vermicompost + Zn led to higher pod (2,570 kg/ha) and seed (1,752 kg/ha) yields, which was on par with 75 per cent RDF + vermicompost + Zn of soybean and both the treatments differed significantly from rest of the treatments. The seed yield of soybean was lower in intercropping systems as compared to sole soybean and this reduction was in the range of 14-38 per cent (Table 3). The highest pigeonpea seed yield (1,348 kg/ha) under intercropping systems was observed in the treatment comprising of 75 per cent RDF + vermicompost + Zn,

Table 3. Plant characteristics and productivity of soybean and productivity of pigeonpea in intercropping system (Mean of two years)

Treatments	Soybean plant height (cm)	Soybean pod (No/ plant)	Soybean seed index (g/100 seeds)	Yield (kg/ha)		
				Soybean pod	Soybean seed	Pigeon-pea seed
Intercropping with						
100% RDF (Control)	29.00	33.32	12.33	1872	1264	987
100% RDF + VC + Zn	36.95	38.77	13.00	2570	1752	1108
100% RDF + VC	30.67	36.80	13.52	2246	1567	1194
75% RDF + VC + Zn	36.57	37.99	12.87	2532	1728	1348
75% RDF + VC	31.65	36.07	12.78	2245	1516	1135
50% RDF + VC + Zn	33.39	36.93	13.48	2332	1607	1251
50% RDF + VC	33.85	35.11	12.06	1954	1316	1033
Sole crop						
RDF + Soybean	34.15	34.21	11.47	2843	2032	120
RDF + Pigeonpea	-	-	-	-	-	1481
SEm (±)	0.30	0.34	0.17	31.10	8.23	39.09
CD (P = 0.05)	**0.85**	**1.03**	**0.36**	**95.64**	**24.85**	**120.45**

RDF- recommended dose of fertilizers; VC- Vermicompost @ 2.5 t/ha; Zn- Zinc @ 5 kg/ha

which was on par with 50 per cent RDF + vermicompost + Zn and significant over rest of the treatments.

The reduction in yield as compared to sole pigeonpea ranged between 9-33 per cent. Response to nutrient application on productivity of component crops in intercropping systems and reduction in seed yield as compared to sole crops has earlier been reported by Billore and Upadhyay (1990).

The maximum soybean equivalent yield (4,019 kg/ha) was associated with application of 75 per cent RDF + vermicompost + Zn followed by 50 per cent RDF+ vermicompost + Zn, which worked out to be 41.38 and 59.73 per cent higher equivalent yield (SEY) than sole soybean and sole pigeon pea, respectively (Table 4) in soybean + pigeonpea intercropping system under integrated nutrient management practices. This treatment also recorded maximum net returns (Rs 68, 251/ha) and returns per rupee invested (1.97). In general, application 75 per cent RDF + vermicompost + Zn can be a viable option for nutrient management practice of soybean + pigeonpea intercropping system under rainfed conditions (Hazari 2014).

Two year pooled data registered that total energy output was highest in 75 per cent RDF + vermicompost + Zn among intercropping treatments. It was maximum in soybean sole crop system

Table 4. Energy and economics as affected by inter-cropping system (Mean of two years)

Treatments	Soybean equivalent yield (kg/ha)	Energy					Economics		
		Total output (Mj)	Specific energy (Mj/kg)	Energy productivity (kg/Mj)	Energy use effici-ency	Output input ratio	Net returns (Rs/ha)	Returns/ rupee	Income (Rs/day)
100% RDF (Control)	2941	37751	0.26	3.87	23.27	4.30	43676	1.38	379
100% RDF + VC + Zn	3635	48596	0.27	3.66	26.31	3.80	58476	1.69	520
100% RDF + VC	3596	46371	0.29	3.40	26.78	3.74	58575	1.75	491
75% RDF + VC + Zn	4019	51593	0.27	3.76	23.99	4.17	68251	1.97	593
75% RDF + VC	3445	44582	0.29	3.40	26.90	3.72	55337	1.68	462
50% RDF + VC + Zn	3733	47935	0.28	3.62	24.92	4.01	61500	1.81	534
50% RDF + VC	3072	39382	0.33	3.06	29.39	3.40	46419	1.44	384
Soybean sole	2843	53041	0.08	12.25	11.20	8.93	49476	2.13	424
Pigeon pea sole	2516	21248	2.21	0.45	26.20	3.82	51214	3.89	398

RDF- recommended dose of fertilizers; VC- Vermicompost @ 2.5 t/ha; Zn- Zinc @ 5 kg/ha; Soybean Rs.25.60/kg; Pigeonpea Rs.43.5/kg; EUE=Total input energy/ Total output energy x 100; Output input ratio= Total input energy/ Total output energy; Specific heat= Total input energy/SEY with 100 per cent RDF. Whereas the specific energy was found to be maximum in sole pigeonpea among all the treatments indicating that to produce 1 kg of pigeonpea seed, we need to expend 2.21 Mj of energy, followed by 50 per cent RDF + vermicompost in soybean + pigeonpea cropping system. Among the intercropping treatments, 75 per cent RDF + vermicompost + Zn showed higher energy productivity along with 100 per cent RDF as also reported by Borin *et al. (*1997).

Considering the mean data of two years, apart from sole crop of soybean and pigeonpea, the output input ratio was found to be better in 100 per cent RDF which was comparable with treatment comprising of 75 per cent RDF + vermicompost + Zn. So, by substituting 25 per cent of RDF better output was achieved in terms of energy which showed a direct reflection in return per rupee and per day income (Sharma *et al.*, 2011).

In general and particularly from economic point of view, it is concluded that integrated management practices of 75 per cent RDF + vermicompost + Zn can be suggested as nutrient management practice for soybean + pigeonpea intercropping system under rainfed conditions. It also saved 25 per cent chemical fertilizer requirement, which opened up the better scope of energy conservation within the soybean + pegionpea cropping system.

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Soybean Research 13(2): 50-54 (2015)

Assessment of Weed Tolerance in Soybean Genotypes

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ABSTRACT

The field experiments were conducted to assess the weed tolerance abilities of soybean varieties. A novel approach, maximin-minimax, was applied to identify the weed tolerant and susceptible soybean varieties. The adoption of weed stress tolerant varieties will help in reducing the herbicides use in soybean crop. Results revealed that the highest yield was recorded with variety PK 1029 which was followed by JS 93- 05 under both the conditions, namely weedy check and weed free. The soybean varieties were categorized based on maximin-minimax method, and the varieties like PK 1029 was categorized as resistant and high yielding, while JS 93-05, JS 95-60, JS 335, PK 1024, MAUS 47 and JS 71- 05 were categorized as resistant and low yielding. The maximum yield loss was recorded with PS 1347 and was found to be the most susceptible to weed stress and low yielder among the soybean verities.

Key words: Relative yield, soybean, susceptible, variety, weedy check, weed free

Soybean genotypes with strong weed suppression ability could become an important tool in integrated weed management strategies. Rapid vegetative vigour in early growth stages, larger leaf area and tall stature have been reported to be the major factors that increase the ability of soybean to compete with weeds (Goldberg, 1996). Weed competitive ability is an important criterion for selecting soybean cultivars for cultivation. However, there is no given yard-stick to compare the competitiveness of soybean cultivars. Improved crop tolerance and weed suppressive ability (crop competitiveness) are tactics that may reduce the negative effect of weeds on crop yield (Lindquist and Kropff, 1996). The distinction between crop tolerance and weed suppressive ability is important for identifying these characteristics. Improved crop tolerance may results in a higher yield, relative to weed-free yield, at a given weed infestation. This definition of crop tolerance includes both avoidance and tolerance in the strict sense. Avoidance refers to an ability to escape the effect of a stress factor (Levitt, 1980). Tolerance in the strict sense refers to an ability to endure competitive stress from the weed without substantial reduction in growth

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or yield. In cases where both crop and weed demand the same resources on a similar time scale, crop tolerance may be the direct result of resource pre-emptive measure by the crop (Jordan, 1993). Crop tolerance will not improve long-term management of weed populations unless weed seed production also is reduced. However, weed-tolerant crops will improve yield stability in weedy fields. Improved weed suppressive ability reduces weed seed production and therefore can improve long-term weed management. Improved weed supper-ssive ability does not, however, ensure crop tolerance (Jordan, 1993). Improved suppressive ability with a reduction in tolerance could occur as a result of trade-offs in allocation patterns. Several recent reviews have documented variation among crop genotypes in their response to weed competition and capacity for suppressing weed growth rate and seed production (Jordan, 1993).

Selecting cultivars with high competitiveness to weeds growth is one of the cultural practices that have been found to reduce weed growth rate. Plant breeding programs directed towards selecting cultivars to increase tolerance of, or increase competitiveness with, weeds are virtually non-existent. However, differential competitiveness among cultivars of several crop species has been observed. Thus, the present study aims to identify the soybean varieties that are resistant/tolerant to competition from weeds, so that large yield losses could be avoided if they are grown on field with minimum cultivation.

MATERIAL AND METHODS

The data have been compiled from different experiments on eight soybean varieties with weedy check and weed free treatments for analyzing and assessing the weed tolerance ability of the eight soybean varieties, namely JS 95-60, JS 93-05, JS 335, JS 71-05 and MAUS 47 (at Indore), PS 1347 (at Pantnagar) PK 1029, PK 1024 (at Dharwad). Soybean crop was raised with the recommended package of practices.

For categorizing evaluated varieties into tolerant groups against weed species, maximin-minimax method (Odulaja and Nokoe, 1993) was employed as given below.

a. Calculate per cent yield loss for each variety on the basis of yields obtained under weed free and weedy check conditions.
b. Identify a tolerant/resistant check, i.e. an entry giving the highest yield under weedy check condition.
c. Identify a susceptible check, i.e. an entry showing maximum per cent yield loss.
d. Calculate Relative Yield (RY) of the entry relative to tolerant check as – $RYi = 100Yi / Yr$

where, Yi is the yield of the entry and Yr is the yield of tolerant check, both under weedy check condition.

e. Calculate per cent yield loss (RP) of i th entry relative to a susceptible check as – $RPi = 100Pi / Ps$

where, Pi is per cent yield loss of the i th entry and Ps is per cent yield loss in susceptible check.

f. Plot a scatter diagram keeping RY on vertical axis and RP on horizontal axis.
g. Divide the diagram into 4 quadrants by drawing perpendicular lines from RY = 75 (which implies that minimum acceptable yield under weedy check condition should be at least 75 % of the yield under weed free condition) and from RP = 25 (which implies that maximum acceptable yield loss is 25 %). Each quadrant of 'maximin – minimax plot' so prepared will house variety in specific category.

RESULTS AND DISCUSSION

The analyses of variance showed highly significant differences for soybean yield under weedy check and weed free conditions, which indicated that genotypes were differing for genes controlling yield and stress tolerance (Saba *et al.*, 2001; Golabdi *et al.*, 2006; Gholipouri *et al.*, 2009; Yagdi and Sozen, 2009). Results revealed that the soybean yield appreciably improved (80.99%) under weed free conditions as compared to weedy conditions (Table 1). Among the genotypes, the maximum yield

Table 1. Soybean yield under weed free and weedy check and percentage yield loss

Variety	Yield (kg/ha)		% yield loss	Relative yield (RY) (%)	RP* (%)
	Weed free	Weedy check			
JS 95 60	1831	1096	67.06	64.32	10.02
JS 93 05	2248	1221	84.11	71.65	12.57
JS 335	1360	1005	35.32	58.98	5.28
PS 1347	2185	284	669.37	16.67	100.00
MAUS 47	1787	885	101.92	51.94	15.23
PK 1029	2407	1704	41.26	100.00	6.16
PK 1024	1135	930	22.04	54.58	3.29
JS 71 05	1438	830	73.25	48.71	10.94
Mean	1799	994	80.99	58.33	12.10
SEm (±)	94.03	81.39			
CD (P = 0.05)	**315.18**	**272.84**			

**RP- Relative percent yield loss*

(2.4 t/ha) was recorded with PK 1029 followed by JS 93-05 (2.2 t/ha) and PS 1347 (2.2 t/ha) under weed-free conditions (without stress). The remaining genotypes produced the yield in between 1 to 2 t per ha. In case of stressed conditions (weedy check), the highest yield was recorded again with PK 1029 followed by JS 93-05 and JS 335.

Under stressed conditions, PS 1347 produced the lowest yield PS 1347 followed by JS 71-05, MAUS 47 and PK 1024. Yield of each variety decreased under weedy check conditions; the magnitude of yield reduction was the maximum with PS 1347 (669.37 %) followed by MAUS 47 (101.92%) and the minimum with PK 1024 (22.04 %) with the average of 80.99 per cent.

The highest relative yield was recorded JS 93-05 and closely followed by JS 95-60, while the lowest was with PS 1347. The RP value was maximum with MAUS 47 and minimum with PK 1024.

The relative yield and RP values were plotted on graph and varieties were grouped in to four categories (Fig. 1). Soybean varieties like PK 1029 was found to be resistant to presence of weeds and also with high yielding abilities, while JS 93-05, JS 95-60, JS 335, MAUS 47 and JS 71-05 were grouped under resistant to presence of weeds but lower yielder. Soybean variety PS 1347 was found to be susceptible to presence of weeds and lower yielder also.

Several reviews have documented variation among crop genotypes in their response to weed competition and capacity for suppressing weed growth rate and seed production (Berkowitz, 1988; Callaway, 1990; Callaway and Forcella 1992; Jordan 1993). Staniforth (1961) showed that an early-maturing corn hybrid was more tolerant

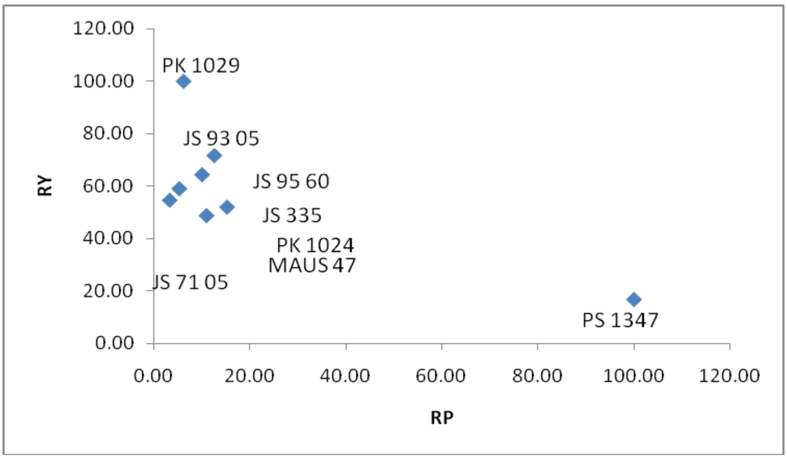

Fig. 1. Relationship between relative yield and relative percent yield loss of different soybean genotypes

to high yellow foxtail [*Setaria glauca* (L.) Beauv.] densities than a late-maturing hybrid, suggesting that the observed tolerance was the result of avoidance. Tollenaar *et al.* (1994) showed that four corn hybrids differed in their yield response to interference from a composite population of weeds, indicating that corn tolerance to weeds can vary among hybrids. However, weed biomass at corn silking did not vary among hybrids, suggesting that these hybrids did not vary in their weed suppressive ability (Tollenaar *et al*., 1994).

On the basis of results it could be concluded that the soybean varieties like

PK 1029, JS 93-05 and JS 95-60 were resistant to presence of weeds and gave high yield, while JS 335, PK 1024, MAUS 47 and JS 71-05 were also found resistant to presence of weeds but lower yielders. Presently farmers are over relied on herbicides to manage the weeds which may results in development of weed resistance and have adverse effect on environment, if one can adopt to grow weed tolerant varieties, the herbicide consumption may reduce to some extent in favour of sound environmental conditions

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Plant Parasitic Nematodes Associated with Soybean [*Glycine max* (L.) Merrill] Cultivation at Indore

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ABSTRACT

A survey was carried out in the research farm of Directorate of Soybean Research (DSR) for studying the association of plant parasitic nematodes with soybean cultivation. A total of 26 representative soil samples were collected from 26 blocks of DSR campus. Community analysis of soil samples revealed the presence of plant parasitic nematodes namely Helicotylenchus *sp.*, Rotylenchulus *sp.*, Pratylenchus *sp.*, Hoplolaimus *sp.*, Heterodera *sp. and* Tylenchorhynchus *sp. with different population densities. Based on the prominence value (PV),* Rotylenchulus *sp. (PV = 328) was found to be more important followed by* Hoploaimus sp. *(PV = 92.2),* Pratylenchus *sp. (PV = 31.1),* Helicotylenchus *sp. (PV = 25.6),* Heterodera *sp. (PV = 23.1) and* Tylechorhynchusn *sp. (PV = 1.7) in the descending order. The prevalence of plant parasitic nematodes in the research farm was documented as nematode distribution map.*

Key words: Community analysis, nematode distribution, plant parasitic nematodes

Soybean crop has shown spectacular growth in area and production in the last three decades and has become an important oilseed crop in India. However, the average productivity of soybean has remained low (about 1.3 t/ha) which is much below the world (2.2 t/ha) and Asian average (1.7 t/ha) (2012-13) (Anonymous, 2014). Among the various factors leading to low productivity in India, biotic stress is considered as one of the most important factors. The soybean crop is highly prone to the attack of various diseases, insect-pests and nematodes. Several times acute seedling mortality and premature sudden drying of soybean plants after flowering were observed in the field due to the association of fungi, insects and nematodes (Pushpendra and Singh, 1999). Nematode activity has also been shown to be antagonistic to *Rhizobium* infection (Barker *et al.,* 1972). The root knot nematodes and reniform nematodes

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are widely distributed throughout the sub-temperate to tropical latitudes of the world. Reniform nematode was reported to be the most prominent plant parasitic nematode in the soybean growing areas of India (Anes and Gupta, 2014). Other nematodes of potential importance affecting soybean are cyst, reniform, lance, lesion and spiral nematodes, which can severely damage soybean crop (Johnson 1977; Rebois and Golden, 1978). Nematode infestation of soybean was reported to cause a yield loss up to 18.7 per cent (Prasad, 2001).

Plant parasitic nematodes are the hidden enemies of crops throughout the world with great potential to act as the agent of yield loss alone and in association with other pathogens. Therefore, it is essential to have a thorough understanding on the present status of plant parasitic nematodes with regard to their distributions in the fields of soybean cultivation.

MATERIALS AND METHODS

A random survey was carried out in the research farm of Directorate of Soybean Research, Indore (Fig. 1) for the plant parasitic nematodes associated with soybean [*Glycine max* (L.) Merrill] during the mid-crop season.

The soil of DSR research farm is deep black cotton soil with pH 7.6 to 8.1 (basic/alkaline), low to medium in organic carbon and available phosphorus and high in potassium. Taxonomically, it is classified as fine, montmorillonitic, hyperthermic family of Typic Chromusterts and fine clay loam, montmorillonitic family of Lithic Vertic Ustochrepts (Anonymous, 2012-13).

Altogether 26 soil samples were collected from root zone of soybean at a depth of 10-15 cm. Each sample was consisted of 500 g soil which was a composite of 10 sub-samples/cores

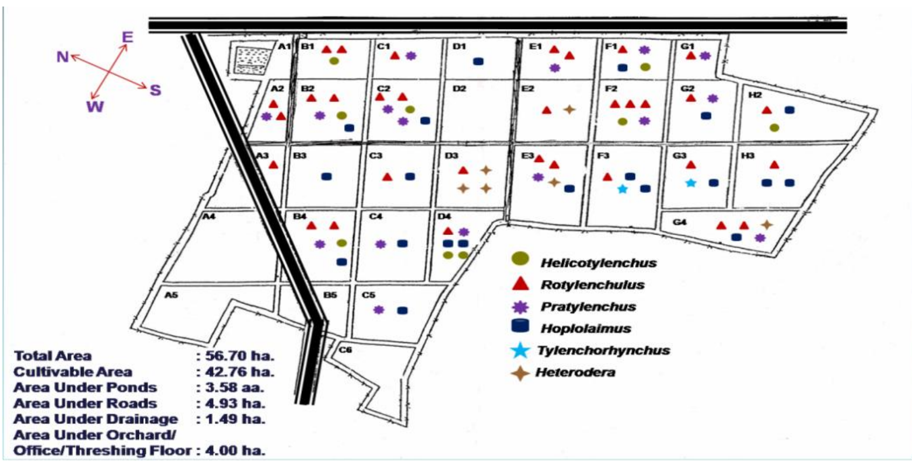

Fig. 1. Distribution of plant parasitic nematodes in the research farm of DSR, Indore

sampled at roughly equal interval (25 m) in a *zig-zag* pattern across a single block and samples were placed in sealed plastic bags. Soil samples were processed for nematode extraction by Cobb's sieving and decanting method followed by modified Baermann's funnel technique (Cobb, 1918; Baermann, 1917). The population of nematodes in each sample was counted using stereoscopic zoom microscope. Community analysis was done by determining absolute frequency (AF), relative frequency (RF), absolute density (AD), relative density (RD) and prominence value (PV) as detailed below (Norton, 1978).

$$\text{Absolute frequency of species } x = \frac{\text{No.of samples containing species } x}{\text{No.of samples collected}} \text{ X } 100$$

$$\text{Relative frequency of species } x = \frac{\text{Frequency of species x}}{\text{Sum of frequencies of all sp. present in the samples}} \text{ X } 100$$

$$\text{Absolute density of species } x = \frac{\text{No.of individuals of species } x \text{ in a sample}}{\text{Volume or mass or units of the sample}} \text{ X } 100$$

$$\text{Absolute frequency of species } x = \frac{\text{No.of individuals of species } x \text{ in a sample}}{\text{Total no.of individuals of all species in a sample}} \text{ X } 100$$

$$\text{Prominence value of species } x = \text{Relative density} \sqrt{\text{Relative frequency}}$$

RESULTS AND DISCUSSION

All the 26 soil samples yielded plant parasitic nematodes, which were identified up to genus level on the basis of morphological characters. A total of six plant parasitic nematode genera, namely *Helicotylenchus* sp. (Spiral nematode), *Rotylenchulus* sp. (Reniform nematode), *Pratylenchus* sp. (Lesion nematode), *Hoplolaimus* sp. (Lance nematode), *Tylenchorhynchus* sp. (Stunt nematode) and *Heterodera* sp. (Cyst nematode) were recorded with varying population densities (Table 1).

Among all the plant parasitic nematodes, reniform nematode was found to be widely distributed as it recorded from 23 blocks followed by lance, lesion and spiral nematodes, which were encountered in 17, 13 and 8 blocks, respectively. However, cyst and stunt nematodes were recorded only in 4 and 2 blocks, respectively. Based on the calculation of prominence value (PV), reniform nematode was found to be more important (PV – 331) followed by lance (PV - 93), lesion (PV - 31), spiral (PV - 26), cyst (PV - 23) and stunt (PV - 2) nematodes.

The association of these nematodes with soybean was reported by several workers (Johnson 1977; Rebois and Golden, 1978). The prevalence of reniform, spiral and lesions nematodes in different soybean growing regions of India were also documented (Anes and Gupta, 2014; Tiwari and Bhatt, 2011;

Table 1. Community analysis of plant parasitic nematodes encountered in the different blocks of research farm of DSR, Indore

	Plant parasitic nematodes (No/kg soil)					
	Praty-lenchus	*Roty-lenchulus*	*Hoplo-laimus*	*Helico-tylenchus*	*Tylencho-rhynchus*	*Hetero dera*
Total nematodes	196	1554	508	206	28	262
Absolute frequency	50.0	88.5	65.4	30.8	7.7	15.4
Relative frequency	19.1	33.8	25.0	11.8	2.9	5.9
Absolute density	7.5	59.8	19.5	7.9	1.1	10.1
Relative density	7.1	56.4	18.4	7.5	1.0	9.5
Prominence value	31.1	328.0	92.2	25.6	1.7	23.1
Rank based on Prominence value	3	1	2	4	6	5

Rathour *et al*., 2006).

In the present survey, reniform nematode was found to be more important in terms of prevalence and prominence value. Therefore, the association of reniform nematode with soybean cultivation is need to be investigated in detail. The cyst nematodes observed during the survey was identified to be *Heterodera cajani* (Pigeonpea cyst nematode) based on the morphology. Even though the prevalence of cyst nematode was relatively low, focus on future research should also be given to this nematode as it is a sedentary endoparasite of proven economic importance in many pulse crops.

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Soybean Research 13(2): 60-64 (2015)

Assessment of Front Line Demonstrations on Soybean in Shajapur District of Madhya Pradesh

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ABSTRACT

Front line demonstrations on soybean were organized consecutively for three years in kharif *seasons of 2009 to 11 in five adopted villages namely, Patlawada, Bhadoni, Jaloda, Khedi Mandalkha and Batawada of Shajapur district by Krishi Vigyan Kendra, Shajapur. The package of improved practices demonstrated, which included a new variety JS 95-60, integrated nutrient management (@ 20:60:20:20:: $N{:}P_2O_5{:}K_2O{:}S$ kg/ha + rhizobium @ 5g/kg seed + PSB @ 5g/kg of seed), integrated pest management (deep ploughing during April + seed treatment with* Trichoderma virdae *@ 5g/kg seed + trizophos @ 750 ml/ha) and sowing on ridge and furrow method led to higher seed yields (1,620 and 1,740 kg/ha with an average of 1,670 kg/ha) as compared to farmers' practice (1,240 and 1,420 kg/ha with an average of 1,350 kg/ha). This increase over farmers' practice ranged from 16.9 and 30.6 per cent during the three years of demonstration. The adoption of improved package of practices, on an average, also resulted in increased gross (by 33.5 %) and net (by 60 %) returns and benefit cost ratio (by 30 %) as compared to farmers' practice.*

Key words: Front line demonstration, improved package of practices, soybean JS 95-60

Soybean [*Glycine max* (L.) Merrill] is a legume that grows in tropical, sub-tropical and temperate climate. It has great potential as a *kharif* oilseed and has emerged as an important commercial oilseed in Madhya Pradesh. The main aim of Krishi Vigyan Kendras is to reduce the time lag between generation of technology at the research institution and its transfer to the farmers for increasing productivity and income from the agriculture and allied sectors on sustained basis. Under front line demonstrations (FLD), introduction of improved technologies/package of practices is the one of the mandate

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of Krishi Vigyan Kendra along with conductance of long-term educational activity in a systematic manner in farmers' fields. In the absence of knowledge of research emanated improved technologies among farmers, it was not feasible to harness the yield potentials of soybean in the state of Madhya Pradesh. Hence, Krishi Vigyan Kendra, Shajapur organized front line demonstrations in its five adopted villages with an objective to convince farmers on benefits of improved package of practices on soybean over practices followed by them.

MATERIAL AND METHODS

Utilizing the information generated during Participatory Rural Appraisal (PRA), the Krishi Vigyan Kendra, Shajapur, organized 36 front line demonstrations (0.4 ha each) between 2009 and 2011 on improved package of practices on farmers fields in adopted villages namely, Patlawada, Bhadoni, Jaloda, Khedi Mandalkha and Batawada of Shajapur district. The study area receives an annual average rainfall of 1047.9 mm, of which about 92.3 per cent is distributed during June to September and only 7.7 per cent between October and May. The soil of the experimental fields is black cotton with pH ranging from 7.0 to 7.5.

The package of improved practices demonstrated encompassed a new variety (JS 95-60), integrated nutrient management (@ 20:60:20:20:: $N:P_2O_5:K_2O$: S kg/ha + rhizobium @ 5g/kg seed + PSB @ 5 g/kg of seed), integrated pest management (deep ploughing during April + seed treatment with *Trichoderma virde* @ 5 g/kg seed + trizophos @ 750 ml/ha) and sowing on ridge and furrow method. Soybean crop was sown between 25th June to 10th July with row to row spacing of 30 cm using seed @ 80 kg per ha. An entire dose of NPK and sulphur through $ZnSO_4$ was applied as basal before sowing.

Under farmers practice existing variety JS 335, was planted on ridge and furrow method without any seed treatment with fungicides and biofertilizers, using higher seed rate (110-120 kg/ha), broadcasting of DAP at 20 days after sowing (DAS), and following injudicious use of insecticide and weedicide.

Before conducting the demonstrations, training to the farmers of respective villages was imparted with respect to envisaged technological interventions. Site selection, farmer's selection, layout of demonstration and farmers participation were considered as suggested by Choudhury (1999). The observations on productive and non-productive pods per plant, seed yield per plant and seed yield per ha were recorded. Other parameters like harvest index, technology gap, extension gap and technology index (%) were worked out as suggested by Kadian *et al.* (1997) using following formulae.

Harvest index (%) = Grain yield/ Biological yield x 100

Technology gap (kg/ha) = Potential yield - Demonstration yield

Extension gap (kg/ha) = Demonstration yield – Farmers' yield

Technology index = Potential yield-Demonstration yield/Potential yield x 100

The economic analysis was done by working out cost of cultivation utilizing the inputs and output prices of commodities which prevailed during three years of demonstration, gross and net returns, and benefit cost ratio.

RESULTS AND DISCUSSION

The number of productive pods per plant of soybean (JS 95-60) ranged from 68.3 to 73.9 with a mean of 71.2 and non-productive pods per plant range from 6.2 to 7.5 with a mean of 6.9 under package of improved practices. In case of farmer's practice the respective figures recorded were 50.6 to 52.6 with a mean of 51.5 and 5.0 to 5.4 with a mean of 5.2, respectively. The result revealed that the seed yield of soybean recorded was in the range of 1,620 to 1,740 kg per ha (average 1,670 kg/ha) by adoption of improved package of practices as compared to farmers' practice of 1,240 to 1,420 kg per ha (average 1,350 kg/ha). In comparison to farmers' practice, an increase of 16.9 to 30.6 per cent (average 24.5 %) in seed yield was recorded during the study period due to improved package of practices. Similarly, higher harvest index was recorded under improved package of practices (ranged from 41.7 to 43.2 % with a mean of 42.3 % as) compared to farmers' practice (37.3 % to 40.3 % with a mean of 39.2 %) (Table 1). The higher number of productive pods and higher harvest index in imparted package of practices justifies the higher yield achieved over farmer's practice. These results are in agreement with findings of Kumar *et al*. (2010), Jain *et al.* (1998) and Tiwari *et al*. (2013). It was also observed that the seed yield during *kharif* 2012 was recorded lower than that of *kharif* 2011 due to moisture stress during September 2012 (only 152 mm rains) in the district. The technological gap were found 840, 760 and 880 kg per ha during the year 2010, 2011 and 2012, respectively with an average of 827 kg per ha (Table 2). The technology gap observed may be attributed to dissimilarity in the soil fertility status and local climatic conditions. Similarly extensions gap of 24, 36 and 38 kg per ha were observed during 2010, 2011 and 2012, respectively. On an average the extension gap was observed 327 kg per ha, which emphasized the need to educate the farmers through various extension activities for adoption of improved agricultural production to narrow it. The technology index varied from 30.4 to 35.2 per cent with an average of 33.07 per cent during the three years of FLD program, which showed the efficacy of technical interventions. This will accelerate the adoption of technological intervention to increase the yield performance of soybean.

Economic analysis (Table 3) revealed that adoption of improved package of practices required an additional cost of Rs 1,066 per ha over farmers' practice. This additional cost led to increased average net returns by Rs 12, 674 per ha, which was higher by about 60 per cent over farmers' practice. The benefit cost ratios of under recommended practices were higher (2.45-2.71) than

Table 1. Productive and non-productive pods, seed yield, biological yield and harvest index of soybean JS 95-60

Year	No of farmers	Productive pods (No /plant)		Non-productive Pods (No /plant)		Seed Yield (kg/ha)		% increase over FP	Biological yield (kg/ha)		Harvest Index (%)	
		IP	FP	IP	FP	IP	FP		IP	FP	IP	FP
2010-11	12	68.3	52.6	6.2	5.4	1660	1420	16.9	3982	3520	41.69	40.34
2011-12	12	73.9	51.2	7.5	5.0	1740	1380	26.1	4026	3465	43.22	39.83
2012-13	12	71.4	50.6	6.9	5.1	1620	1240	30.6	3852	3325	42.06	37.29
Average	**12**	**71.2**	**51.47**	**6.87**	**5.17**	**1673**	**1347**	**24.54**	**3953**	**34.37**	**42.32**	**39.15**

IP- Improved package of practices; FP – Farmers' practices

Table 2. Technology gap, extension gap and technology index of soybean JS 95-60

Year	No of farmers	Seed yield (kg/ha)		Technology gap (kg/ha)	Extension gap (kg/ha)	Technology Index (%)
		IP	FP			
2010-11	12	1660	1402	840	240	33.6
2011-12	12	1740	1380	760	360	30.4
2012-13	12	1620	1240	880	380	35.2
Average	**12**	**1673**	**1347**	**827**	**327**	**33.07**

IP- Improved package of practices; FP – Farmers' practices

Table 3. Economics evaluation of demonstrated package of practices

Year	No of Demonstration	Gross Expenditure (Rs/ha)		Gross returns (Rs/ha)		Net Returns (Rs/ha)		B:C Ratio	
		IP	FP	IP	FP	IP	FP	IP	FP
2010-11	12	20890	20080	54800	43340	33910	23260	2.62	2.16
2011-12	12	21080	20100	57200	42260	36120	22160	2.71	2.10
2012-13	12	21910	20500	53600	38480	31690	17980	2.45	1.88
Average	**12**	**21293**	**20227**	**55200**	**41360**	**33907**	**21133**	**2.6**	**2.0**

IP- Improved package of practices; FP – Farmers' practices

farmer's practice (1.88-2.16). This may be due to higher yields obtained under recommended practices compared to farmers' practices. Similar results have earlier been reported on soybean (Sharma *et al.*, 2013; Tiwari *et al*., 2013) and on chickpea (Tomar *et al.*, 1999). The result of front line demonstrations on the package of practices suggested that by its adoption, the farmers can realize higher yields and net profit in soybean cultivation.

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Profitability of Soybean *vis-à-vis* Major *Kharif* crops in Madhya Pradesh

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ABSTRACT

The pattern of input use and profitability of crops have been analysed to find the most profitable crops for the state of Madhya Pradesh, and know the level of input use in cultivation of crops with a view to maximise profits. The analysis of trends in input use pattern in cultivation of major kharif *crops in Madhya Pradesh revealed that human labour followed by machine labour accounted for major share in operational cost of cultivation in majority of crops, particularly in* kharif *crops. The share of fertilizers and manure in operational cost is declining continually for all the major* kharif *crops in the state. The share of insecticides in operational cost was found to be increasing in soybean. The share of seed in operational cost of cultivation was found to be higher in case of soybean and cotton. Among the* kharif *crops, soybean was found to be yielding higher real net returns and real farm business income in Madhya Pradesh, after cotton and pigeon pea. The trends in input use pattern in cultivation of crops indicated that still farmers seems not encouraged to invest on yield increasing technologies like high yielding variety seeds, fertilisers, pest management practices,* etc.*, particularly in* kharif *crops. The net income realised was higher for the crops where farmers have invested more on the yield increasing technologies.*

Key words: Cost of cultivation, comparative profitability, *kharif* crops, rate of returns

Soybean [*Glycine max* (L.) Merrill] is one of the most important and fastest growing oil-bearing crops in the world. During 1980-2013, the world's soybean area grew at an annual rate of 2.65 per cent and production by about 4 per cent, higher than the growth in area and production of most other food crops. Soybean accounts for 37.4 per cent of the global area under oilseeds, and contributes to 28 per cent of vegetable oil production. The crop's adaptability to varied agro-ecological environments – the tropics,

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sub-tropics and temperate– has been responsible for its rapid spread across the globe. During the last three decades, India's oilseed production had increased by more than three times, from 9.37 million tons in 1980-81 to 32.48 million tons in 2010-11.

The per capita availability of edible oils has increased from 3.5 kg per person per year in 1970-71 to 15.8 kg in 2012-13 (GoI, 2014). India, one of the major consumers of oilseeds and their products, accounts for approximately 10.2 per cent of global consumption of edible oils as well as oilcake meals. Further, per capita consumption of edible oils had been increasing. This increase in demand for oilseeds and their products has been accompanied by increases in their domestic production. The demand for edible oils and oilcake meals is growing rapidly in the country accelerated with the sustained growth in per capita income, increasing population and urbanization (Birthal *et al.,* 2010; Gowda *et al.,* 2009).

Soybean accounted for 55.6 per cent of area under *kharif* oilseeds and 38 per cent of area under total oilseeds in the country during Triennium average Ending (TE) 2012-13. It accounted for 62.5 per cent of the *kharif* oilseed production and 42.5 per cent of total oilseeds production in the country, contributing to about 28.6 per cent of the total vegetable oils and two-thirds of the oil meals supplies during the corresponding period. Madhya Pradesh is the leading producer of soybean in the country, and regarded as 'Soy State'. The state alone contributes to more than half of the total soybean production in the country. During TE 1980, total production of soybean in the country was 2.55 lakh tonnes, of which about 80 per cent was contributed by Madhya Pradesh. It was introduced for commercial cultivation in rainfed regions of Madhya Pradesh in the early 1970s and since then its cultivation has expanded rapidly (Bisaliah, 1986; Chand, 2007; Dupare *et al.,* 2008). Initially, the crop was targeted for utilizing rainy season fallow lands, but subsequently it started replacing less profitable food grain crops such as sorghum, pearl millet and black gram (Bisaliah, 1986). The expansion in area was highest under soybean despite low yield; mainly on account of economic superiority of soybean over other corps and its suitability of cultivation in fallow land (Jha *et al.,* 2012).

Even being a leading oilseed crop, the yield level is well below the potential and almost stagnated at around 10-11 q per ha in the country. Looking at the growing importance of crop and slow growth in yield, the profitability of crop *vis-à-vis* other competing crops of the season needs to be worked out. In this context, an attempt was made in this paper to understand growth pattern in yield of soybean and other competing crops of the state, and their comparative profitability.

MATERIAL AND METHODS

The paper is mainly based on secondary data, collected from published sources of Commission on Agricultural Cost and Prices (CACP) and Directorate of Economics and Statistics, Ministry of

Agriculture. The data on area, production and productivity from 1980-81 to 2011-12 for *kharif* crops were used for the study. The data on costs incurred in and returns from cultivation of crops during *kharif* season for the period 1986-87 to 2010-11 were analysed.

The compound growth rates (CGR) of area, production and yield of soybean for each decade were estimated to study the growth rate. The CGRs are usually estimated by fitting a semi-log trend equation of the form

$$\ln Y = a + bt \quad (1)$$

where, y is the time series data (response variable) of area, production and yield of soybean, t is the trend term (explanatory variable) and *a* is the constant coefficient. The slope coefficient b measures the relative change in y for a given absolute change in the value of the explanatory variable t. If we multiply the relative change in y by 100, we get the percentage change or growth rate in y for an absolute change in variable t. The slope coefficient b measures the instantaneous rate of growth. We calculated the compound growth rate (r) as follows:

$$r = [(\text{Anti ln of } b)-1] \times 100 \quad (2)$$

To workout the comparative profitability of *kharif* crops, the data collected from reports of cost of cultivation of CACP were deflated with wholesale price index (base 2004-05=100) and analysed for cost incurred in cultivation of *kharif* crops and their returns. Cost concepts used in the paper are as followed in the CACP reports.

RESULTS AND DISCUSSION

Growth in area, production and yield of *kharif* crops in Madhya Pradesh

Compound annual growth and instability in area, production and yield of major *kharif* crops of Madhya Pradesh has been worked out (Table 1). The results clearly indicated that soybean is the fastest growing *kharif* crop in Madhya Pradesh as well as at overall India level. The growth in area and production of soybean was highest during 1980s, as the crop was introduced for cultivation during mid-1970s to occupy the *kharif* fallow lands in the state (Dupare *et al.* 2008; Bisaliah, 1986). Thereafter, the crop area has expanded very fast and replaced less remunerative crops in the state in the later stages (Chand 2007; Birthal *et al.*, 2010). Therefore, the growth in area under sorghum in Madhya Pradesh was found to be negative during all the decades analysed. The area under sorghum has decreased in Madhya Pradesh by 5.82 per cent per annum during the period 1980-81 to 2011-12. Area under sorghum has decreased during the period by 2.8 per cent per annum in the country. All other *kharif* crops in the country have registered positive growth in area. During 1980s and 1990s, the rate of growth in area under *kharif* crops was found to be negative in the state with the exception of soybean and paddy. However the growth in area under the *kharif* crops has turned out to be positive during the recent decade.

In terms of growth in yield of *kharif* crops, soybean outpaced other crops except cotton in Madhya Pradesh as well as at overall country level. The rate of growth in production and productivity of cotton was found to be highest during 2000s in Madhya Pradesh (14 % and 11.34 % per annum) as well as in India (13.61 % and 11.34 % per annum), mainly on account of introduction of Bt cotton during the decade.

Table 1. Growth performance of major *kharif* crops of Madhya Pradesh (CGR in %)

Crop	Period	Undivided M P			India		
		Area	Production	Yield	Area	Production	Yield
Pigeon pea	1981-1990	-2.15	2.98	5.25	2.31	2.87	0.54
	1991-2000	-2.53	-3.65	-1.16	-0.66	0.93	1.60
	2001-2010	1.26	2.36	1.09	0.16	1.62	1.47
	1981-2012	-1.28	-2.35	-1.08	0.64	0.39	-0.25
Black gram	1981-1990	-0.41	-0.35	0.06	1.79	4.30	2.47
	1991-2000	-0.85	0.55	1.42	-1.02	-0.99	0.03
	2001-2010	0.22	3.41	3.16	-1.43	-0.51	0.93
	1981-2012	-1.12	0.11	1.25	0.23	1.29	1.05
Paddy	1981-1990	0.36	2.03	1.67	0.41	3.62	3.19
	1991-2000	0.74	-0.12	-0.85	0.68	2.02	1.34
	2001-2010	-1.41	1.85	3.30	-0.02	1.59	1.61
	1981-2012	-4.76	-4.47	0.31	0.30	2.04	1.74
Sorghum	1981-1990	-2.10	0.05	2.20	-1.00	0.28	1.29
	1991-2000	-9.17	-9.57	-0.45	-3.53	-3.07	0.48
	2001-2010	-4.37	0.17	4.74	-3.10	-0.29	2.90
	1981-2012	-5.82	-4.39	1.52	-2.98	-2.01	1.01
Maize	1981-1990	1.28	5.07	3.75	-0.18	1.92	2.10
	1991-2000	-0.23	1.17	1.40	0.95	3.28	2.31
	2001-2010	-0.17	-4.64	-4.48	2.93	5.29	2.29
	1981-2012	0.15	1.23	1.07	1.34	3.77	2.40
Soybean	1981-1990	19.94	20.04	0.08	17.22	17.95	0.62
	1991-2000	8.23	10.35	1.95	10.23	13.06	2.57
	2001-2010	2.34	7.95	5.48	5.73	8.93	3.03
	1981-2012	8.24	9.93	1.57	9.61	11.57	1.79
Cotton	1981-1990	-1.02	2.59	3.64	-1.26	2.79	4.10
	1991-2000	-1.25	3.97	5.30	2.71	2.30	-0.40
	2001-2010	2.39	13.99	11.34	2.03	13.61	11.34
	1981-2012	0.43	5.09	4.64	1.12	4.46	3.31

Source: Calculated by authors on the basis of data collected from DAC, Ministry of Agriculture, GoI.

Share of inputs in operational cost of cultivation of major *kharif* crops

Labour component (including human, animal and machine labour) was found to be as high as 80 per cent of total operational cost of cultivation of *kharif* crops in Madhya Pradesh, indicating minimal use of productive and protective inputs in the season. In case of soybean the labour component constituted about 47 per cent of the operational cost during 1988 -1990, which has increased to 63.4 per cent in 2010-2012, though lowest among *kharif* crops (Table 2). The other crop is cotton, in which the share of labour component was found to be less than 70 per cent of the operational cost, while more than 70 per cent for all other *kharif* crops. Sorghum and maize are the crops which are being grown mainly on labour component and minimal use of productive and protective inputs. Human labour shares the major share in operational cost of cultivation of *kharif* crops in Madhya Pradesh.

With regards to other material inputs, cost of seed is another major

Table 2. Per cent share of labour inputs in operational cost of major *kharif* crops in Madhya Pradesh

Crops	Cost and returns	1988-90	1998-00	2008-10	2010-12
Soybean	Human Labour	26.7	38.2	35.1	35.6
	Animal Labour	13.1	10.9	10.1	6.9
	Machine Labour	8.1	12.5	18.8	20.9
Maize	Human Labour	47.6	54.0	53.4	53.8
	Animal Labour	22.1	20.9	18.1	15.6
	Machine Labour	2.3	6.5	7.2	9.5
Sorghum	Human Labour	45.9	57.3	43.4	45.3
	Animal Labour	26.5	21.6	26.1	15.2
	Machine Labour	4.4	4.8	9.9	18.5
Cotton	Human Labour	38.6	47.0	43.0	49.9
	Animal Labour	14.6	16.3	16.0	14.3
	Machine Labour	2.5	5.1	3.7	4.0
Pigeon pea	Human Labour	45.8	54.3	49.7	49.6
	Animal Labour	20.3	16.5	14.1	7.4
	Machine Labour	2.4	8.5	12.6	16.8
Paddy	Human Labour	44.8	46.3	47.1	46.7
	Animal Labour	21.5	21.2	14.8	13.4
	Machine Labour	0.5	2.9	8.5	11.3
Black gram	Human Labour	47.8	49.6	43.2	43.4
	Animal Labour	24.0	23.3	10.5	6.1
	Machine Labour	0.5	5.9	22.2	26.7

Source: Calculated by authors from CACP Data.

component of operational cost of soybean cultivation in Madhya Pradesh; however, the share had declined from 28.4 per cent during 1987-90 to 17.2 per cent presently (Table 3). This decline in share of seed in total operational cost was mainly due to increase in share of machine labour cost, human labour, and plant protection chemicals (Table 2 and 3). The matter of

Table 3. Per cent share of material inputs in operational cost of major *kharif* crops in Madhya Pradesh

Crops	Cost and returns	1988-90	1998-00	2008-10	2010-12
Soybean	Seed	28.4	20.2	18.2	17.2
	Fertilizer and Manure	19.0	13.2	10.2	9.4
	Insecticide	0.6	2.3	4.9	7.4
	Irrigation	1.5	0.1	0.1	0.0
Maize	Seed	4.8	4.3	6.3	8.5
	Fertilizer and Manure	20.9	12.3	12.5	10.0
	Insecticide	0.1	0.0	0.4	0.5
	Irrigation	0.1	0.2	0.2	0.0
Sorghum	Seed	4.1	3.9	4.3	7.8
	Fertilizer and Manure	16.6	10.0	13.6	10.2
	Insecticide	0.1	0.4	0.5	1.0
	Irrigation	0.1	0.1	0.0	0.0
Cotton	Seed	7.9	9.3	12.5	11.0
	Fertilizer and Manure	21.1	11.8	13.1	9.7
	Insecticide	8.5	4.2	7.1	7.8
	Irrigation	4.3	4.1	2.2	1.2
Pigeon pea	Seed	8.5	8.6	9.4	10.1
	Fertilizer and Manure	17.3	9.1	8.1	7.1
	Insecticide	3.4	0.3	3.3	6.3
	Irrigation	0.0	0.6	0.6	0.4
Paddy	Seed	10.3	8.7	9.6	8.5
	Fertilizer and Manure	18.6	16.1	13.4	14.7
	Insecticide	0.1	0.6	1.8	1.9
	Irrigation	2.0	2.1	2.5	1.1
Black gram	Seed	11.2	10.6	10.3	10.9
	Fertilizer and Manure	13.9	7.4	10.7	7.5
	Insecticide	0.2	0.1	1.0	1.4
	Irrigation	0.5	1.2	0.0	1.8

Source: Calculated by authors from CACP Data.

concern here is that the share of fertilizers and manures, the productive inputs, is continuously declining in operational cost of cultivation of soybean in Madhya Pradesh. The share of fertilizers and manures in operational cost has declined in all the *kharif* season crops in Madhya Pradesh. This is one of the factors resulting in stagnation or lower growth in productivity of most of the *kharif* crops in the state. The increasing share of plant protection chemicals in operational cost of cultivation of soybean indicated that the crop in increasingly being affected by insect-pests and diseases. Developing and popularising insect/disease resistant /tolerant varieties has become inevitable in this situation. Nahatkar (2014) also reported that the share of fertilizers and manures is decreasing in operational cost of soybean cultivation in Madhya Pradesh, while the use of plant protection chemicals is increasing.

Cost in and returns from cultivation of major *kharif* crops in MP

In case of the major *kharif* crops produced in Madhya Pradesh, the real paid out cost (cost A_2 at constant 2004-05 prices) was found to be highest for cotton (Rs 9,307/ha during TE 2012) followed by paddy (Rs 8,522/ha), soybean (Rs 7,857/ha) and lowest for black gram (Rs 5,609/ha). Similarly, the real total cost of cultivation (cost C_2 at constant 2004-05 prices) was also highest for cotton (Rs 23,860/ha) followed by paddy (Rs17, 477/ha) and soybean (Rs 15,564/ha) and lowest for maize (Rs 11,049/ha) in TE 2012). The real paid out cost in cultivation of soybean in Madhya Pradesh has increased from Rs 5,487 per ha in TE 1990 to Rs 7,857 per ha in TE 2012. Likewise, the real total cost of cultivation of soybean also increased from Rs 9,757 per ha in TE 1990 to Rs 15,564 per ha in TE 2012. The increase in paid-out cost and total cost of cultivation (at constant prices) was found to be higher for other *kharif* crops like sorghum, maize, pigeon pea, paddy and black gram as compared to soybean (Table 4) over the corresponding period. The paid-out cost for crops like sorghum, maize, pigeon pea and black gram was about half of the amount required in cultivation of soybean during TE 1990, which has increased to more than 70 per cent presently. The capital cost requirement in cultivation of *kharif* crops in Madhya Pradesh was highest for cotton, which has increased from Rs 6,436 per ha in TE 1990 to Rs 10,708 per ha in TE 2012. The crops like cotton, paddy and sorghum were more capital intensive than other *kharif* crops in Madhya Pradesh.

The real gross returns were found to be higher in case of cotton, paddy and soybean as compared to other major *kharif* crops in Madhya Pradesh, while the real net returns were higher from cotton and pigeon pea (Table 4). Gross returns at constant prices from maize and sorghum were worked out to be about half of the returns from soybean, whereas the net returns were found to be negative from both these crops. Though, the net returns from cotton and paddy were also negative during TE 2000, however, turned positive during recent periods. The farm business income at constant prices was also worked out to be higher for cotton (Rs 29,158/ha) followed by pigeon pea (Rs 13,117.7/ha), paddy (Rs 13,009/ha) and soybean (Rs 12,579/ha). Thus, soybean is one of the economically

Table 4. Profitability of major *kharif* crops in Madhya Pradesh (Rs/ha)

	Crop	Real cost and returns (Rs/ha)				Soybean relative cost and returns			
		1988-90	1998-00	2008-10	2010-12	1988-90	1998-00	2008-10	2010-12
Paid-out cost (Cost A_2)	Soybean	5487	6658	7443	7857	100	100	100	100
	Sorghum	2957	4362	5381	5810	53.9	65.5	72.3	74.0
	Maize	3090	4140	5149	5667	56.3	62.2	69.2	72.1
	Cotton	6437	7173	10708	9307	117.3	107.7	143.9	118.5
	Pigeon pea	3255	4380	4992	5988	59.3	65.8	67.1	76.2
	Paddy	5009	7475	7286	8522	91.3	112.3	97.9	108.5
	Black gram	2579	3455	4893	5609	47.0	51.9	65.7	71.4
Total cost of cultivation	Soybean	9757	12322	14387	15564	100	100	100	100
	Sorghum	6368	9661	10766	12226	65.3	78.4	74.8	78.6
	Maize	6386	9408	9971	11049	65.4	76.4	69.3	71.0
	Cotton	12425	13693	22523	23860	127.3	111.1	156.6	153.3
	Pigeon pea	7351	10274	12624	13848	75.3	83.4	87.8	89.0
	Paddy	9871	14628	15384	17477	101.2	118.7	106.9	112.3
	Black gram	5688	7394	10209	12231	58.3	60.0	71.0	78.6
Gross returns	Soybean	12373	14088	18302	20435	100	100	100	100
	Sorghum	6861	8749	8291	11414	55.4	62.1	45.3	55.9
	Maize	6941	9788	9050	9993	56.1	69.5	49.4	48.9
	Cotton	14850	12884	29683	38465	120.0	91.5	162.2	188.2
	Pigeon pea	10305	13232	19324	19106	83.3	93.9	105.6	93.5
	Paddy	9890	14462	19110	21530	79.9	102.7	104.4	105.4
	Black gram	6421	7511	11155	15446	51.9	53.3	60.9	75.6
Net returns	Soybean	2616	1766	3915	4871	100	100	100	100
	Sorghum	493	-912	-2476	-813	18.8	-51.6	-63.2	-16.7
	Maize	555	380	-922	-1056	21.2	21.5	-23.5	-21.7
	Cotton	2425	-809.0	7161	14605	92.7	-45.8	182.9	299.8
	Pigeon pea	2954	2958.2	6700	5257	112.9	167.5	171.1	107.9
	Paddy	19	-166.0	3726	4054	0.7	-9.4	95.2	83.2
	Black gram	732	117.6	946	3215	28.0	6.7	24.2	66.0
Farm Business Income	Soybean	6885	7429.7	10859	12579	100	100	100	100
	Sorghum	3904	4386.6	2910	5603	56.7	59.0	26.8	44.5
	Maize	3851	5647.6	3901	4326	55.9	76.0	35.9	34.4
	Cotton	8413	5710.8	18975	29158	122.2	76.9	174.7	231.8
	Pigeon pea	7051	8851.8	14331	13118	102.4	119.1	132.0	104.3
	Paddy	4881	6987.4	11823	13009	70.9	94.0	108.9	103.4
	Black gram	3842	4055.9	6262	9837	55.8	54.6	57.7	78.2

Source: Calculated by authors from CACP Data.

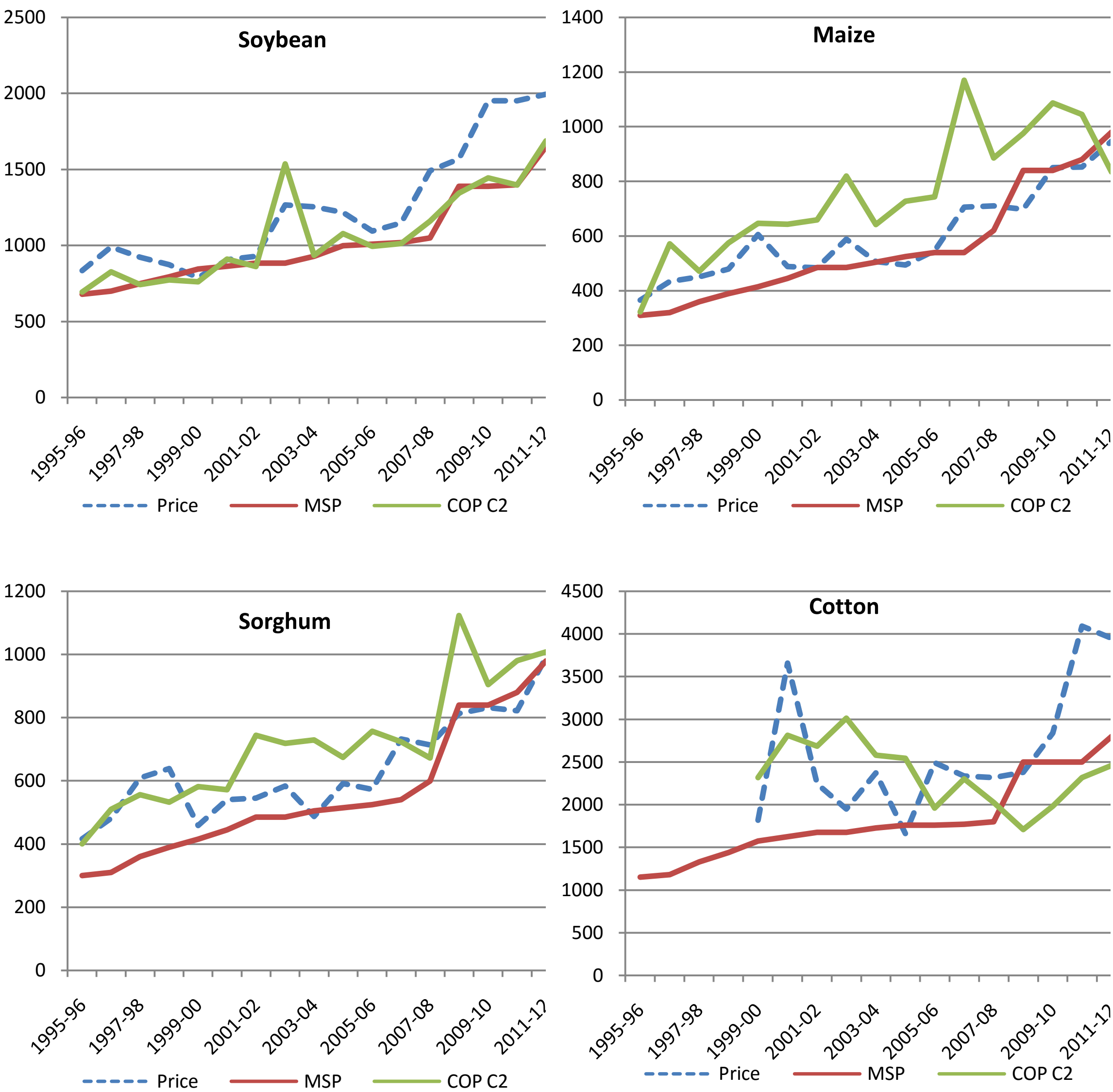
superior *kharif* crops in Madhya Pradesh after cotton and pigeon pea. Earlier studies referring to the early 1970s (Dovring *et al.*, 1974) and mid-1980s (Bapna *et al.*, 1992) and recently (Chand, 2007; Jaiswal and Hugar, 2011) have also reported the economic superiority of soybeans over competing crops. Jaiswal and Hugar (2011) reported that net returns from soybean cultivation were higher by 868 per cent than sorghum and by 122 per cent as compared to maize. Soybean crop being leguminous in nature fixes atmospheric nitrogen and improves soil health, which is an added advantage from soybean cropping system. Study by Badal *et al*. (2000) reported that soybean-wheat system was found to yielding 20 per cent higher returns compared to sorghum-wheat and maize-wheat.

Table 5. Rate of returns from cultivation of major *kharif* crops in Madhya Pradesh

Year	Soybean	Maize	Sorghum	Cotton	Pigeon pea	Paddy	Black gram
			Rate of returns over cost A_2				
TE 1990	2.24	2.32	2.25	2.31	3.17	1.97	2.49
TE 1995	2.17	2.35	2.27	2.26	3.41	2.17	2.28
TE 2000	2.11	2.01	2.36	1.80	3.02	1.93	2.17
TE 2005	2.09	1.49	1.53	1.34	2.73	1.58	1.60
TE 2010	2.46	1.54	1.76	2.27	3.87	2.62	2.28
TE 2012	2.59	1.96	1.76	4.13	3.19	2.53	2.75
			Rate of returns over total cost of cultivation				
TE 1990	1.26	1.08	1.09	0.80	2.10	1.00	1.13
TE 1995	1.16	1.10	0.69	0.40	1.36	1.12	1.00
TE 2000	1.14	0.91	1.04	0.63	1.29	0.99	1.02
TE 2005	1.11	0.74	0.78	0.73	1.17	0.85	0.74
TE 2010	1.27	0.77	0.91	1.32	1.53	1.24	1.09
TE 2012	1.31	0.93	0.90	1.61	1.38	1.23	1.26

Source: Calculated by authors from CACP Data.

The ratio of gross returns to total cost of cultivation and cost A_2 for major *kharif* crops of Madhya Pradesh have been worked out (Table 5). It is revealed from the per rupee rate of returns from cultivation of maize and sorghum have declined over time (Table 5), while improved for cotton during the recent period. Rupee one invested in cultivation of soybean crop in Madhya Pradesh yielded back rupee 1.31 over total cost in TE 2012, lower to cotton (1.61) and pigeon pea (1.38). The rate of returns from cotton had increased fast in the recent years, mainly due to increased productivity by the introduction of Bt cotton. As explained above, the soybean is economic superior crops compared to other *kharif* crops like sorghum, maize and black gram.



Soybean
2500
2000
1500
1000
500
0
1995-96
1997-98
1999-00
2001-02
2003-04
2005-06
2007-08
2009-10
2011-12
Price
MSP
COP C2
Maize
1400
1200
1000
800
600
400
200
0
1995-96
1997-98
1999-00
2001-02
2003-04
2005-06
2007-08
2009-10
2011-12
Price
MSP
COP C2
Sorghum
1200
1000
800
600
400
200
0
1995-96
1997-98
1999-00
2001-02
2003-04
2005-06
2007-08
2009-10
2011-12
Price
MSP
COP C2
Cotton
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1995-96
1997-98
1999-00
2001-02
2003-04
2005-06
2007-08
2009-10
2011-12
Price
MSP
COP C2

Fig. 1. Cost of production and price realised for major *kharif* crops of Madhya Pradesh (Rs/q)

The movement of price received by farmers, minimum support price and cost of production of the major *kharif* crops of Madhya Pradesh were plotted (Fig. 1). It is clearly evident from the figures that price received by farmers for soybean, cotton and paddy was greater than the minimum support price as well as the per quintal cost of production. In case of pigeon pea, the price received was higher than minimum support price and cost of production till the year 2009-10, but now decreased to the minimum support price level, though still higher than the cost of production. There was high year-to-year fluctuation in the price received by the farmers and the cost of production of the cotton.

Soybean is the fastest growing *kharif* crop in Madhya Pradesh as well as at overall India level. Labour component (including human, animal and machine labour) was found to be as high as 80 per cent of total operational cost of cultivation of *kharif* crops in Madhya Pradesh, indicating minimal use of productive and protective inputs in the season. In case of soybean, the labour component constituted nearly half of the operational cost during TE 1990, which has increased to 63.4 per cent in TE 2012, though lowest among *kharif* crops.

The share of fertilizers and manures, the productive inputs, is continuously declining in operational cost of cultivation of all major *kharif* season crops including soybean in Madhya Pradesh. This may be the resulting in stagnation or lower growth in productivity of most of the *kharif* crops in the state along with other factors. The use of protective irrigation is found negligible, resulting in drastic decline in productivity, and hence profitability particularly in abnormal monsoon years. The share of plant protection chemicals in operational cost of cultivation of soybean is increasing fast implying thereby that the crop in increasingly being affected by insects and diseases. Developing and popularising insect/ disease resistant/ tolerant varieties has become inevitable in this situation.

In case of the major *kharif* crops produced in Madhya Pradesh, the real paid out cost and the real total cost of cultivation was found to be highest for cotton followed by paddy and soybean. The increase in real paid-out cost and real total cost of cultivation was found to be higher for other *kharif* crops like sorghum, maize, pigeon pea, paddy and black gram as compared to soybean over the period from TE 1990 to TE 2012. The crops like cotton, paddy and sorghum were more capital intensive than other *kharif* crops in Madhya Pradesh. The real gross returns were found to be higher in case of cotton, paddy and soybean as compared to other major *kharif* crops in Madhya Pradesh, while the real net returns were higher from cotton and pigeon pea. Soybean is one of the economically superior *kharif* crops in Madhya Pradesh after cotton and pigeon pea.

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Generation Mean Analysis for Seed Yield and its Contributing Traits in Soybean [*Glycine max* (L.) Merrill]

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All the traits are controlled mainly by two effects; genetically and environmentally. The impacts of genetics are of two types of actions, additive and non-additive. Additive genetic action refers to the effect of gene that is independent of other genes and the environment. In other words, there is no influence of dominance or epistasis. Most traits are controlled to some extent by both additive and non-additive genetic action. We can take advantage of additive genes through our selection decisions, but we can also take advantage of non-additive genes on additive genetic actions which involve interactions between alleles at the same loci (dominance), at different loci (epistasis), and between genes and the environment.

In genetic studies, one approach that contributes to determine the magnitudes of gene effects is the use of scaling tests or generation mean analysis. This has been described by Mather and Jinks (1982), based on Cavalli's method (1952). Their theory was developed for diploid organisms, whose genes segregate independently and are homozygous in the parent lines. In different generation of the same cross between individuals and their backcrosses, it is possible to find gene action based on Mendelian segregation ratios, the additive, dominance and interaction (epistasis) effects of the genes. Therefore, the present investigation was carried out to study the nature and magnitude of gene effects for the yield and its components. Five generations, namely P_1, P_2, F_1, F_2, and F_3 of one cross JS 88-66 x JS 93-05 were evaluated in randomized block design with three replications during the *kharif* seasons of 2010 and 2011 under All India Coordinated Research Project on Soybean at R A K College of Agriculture, Sehore. The row length was three meters and the number of rows in P_1 and P_2 (2) and F_1 (13), F_2 (33) and F_3 (81) with row to row spacing of 40 cm. The plant to plant was maintained at 7.5 cm. Recommended

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package of practices were adopted for optimum crop growth.

Twenty competitive plants from P_1, P_2 and 100 plants in F_1, F_2, and F_3 generations were randomly selected. The observations were recorded on quantitative characters, namely days to 50 per cent flowering, days to physiological maturity, plant height at harvest, primary branches per plant, number of pods per plant, seeds per plant, 100 seed weight and seed yield per plant. Data were subjected to individual scaling tests, namely C and D to detect the presence of epitasis following the method prepared by Mather (1949). The gene effects were estimated by the five parameter model as proposed by Haymen (1958).

Importance of epistatic variation in the inheritance of various quantitative traits was observed from significant estimates of gene effects in the cross. Presence of significant and highly significant estimates of either one or two scaling tests were found for all traits studied except, primary branches, plant height, pods per plant and seeds per plant in cross (JS 88-66 x JS 93-05). These results (Table 1) indicated the presence of epistatic variation in the inheritance of various quantitative traits studied. In scaling test (C) higher values were recorded for days to physiological maturity and lower value for plant height at harvest and in the scaling test (D), similar observations were recorded. In scaling test greater magnitude was recorded for days to 50 per cent flowering, 100 seed weight and yield per plant, in scale (C) than scaling test (D).

Higher magnitude for days to physiological maturity, plant height, pods per plant, primary branches and seeds per plant have been observed in scaling test (D). Maloo and Nayer (2005) also found significant estimates at least one or two scales for days to 50 per cent flowering, days to full maturity, yield per plant, harvest index, number of pods per plant, and plant height.

The estimates of mean (m) were highly significant for all the traits studied in all crosses. Highly significant value of "m" from generation mean analysis showed that the five generations differed from each other significantly. The estimates of mean (m) were highly significant for the character 50 per cent flowering, days to physiological maturity, primary branches, plant height, pods per plant, 100 seed weight and seed yield per plant. Similar results obtained by Singh and Singh (1994).

There was gradual decrease for 50 per cent flowering in generation F_2 and F_3 ending towards larger day's parent 2 (JS 93-05). The additive gene effect of early maturity is expressed in advance generations favoured crop improvement programme looking to the selection of genotypes for rainfed conditions.

Days to physiological maturity showed a drastic reduction from either of the parents, which has been reduced from96 days in parent 2 (JS 93-05) to 88 days in F_3. This reduction was highly significant as compared to parental generations. There was unexpected reduction in primary branches per plant from F_1 to F_3 generations. However, reduction in primary branches

Table 1. Scaling tests and gene effects for different quantitative traits in soybean cross JS 88-66 x JS 93-05

Characters	scales		Genetic components				
	$t_{(C)}$	$t_{(D)}$	$t_{(m)}$	$t_{(d)}$	$t_{(h)}$	$t_{(i)}$	$t_{(l)}$
Days to 50% flowering	-16.10**	-6.14**	42.37**	2.25**	6.28**	7.45**	0.8
Days to physiological maturity	-19.21**	-27.80**	90.59**	4.00**	7.55**	2.25**	-5.30**
Primary branches	-1.54	-5.53**	7.94**	-0.72	4.08**	2.15**	-6.72**
Plant height at harvest	-0.34	0.40	69.03**	-2.34**	1.00	-5.32**	3.38**
Pods (No/plant)	1.19	1.25	30.87**	-0.32	0.45	-0.88	-3.14**
Seeds (No/plant)	-1.85	11.90**	79.15**	-1.29	-7.63**	-9.82**	10.23**
100 seed weight (g)	3.14**	1.73	8.44**	0.33	-1.03	-0.23	0.23
Yield (g/plant)	4.35**	2.09**	6.69**	0.08	-1.20	-0.93	0.53

*** Significant at 5% level*

has not affected the very important traits like pods per plant and seeds per plant. Plant height (74.8 cm) in F_1 generation was in between parent 1 (66.4 cm) and parent 2 (71.1 cm) although there is some reduction in F_2 and F_3 generations which was not significant, mainly due to complementary effects of gene action. Pods per plant in advance generations, however, differed significantly from the parental mean and there was gradual increase in this trait from F_1 to F_3 from parental means although the gene effect was not significant for any actions of the gene, the duplicate effect has been exhibited for the same.

Seeds per plant have incremental variation from F_1 to $F_{3,}$ which has highest (81.7) seeds per plant in F_3 generation. Additivity of genes exhibited the duplicate gene action because of significance of additive x additive gene action.

For 100 seed weight, generation mean of all these generation differed from generation to generation. Because of duplicate action of the genes coupled with dominance effect advance generation tended to increase 100 seed weight in F_3 generation. Seed yield per plant differed significantly from generation to generation and there was gradual increment from 6.22 g per plant in F_1 to 7.03 g per plant in F_3 generation. The epistasis of the genes exhibited the duplicate gene action.

Additive effects have important implications in genetic variation. We have found additive gene effects make a greater contribution to the total genetic variation. In five parameter model, both fixable and non-fixable gene effects were significant for most of the characters in this cross (JS 88-66 x JS 93-05). Additive effect (d) for days to 50 per cent flowering, days to physiological maturity and primary branches were significantly higher than other yield components. Similar findings are also obtained by Singh *et al.* (2010).

The contribution of the dominance effects varied according to the traits. The estimates of the five parameters for the various gene effects considered, showed that dominance gene effects made the major contribution to variation in yield of soybean in the cross studied. The dominance effects were greater than the additive effects for all the characters. The dominance gene effect (h) was positive and significant in days to 50 per cent flowering, days to physiological maturity and primary branches. The results are in close proximity for days to 50 per cent flowering to Singh *et al.* (2010). The dominance gene effect (h) was greater in days to 50 per cent flowering, days to physiological maturity, primary branches. The dominance (h) effect was predominant than dominance x dominance (l) effect for days to 50 per cent flowering and primary branches. Similar findings were also reported by Srivastava and Jain (1994) and Choukan (1996). Under the highly productive environmental conditions, dominance effect have accounted for most of the variability in yield with epistasis having small and significant influence in the final performance of different generations.

The presence of epistasis has important implications for any plant breeding program. The possibility that epistasis accounts for a significant proportion of the genetic variance of quantitative traits have been investigated extensively; our results showed that, besides the additive and dominance genetic effect, epistatic components have also contributed to genetic variations for most of the characters studied. In this study, in addition to additive gene effects, additive and additive x additive gene effects had high contributions in controlling the studied traits. The additive by additive effects is important for the inheritance of most of the quantitative traits. The digenic interaction effects, additive x additive (i) was significant for days to 50 per cent flowering, primary branches, seeds per plant and yield per plant. The additive x additive effect was not significant for all the remaining traits in this cross (JS 88-66 x JS 93-05). The additive x additive effect was positive and highly significant in days to 50 per cent flowering. These findings are in agreement with the results obtained by Raut *et al.* (2000) and Saleem *et al.* (2005).

The signs associated with estimates of additive x additive and dominance x dominance types of epistasis indicates the direction in which the gene effect influences the mean of population. For additive x additive the sign also provides information on the association or dispersion of genes in the parents (Mather and Jinks, 1982). Dominance x dominance (l) type of interaction was negative and highly significant in primary branches than days to 50 per cent flowering, days to physiological maturity, plant height, seeds per plant, 100 seed weight and yield per plant. The results are in close proximity for plant height and days to 50 per cent flowering to Singh *et al* (2010). Complementary epistasis was observed for days to 50 per cent flowering and plant height in cross JS 88-66 x JS 93-05, which appeared to be desirable and would be helpful in further improvement of these traits and the duplicate epistasis was observed in days to physiological maturity, primary branches, pods per plant, seeds per plant, 100 seed weight and yield per plant. The opposite and significant signs of 'h' and 'I' complements indicated the importance of duplicate epistasis in almost various quantitative characters. Similar findings are also obtained by Kumar and Sreelakshmi *et al.* (2009).

It has appeared from the present study and may be concluded that most of the characters were found to be under the control of additive and non-additive gene effects coupled with duplicate type of epitasis. This indicated that heterosis breeding and recurrent selection would be more fruitful for the improvement of most of the characters. The duplicate epitasis for most characters showed their complex nature of inheritance. Recurrent selection may be used to improve the characters when both additive and non-additive gene effects are involved in expression of the traits. Therefore, breeding strategies should be designed accordingly to get desired results in soybean.

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Genetic Diversity in Soybean Germplasm

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Key words: Genetic diversity, D^2 statistics, selection indices, seed yield, soybean

With the advancement of biometrical methods, such as multivariate analysis (Rao, 1952) based on Mahalanobis (1936) D^2 statistic (Smith, 1966), the magnitude of genetic diversity among all the possible pairs of populations at genotypic level before effecting actual crosses in modelling the genotypes in a desired genetic architecture has become possible for sustainable yield. In India, majority of soybean varieties under commercial cultivation have their origin from Bragg, JS 335 and Punjab 1, which needs diversified breeding approaches to develop varieties suiting to the existing cropping pattern and area of adaptation.

The experimental material consisted of 80 soybean lines obtained from germplasm collection of All India Coordinated Research Project on Soybean (AICRPS), RAK College of Agriculture, Sehore. The experiment was carried out in randomized block design with three replications. Each genotype was planted in 3 m row length with 50 cm x 5-7cm crop geometry on July 7, 2012. The crop was raised by following recommended package of practices.

Observations were recorded on days to 50 per cent flowering, plant height, primary branches per plant, pods per plant, seeds per pod, days to maturity, biological yield per plant, 100 seed weight, harvest index and seed yield per plant on randomly selecting five competitive plants. The mean data was subjected to statistical analysis as described by Panse and Sukhatme (1969). The genetic divergence was computed using Mahalanobis's (1936) D^2 statistics among all possible combinations of 80 genotypes. Based on D^2 values, the constellation of genotypes into clusters was done following Tocher's method (Rao, 1952). The relative contribution of different characters towards the expression of genetic divergence was calculated following standard method as suggested by Chaudhary and Singh (1977). Finally selection indices were worked out using method suggested by Smith (1936).

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D^2 statistics helps in the selection of genetically divergent parents for their exploitation in hybridization programme. The technique measures the degree of diversification and determines the relative proportion of each component characters to the total divergence. It measures the forces of differentiation at two levels, namely intra- and inter-clusters levels. It provides reliable estimates of genetic divergence and a large number of germplasm lines can be evaluated at a time for genetic diversity by this technique. In the present investigation, the intra- and inter- cluster distances were calculated by using D^2 values. The grouping of 80 genotypes in 14 clusters using D^2 value in such a way that the genotypes within a cluster have smaller D^2 value than those in between clusters. Cluster I–XIV included 4, 4, 7, 2, 7, 11, 7, 4, 1, 4, 9, 3, 9 and 8 genotypes, respectively (Table 1). From the composition of genotypes of most of the clusters, it was found that the genotypes included in clusters are heterogeneous in term of their origin. These results revealed that geographic diversity might not be an

Table 1. Clustering pattern of advance generation line by using D^2 analysis in the advance generation line of soybean

Clusters	Number of genotypes	Genotypes
I	4	CAT 3229, CAT 50, PK 472 , MAUS 173
II	4	CAT 3036, MAUS 7, JS 20-75, MAUS 113
III	7	CAT 3269, MAUS 704, JS 20-31, JS-20-70, CAT 3166, JS 20-65, Bhatt
IV	2	MAUS 705, JS 20-69
V	7	CAT 3148, JS 20-34, PS 2039, CAT 3063, CAT 143, MAUS 611, CAT 76
VI	11	CAT 70, Hardee, CAT 2800, MAUS 702, CAT 2926, JS 2053, CAT 3182, JS 20-36, MAUS 607, JS 20-84, CAT 76
VII	7	JS 20-39, MAUS 509, CAT 81, MAUS 453, JS 20-29, PS 1029, CAT 73
VIII	4	JS 20-41, CAT 197, JS 8821, CAT 96
IX	1	CAT 198
X	4	JS 2077, CAT 72, CAT 3221, MAUS 173
XI	9	CAT 3119, CAT 139, CAT 3163, CAT 3194, CAT 65, CAT 184, PS 1225, CAT 55, MAUS 470
XII	3	MACIS 41-1, JS 2077, CAT 84
XIII	9	MACIS 613, CAT 2371, MAUS 199, MAUS 449, MAUS 496, CAT 2268, JS 20-87, MAUS 608, MAUS 503
IVX	8	CAT 3060, MAUS 26-1, JS 20-41, JS 2068, Ankur 142, MAUS 106, MAUS 162, MAUS 423

important factor in determining genetic divergence. These findings are in agreement with the result obtained by Jain and Ramgiry (2002), Veni *et al.* (2008) and Qin *et al.* (2009). Inter- and intra-cluster D^2 and D values (Table 2) exhibited that the inter-cluster distance had a highest value of 3.182 between cluster-IV and cluster-IX, followed by the distance of 3.063 between cluster-VIII and cluster-IX and distance 2.829 between cluster-III and cluster-IX. These results are in close proximity to Bhartiya *et al.* (2011). The highest intra-cluster distance was found between cluster IV (1.898) followed by cluster XII (1.679), cluster VIII (1.667), cluster XIV (1.627) and cluster XIII (1.615). The result corroborates the findings of Chandarkar *et al*. (2002) and Rajesh *et al*. (2004).

The cluster means (Table 3) revealed that the highest mean value estimated was for days to 50 per cent flowering in cluster V (59.67) followed by cluster VIII (59.25), cluster III (58.90) and cluster XIII (55.11). Days to maturity had the highest mean in cluster VIII (97.67) followed by cluster V (96.48), cluster III (96.10), cluster XIII (95.22) and cluster XIV (93.50). Plant height showed the highest mean value for cluster XII (59.72) followed by cluster XIV (59.66), cluster IX (59.20), cluster XIII (57.69) and cluster VII (55.59). Primary branches per plant recorded the highest mean value for cluster XIII (9.27) followed by cluster V (8.70), cluster VI (8.44), cluster XIV (8.32) and cluster X (8.25). Number of pods per plant gave the highest mean value for cluster IV (37.27) followed by cluster XIV (32.73), cluster X (29.48), cluster VIII (29.27) and cluster VI (28.86). Number of seeds per pod exhibited the highest mean value for cluster IV (2.84) followed by cluster XIV (2.71), cluster X (2.56) and cluster II (2.28). Seeds per plant recorded the highest mean value for cluster II (60.05) followed by cluster IV (59.68), cluster XIV (57.27), cluster VI (53.44) and cluster III (51.28). Biological yield per plant had the highest mean value for cluster IX (24.03) followed by cluster XII (23.11), cluster X (22.04), cluster XI (21.94). 100 seed weight expressed the highest mean value for cluster IV (11.43) followed by cluster XII (10.86), cluster XIII (9.26) and cluster III (8.94). Harvest index showed the highest mean value for cluster I (59.94) followed by cluster II (59.83), cluster VIII (56.20) and cluster VI (54.83). Seed yield per plant had the highest mean value for cluster XI (10.93) followed by cluster IX (9.81), cluster XIII (9.32), cluster IV (9.12), cluster I (8.59), cluster VIII (8.38) and cluster II (8.31).

Selection indices

On the basis of genotypic and phenotypic variances and co-variances, the character relationship is closely related. Discriminate function is calculated for each individual character. The respective mean value of individual genotype was multiplied by the discriminate function and thus, varietal indices of each genotype were calculated. These selection indices for all the genotypes are presented in the (Table 4). Selection indices were found ranging from 5.94 to 9.67. The highest index was recorded for genotype MACIS 41-1 and lowest one was recorded for genotype

Table 2. Intra and Inter cluster distance among 14 clusters in soybean

Cluster	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**1.45**	1.75	1.993	2.391	1.827	0.230	1.700	1.86	2.754	1.948	1.665	2.166	1.825	2.069
	(2.11)	(3.094)	(3.974)	(5.721)	(3.340)	(0.053)	(2.891)	(3.488)	(7.587)	(3.796)	(2.775)	(4.690)	(3.331)	(4.282)
2		**1.252**	2.010	2.62	2.177	1.706	2.022	1.924	2.793	1.957	1.967	2.450	2.182	1.904
		(1.57)	(4.044)	(4.252)	(4.742)	(2.913)	(4.090)	(3.705)	(7.801)	(3.832)	(3.871)	(6.007)	(4.762)	3.629
3			**1.349**	2.223	1.743	1.829	1.712	1.814	2.829	1.786	1.603	2.276	1.770	1.896
			(1.82)	(4.956)	(3.039)	(3.346)	(2.933)	(3.293)	(8.004)	(3.193)	(2.571)	(5.182)	(3.133)	(3.597)
4				**1.898**	2.608	2.366	2.542	2.203	3.182	2.327	2.277	2.256	2.338	2.119
				(3.606)	(6.803)	(5.598)	(6.463)	(4.854)	(10.129)	(5.418)	(5.188)	(5.093)	(5.470)	(4.493)
5					**1.459**	1.752	1.568	1.786	2.923	2.014	1.854	2.433	1.640	1.988
					(2.13)	(3.072)	(2.749)	(3.190)	(8.549)	(4.059)	(3.439)	(5.924)	(2.690)	(3.956)
6						**1.435**	1.675	1.879	2.792	1.508	1.765	2.470	1.819	1.567
						(2.060)	(2.807)	(3.533)	(7.797)	(2.275)	(2.310)	(6.102)	(3.309)	(2.456)
7							**1.503**	2.121	2.617	1.694	1.767	2.418	1.820	2.021
							(2.26)	(4.502)	(6.851	(2.872)	(3.124)	(5.851)	(3.315)	(4.085)
8								**1.667**	3.063	2.079	1.811	2.226	1.882	1.886
								(2.780)	(9.384)	(4.326)	(3.283)	(4.957)	(3.545)	(3.557)
9									**0.00**	2.677	2.768	2.986	2.919	2.944
									(0.00)	(7.169)	(7.663)	(8.917)	(8.524)	(8.669)
10										**1.483**	1.624	2.367	1.869	1.794
										(2.200)	(2.640)	(5.604)	(3.494)	(3.222)
11											**1.410**	2.041	1.662	2.033
											(1.990)	(4.168)	(2.763)	(4.136)
12												**1.679**	2.005	2.360
												(2.82)	(4.023)	(5.571)
13													**1.615**	1.812
													(2.61)	(3.286)
14														**1.627**
														(2.65)

Bold figures denote the intra cluster distance'; Figures in parenthesis denote √ D^2 values

Table 3. Cluster mean of different characters in the genotypes of soybean

Clusters	Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches per plant	Pods per plant	Seeds per pod	Seeds per plant	Biological yield per plant (g)	Harvest index (%)	100 seed weight (g)	Seed yield plant (g)
I	48.08	88.67	52.44	7.73	23.26	1.67	40.46	14.33	59.94	8.43	8.59
Il	46.75	88.75	49.40	6.73	26.72	2.28	60.05	13.89	59.83	8.04	8.31
III	58.90	96.10	51.96	7.47	26.91	2.20	51.28	20.92	35.99	8.94	7.53
IV	50.50	93.50	49.62	6.95	37.27	2.84	59.68	18.92	48.20	11.43	9.12
V	59.67	96.48	54.25	8.70	21.95	1.94	42.47	14.28	52.66	7.17	7.52
VI	49.91	91.48	54.58	8.44	28.86	2.24	53.44	14.61	54.83	7.00	8.01
VII	50.90	91.10	55.59	7.81	20.72	2.23	43.02	17.82	43.88	8.26	7.82
VIII	59.25	97.67	50.77	7.55	29.27	2.03	46.96	14.91	56.20	7.55	8.38
IX	53.67	93.68	59.20	6.63	21.50	1.98	45.59	24.03	40.82	7.60	9.81
X	48.67	89.92	55.33	8.25	29.48	2.56	49.50	22.04	31.81	7.02	7.01
Xl	52.37	91.67	50.90	8.09	28.30	1.67	44.36	21.94	49.82	8.11	10.93
Xll	53.44	91.00	59.72	7.53	27.17	1.47	41.07	23.11	34.83	10.86	8.05
Xlll	55.11	95.22	57.69	9.27	24.27	1.96	46.72	18.89	49.34	9.26	9.32
XIV	53.96	93.50	59.66	8.32	32.73	2.71	57.27	14.58	42.59	8.40	6.21

Table 4. Top ten genotypes on the basis of values of selection indices for seed yield and per se in the soybean germplasm

S. No.	Genotypes	Seed yield *per se*	Genotypes	Selection indices for seed yield
1	MACIS-41-1	6.14	MACIS-41-1	9.67
2	CAT-2926	6.14	CAT-2926	9.50
3	PK-472	5.79	JS-20-34	9.50
4	JS-2077	5.66	JS-20-84	8.98
5	CAT-72	5.66	MAUS-173	8.66
6	PS-1029	5.10	PS-1029	8.58
7	CAT-139	4.66	JS-2068	8.55
8	MAUS-106	4.63	CAT-72	8.52
9	PS-1225	4.59	MAUS-702	8.26
10	MAUS-608	4.53	JS-20-53	8.15

CAT143. On the basis of value of selection indices the top ten genotypes among 80 genotypes studied, were selected considering characters together and they were arranged in ascending order as follows: MACIE 41 1, CAT 2926, JS 20-34, JS 20-84, MAUS 173, PS 1029, JS 20-68, CAT 27, MAUS 702 and JS 20-53. Moreover, on the basis of performance, different characters together, the better genotypes selected were MACIS-41-1, CAT-2929, PK 472, JS 2077, CAT 72, PS 1029, CAT 139, MAUS 106, PS 1225 and MAUS 608.

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Effect of Methods of Nitrogen Application on Growth and Productivity of Soybean [*Glycine max* (L.) Merrill]

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Foliar fertilization or top dressing of nitrogen to soybean during the seed filling period is likely to increase soybean yield. Such applications could be used to avoid the depletion of nitrogen in the leaves and the resulting reduction in photosynthetic rate during this period due to poor nutrient uptake from the soil and translocation of nitrogen from the leaves to the developing seeds. In view of this, a field experiment was conducted during *kharif* 2013 under randomized block design with nine treatments replicated thrice at RAK College of Agriculture, Sehore under All India Coordinated Research Project on Soybean to evaluate the effect of nitrogen application at varying levels as basal, combinations of basal with top dressing at seed initiation and foliar application at seed initiation along with control (Table 1). The variety JS 20-34 was planted in rows at a distance of 45 cm from each other.

Observations on plant height, branches per plant, pods per plant, seeds per pod, seed yield, root length and dry weight per plant were recorded at harvest using randomly selected 5 plants from each treatment. Nodule count and their dry weight per plant were recorded at 45 days after sowing. The soil of the experimental site analyzed low in available N (205.23 kg N/ha), medium in available P (13.2 P_2O_5 kg/ha) and high in available K (423.24 kg K_2O/ha). Nitrogen was applied in the form of urea as per the treatment. Phosphorus, potassium and sulphur were applied as basal (60:20:20:: P_2O_5:K_2O:S kg/ha respectively). At harvest, soil samples were collected from treatments, analyzed for nitrogen using Kjeldahl method and balance sheet for nitrogen was drawn. Seed and straw samples were drawn at harvest and analyzed for N content and uptake and protein content was worked out. Net returns were calculated by taking the prevailing cost of input/output to work out cost of cultivation and gross returns.

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Growth parameters

The methods of nitrogen application had significant influence on plant height, root length, number and dry weight of root nodules per plant, and dry weight per plant (Table 1). The maximum plant height (44.73 cm) was obtained under 40 kg N per ha applied as basal. It was closely followed by 30 kg N per ha as basal application. Nitrogen has been widely accepted as a dominant growth promoter. The significant increase in plant height might be due to the vigorous root growth. The results are in close agreement with the findings of Saxena and Chandel (1992).

The number of branches per plant was significantly higher with the application of 40 kg N per ha as basal over other treatments, except application of 30 kg N per ha as basal and 20 kg N per ha as basal + 20 kg N per ha as top dressing at seed initiation stage (Table 1). The increase in branches per plant due to the increased availability of nitrogen, which helped in acceleration of various metabolic processes like photosynthesis, energy transfer reaction and symbiotic biological N- fixation process. These results are in close agreement with the findings of Orellana *et al.* (1990). The effect of methods of nitrogen application on root length per plant was significant. Application of 40 kg N per ha as basal had maximum root length per plant (23.0 cm) and minimum was recorded for control treatment.

Number of root nodules and their dry weight per plant recorded at 45 DAS was maximum by basal application of N @ 40 kg per ha, which were significantly higher than most of the treatments, except basal application of N @ 30 kg per ha. The value for dry weight of nodules with application of 20 kg N as basal + 20 kg N as top dressing at seed initiation stage was at par (Table 1). This showed that application of N at higher levels might have influenced better root development of the plant and induction of profuse nodulation. These results are in close agreement with the findings of Singh *et al*. (1992).

At maturity, treatment 20 kg N per ha as basal + 20 kg N per ha as top dressing at seed initiation stage recorded highest dry matter production per plant (11.03 g). It can also be seen that treatments involving application of N as basal + top dressing at seed initiation invariably produced higher dry matter per plant as compared to basal or top dressing or foliar applications (Table 1). The significant increase of dry weight was due to the fact that nitrogen helps in maintaining higher auxin level which might have resulted in better plant height, leaf area and presumably chlorophyll content of the leaves. This might have resulted into better interception, absorption and utilization of radiant energy, leading to higher photosynthetic rate and finally more accumulation of dry matter by plants. Similar results with higher dose of nitrogen were also reported by Yinbo *et al*. (2002).

Yield and yield attributing characters

Application of 20 kg N per ha as basal + 20 kg N per ha as top dressing at seed initiation stage, produced significantly higher number of pods per plant. Higher number of pods per plant

Table 1. Effect of methods of nitrogen application on growth/yield attributes and yield of soybean

Treatments	Plant height (cm)	Branches (No/ Plant)	Root length (cm/ plant)	Nodules* (No/ plant)	Nodules dry weight* (g/plant)	Plant dry weight (g/ plant)	Pods (No/ plant)	Seeds (No/ pod)	Seed yield (g/ plant)	Seed yield (kg/ha)
0 kg N/ha as basal	40.77	5.37	16.47	35.00	94.67	7.55	14.60	2.33	3.60	1244
20 kg N/ha as basal	41.80	5.50	17.00	35.67	109.3	8.82	15.93	2.41	3.80	1430
30 kg N/ha as basal	43.07	6.10	21.47	45.53	122.0	8.93	16.60	2.44	3.90	1548
40 kg N/ha as basal	44.73	6.20	23.00	47.47	132.7	8.65	18.33	2.51	4.50	1585
20 kg N/ha as top dressing**	41.87	5.70	18.53	39.47	106.4	8.53	16.33	2.43	3.90	1511
10 kg N/ha as basal + 10 kg as top dressing**	42.07	5.82	20.47	41.33	114.0	9.57	18.07	2.48	4.30	1563
Foliar application of 2% urea**	42.53	5.53	19.33	40.87	109.0	8.82	16.92	2.45	3.90	1556
20 kg N/ha as basal +10 kg N/ha as top dressing**	42.53	5.77	18.80	40.00	110.0	9.90	18.73	2.60	5.10	1600
20 kg N/ha as basal + 20kg N/ha as top dressing**	42.73	5.83	21.00	42.00	121.0	11.03	19.47	2.63	5.30	1622
SEm (±)	0.61	0.17	1.18	1.74	4.11	0.38	0.82	0.20	0.32	59
CD (P = 0.05)	**1.85**	**NS**	**3.53**	**5.23**	**12.33**	**1.15**	**2.46**	**NS**	**0.97**	**185**

**At 45 days; **At seed initiation*

with increasing level of nitrogen was also reported by Brevedan *et al*. (1987). Application of 20 kg N per ha as basal + 20 kg N per ha as top dressing at seed initiation stage, resulted in the highest number of seeds per pod as compared to other treatments. Number of seeds per pod of soybean ranged from 2.33 to 2.63 due to the treatment variation, but the values were statistically non-significant.

The highest seed yield per plant (5.3 g) and seed yield per ha (1,622 kg) was observed when 20 kg N per ha was applied as basal + 20 kg N per ha as top dressing at seed initiation stage, which was 47.22 and 30.39 per cent higher than control treatment (Table 1). It might be due to enhanced growth leading to higher production of dry matter in early stages and subsequent partitioning of photosynthetes to reproductive units**.** The above results are in conformity of findings reported by Singh *et al*. (2001) and Yadav and Chandel (2010). Moreover, nodulation in soybean remains effective from 20 days to 50 days and there after senescence sets in at the post-flowering stage. Hence, due to nodule degeneration, nitrogen requirement of crop at the later stages may be affected culminating in the loss of productivity. Therefore, the application of nitrogen as top dressing or foliar application at seed initiation stage would be beneficial for obtaining optimum yield of soybean. The increase in seed yield of soybean due to nitrogen availability at this stage may be because nitrogen plays an important role in the synthesis of chlorophyll and amino-acids, which are the indispensable ingredients of the process of auto-trophization. Nitrogen influenced the seed yield through source-sink relation-ship resulting in higher production of photosynthates and their increased translocation to reproductive parts (Takahashi *et al.* 1992).

Nitrogen content and total uptake

Application of 20 kg N as basal + 20 kg N as top dressing at seed initiation stage recorded maximum N content and uptake in seed and total uptake, which were on par with application of 20 kg N as basal + 10 kg N as top dressing and foliar application of urea at seed initiation, except in case of N uptake by seed, wherein the combined application treatments were on par. Straw N content was maximum when nitrogen was applied @ 40 kg per ha as basal, which was on par with all the treatment except that of control. Uptake in straw was also maximum on application of 40 kg application of N as basal, which was significantly higher than rest of the treatments. Total uptake of N by application of 20 kg N as basal + 20 kg N as top dressed at seed initiation with other combination treatment, foliar application at seed initiation and 40 kg N application as basal.

Jahangir *et al*. (2009) also reported increase in nitrogen content in seed with application of higher levels of N. The increase in uptake of nitrogen could be the result of enhanced physiological processes within the plant system which led to in the increased absorption of nitrogen by soybean plant and thereby translocation of nitrogen might have been occurred. Further, it might be accumulated in soybean seeds, which resulted in accelerated soybean seed yield and thus, the increased uptake of nitrogen. These results are in close conformity of the results observed by Kaul (2004).

Table 2. Effect of methods of nitrogen application on nitrogen content and uptake and seed protein content

Treatments	N content (%)		Seed protein content (%)	N uptake (kg/ha)		
	Seed	Straw		Seed	Straw	Total
0 kg N/ha as basal	5.08	0.97	29.01	63.19	16.86	79.85
20 kg N/ha as basal	6.02	1.23	34.37	86.08	22.85	108.93
30 kg N/ha as basal	5.32	1.36	30.20	82.30	22.92	105.22
40 kg N/ha as basal	5.86	1.50	33.46	92.88	33.69	126.57
20 kg N/ha as top dressing *	6.10	1.07	34.83	92.17	20.96	113.13
10 kg N/ha as basal + 10 kg/ha as top dressing*	6.17	1.13	35.21	96.38	18.68	115.06
Foliar application of 2 % urea*	6.37	1.18	36.39	99.16	25.85	125.02
20 kg N/ha as basal + 10 kg N/ha as top dressing*	6.50	1.05	37.11	104.00	21.38	125.38
20 kg N/ha as basal + 20 kg N/ha as top dressing*	6.72	1.18	38.35	108.99	23.95	132.94
SEm (±)	0.13	0.05	0.76	1.94	2.01	2.94
CD (P = 0.05)	0.40	0.17	2.29	5.82	6.02	8.83

**At seed initiation*

Protein content

Although, increase in protein content, in general, was observed in most of the treatments over control, maximum was associated with application of 20 kg N per ha as basal + 20 kg N as top dressing at seed initiation stage, which was on par with 20 kg N as basal + 10 kg N as top dressed at seed initiation stage and foliar application of N. (Table 2). The trend of variation in protein content was similar to that of N content as protein content was computed by multiplying the N content in seeds with 5.71 (Sadasivam and Manickam, 1996). These results are in close conformity of the results observed by Yadav and Chandel (2010). The increase in protein per cent in seeds might be because of the high accumulation of nitrogen content in seeds. Application of nitrogenous fertilizers is known to improve the protein content of soybean seeds. The present findings are supported with the results obtained by Tingre *et al.* (1995).

Table 3. Nitrogen status of in soil after harvest and net returns as influenced by methods of nitrogen application

Treatments	Initial N (kg/ha) a	N-added through fertilizer (kg/ha) b	Total N (a+b)=c c	Crop removal N-balance (kg/ha) d	Theoretical N-balance (kg/ha) e = (c-d)	Actual N after harvest (kg/ha) f	Loss/ gain of available N (kg/ha) g = (f-e)	Net returns (Rs/ha)
0 kg N/ha	205.23	0	205.23	**79.85**	125.38	179.00	53.62	30144
20 kg N/ha as basal	205.23	20	225.23	108.93	116.3	218.34	102.04	36761
30 kg N/ha as basal	205.23	30	235.23	105.22	130.01	191.42	61.41	40278
40 kg N/ha as basal	205.23	40	245.23	126.57	118.66	199.67	81.01	42435
20 kg N/ha as topdressing*	205.23	20	225.23	113.13	112.1	183.60	71.51	39734
10 kg N/ha as basal+ 10 kg as top dressing*	205.23	20	225.23	115.06	110.17	222.00	111.83	41415
Foliar application of 2% urea*	205.23	12	217.23	125.02	92.21	214.71	122.5	42043
20 kg N/ha as basal+10 kg N/ha as top dressing*	205.23	30	235.23	125.38	109.85	239.67	129.82	42948
20 kg N/ha as basal + 20 kg N/ha as top dressing*	205.23	40	245.23	132.94	112.29	241.00	128.71	43705

**At seed initiation*

Nitrogen balance in soil

All the treatments revealed a positive balance of N in soil (Table 3). The gain of nitrogen left in the soil ranged from 53.62 to 129.82 kg N per ha. The maximum gain (129.82 kg N/ha) was recorded in treatment 20 kg N per ha as basal + 10 kg N per ha as top dressing at seed initiation stage and minimum gain (53.62 kg N/ha) in control treatment. The increase in actual nitrogen left in the soil may be due to increased nodulation, symbiotic nitrogen fixation and applied fertilizer nitrogen. The increase in soil nitrogen with increasing level of applied nitrogen were also reported by Kaul (2004)

The study suggested that methods of nitrogen application have positive effect on yield, protein content and nutrient uptake of soybean. Application of 20 kg N per ha as basal + 20 kg N per ha as top dressing at seed initiation stage, gave the maximum yield (1,622 kg/ha) and higher net returns (Rs 43,705/ha). This was followed by application of 20 kg N per ha as basal + 10 kg N per ha as top dressing at seed initiation with yield of 1,563 kg per ha and net returns of Rs 41,415 per ha, which was at par with treatment 20 kg N per ha as basal + 20 kg N per ha as top dressing at seed initiation stage.

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SOYBEAN RESEARCH

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Ansari M M and Gupta G K. 1999. Epidemiological studies of foliar diseases of soybean in Malwa plateau of India. Proceedings, World Soybean Research Conference VI, Aug 4-7, 1999, Chicago, Illinois, USA, 611p. **(Symposium/ Conf./Workshop)**

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