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Study on Heritability, Genetic Advance and Correlation for Major Quantitative Traits in Soybean [*Glycine max* (L.) Merrill]

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ABSTRACT

The present investigation was carried out at Crop Research Centre, Pantnagar, Uttarakhand during kharif season of 2008-2009. Five generations viz. P_1 , P_2 , F_1 , F_2 and F_3 of three soybean single crosses (PS 1347 x G. soja, JS 335 x UPSM 534 and PS 1347 x JS 335) were evaluated in an experiment under compact family block design to estimate heritability, genetic advance and correlation of nine quantitative traits. The broad sense heritability estimates were higher for dry matter weight per plant, whereas, number of pods per plant, dry matter weight per plant and plant height revealed high genetic advance. Breeding program may be designed to increase seed yield considering these traits having high heritability and good associations between certain agronomical characters and seed yield. Knowledge of relationship among yield and the other agronomic traits is of great importance in plant breeding, especially for the selection of genotypes for higher seed yield. Correlation studies showed that seed yield had significant positive correlation with plant height, number of pods per plant, dry matter weight and harvest index. It is evident that these traits had major contribution in determining seed yield in soybean. On the basis of results obtained from the present investigation, it is suggested that major quantitative traits viz., plant height, number of pods per plant, dry matter weight and harvest index in the desirable genotypes play a major role in the improvement of high yielding varieties of soybean.

Key words: Genetic advance and correlation, heritability, quantitative traits, soybean

Heritability estimates and genetic advance for a trait guide us genetic advance are important in deciding the scope of genetic parameters in a breeding improvement of that particular trait program. The knowledge of through selection (Johnson *et al.*, 1955). heritability coupled with expected Expected genetic advance

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indicates about the genetic progress for a particular trait under a selection cycle and measures the extent of its stability under selection pressure. Seed yield is a complex character resulting from multiple interactions of yield components. Improvement in this trait by selection based on component characters appears to be more useful as compared to selection of yield. Since most of the characters are correlated with seed yield per plant in all the crosses under investigation, the change in one of the character brings about a series of changes in other characters. Most of the traits included in this investigation were considered highly heritable as they have shown to be associated with high to moderate broad sense heritability. Hence, in the present investigation, an effort has been made to find out the inheritance of yield and its attributes for their further utilization in the breeding program.

MATERIAL AND METHODS

Five generations namely, P_1 , P_2 , F_1 , F_2 and F_3 of each of three crosses *viz.* PS 1347 $\times$ *G. soja*, PS 1347 $\times$ JS 335 and JS 335 $\times$ UPSM 534, were evaluated in a compact family block design with three replications during *khariif* 2008-09. Each plot had three rows of 3 m length, spaced at 60 cm apart and plant to plant distance was maintained at 5 to 7 cm by appropriate thinning of plants. The standard agronomic practices were followed to raise a healthy crop of

soybean. Ten competitive plants from generations namely, P_1 , P_2 and F_1 and 30 in F_2 and 50 in F_3 were randomly selected from each replication in each plot to record observations on nine major quantitative characters *viz.*, plant height, days to 50 per cent flowering, days to full maturity, number of pods per plant, seed yield per plant, dry matter weight per plant, harvest index, oil and protein content. Heritability in broad sense (h^2_b) as the ratio of genotypic variance to phenotypic variance and expected genetic advance under selection for different characters was estimated (Allard, 1960). The intensity of relationship among different quantitative traits was measured by correlation coefficients (r) as given by Searle (1961).

RESULTS AND DISCUSSION

The estimates of heritability are presented in table 1. In case of interspecific cross PS 1347 $\times$ *G. soja*, very high level of broad sense of heritability (h^2_b) was observed for plant height (99.03), followed by days to 50 per cent flowering (97.39), days to full maturity (93.69), dry matter weight (96.64), seed yield per plant (96.39), number of pods per plant (96.10) and oil content (83.27). Moderate heritability estimate was associated for protein content (78.18) and harvest index (61.29).

Table 1. Per cent heritability (h^2_b) and genetic advance (GA) for different characters

Characters	PS 1347 x <i>G. soja</i>		PS 1347 x JS 335		JS 335 x UPSM 534	
	h^2_b	GA	h^2_b	GA	h^2_b	GA
Plant height	99.03	36.73	70.35	20.35	57.92	11.48
Days to 50 %	97.39	20.18	46.35	3.94	62.98	1.65
Days to full maturity	93.69	7.77	53.99	5.83	77.80	2.14
Pods per plant	96.10	26.44	36.23	45.15	66.44	12.95
Dry matter weight per plant	96.64	16.36	80.18	53.07	86.67	12.54
Harvest index	61.29	0.16	60.15	9.13	82.69	0.15
Seed yield	93.69	11.93	75.47	24.47	73.71	22.91
Oil content	83.27	1.98	37.23	1.30	32.04	0.95
Protein content	78.18	5.12	28.59	1.50	16.27	0.14

Expected genetic advance under selection (Table 1) recorded the highest for plant height (36.73) followed by number of pods per plant (26.44), days to 50 per cent flowering (20.18) and dry matter weight per plant (16.36), whereas low expected genetic advance was found in seed yield per plant (11.93), followed by days to full maturity (7.77), protein content (5.12), oil content (1.98) and harvest index (0.16) in the interspecific cross (PS 1347 x *G. soja*). In intervarietal cross (PS 1347 x JS 335), the highest estimate of broad sense heritability was observed for dry matter weight (80.18), followed by seed yield per plant (75.47), days to 50 per cent flowering (70.35) and harvest index (60.15). High to moderate heritability estimates (%) were present in

days to full maturity (53.99) and plant height (46.35) while, low heritability was observed for oil content (37.23), number of pods per plant (36.23) and protein content (28.59).

Expected genetic advance under selection was the highest for dry matter weight per plant (53.07) followed by number of pods per plant (45.15), whereas moderate to low values for expected genetic advance under selection was observed for seed yield per plant (24.27), plant height (20.35), Low to very low estimates for expected genetic advance were found in harvest index (9.13), followed by days to full maturity (5.83), days to 50 per cent flowering (3.94), oil content (1.30) and protein content (1.50).

Like-wise cross JS 335 x UPSM 534 also exhibited very high level of broad sense heritability for dry matter weight (86.67), followed by harvest index (82.69), days to full maturity (77.80), seed yield per plant (73.71), number of pods per plant (66.44), days to 50 per cent flowering (62.98). High to moderate heritability estimate was present in plant height (57.92) whereas, low heritability was observed for oil content (32.01) and protein content (16.27).

Expected genetic advance under selection was highest for seed yield per plant (22.91), followed by number of pods per plant (12.95), dry matter weight per plant (12.54) and plant height (11.48) whereas, very low expected genetic advance under selection was observed for days to full maturity (2.14), days to 50 per cent

flowering (1.65), oil content (0.95), harvest index (0.15) and protein content (0.14).

In the present study, only simple genotypic correlation was estimated to understand the direction and magnitudes of the association of different characters with seed yield. The pooled mean of different generations of each cross for different characters under study was used for the correlation study. The results of correlation coefficient (Table 2) revealed that, in cross PS 1347 x *G. soja*, seed yield per plant exhibited significant positive correlation with plant height, number of pods per plant, dry matter and per cent oil content whereas days to 50 per cent flowering, protein content and harvest index exhibited significant negative association with seed yield per plant.

Table 2. Inter-character correlation coefficient of different characters with seed yield per plant

Characters	Crosses		
	PS 1347 x <i>G. soja</i>	PS 1347 x JS 335	JS 335 x UPSM 534
Plant height	0.959**	0.977**	0.965**
Days to 50 % flowering	-0.995**	-0.973**	-0.877
Days to full maturity	0.821	0.977**	0.968**
Pods per plant	0.991**	0.975**	0.967**
Dry matter weight per plant	0.978*	0.931*	0.956*
Harvest index	-0.981**	0.979**	0.971**
Oil content	0.951*	0.977**	0.972**
Protein content	-0.942*	-0.055	-0.181**

*, ** = Significant at 0.05 and 0.01 probability levels, respectively

In PS 1347 x JS 335, the seed yield had highly significant positive correlation with days to full maturity, number of pods per plant, plant height, dry matter weight, harvest index and oil content and negative association with days to 50 per cent flowering and protein content.

In case of cross JS 335 x UPSM 534, seed yield exhibited highly significant positive correlation with plant height, days to full maturity, number of pods per plant, dry matter weight, harvest index and oil content whereas protein content showed highly significant negative correlation with seed yield. Dhillon *et al.* (2005), Karad *et al.* (2005), Shrivastava *et al.* (2005), Gohil *et al.* (2006), Malik *et al.* (2006), Pandey *et al.* (2008) and Lee *et al.* (2008) also reported similar of results. These results indicated

that knowledge of expected genetic advance under selection and heritability of the character is necessary for deciding the scope of improvement through selection. High heritability alone does not guarantee large gain from selection unless sufficient genetic advance (GA) attributed to additive gene action is present. Although, it may not be a rule always because expected genetic advance under selection is dependent not only on heritability of the trait but also on the phenotypic variation and selection intensity. On the basis of results obtained from character association at genotypic level, it is evident that traits *viz.* plant height, number of pods per plant, dry matter weight and harvest index had major contribution in determining seed yield in soybean.

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Effect of Sulphur and Boron Nutrition on Yield, Yield Attributes and Economics of Soybean

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ABSTARCT

A field experiment was conducted at Crop Research Centre of GBPUA & T, Pantnagar to evaluate the response of sulphur and boron nutrition on yield and yield attributes, harvest index (HI) and economics of soybean (variety PS 1042) in kharif seasons of 2007 and 2008. The experiment was conducted under factorial randomized block design with three replications and consisted of five levels of sulphur (0, 10, 20, 30 and 40 kg S/ha) and five levels of boron (0, 0.5, 1.0, 1.5 and 2.0 kg B /ha) as factor one and two, respectively. The effect of different doses of sulphur and boron application on seed yield of soybean was significant and its interaction was also significant indicating that there is differential requirement of sulphur and boron to maximize yield. On mean performance basis, the application of 30 kg S per ha gave maximum yield. Boron application resulted into highest yield at 1.5 kg B per ha.

Key words: Boron, economics, soybean, sulphur, yield

Soybean (*Glycine max* L. Merrill) is a leguminous crop rich in high quality protein (40-42 %), oil (18-20 %) and other nutrients like calcium, iron and glycine. It is a good source of isoflavones and therefore it helps in preventing heart diseases, cancer and HIVs (Kumar, 2007). So it has established its potential as an industrially and economically viable oilseed crop in the world. Because of its high nutritional value and myriad form of uses, it is recognized as 'Golden Bean'.

In India, soybean has emerged as an important oilseed crop. There is continuous increase in area and production of the crop since it was adopted for commercial cultivation in 1970's. In 2007-08, the area under soybean cultivation has increased up to 8.87 mha with production of 9.46 mt. But the productivity still remains low (about 1 t/ha), though the crop has potential to harvest 2.5 - 3.0 t/ha (AICRP Soybean, 2008). The low productivity of soybean

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may be due to nutritional deficiencies and also imbalanced fertilization. Being an oilseed crop, soybean also showed response to applied sulphur and boron (Prasad, 2006). Sulphur is involved in the synthesis of fatty acids and also increased protein quality through the synthesis of certain sulphur containing amino acids such as cystine, cysteine and methionine (Havlin *et al.*, 1999). On the other hand, boron is involved in synthesis of protein (Sauchelli, 1969) as well as oil (Malewar *et al.*, 2001). Non-judicious use of chemical fertilizers, intensive cultivation of crops, higher cropping intensity and limited use of organic matter are the most possible causes for sulphur deficiency limiting soybean yields. Since limited work has been carried out on sulphur and boron nutrition of soybean, a study has been undertaken to investigate the effect of sulphur and boron on yield and yield attributes of soybean.

MATERIAL AND METHODS

A field experiment was laid out at the Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar during *khariif* seasons 2007 and 2008. The experimental soil belonged to Haldi series (coarse loamy, mixed, thermic, Typic Hapludolls) and showed silty clay loam texture, 0.54 per cent organic carbon, 0.066 per cent total nitrogen, 24.18 kg P₂O₅ per ha available phosphorus, 190.8 kg K₂O per ha available potassium, 0.004 mg S per kg soil and < 0.25 ppm B (deficient) with pH of 7.2. The experiment was designed in factorial

RBD with three replications and planted on June 27, 2007 in first season and July 10, 2008 in second season at a fixed site. The crop was harvested on November 10, in both the seasons. The experiment consisted of five levels of sulphur (0, 10, 20, 30 and 40 kg S/ha) and five levels of boron (0, 0.5, 1.0, 1.5 and 2.0 kg B/ha) as factor one and two, respectively. The source for sulphur and boron were gypsum (18 % S) and borax (11 % B). A recommended dose of fertilizer 20 N: 60 P₂O₅: 40 K₂O + 5 kg Zn per ha was applied as basal through urea, DAP, MOP and zinc sulphate, respectively. Soybean seeds were inoculated with *Bradyrhizobium japonicum* culture @ 7g per kg seed after treating with thiram (75 % WP) @ 2g + bavistine @ 1.0 g per kg seed. The weed management was ensured by pre-emergence spray of alachlor (50% EC) @ 2.0 kg per ha followed by one manual weeding at 30-35 DAS (days after sowing). For plant protection 2 to 3 protective sprays of trizophos (40 EC) @ 800 ml in 600 – 700 litre of water per ha was done. Thinning to maintain optimum plant population (i.e. 0.4 million plants /ha) was completed within 15-20 DAS during both the years. The observations on yield attributes were taken on randomly selected five plants from each treatment at harvest.

RESULTS AND DISCUSSION

Effect on yield attributes

Perusal of data revealed that the different yield attributes of soybean like number of

branches and pods per plant and seed index were significantly influenced by different levels of sulphur and branches per plant and seed index by different levels of boron and branches per plant and pods per plant by their interaction. Sulphur application at 30 kg per ha resulted into the highest number of branches per plant, pods per plant and maximum seed index of the soybean crop, which was significantly superior over control and was at par with other levels of sulphur. Boron at 1.5 kg per ha recorded the highest number of branches and maximum seed index, which were on par with boron at 2.0 kg per ha and significantly higher than other levels of boron (Table 1). The above results are in conformity with the results of Joshi and

Billore (1998) who reported a gradual increase in these yield attributes of soybean with increasing levels of sulphur. Chaubey *et al.* (2000) observed that numbers of primary branches, pods per plant, plant height and 100-kernel weight of groundnut were significantly higher by the application of sulphur. Sulphur application also was also reported to increase the pod length of soybean (Hemantrajan and Trivedi, 1997). Tripathy *et al.*, (1999) also conclusively suggested that application of boron increased pod per plant in groundnut and Havlin (1999) also reported that flowering and fruit development were restricted by a shortage of boron.

Table 1. Effect of sulphur and boron nutrition on yield attributes of soybean (pooled data of 2007 and 2008)

Treatments	Plant height (cm)	Branches (No/plant)	Pods (No/plant)	Seed index (g/100 seeds)
<i>S- level (kg/ha)</i>				
0	68.1	7.5	87.1	12.3
10	69.5	7.6	90.6	12.5
20	71.2	7.7	92.2	12.6
30	72.6	8.3	99.2	13.1
40	71.3	7.9	93.0	12.8
SEm ($\pm$)	1.8	0.3	2.7	0.3
C D (P = 0.05)	NS	0.7	9.7	0.6
<i>B- level (kg/ha)</i>				
0.0	68.2	7.1	79.1	12.2
0.5	69.6	7.5	91.5	12.4
1.0	70.4	7.8	92.6	12.5
1.5	72.5	8.3	95.5	13.2
2.0	71.8	8.2	94.2	12.8
SEm ($\pm$)	1.8	0.3	4.1	0.3
C D (P = 0.05)	NS	0.7	NS	0.6
S X B, CD (P = 0.05)	NS	1.3	15.2	NS

Effect on yield

The effect of different levels of sulphur nutrition on soybean seed and straw yield was found to be significant. The highest seed yield (2,694 kg/ha) was obtained by application of 30 kg S per ha, which might be due to the cumulative favourable effect of higher number of branches and pods per plant and higher seed index of soybean (Table 2). With increased supply of sulphur, the process of tissue differentiation from somatic to reproductive, meristematic activity and development might have increased, resulting in increase in number and size of leaves (Mengel and Kirkby, 1987). As in soybean, sink lies in leaves, when supply of sulphur is optimum, greater translocation of photosynthate occurs from leaves to the site i.e. seed (Mengel and Kirkby, 1987). The sum total effect will be higher seed yield. Our results confirm the findings of Kumar *et al.*, (1992) and Sarker *et al.*, (2002).

The effect of different levels of boron nutrition on seed yield was also found to be significant. However, the straw yield of soybean was not significantly influenced by different levels of boron. The interaction between

different sulphur and boron levels was also significantly affected the grain and straw yield of soybean (Table 2). The seed yield was significantly higher when the crop received 1.5 kg boron per ha and the lowest was found from control. This might be due to boron deficiency as it has been reported to help in seed formation (Brady, 1996). Results are in accordance with that of Singh *et al.* (2003), who documented that crop yields, in general, have been promoted by regular application of boron. Chowdhury *et al.* (2000) also reported that seed yield of cowpea increased significantly with incremental application of boron.

Harvest index of the soybean crop was significantly affected by different levels of boron and their interaction with sulphur levels. However, it was non-significantly affected by different levels of sulphur nutrition. The highest harvest index (44.7 %) was obtained with 1.5 kg boron per ha, which was significantly higher over control as well as other levels of boron except at boron at 2.0 kg per ha, which might be due to higher seed yield of soybean at this level (Table 2).

Table 2. Effect of sulphur and boron nutrition on seed and straw yield and economics of soybean (pooled data of 2007 and 2008)

Treatments	Straw yield (kg/ha)	Seed yield (kg/ha)	Harvest index (%)	Net returns (Rs/ha)	B: C ratio
<i>S- level (kg/ha)</i>					
0	4, 874	2, 489	41.5	26, 733	2.23
10	4, 969	2, 589	41.6	27, 969	2.34
20	5, 076	2, 633	42.2	29, 080	2.40
30	5, 340	2, 694	43.7	30, 208	2.54
40	5, 203	2, 666	42.9	29, 662	2.41
SEm ($\pm$)	67.1	67.1	0.5	853	0.9
C D (P = 0.05)	209	124	NS	2516	0.26
<i>B- level (kg/ha)</i>					
0	4, 930	2, 502	41.0	25, 741	2.04
0.5	5, 034	2, 533	41.4	27, 298	2.18
1.0	5, 132	2, 599	41.9	28, 573	2.36
1.5	5, 193	2, 739	44.7	31, 522	2.73
2.0	5, 172	2, 700	42.4	30, 518	2.63
SEm ($\pm$)	114.2	89.1	1.3	1, 213	1.2
C D (P = 0.05)	NS	124	2.1	2, 744	0.23
S X B	445	277	3.0	NS	NS
C D (P = 0.05)					

Perusal of the data revealed that different level of sulphur and boron significantly enhances the net returns and B: C ratio. However, their interaction was found to be non-significant. Sulphur at 30 kg per ha recorded significantly higher B: C ratio than other levels of sulphur nutrition. The B:C ratio was also found on par with sulphur at 40 kg per ha (Table 2). Significantly higher B: C ratio was also obtained at application level of boron @ 1.5 kg per ha over other levels. This higher B: C ratio application of

sulphur at 30 kg per ha and boron at 1.5 kg per ha might be due to higher net returns obtained by these treatments (Table 2).

From the above discussion, it may be interpreted that 30 kg sulphur and 1.5 kg boron per ha individually or in combination along with the recommended rates of NPK and Zn fertilizers should be applied for increasing the productivity and profitability of soybean.

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Response of Soybean [*Glycine max* (L.) Merrill] and Chickpea (*Cicer arietinum*) Cropping Sequence to Phosphorus Nutrition

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ABSTRACT

Field experiments were conducted during 2002-03 and 2003- 04 at the research farm of College of Agriculture, Indore, with three levels of phosphorus applied at six frequencies to assess its response on soybean - chickpea cropping system. A progressive increase in yield of both the crops as well as of the system was observed by application of phosphorus up to 39.6 kg per ha as compared to recommended level of 13.2 kg P per ha. Application of phosphorus @ 39.6 kg per ha to both the crops enhanced the system productivity (SEY 5, 202 kg/ha) to about 30 per cent with higher net profit (Rs 36, 683) and B: C ratio (3.62). Application of P to both kharif and succeeding rabi crop followed by application to kharif crop only in soybean-chickpea cropping system were found to promote growth and yield of both the crops with higher net returns and B: C ratios as compared to other frequencies of P application. The superior treatments as above also revealed improvement in protein content and P uptake by the crops.

Key words: Chickpea, protein content, phosphorus, soybean, yield

Soybean and chickpea, both are the premier crops grown in the state of Madhya Pradesh in which chickpea covers 2.44 million hectares (http://dacnet.nic.in/eands/Book_3pdf) and in majority of this area soybean is grown as succeeding *kharif* providing a niche for soybean-chickpea cropping system under rainfed situation. Both the crops like other energy rich crops are cultivated under energy starved conditions (Hegde, 2009) by majority of resource poor farmers for their subsistence. Since phosphorus is of special significance for these crops and its

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losses from Vertisols are restricted on account of high fixation, information on appropriate dose and frequency of its application may help in advising farmers to follow balanced application of fertilizer nutrients to optimize system efficiency. In view of restricted mobility and accumulation of phosphorus in these soils, and long residual effect extending benefit to succeeding crops, skipping the application of phosphorus in cropping pattern may lead to fertilizer economy without exerting any adverse effect on performance of cropping system. Skipping of phosphorus dressing for a period of 10 years in red soils by keeping an eye over soil and foliar P levels in coconut has been found feasible (Khan, 1983). Hence, an attempt was made to evaluate the effect of phosphorus application at variable frequencies on the growth, yield, and P uptake of soybean and chickpea in swell shrink soils of Madhya Pradesh.

MATERIAL AND METHODS

Field experiments were conducted at research farm of College of Agriculture, Indore during 2002-03 and 2003-04. The soil of experimental site belonged to *Sarol* series (fine, isohypothermic, montmorillitic, Typic Haplustert) having sand 17 per cent, silt 28 per cent and clay 55 per cent. It analyzed: pH 7.5, organic carbon 0.56 per cent, electrical conductivity 0.42 dS per m, available N 220, available P 5.72 and available K 511 kg per ha. The total rainfall during cropping period was 871 mm in 2002 and 945 mm in 2003. The treatments comprised three levels of phosphorus (13.2, 26.4 and 39.6 kg P/ha) as main plots and six frequencies of P application to both *kharif* and *rabi* crops, to *kharif* crop only, to

rabi crop only, to *kharif* crop in alternate years, to *rabi* crop in alternate and to both *kharif* and *rabi* crops in alternate years as sub-plots. The treatments were laid out in split plot design with three replications. Soybean 'JS-335' @ 100 kg per ha and chickpea 'JG 218' @ 80 kg per ha were sown in the last week of July and first week of November, respectively during both the years. The soybean seed was first treated with fungicide Vitavax @ 3 g per kg seed followed by *Bradyrhizobium japonicum* @ 5 g per kg seed just before sowing. Nitrogen (20 kg N/ha) and potash (16.6 kg K/ha) were uniformly supplemented through urea and muriate of potash, respectively as basal during both the season. The proposed levels of phosphorus as per treatments were applied through single superphosphate. Both the crops were raised following the recommended package of practices. Plant and soil samples were collected at harvest, processed and analyzed as per standard procedures. Soil phosphorus was determined by Olsen's method (Olsen, *et al.*, 1954). Seed protein was determined by estimating nitrogen using conventional micro-Kjeldahl's method as per the as the procedure of AOAC (1984). The factor 5.71 and 6.25 was used to convert protein in soybean and chickpea, respectively. Observation on yield and yield attributing characters were recorded at harvest and statistically analyzed in split plot design.

RESULTS AND DISCUSSION

Effect of phosphorus levels

A progressive increase in growth and yield attributes of soybean as well as that of succeeding chickpea was observed with increasing levels of phosphorus from

Table1. Effect of phosphorus levels and P application frequency on growth and yield attributes of soybean and chick pea (Pooled data of two years)

Treatments	Soybean				Chickpea			
	Plant height (cm)	Bran-ches (No/plant)	Pods (No/plant)	Seed Index (g/100 seeds)	Plant height (cm)	Bran-ches (No/plant)	Pods (No/plant)	Seed Index (g/100 seeds)
<i>Levels of P (kg/ha)</i>								
13.2	59.79	2.60	44.67	11.02	40.02	3.39	16.99	18.43
26.4	63.12	2.84	50.33	11.50	42.11	3.79	19.53	19.82
39.6	66.10	3.06	55.51	11.76	43.69	4.00	21.23	21.93
SEm ($\pm$)	0.95	0.03	0.61	0.03	0.38	0.08	0.39	0.03
C D (P = 0.05)	3.75	0.10	2.39	0.11	1.49	0.34	1.55	0.11
<i>P application frequencies</i>								
Kharif and rabi crop both	70.40	3.15	57.61	11.70	42.95	4.22	23.66	20.28
Kharif crop only	65.85	2.99	55.15	11.57	42.47	3.86	21.47	20.07
Rabi crop only	60.32	2.70	46.41	11.29	41.95	3.71	19.71	20.06
Kharif, alternate year	61.46	2.84	49.40	11.41	41.78	3.64	17.61	19.99
Rabi, alternate year	59.20	2.54	46.05	11.22	41.68	3.51	17.14	19.99
Kharif and rabi, alternate year	60.82	2.79	46.41	11.38	40.81	3.41	15.88	19.94
SEm ($\pm$)	1.34	0.12	1.77	0.05	0.26	0.15	0.78	0.03
C D (P = 0.05)	3.85	0.34	5.12	0.13	0.76	0.42	2.24	0.08

13.2 to 39.6 kg per ha (Table 1). Each level of P significantly increased number of branches per plant, pods per plant and seed index in case of soybean and plant height, pods per plant and seed index in case of chickpea. Maximum increase in all the growth and yield attributes was noticed on application of 39.6 kg P per ha. Phosphorus application to crops, particularly to oilseeds and

pulses has been reported to enhance growth attributes (Kumar *et al.*, 2008) in chickpea as well as the vigorous root development in soybean (Hallmark and Barber, 1984) and also accelerated rhizobium activity in legume crops (Anonymous, 1999). The response of applied P in improving the seed size may be attributed to its significant role in

Table 2. Effect of phosphorus levels and P application frequency of on seed, straw yield, total P uptake, net return and B: C ratio of soybean – chickpea crop sequence. (Pooled data of two years)

Treatment	Grain yield (kg/ha)		Straw yield (kg/ha)		SEY* (kg/ha)	Net returns(Rs/ha)	B:C ratio	P uptake (kg/ha)			Seed protein (%)	
	Soybean	Chickpea	Soybean	Chickpea				Soybean	Chickpea	Total	Soybean	Chickpea
<i>Levels of P (kg/ha)</i>												
13.2	1,686	1,711	3,033	3,081	3,967	25,661	2.55	9.06	12.17	21.23	36.09	20.1
26.4	2,025	2,014	3,644	3,625	4,710	32,305	3.20	11.52	15.30	26.82	37.64	21.1
39.6	2,214	2,241	3,975	4,003	5,202	36,683	3.62	13.46	18.02	31.48	38.10	21.5
SEm (±)	27	42	51	79	72	651	0.06	0.19	0.34	-	0.12	0.06
C D (P = 0.05)	106	166	201	312	209	1,880	0.19	0.76	0.99	-	0.48	0.25
<i>P application frequencies</i>												
Kharif and rabi crop both	2,250	2,052	4,050	3,717	4,986	34,689	3.40	14.33	17.06	31.39	37.91	21.4
Kharif only	2,022	2,018	3,625	3,642	4,713	32,332	3.21	14.22	16.11	30.33	37.64	21.2
Rabi only	1,835	2,016	3,330	3,586	4,523	30,707	3.07	9.75	15.41	25.16	36.91	21.0
Kharif alternate year	2,003	1,971	3,605	3,561	4,631	31,510	3.10	11.67	14.83	26.5	37.37	20.7
Rabi alternate year	1,775	1,949	3,192	3,481	4,374	29,366	2.93	9.05	13.79	22.84	36.64	20.6
Kharif and rabi alternate year	1,905	1,927	3,536	3,436	4,534	30,721	3.05	11.05	13.80	24.85	37.18	20.4
SEm (±)	43	41	77	78	218	1,955	0.19	0.26	0.27	-	0.06	0.04
C D (P = 0.05)	123	119	223	226	637	5,708	0.55	0.76	0.79	-	0.18	0.12

*SEY- Soybean equivalent yield

regulating the photosynthesis, root enlargement and better microbial activities (Jain and Tiwari, 2001). The increase in seed and straw yield of soybean and chickpea as well soybean equivalent yield by application of 39.6 kg P per ha over 13.2 kg per ha was about 30 per cent. The economic analysis in terms of net returns and B: C ratio also revealed profitability and economic viability of increasing the phosphorus levels from recommended level.

The highest net profit (Table 2) of Rs 36, 683 and B: C ratio of 3.62 was associated with application of phosphorus at 39.6 kg per ha as compared to that of recommended level of 13.2 kg per P ha (Rs 25, 661 and 2.55, respectively). The application of highest level of phosphorus also led to significant increase in protein content of soybean and chickpea seed and total uptake of phosphorus by these crops. Such favourable effects of phosphorus applications on soybean (Morshed *et al.*, 2008), chickpea (Meena *et al.*, 2005, Chandra and Khandelwal, 2009) and soybean-chickpea (Arya *et al.*, 2002) have earlier been documented.

Effect of frequency of phosphorus application

The application of phosphorus to both *kharif* and succeeding *rabi* crops proved to be the best for the soybean-chickpea cropping system. In general, all the observed yield attributes showed highest values with application of phosphorus in *kharif* and *rabi* seasons followed by application in *kharif* only (Table 1). This enhancement in yield

attributing characters has been reflected in individual production of the two crops in the season and in system productivity (Table 2). This is in conformity of the results reported by Prasad *et al.* (1998), who have suggested application of phosphorus to soybean in cropping systems (*kharif-rabi* seasons) to optimize the system productivity. The economic analysis too revealed better economic viability of application of phosphorus in both the seasons (net returns Rs 34, 689 and B:C ratio 3.40) followed by its application in *kharif* (net returns Rs. 32, 332 and B:C ratio 3.21) over other frequencies of P application (net returns Rs. 29, 366 - 31, 510 and B:C ratio 2.93 - 3.07). The above two superior treatments had an edge over other treatments for seed protein content and phosphorus uptake in both the crops as well. It is interesting to note that different frequencies of phosphorus attempted in this experiment, showed higher productivity of both the crops and from the soybean-chickpea cropping system as compared to recommended level of phosphorus application establishing the importance of adequate application of this nutrient in nutritional schedule to optimize the cropping system productivity, particularly involving oilseeds/pulses.

Phosphorus being vital nutritional element for crops, particularly oilseeds and pulses was able to enhance system productivity and profitability from soybean-chickpea beyond the recommended levels for individual crop. Highest productivity and profitability was

visualized with application of phosphorus at 39.6 kg per ha. The frequency of application revealed that one can go for application of phosphorus for *kharif* crops only in soybean-chickpea sequence with some compromise with system productivity. In view of progressive advantages of increasing levels of phosphorus application and

better performance of phosphorus application frequencies over recommended application, option lies with the farmers to opt for any frequency depending on financial resources available with him and to the extent he is prepared to compromise with yield performance.

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Weed Control Efficiency of Diclosulam against Weeds in Soybean

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ABSTRACT

Field experiments were conducted for two seasons (kharif 2006 and 2007) to evaluate the bio-efficacy of diclosulam 84 WDG against weeds in soybean. The existence of weeds throughout the crop season led to maximum reduction (41.0 %) in seed yield. Significantly higher soybean yield (69.8 %) was recorded when weeds were managed by manual weeding (at 30 and 45 days after sowing) over control. Among different levels of diclosulam tried, its application either @ 30 or @ 22 g a i per ha as pre-emergence yielded maximum (2, 480 kg/ha and 2, 446 kg/ha, respectively) and out-yielded check herbicides viz. clomazone @ 1 kg a i per ha (2, 191 kg/ha), pendimethalin @ 1 kg a i per ha (2, 169 kg/ha) and diclosulam @ 14 g a i per ha (2, 247 kg/ha) applied as pre-emergence. The physical maximum dose of diclosulam was to the tune of 24 g a i per ha with corresponding yield of 3, 001 kg per ha. Manual weeding was superior to chemical weed control in limiting the weed load (weed density as well as their dry biomass) in soybean crop. Application of diclosulam was found to be effective to maintain the higher weed control efficiency continuously up to 60 DAS as compared to check herbicides. The result brought out that for effective management of weeds in soybean, diclosulam @ 22 g or 30 g a i per ha is another potent pre-emergence herbicide. For fields dominated by dicots, the use of diclosulam at said levels might be better alternative for weed management.

Keywords: Efficacy, herbicide, optimum dose, pre-emergence, post-emergence, soybean

Matching with its global significance as edible oil generating crop, soybean is now a major oilseed crop in India. In central India, it is grown as rainfed crop mostly on Vertisols and associated soils and most of the area is rain dependent. Thus, it is exposed to vagaries of climate, insect-

pests and diseases, and suffers from co-existence of weeds, if not managed properly. Weeds, depending on their type, intensity and duration of competition with crop were found to reduce soybean yields to an extent of 35 to 70 per cent (Billore *et al.*, 1999). Vertisols tend to become sticky

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when wet. Under such conditions, mechanical / manual methods of weeding are either not possible or effective. The limited and expensive availability of labour is another factor which does not permit manual weed control. Use of herbicide is an option available for the farmers. At present only few options in pre-emergence (alachlor, metatolchlor and pendimethalin and clomoxone) and post - emergence (imezethapyr and quazalofop ethyl) are available with restricted availability in areas of soybean cultivation. Hence, the present investigation was aimed at establishing the bio-efficacy of diclosulam 84 per cent WDG, a triazolopyrimidine sulfonanilide ([N-(2,6-dichlorophenyl)-5-ethoxy-7-fluoro [1,2,4] triazolo [b,1,5-c] pyrimidine-2-sulfonamide]) molecule against weeds in soybean.

MATERIAL AND METHODS

Field experiments were conducted for two seasons (*kharif* 2006 and 2007) to evaluate the bio-efficacy of diclosulam 84 per cent WDG against weeds in soybean at the Directorate of Soybean Research, Indore. The soil belonged to fine, montmorillonitic, isothermic family of Typic Haplusterts. It analyzed: pH 7.8, EC 0.14 dS per m, organic carbon 0.3 per cent, available phosphorus 10.1 kg per ha and potassium 280 kg per ha. The experiment was laid out in a randomized block design with three replications and consisted of nine treatments i. e. 3 levels of diclosulam (18, 22 and 26 g a i /ha) as pre-emergence, pendimethalin @ 1 kg a i per ha as pre-emergence, clomoxone @ 1

kg a i per ha as pre-emergence, quazalofop ethyl @ 50 g a i per ha as post-emergence, Imazethapyr @ 75 g a i per ha as post emergence, two hand weeding at 30 and 45 days after sowing (DAS) and a weedy check. Soybean 'JS 93-05' was sown on 1 July 2006 and 22 June 2007 and was harvested in the month of October. A uniform dose of nutrients i. e. 20: 26: 17 kg N:P:K per hectare as basal was applied through urea, single super phosphate and muriate of potash to all the treatments. The crop was raised using recommended package of practices.

The observations on yield and yield attributes were recorded at harvest. Weed population and oven-dry weight was recorded at 30 and 60 days after sowing. Weed control efficiency was calculated as per standard formula i. e. Weed control efficiency (%) = $\frac{\text{Weed dry matter in control} - \text{Weed dry matter in treatment}}{\text{Weed dry matter in control}} \times 100$. Statistical analysis was carried out by method of Sokal and Rohlf (1981). The relationship between yield and levels of diclosulam was determined by using the quadratic equation, i.e. $Y = a + bx + cx^2$.

RESULTS AND DISCUSSION

Yield and yield attributes

Plant height, yield and yield attributes were significantly influenced by the weed control treatments (Table 1). The highest soybean plant height recorded was under control which remained at par with pendimethalin @ 1 kg a i per ha. The significant increase in number of branches was noticed in case of quazalofop ethyl @ 50 g a i per ha followed by two hand weeding

at 30 and 45 days only. Pod bearing ability of soybean plant was improved when different weed management treatments were imparted to the crop. The highest pods per plant was recorded with two hand weeding, which was closely followed by quizalofop ethyl @ 50 g a i per ha and diclosulam @ 22 g a i per ha. The boldest seeds were also noted with two hand weeding at 30 and 45 DAS

which remained at par with clomazone @ 1 kg a i per ha and diclosulam @ 22 g a i per ha, while other treatments differed non-significantly among themselves. All the weed management treatments yielded higher (from 35 to 69 %) than the weedy check (1, 607 kg/ha); the maximum seed yield being with two hand weeding at 30 and 45 days.

Table 1. Effect of various levels of Diclosulam on yield and yield attributes of soybean (pooled 06-07)

Treatment	Plant height (cm)	Branches (No/ Plant)	Pods (No/ Plant)	Seed index (g/100 seeds)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
Diclosulam @ 14 g a.i./ ha as PE	51.23	3.08	24.70	10.79	2, 247	3, 231	41.01
Diclosulam @ 22 g a.i./ ha as PE	47.15	3.84	29.42	11.50	2, 446	2, 548	50.43
Diclosulam @ 30 g a.i./ ha as PE	53.27	3.47	27.17	10.80	2, 480	2, 775	48.30
Quizalofop ethyl @ 50 g a.i./ha as POE	48.00	4.40	30.00	10.75	2, 314	3, 241	41.58
Pendimethalin @ 1 kg a.i./ ha as PE	56.93	3.73	20.27	10.58	2, 169	3, 214	40.51
Clomazone @ 1 kg a.i. /ha as PE	50.90	3.80	26.40	11.61	2, 191	2, 701	44.79
Imazethapyr @ 75 g a.i./ha as POE	54.72	3.27	27.67	11.14	2, 459	2, 632	49.52
Two hand weeding at 30 and 45 DAS	51.01	3.95	31.30	11.73	2, 722	2, 676	51.35
Weedy check	62.15	3.13	18.24	10.48	1, 607	2254	43.94
SEm (±)	1.99	0.26	1.27	0.17	68.59	92.76	0.99
C D (P = 0.05)	6.10	0.77	3.76	0.49	203.11	274.47	2.93

PE – Pre-emergence; POE – Post-emergence

The seed yield achieved through weed management by two hand weeding at 30 and 45 DAS was 16.9 per cent higher over that obtained by chemical weed control together. The seed yield levels achieved by application of diclosulam @ 30 g a i per ha and 22 g a i per ha, imazethapyr @ 75 g a i per ha and quizalofop ethyl @ 50 g a i per ha were not different. However, yields were significantly lower (9-15 %) compared to two hand weeding at 30 and 45 DAS. Weed management treatments, in general, led to significantly higher straw yield (13 to 43 %) as compared to weedy check. Highest harvest index was associated with two hand weeding (51.35 %) closely followed by diclosulam @ 22g a i per ha. Andrew and Wilcut (2002) also stated that the peanut yields and net returns were reflective of levels of weed management. The relationship between yield and levels of diclosulam was found curvilinear ($Y = 406.66 + 216.255x - 4.506x^2$) and the physical maximum dose of diclosulam was 24 g a i per ha which yielded maximum i.e. 3,001 kg/ha.

Weed dynamics

Weed management through two hand weeding at 30 and 45 DAS found to be most efficient to contain weed load at

both the stages of observations i.e. 30 and 60 days after sowing (Table 2). Application of diclosulam @ 22 and 30 g a i per ha, imazethapyr @ 75 g a i per ha and clomazone @ 1 kg a i per ha were found to be more effective to control the total weeds as evidenced from more than 80 per cent weed control efficiency at 30 days after sowing, while at 60 days after sowing, only diclosulam @ 22 or 30 g a i per ha as well as imazethapyr showed more than 69 per cent weed control efficiency as compared to other herbicidal treatments. Modal *et al.* (2009) also reported that application of diclosulam @ 22 to 26 g a i per ha in soybean resulted in superior weed control (85.9 to 90.6 %) over control and check herbicide i.e. imazethapyr @ 75 g a i per ha as post-emergence. Andrew and Wilcut (2002) also stated that pre-emergence treatments that contained diclosulam, provided cent per cent control of common lambsquarters, common ragweed, and eclipta. It also controlled entireleaf morningglory by 88 per cent, ivyleaf morningglory by 90 per cent, pitted morning glory by 81 per cent, and *Prickly sida* by 94 per cent. Yellow nut sedge control with diclosulam ranged from 65 to 100 per cent depending on location.

Table 2. Effect of different levels of diclosulam on total weed count and their dry matter at 30 and 60 days after sowing in soybean

Treatment	At 30 DAS		At 60 DAS		WCE (%)	
	Total weed count (No/m ²)	Total weed dry matter (g/m ²)	Total weed count (No/m ²)	Total weed dry matter (g/m ²)	30 DAS	60 DAS
Diclosulam @ 14 g a.i./ ha as PE	34.66	2.81	20.00	12.18	62.58	49.84
Diclosulam @ 22 g a.i./ ha as PE	26.33	1.61	23.00	16.40	82.27	68.60
Diclosulam @ 30 g a.i./ ha as PE	15.34	1.07	17.67	14.03	86.82	74.95
Quizalofop ethyl @ 50 g a.i./ha as POE	31.33	1.37	18.33	14.53	79.09	52.08
Pendimethalin @ 1 kg a.i./ ha as PE	24.33	1.39	21.33	19.41	75.10	35.98
Clomazone @ 1 kg a.i. /ha as PE	23.00	1.13	14.00	15.84	93.00	57.70
Imazethapyr @ 75 g a.i./ha as POE	9.50	1.11	21.00	11.35	93.13	80.64
Two hand weeding at 30 and 45 DAS	0.00	0.00	4.17	1.67	100.00	96.16
Weedy check	53.83	11.84	23.67	50.44	-	-
SEm (±)	5.39	0.67	2.49	4.81	-	-
C D (P = 0.05)	15.92	3.26	7.36	14.14	-	-

PE – Pre-emergence; POE – Post-emergence; WCE – Weed control efficiency

Although, the level of containing monocot weeds at 30 and 60 days varied, all the weed management treatments could reduce the weed load as expressed in terms of number and dry biomass over control. Imazethapyr @ 75 g a i per ha and quizalofop ethyl @ 50 g a i per ha, in general, were promising as also indicated by weed control efficiency values of 96.2

and 79.8 per cent, and 84.4 and 77.0 per cent at 30 and 60 DAS, respectively. The new molecule diclosulam could reveal weed control efficiency of 61.30 to 84.22 per cent at 30 DAS and around 50 per cent at 60 DAS for monocot weeds. Application of this herbicide at 30g a i per ha appeared to be better for monocot weed management (Table 3).

All the herbicides evaluated were more effective in reducing the dicot weed load over weedy check. Weed count as well as weed biomass recorded in these

treatments were significantly lower than weedy check. Weed control efficiency values at 30 and 60 DAS indicated that apart from imazethapyr @75 g a i per ha

Table 3. Effect of different levels of diclosulam on monocot weed count and their dry matter at 30 and 60 days after sowing in soybean

Treatment	At 30 DAS		At 60 DAS		WCE (%)	
	Weed count (No/m ²)	Weed dry matter (g/m ²)	Weed count (No/m ²)	Weed dry matter (g/m ²)	30 DAS	60 DAS
Diclosulam @ 14 g a.i./ ha as PE	25.33	2.50	5.00	7.78	61.30	54.34
Diclosulam @ 22 g a.i./ ha as PE	22.17	1.47	21.00	13.32	79.21	50.74
Diclosulam @ 30 g a.i./ ha as PE	14.00	1.06	17.17	13.00	84.22	51.16
Quizalofop ethyl @ 50 g a.i./ha as POE	20.33	1.01	10.33	3.92	84.37	76.99
Pendimethalin @ 1 kg a.i./ ha as PE	14.33	1.38	13.00	7.86	78.64	53.87
Clomazone @ 1 kg a.i./ha as PE	8.67	0.33	9.00	10.10	96.23	67.73
Imazethapyr @ 75 g a.i./ha as POE	4.34	0.80	14.33	5.70	90.87	79.80
Two hand weeding at 30 and 45 DAS	18.34	2.36	3.34	0.28	100.00	98.36
Weedy check	31.50	7.61	24.83	24.17	-	-
SEm (±)	3.55	0.86	2.33	4.02	-	-
CD (P = 0.05)	10.47	2.53	6.90	11.89	-	-

PE – Pre-emergence; POE – Post-emergence; WCE – Weed control efficiency

(95.8 and 80.4 %, respectively) and clomazone @ 1 kg a.i. per ha (89.2 and 75.2 %, respectively), diclosulam @ 30 g a.i. per ha (99.8 and 97.3 %, respectively) and 22 g a.i. per ha (90.3 and 85.2 %,

respectively) holds promise to control dicot weeds. This also revealed that diclosulam is more effective for longer duration for management of dicot weeds.

Table 4. Effect of different levels of diclosulam on dicot weed count and their dry matter at 30 and 60 days after sowing in soybean

Treatment	At 30 DAS		At 60 DAS		WCE (%)	
	Weed count (No/m ²)	Weed dry matter (g/m ²)	Weed count (No/m ²)	Weed dry matter (g/m ²)	30 DAS	60 DAS
Diclosulam @ 14 g a.i./ ha as PE	9.33	0.31	5.00	4.40	70.48	66.87
Diclosulam @ 22 g a.i./ ha as PE	4.17	0.14	2.00	3.07	90.34	85.21
Diclosulam @ 30 g a.i./ ha as PE	1.34	0.02	0.50	1.04	99.79	97.34
Quizalofop ethyl @ 50 g a.i./ha as POE	11.00	0.56	8.33	10.61	46.67	20.10
Pendimethalin @ 1 kg a.i./ ha as PE	10.00	0.49	1.00	11.55	53.33	13.03
Clomazone @ 1 kg a.i./ha as PE	14.33	0.80	5.00	9.74	89.19	75.19
Imazethapyr @ 75 g a.i./ha as POE	5.67	0.31	6.67	5.65	95.81	80.41
Two hand weeding at 30 and 45 DAS	0.00	0.00	0.84	1.39	100.00	93.95
Weedy check	22.34	4.23	9.67	26.27	-	-
SEm (±)	2.24	0.56	1.26	3.56	-	-
C D (P = 0.05)	6.62	1.66	3.73	10.52	-	-

PE – Pre-emergence; POE – Post-emergence; WCE – Weed control efficiency

The results are in line with the findings of Grichar *et al.* (2006), who reported that application of diclosulam alone as pre-plant incorporation, or pre-

emergence or post-emergence controlled *Palmer amaranth* and pitted morningglory greater than 81 per cent, devil's-claw at least 80 per cent, *Texas panicum* 33 to 97

per cent, and yellow nutsedge 48 to 88 per cent four weeks after treatment.

The effect of different chemical herbicides was also more or less similar to that observed in case of monocot and dicot weeds. All of them significantly reduced the total weed dry-biomass as compared to control at both the stages of observations.

The present study brought out that

for effective management of weeds in soybean, diclosulam @ 22 g or 30 g a i/ha is another potent pre-emergence herbicide along with clomazone @ 1 kg a i per ha as pre-emergence and imazethapyr @ 75 g a i per ha as post-emergence. For fields dominated by dicots, the use of diclosulam at said levels might be better alternative for weed management.

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Utilization Indices of *Spodoptera litura* Fab. Larvae as Influenced by Some Plant Extracts

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ABSTRACT

Three utilization indices viz., Approximate Digestibility, Efficiency of Conversion Index and the Efficiency of Conversion of Digested food were used to assess the effect of aqueous extracts from leaves/seeds of *Acacia arabica*, *Annona squamosa*, *Datura stramonium*, *Eucalyptus globulus*, *Ipomoea carnea*, *Lantana camara*, *Nicotiana tabacum* and *Pongamia pinnata* on food consumption and utilization by 3rd instar *Spodoptera litura* Fab. larvae. The amount of food ingested, larval weight gain and amount of frass were inversely proportional to the concentration of plant extract used. Although, leaf extract of *D. stramonium* had maximum antifeedant effect on *S. litura* larvae, minimum larval weight gain was found in case of larvae treated with *A. squamosa* seed extract. However, no consistent relationship could be observed between amount of food ingested and weight gain by larvae. Leaf extracts of *I. carnea* and *Lantana camara* reduced Approximate Digestibility. In general, other indices viz. Efficiency of Conversion Index and the Efficiency of Conversion of Digested food were less in larvae exposed to plant extracts than the untreated ones. Collective consideration of all the utilization indices revealed that *D. stramonium*, *E. globules* and *P. pinnata* could be exploited as potential sources for developing effective alternate strategy for the management of *S. litura* larvae.

Key words: Food consumption and utilization indices, plant extracts, *Spodoptera litura*

Tobacco caterpillar, *Spodoptera litura* Fab. has attained considerable significance in Indian agriculture, mainly because of its polyphagous nature, three outbreaks during last decade on soybean and development of resistance against many chemical insecticides. Although, efforts have been made to popularize IPM strategies for its management, still sole-dependence on chemical insecticides by farmers is leading to several problems. In order to overcome inevitable hazardous consequences of non-judicious use of chemical and poisonous insecticides, more

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emphasis is now being given to use of alternate and eco-friendly insect management technologies like insecticides of plant origin, which provide ideal and sustainable management strategy. Several plant species have been reported to possess insecticidal properties (Raheza, 1998; Singh, 2000). To exploit their insecticidal potential, studies on efficacy against many insect pests of economic importance have also been conducted (Benedicto *et al.*, 1998; Babu *et al.*, 1999; Kulat *et al.*, 2000; Boreddy and Chitra, 2001). It is well known that when larvae are treated with extracts of plants having insecticidal properties, their feeding capacity gets adversely affected, which is ultimately reflected in their growth and development, and can be quantified through some indicators like digestibility utilization indices (Waldbauer, 1968; Jacob and Chippendale, 1971; Brewer and King, 1978).

Therefore, in order to assess the feasibility of using plant extracts for the management of *S. litura*, attempts have been made to elucidate the effect of some selected plant species on its consumption and utilization of food.

MATERIAL AND METHODS

In this study, three utilization indices were used as the indicators of effect of plant extracts on growth of *Spodoptera* larvae : (i) the Approximate Digestibility (AD) is the measure of approximate percentage of food consumed that is utilized by the larvae; (ii) the Efficiency of Conversion Index

(ECI) is an overall measure of ability of larvae to utilize the ingested food for their growth; (iii) the Efficiency of Conversion of Digested food (ECD) is the percentage of digested food that contributes to weight gain of the larvae (Waldbauer, 1968; Jacob and Chippendale, 1971; Brewer and King, 1978). In short, AD indicates how much digestible is the treated food, whereas ECI and ECD indicate how the insect converts that food into its biomass (Lindroth, 1993). These three indices were calculated as follows:

$$\begin{aligned} \text{AD} &= (\text{Fi} - \text{Wf}) / \text{Fi} \times 100 \\ \text{ECI} &= \text{Wg} / \text{Fi} \times 100 \\ \text{ECD} &= \text{Wg} / (\text{Fi} - \text{WF}) \times 100 \end{aligned}$$

where, Fi is weight of food ingested, Wf is weight of frass, and Wg is weight gain by larvae.

To enumerate above indices, a laboratory experiment was conducted at Directorate of Soybean Research (ICAR), Indore under controlled conditions ($27 \pm 1^\circ \text{C}$, $80 \pm 5\%$ RH and 12 h photophase and scotophase) with 4 concentrations of 11 plant extracts and one control (Table 1), each having three replications. Ten 3rd instar (pre-starved for 3 h), pre-weighed larvae were released in plastic petriplates and were provided with pre-weighed soybean leaves and different concentrations of plant extracts were sprayed with the help of hand sprayer. The left over leaves and excreta were removed from the petriplates after every 24 h, oven dried at 50°C for 30 minutes and weighed with Mettler balance (Model AT 201). Larval weight was also recorded daily. Fresh, treated and weighed leaves were supplied on daily basis. To know the dry weight of leaves supplied, fresh leaves

of known weight were oven dried and again weighed. This relationship of fresh weight and dry weight was used to extrapolate the dry weight of leaves supplied as and when required. Similarly, the relationship between fresh and dry weight of larvae was also arrived at following same procedure.

RESULTS AND DISCUSSION

Food ingested (Fi): The concentration of extracts and the food ingestion were found to be inversely proportional. Data presented (Table 1) revealed that ingestion of food decreased with the increase in concentration from 25 to 100 per cent. On mean basis maximum food ingestion was observed in case of control i.e. untreated leaves (1085 mg) (Table 2). Medhini *et al.* (2009) also reported similar results while assessing the effect of different concentrations of pot marigold, *Calendula officinalis* extracts on *S. litura* larvae. The chemical composition of *Calendula officinalis* includes sesquiterpines, flavonoids, triterpenoid saponins, triterpene alcohols etc (Ahmed *et al.*, 1993). In the present investigation, among the treated leaves, maximum ingestion was found in case of leaves treated with *A. squamosa* leaf extract (736 mg), followed by *A. arabica* (seed) (513 mg), *Pongamia pinnata* (493 mg), *D. stramonium* (seed) (401 mg), *E. globulus* (386 mg), *A. arabica* (378 mg), *A. squamosa* (seed) (372 mg), *I. carnea* (349 mg) and least was in case of *L. camara* (255 mg). These differences in food ingestion could be attributed to the differences in the chemical composition of plant species used. A review by Champagne *et al.*

(1992) revealed that majority of the bioactive triterpenes from limnoids had antifeedant activity. Saponins from alfalfa are also responsible for reduced food consumption and reduced growth rate in *S. litura* larvae (Adel *et al.*, 2000).

On the basis of amount of food “not consumed” with respect to untreated control, it was possible to quantify the antifeedant activity of plant extracts. The per cent antifeedant activity in various extracts was therefore worked out and found to be as follows : *D. stramonium* – 77.61 per cent, *L. camara* – 76.50 per cent, *N. tabacum* – 71.43 per cent, *I. carnea* – 67.84 per cent, *A. squamosa* (seed) – 65.72 per cent, *A. arabica* – 65.16 per cent, *E. globulus* – 64.42 per cent, *D. stramonium* (seed) – 63.04 per cent, *P. pinnata* – 54.56 per cent, *A. arabica* (seed) – 52.72 per cent and *A. squamosa* – 32.17 per cent. In earlier study Babu *et al.* (1998) also reported that the feeding deterrence rate of *A. squamosa* crude oil against *S. litura* ranged from 19 to 69 %.

Weight gain (WG): As in case of the amount of food ingested, weight gain by the larvae was also found to be inversely proportional to the concentration of the extracts (Table 1). Maximum mean weight gain (479.33 mg) was found when the larvae were fed on untreated leaves (Table 2), which was remarkably more than the weight gain of larvae feeding on leaves treated with different extracts. Least weight gain was recorded with, *A. squamosa* seed (46.33 mg) followed by *E. globulus* (49.42 mg), *N. tabacum* (59.08 mg), *P. pinnata* (62.25 mg), *A. squamosa*

Table 1. Food consumption by *Spodoptera litura* larvae and utilization indices

Plant extract	Conc. of extracts (%)	Dry weight of leaves ingested (Fi) mg	Weight gain (Wg) mg	Dry weight of frass (Wf) mg	AD (Fi-Wf)/Fi x 100	ECI (Wg/Fi) x 100	ECD Wg/(Fi-Wf) x 100
<i>Acacia arabica</i>	25	503	101.00	58.80	88.51 (71.83) *	18.02 (20.73)*	22.30 (23.30) *
	50	358	122.00	102.43	71.25 (57.60)	34.26 (35.87)	48.35 (44.05)
	75	276	92.33	120.60	58.93 (50.19)	39.91 (38.90)	65.58 (57.64)
	100	375	37.00	126.47	65.75 (54.19)	11.13 (18.99)	17.21 (23.85)
<i>Annona squamosa</i>	25	1089	112.33	353.93	68.94 (40.02)	11.13 (19.33)	15.92 (23.43)
	50	737	67.00	204.63	71.81 (58.89)	9.14 (17.60)	12.80 (20.94)
	75	640	47.00	117.87	81.32 (64.61)	7.37 (15.72)	9.14 (17.54)
	100	479	36.00	159.37	66.32 (55.16)	7.55 (15.92)	11.92 (20.11)
<i>Datura stramonium</i>	25	335	96.00	73.67	76.81 (61.35)	34.31 (35.42)	45.63 (42.56)
	50	250	86.00	73.40	68.19 (57.52)	35.50 (36.56)	56.34 (48.78)
	75	247	58.67	73.67	68.63 (56.80)	24.28 (29.43)	39.71 (38.75)
	100	141	29.67	58.30	58.52 (49.91)	26.63 (30.04)	45.87 (43.09)
<i>Eucalyptus globulus</i>	25	561	69.67	85.03	84.29 (66.78)	12.84 (20.89)	15.41 (22.95)
	50	414	64.33	88.20	77.70 (61.95)	16.19 (23.63)	21.18 (27.22)
	75	391	36.00	88.33	77.37 (61.60)	9.28 (17.60)	12.01 (20.13)
	100	178	27.67	43.30	76.54 63.13)	14.75 (18.50)	24.11 (24.26)
<i>Ipomoea carnea</i>	25	635	133.67	156.40	64.39 (54.25)	30.55 (32.64)	55.65 (47.85)
	50	364	78.67	151.27	58.90 (50.17)	21.62 (27.70)	37.00 (37.45)
	75	237	67.67	128.83	45.69 42.52)	28.92 (32.41)	62.95 (52.78)
	100	158	30.00	37.70	76.00 (60.92)	18.87 (25.20)	25.08 (29.43)
<i>Lantana camara</i>	25	401	180.00	144.20	65.91 (54.58)	46.80 (43.15)	70.64 (57.33)
	50	280	77.67	136.47	51.35 (45.77)	28.03 (31.88)	56.76 (49.22)
	75	186	47.33	112.13	39.81 (39.10)	25.42 (30.26)	64.83 (53.84)
	100	154	32.00	51.27	65.62 (54.40)	21.26 (27.34)	34.09 (35.41)

Table 1 contd.

Plant extract	Conc. of extracts (%)	Dry Wt of leaves ingested (Fi) mg	Weight gain (Wg) mg	Dry Wt of frass (mg) (Wf) mg	AD (Fi-Wf)/Fi x 100	ECI (Wg/Fi) x 100	ECD Wg/(Fi-Wf) x 100
<i>Nicotiana tabacum</i>	25	506	109.67	90.03	81.34 (64.86) *	22.06 (27.96) *	27.57 (31.56) *
	50	288	54.67	149.43	54.11 (47.42)	13.27 (13.04)	25.91 (20.61)
	75	285	56.00	45.47	78.14 (63.12)	26.64 (30.13)	39.95 (38.88)
	100	162	16.00	43.67	73.17 (59.00)	9.77 (17.58)	14.10 (21.11)
<i>Pongamia pinnata</i>	25	817	100.00	116.00	86.18 (68.35)	12.39 (20.56)	14.32 (22.21)
	50	518	76.00	166.33	67.28 (57.95)	16.93 (23.95)	33.99 (24.71)
	75	306	49.00	55.70	81.07 (64.62)	16.99 (23.99)	21.15 (26.99)
	100	331	24.00	127.57	65.57 (55.21)	7.15 (15.49)	12.03 (20.03)
<i>Acacia arabica</i>	25	833	281.00	163.07	78.12 (63.44)	36.08 (36.62)	49.70 (44.65)
	50	584	101.00	126.80	78.96 (62.89)	18.68 (25.42)	23.77 (28.9)
(Seeds)	75	416	83.33	166.40	60.93 (51.43)	23.29 (28.38)	38.78 (38.18)
	100	217	39.00	74.00	65.24 (54.57)	17.95 (24.84)	29.06 (32.29)
<i>Annona squamosa</i>	25	703	89.33	67.30	84.96 (68.34)	24.62 (28.31)	30.92 (32.08)
	50	257	51.67	8.67	93.52 (76.16)	45.17 (40.84)	49.23 (43.39)
(Seeds)	75	317	30.33	93.70	74.64 (60.41)	9.59 (17.55)	13.28 (20.76)
	100	213	14.00	31.73	84.23 (67.42)	6.16 (14.07)	7.58 (15.56)
<i>Datura stramonium</i>	25	621	124.67	97.90	73.86 (60.64)	29.96 (32.23)	47.74 (43.37)
	50	374	95.33	118.50	67.70 (55.41)	25.94 (30.54)	38.81 (38.44)
(Seeds)	75	330	72.33	134.63	58.66 (50.01)	23.30 (28.68)	40.23 (39.23)
	100	277	18.00	91.27	67.32 (55.15)	6.82 (14.57)	9.92 (17.77)
Control		1085	479.33	368.23	65.85 (54.28)	42.82 (40.91)	79.78 (63.71)
SEm (+)		108	12.89	32.61	(5.48)	(4.89)	(7.56)
C D (P=0.05)		316	37.43	95.10	(15.07)	(13.62)	(21.55)

* Figures in parentheses are Arcsin transformed values

(65.58 mg), *D. stramonium* (67.58 mg), *I. carnea* (77.50 mg), *D. stramonium* seed (77.58 mg), *L. camara* (84.25 mg), *A. arabica* (88.08 mg) and maximum with *A. arabica* seed extract (129.08 mg). This weight gain was 9.66 per cent of that of untreated control in case of *A. squamosa* seed, 10.31 per cent in *E. globulus*, 12.23 per cent in *N. tabacum*, 12.98 per cent in *P. pinnata*, 13.68 per cent in *A. squamosa*, 14.10 per cent in *D. stramonium*, 16.17 per cent in *I. carnea*, 16.18 per cent in *D. stramonium* seed, 17.58 per cent in *L. camara*, 18.36 per cent in *A. arabica* and 26.30 per cent in case of *A. arabica* seed extracts. Significant reduction in body weight of *S. litura* larvae has been also reported by Sahayaraj (1998) when fed on castor leaves treated with extracts of *Pedaliium murex*.

Considering both, the amount of food ingested and the weight gain together, it was observed that the later was somewhat commensurate with the food ingested only with extracts of *N. tabacum*, *A. arabica* seed and *D. stramonium* seed, i.e. less was the food ingested and less was the weight gain by the larvae. With rest of the extracts, the amount of food ingested did not show any relationship with the weight gain. However, Rathi and Gopalakrishnan (2005) reported growth reduction and toxic effects of *Syndrella nodiflora* Gaertn (Asteraceae) extracts on *S. litura* larvae.

Weight of frass : As the untreated leaves posed no feeding deterrence, maximum frass (368.23 mg) was produced by larvae feeding on untreated food material,

which was commensurate with maximum food ingestion and weight gain (Table 1). Among the treatments, maximum frass was produced by larvae feeding on *A. squamosa* (208.95 mg), followed by those feeding on *A. arabica* seed (132.57 mg), *I. carnea* (118.55 mg), *P. pinnata* (116.40 mg), *L. camara* (111.02 mg), *D. stramonium* seed (110.58 mg), *A. arabica* (102.08 mg), *N. tabacum* (82.15 mg), *E. globulus* (76.22 mg), *D. stramonium* (69.76 mg) and the least frass produced with *A. squamosa* seed (50.35 mg) extract. Data on food ingested, weight gain and weight of frass produced (Table 2) clearly revealed that extracts of *N. tabacum*, *A. arabica* seed and *D. stramonium* seed exerted strong antifeedant reaction to *S. litura* larvae. In case of *A. squamosa*, although food ingested was second highest (736 mg), but the weight gain was very less (65.58 mg) because most of the food was excreted as frass (208.95 mg) without any contribution to larval growth. This showed that initially the larvae consumed leaves treated with *A. squamosa* leaf extract, probably because of lack of antifeedant compounds, but because of some chemical constituents like, aporphine alkaloids (Oliver-Bever, 1986), the food material could not be digested and was excreted as frass.

In general, the quantity of food ingested (Fi), weight gain by the larvae (Wg) and the weight of the frass produced (Wf) were higher in case of untreated control larvae as compared to those treated with plant extracts.

Precise contribution of food ingested towards larval development was assessed on the basis of utilization indices, i.e. AD, ECI and ECD as described below.

Approximate Digestibility (AD): As stated earlier, the AD is the measure of approximate percentage of food consumed that is utilized by the insect, and is a function of quantity of food ingested and quantity of frass produced. In the present study, the mean AD was found to vary between 55.67 per cent in case of larvae treated with *L. camara* and 84.34 per cent in case of *A. squamosa* seed extracts (Tables 2). The untreated control had AD of 65.85 per cent, which was higher than that recorded in cases of *I. carnea* (61.25 %) and *Lantana camara* (55.67 %) treated larvae, while it was lower than that recorded in case of larvae treated with the remaining plant extracts, which ranged from 84.34 per cent with *A. squamosa* seed extract to 70.81 per cent with *A. arabica* seed extract. Increase in AD values for some plant extracts compared to control could be due to induction of detoxifying enzymes like mid-gut esterase's because of certain plant allelochemicals (Ghumare *et al.*, 1989; Mukherjee, 2003). On the other hand decrease in AD values for other extracts could be explained on the basis of presence of phytochemicals in different plants as studied by several workers. Similar results were reported by Medhini *et al.* (2009) also while studying the effect of benzene and chloroform extracts of *Calendula officinalis* on *S. litura* larvae. Sahayaraj (1998) reported that among three plant extracts viz. *Azadirachta indica*,

Citrus sinensis and *Vitex negundo* tested against *S. litura*, *Vitex negundo* has highest deterrent action on larvae, which was reflected by very low food consumption, approximate digestibility, faecal pellets production and reduction in percentage body weight. Hubner and Chiang (1982) found that larvae of European corn borer, *Ostrinia nubilalis* exhibit higher AD when parasitized with *Lixophaga diatraeae* than the un-parasitized larvae. These results show that the larvae tend to feed relatively more and excrete more when they experience stress due to any external factors. *S. litura* larvae continue feeding on the food material despite being treated with extracts having negative effect on their growth.

Efficiency of Conversion Index (ECI):

This index is precisely the insect's ability to utilize the ingested food for its growth. In present study, the highest ECI was observed in case of untreated leaves i.e. 42.82 (Table 2), which was *on par* with that recorded in cases of *A. arabica* (25.83), *D. stramonium* (30.18), *I. carnea* (24.99), *L. camara* (30.38) and *A. arabica* seed extracts treated larvae (24.00) (Table 2). But the ECI of untreated control was significantly higher than larvae treated with rest of the extracts. However, among the plant extracts no significant differences were observed. Waldbauer (1968) reported that ECI values rise and fall with AD. Sahayaraj (1998) also reported lower ECI by *S. litura* larvae when fed on groundnut shoots dipped in extracts of *Azadirachta indica*, *Citrus sinensis*, *Vitex negundo* and *Zingiber officinale*. Rahman and Mozini (2007) noticed remarkable

Table 2. Mean food consumption by *Spodoptera litura* larvae, weight gain, excreta and utilization (over Concentrations)

Plant extract	Dry weight of leaves ingested (Fi)	Weight gain (Wg)	Dry weight of frass (mg) (Wf)	AD (Fi-Wf)/Fi x 100	ECI (Wg/Fi) x 100	ECD Wg/(Fi-Wf) x 100
<i>Acacia arabica</i>	378	88.08	102.08	71.11	25.83	38.36
<i>Annona squamosa</i>	736	65.58	208.95	72.10	8.80	12.44
<i>Datura stramonium</i>	243	67.58	69.76	68.04	30.18	46.89
<i>Eucalyptus globulus</i>	386	49.42	76.22	78.98	13.26	18.18
<i>Ipomoea carnea</i>	349	77.50	118.55	61.25	24.99	45.17
<i>Lantana camara</i>	255	84.25	111.02	55.67	30.38	56.58
<i>Nicotiana tabacum</i>	310	59.08	82.15	71.69	17.94	26.88
<i>Pongamia pinnata</i>	493	62.25	116.40	75.03	13.37	20.37
<i>Acacia arabica</i> (seed)	513	126.08	132.57	70.81	24.00	35.33
<i>Annona squamosa</i> (seed)	372	46.33	50.35	84.34	21.38	25.25
<i>Datura stramonium</i> (seed)	401	77.58	110.58	66.89	21.50	34.17
Untreated control	1085	479.33	368.23	65.85	42.82	79.78

inhibitory activity of extracts of *Calotropis procera*, *Rhazya stricta* and *Solenostemma argel* on digestive carbohydrate enzymes, amylase and invertase *in vitro* in *Spodoptera littoralis*.

Efficiency of Conversion of Digested food (ECD): It is the percentage of digested food that contributes weight gain by the insect. The ECD, as expected, was highest in untreated control (63.71), which was significantly higher than that observed in insects treated with all the extracts except *D. stramonium* (46.89) and *L. camara* (56.58) (Table 2). Among the extracts, least ECD was recorded in case

of *A. squamosa* (12.44), which was significantly less than above mentioned two extracts but *on par* with the remaining extracts. It could be inferred that except *D. stramonium* and *L. camara* extracts, all other extracts prevented *S. litura* larvae to convert the digested food for their development. Similar findings were also reported by Medhini *et al.* (2009) when they used extract of *Calendula officinalis* against *S. litura* larvae, and attributed to chronic toxicity as a result of triterpines ingestion present in *Calendula*. Decrease in ECD in *S. litura* larvae due to *Trichilia* extracts was reported by Wheeler and Isman (2001).

In general, all the three indices i.e. AD, ECI and ECD decreased with increase in concentration of the extracts. Barring few cases, AD was more in case of larvae treated with plant extracts as compared to untreated larvae, while ECI and ECD were less. This trend clearly showed that when treated with plant extracts, the larvae initially tend to ingest more without showing any food aversion in order to overcome stress posed by bioactive toxic principles present in the plant extracts, but fail to utilize the digested food for their growth and development. Higher feeding rate could also possibly be due to preferred chemical constitution like higher N, higher N:tannin ratio, sucrose content, glucose content, etc (Albert and Bauce, 1994). In an earlier study by Nathan and Kalaivani (2005), food consumption, efficiency of conversion of ingested and digested food, relative growth rate, and consumption index values were found to decline significantly by treatment of azadirachtin (AZA) and nucleopolyhedrosis virus (NPV), but at the

same time an increase in approximate digestibility was also observed. Ghumare and Mukherjee (2004), in a study found that preference of *S. litura* larvae for castor leaves could not be overcome by exposure of some deleterious naturally occurring allelochemicals. Failure of *S. litura* larvae to learn aversion of food treated with deleterious chemicals is a blessing in disguise. This failure would ensure ingestion of treated food material in sufficient quantity to result larval mortality. Moreover, owing to this failure, the insect would not be able to develop resistance against inbuilt chemicals for a very long time.

The three digestibility indices AD, ECI and ECD decreased with increase in concentration of the extracts. It was found that AD of plant extracts was more than untreated control, while ECI and ECD were less than untreated control. Considering ECD as an indicator of assessing the effect of extracts against *S. litura* larvae, leaf extract of *A. squamosa* was found to be the best, followed by leaf extracts of *E. globuls* and *P. pinnata*.

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Integrated Management of Charcoal Rot of Soybean Caused by *Macrophomina phaseolina* (Tassi) Goid

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ABSTRACT

Charcoal rot of soybean caused by *Macrophomina phaseolina* (Tassi.) Goid is a seed as well as soil borne disease, predominantly occurring in most of the soybean growing states of India and causes 70 per cent or more yield loss. Dry conditions, relatively low moisture and nutrients (NPK) and high temperature ranging from 25-35 °C are favourable for the disease at pod formation and filling stage. There are no resistant lines; hence the disease has to be managed by other methods.

A field experiment was conducted in three consecutive years during 2005 to 2007 with variety NRC 7 (susceptible to charcoal rot) with 13 treatments, which included seed treatment (ST) with *Bradyrhizobium japonicum*, *Trichoderma viride*, Vitavax power (carboxin 37.5% + thiram 37.5%), irrigation at the time of moisture stress, and soil application of Zn, B and Fe alone or in different combinations. Significant treatment effects on disease incidence, number of chaffy (empty) pods per plant, yield and 100 seed weight were recorded. The maximum chaffy pods were noticed in untreated control and minimum in combined soil application of Zn along with *Bradyrhizobium japonicum* and *Trichoderma viride* followed by combinations of bio-agents with B + Fe and Zn + Fe. B, Zn and Fe individually and in their combinations reduced charcoal rot incidence. Seed treatment with *Bradyrhizobium japonicum* and *Trichoderma viride* and soil application of Zn with B and Fe reduced chaffy pods as well as the disease incidence up to 75 per cent over untreated control. Seed treatment with *Trichoderma* and irrigation at the time of moisture stress reduced the intensity of disease to about 50 per cent.

Key words: Charcoal rot, *Glycine max*, integrated management, *Macrophomina phaseolina*, micronutrients, soybean

Charcoal rot, also known as dry- *Macrophomina phaseolina* (Tassi.) Goid weather wilt, caused by the fungus (= *Rhizoctonia bataticola*), is the most

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common root disease occurring on soybean (*Glycine max* (L.) Merrill) (Wrather *et al.*, 1994). The fungus has a widespread distribution and large host range (Ghaffar and Zentmyer, 1968; Figueiredo *et al.*, 1969). Microsclerotia (hardened fungal survival bodies) are formed inside the infected tissue through which the fungus over-winters in infested crop debris over-winters in infested crop debris and in soil (Pearson *et al.*, 1984; Almeida *et al.*, 2001). Microsclerotia survive for several years in dry soil but only a few weeks in wet and saturated soils. Infection of soybean typically occurs early in season at emergence and early seedling growth stages. These seedling infections remain latent until environmental stresses (drought and high ambient temperature) occur during the R1 (flowering) - R7 (mature pod) growth stages. The most practical and cost-effective method to control this disease is the use of resistant cultivars. In the absence of resistant varieties, the alternative control practice could be the management of the soil by interfering with the biology or survival of the pathogen by altering the environment or favouring antagonists. The use of *Trichoderma* spp. (Sharma *et al.*, 2005; Jha *et al.*, 2008; Rajani and Parakhia, 2009) in plant disease management has been well documented. Hence, this investigation was made to manage the disease with soil amendments, irrigation and application of bio-agents alone and in different combinations.

MATERIAL AND METHODS

Site selection: Field experiments were conducted for three consecutive years from *kharif* 2005-2007 at Directorate of Soybean Research, Indore (M P), India, which lies in Vindhyaachal range of *Malwa* Plateau at 22° 4' 37" N latitude and 74° 52' 7" E longitudes and placed at an altitude of 550 m amsl. The soil is medium black soil with pH ranging from 7.6 to 8.1. The *Malwa* plateau enjoys the semi-arid climate with 90-100 days of monsoon with about 800 mm rainfall.

Biological agents and micronutrients: Biological agents viz., *Bradyrhizobium japonicum* (commercial product, NAFED) culture and *Trichoderma* spp. (Pathology Deptt, DSR) were used for seed treatment. The micronutrients viz, zinc in the form of zinc sulphate, boron in the form of borax and iron in the form of ferrous sulphate were applied to the soil prior to sowing individually and in different combinations as described in the treatments.

Plant material: A charcoal rot susceptible soybean variety NRC 7 (Ahilya 3) (Ansari, 2007) was used during the years of experimentation.

Experimental plan: An experiment was conducted under randomized block design with three replications and comprised thirteen treatments, viz. (i) Seed treatment (ST) with *Bradyrhizobium japonicum* @ 5 per kg seed, (ii) ST with

Vitavax power (carboxin 37.5 % + thiram 37.5 %) @ 3 g per kg seed, (iii) ST with Vitavax power + *B. japonicum* @ 5 per kg seed, (iv) ST with *B. japonicum* @ 5 per kg seed + irrigation up to field saturation (at the time of 50 % moisture stress), (v) ST with *B. japonicum* @ 5 per kg seed + *Trichoderma viride* @ 10 g per kg seed, (vi) ST with *B. japonicum* @ 5 per kg seed + *T. viride* @ 10 g per kg seed+ Zn @ 25 kg zinc sulphate per ha, (vii) ST with *B. japonicum* @ 5 per kg seed + *T. viride* @ 10 g per kg seed+ B @ 0.5 kg borex per ha, (viii) ST with *B. japonicum* @ 5 per kg seed + *T. viride* @ 10 g per kg seed+ Fe @ 10 kg ferrous sulphate per ha, (ix) ST with *B. japonicum* @ 5 per kg seed + *T. viride* @ 10 g per kg seed+ Zn @ 25 kg zinc sulphate per ha + B @ 0.5 kg borex per ha, (x) ST with *B. japonicum* @ 5 per kg seed + *T. viride* @ 10 g per kg seed+ Zn @ 25 kg zinc sulphate per ha + Fe @ 10 kg ferrous sulphate per ha, (xi)) ST with *B. japonicum* @ 5 per kg seed + *T. viride* @ 10 g per kg seed+ B @ 0.5 kg borex per ha + Fe @ 10 kg ferrous sulphate per ha, (xii) ST with *B. japonicum* @ 5 per kg seed + *T. viride* @ 10 g per kg seed + Fe @ 10 kg ferrous sulphate per ha + B @ 0.5 kg borex per ha + Zn @ 25 kg zinc sulphate per ha, and (xiii) untreated control.

In case of treatment number (iv), the irrigation was applied after flowering at the time moisture stress (50 % of field capacity). Seed treatment (ST) with Vitavax power @ 3 g per kg (chemical control) and untreated control (absolute control), in the experiment served the purpose of comparison. The individual

plot for each treatment had 6 rows of 5 m length with spacing of 45 cm x 5 cm. The soybean variety was sown on onset of monsoon and harvested in the month of October. All the recommended cultivation practices were followed. The data were subjected to ANOVA and means were separated by LSD (Sokal and Rohlf, 1981).

Observations: Observations on germination, total plant population, pre- and post- emergence mortality caused by disease, per cent disease incidence, and effect of charcoal rot on plant height, number of branches per plant, number of pods per plant , number of chaffy (empty) pods per plant, yield per plot and 100 seed weight were recorded. The per cent disease incidence and disease reduction over control were calculated after taking total plant population and total number of plants wilted up to harvest into account.

RESULTS AND DISCUSSION

Pathogenicity: The pathogen was isolated from infected stem bits of soybean using CMRA medium (Meyer *et al.*, 1972), purified and identified as *M. phaseolina* and the pathogenicity was confirmed by soil infestation method under artificial inoculation conditions. The characteristic disease symptoms like wilting and drying of leaves were observed. Roots of the infected plants exhibited blackening of tap root and formation of numerous sclerotia on roots.

Plant Growth parameter: There were no significant differences between plant height and number of branches per plant; however significant effect of treatments were recorded on number of chaffy (empty) pods per plant and 100 seed weight (Table 1). The reduction in yield was mainly due to more number of unfilled pods which occurred due to the disease. Maximum per plant yield (9.45 g) was recorded in ST with Vitavax power + *B. japonicum* and lowest (5.93 g) in untreated control. Like-wise highest seed index (12.76 g) was recorded in ST with Vitavax power followed by ST with *B. japonicum* + *T. viride* + Zn + B (12.31 g) and minimum (10.61 g) in untreated control. Number of chaffy pods per plant was maximum (7.3) in untreated control and minimum (1.3/plant) in ST with *B. japonicum* + *T. viride* + Fe + B + Zn. The number of unfilled (chaffy) pods per plant was less than 2 per plant in treatments ST with *B. japonicum* + irrigation up to field saturation, ST with *B. japonicum* + *T. viride* + Zn + Fe, ST with *B. japonicum* + *T. viride* + B + Fe and (xii) ST with *B. japonicum* + *T. viride* + Fe + B + Zn (Table 1).

Disease incidence: The disease started appearing after flowering when soil moisture decreased below 50 per cent moisture of field capacity. The integrated disease management of charcoal rot of soybean (Table 1) revealed that all the treatments were significantly superior to untreated control in reducing per cent disease incidence (PDI). The disease incidence ranged from 20 per cent to 60 per cent in treatments, whereas it was 80 per cent in control. Minimum disease

incidence, i.e. 20 per cent recorded was in (ST with *B. japonicum* and *T. viride* + soil application of B + Zn and (ST with *B. japonicum* and *T. viride* + soil application of Zn and Fe followed by (ST with Vitavax power + *B. japonicum* (27 %), ST with *B. japonicum* + *T. viride* + Zn (27 %), ST with *B. japonicum* + *T. viride* + B @ 0.5 kg/ha (27 %) and (ST with *B. japonicum* + *T. viride* + Fe + B+ Zn (27 %). In ST with *B. japonicum*, which received only *Bradyrhizobium* inoculation produced 60 per cent disease which was 25 per cent less than the absolute control. In ST with *B. japonicum* + irrigation up to field saturation 50 per cent disease reduction was noticed, wherein after seed inoculation irrigation was supplemented at flowering when soil moisture was less than 50 per cent. In dual inoculated treatment (ST with *B. japonicum* + *T. viride*) as well only 50 per cent disease reduction was noticed (Table 1). It is noteworthy to understand that charcoal rot can be managed up to 50 per cent with either ST with *B. japonicum* + *T. viride* or with ST with *B. japonicum* and irrigation at the time of moisture stress. Application of bio-agent *T. viride* was found to reduce the disease caused by *M. phaseolina* in chickpea (Parakhia and Vaishnav, 1988), groundnut (Chaudhary *et al.*, 1989), lentil (Haque *et al.*, 1992), melon (Elad *et al.*, 1986) and *Vigna mungo* (Mani and Marimuthu, 1994) which is in corroboration with our results, which showed 41.3 per cent reduction in disease over absolute control in case of seed treatment with *T. viride*. *Trichoderma* spp. have been found to

Table 1. Effect of different treatments on plant characters and incidence of charcoal rot (Data pooled for three years)

Treatment	Plant height (cm)	Branches /plant (No)	Pods/plant (No)	Chaffy pods/plant (No)	% Disease incidence (PDI)	% disease reduction over control	% reduction in chaffy pods over control	100 seed weight (g)	Yield (kg/ha)
ST with <i>Bradyrhizobium japonicum</i> @ 5 g/kg seed	50.3	2.0	36.5	4.0	60.0 (36.86)	25.0 (14.47)	45.20 (26.86)	11.11	2, 032
ST with Vitavax power @ 3g/kg	46.7	2.3	35.9	4.6	33.4 (19.50)	58.3 (35.65)	36.98 (21.69)	12.76	2, 843
ST with Vitavax power @ 3g/kg + <i>B. japonicum</i>	50.2	1.3	28.0	3.0	27.0 (15.66)	66.3 (41.51)	58.90 (36.07)	11.83	3, 164
ST with <i>B. japonicum</i> @ 5 g/kg seed + irrigation at moisture stress	45.5	2.4	42.0	1.8	40.0 (23.57)	50.0 (29.99)	75.34 (48.87)	11.34	2, 350
ST with <i>B. japonicum</i> @ 5 g/kg seed + <i>Trichoderma viride</i> @ 10 g/kg seed	51.5	1.8	31.6	5.0	47.0 (28.02)	41.3 (24.38)	31.50 (18.35)	11.94	2, 347
ST with <i>B. japonicum</i> @ 5 g/kg seed + <i>T. viride</i> @ 10 g/kg seed + Zn @ 25 kg zinc sulphate/ha	40.6	2.3	40.9	5.1	27.0 (15.66)	66.3 (41.51)	30.13 (19.34)	11.26	2, 713
ST with <i>B. japonicum</i> @ 5 g/kg seed + <i>T. viride</i> @ 10 g/kg seed + B @ 0.5 kg borex/ha	52.0	2.6	41.9	5.2	27.0 (15.66)	66.3 (41.51)	28.76 (16.71)	11.19	2, 557
ST with <i>B. japonicum</i> @ 5 g/kg seed + <i>T. viride</i> @ 10 g/kg seed + Fe @ 10 kg ferrous sulphate /ha	37.3	3.6	41.9	5.8	40.0 (23.57)	50.0 (29.99)	20.54 (11.85)	11.71	2, 056

Table 1 contd.

Treatment	Plant height (cm)	Branches /plant (No)	Pods/ plant (No)	Chaffy pods/ plant (No)	% Disease incidence (PDI)	% disease reduction over control	% reduction in chaffy pods over control	100 seed weight (g)	Yield (kg/ha)
ST with <i>B. japonicum</i> @ 5 g/kg seed + <i>T. viride</i> @ 10 g/kg seed + B @ 0.5 kg borex/ha + Zn @ 25 kg zinc sulphate/ha	44.4	3.1	50.7	3.3	20.0 (11.53)	75.0 (48.57)	54.79 (33.21)	11.36	2, 428
ST with <i>B. japonicum</i> @ 5 g/kg seed + <i>T. viride</i> @ 10 g/kg seed + Zn @ 25 kg zinc sulphate/ha + Fe @ 10 kg ferrous sulphate /ha	45.4	3.0	45.5	1.9	20.0 (11.53)	75.0 (48.57)	73.97 (47.69)	11.36	2, 428
ST with <i>B. japonicum</i> @ 5 g/kg seed + <i>T. viride</i> @ 10 g/kg seed + B @ 0.5 kg borex/ha + Fe @ 10 kg ferrous sulphate /ha	45.0	3.3	45.3	1.8	30.6 (17.81)	61.7 (38.08)	75.34 (48.87)	11.65	2, 107
ST with <i>B. japonicum</i> @ 5 g/kg seed + <i>T. viride</i> @ 10 g/kg seed + Fe @ 10 kg ferrous sulphate /ha + B @ 0.5 kg borex/ha + Zn @ 25 kg zinc sulphate/ha	42.9	2.5	40.3	1.3	27.0 (16.66)	66.2 (41.44)	82.19 (55.25)	12.19	2, 857
Untreated control	46.4	2.3	45.1	7.3	80.0 (53.11)	0.0 (0.0)	0.0 (0.0)	10.61	1, 859
SEm (±)	2.90	0.39	5.97	1.42	12.34	-	-	0.741	27.00
C D (P = 0.05)	NS	NS	17.30	4.13	35.89	-	-	2.15	592

*Figures in parenthesis are arc sine transformed values

reduce the dry root rot of castor, *Vigna radiata* and charcoal rot of sesame caused by *M. phaseolina* (Rajani and Parakhia, 2009; Raguchander *et al.*, 1993; Durai *et al.*, 2006). Irrigation at moisture stress and application of micronutrients have been reported to cause reduction in disease in our report. The provision of tolerance to moisture stress by micronutrient, especially Zn and B, (Sarkar *et al.*, 2000) could have caused the reduction in chaffy pods (Table 1). The reduction in PDI in case of ST with *B. japonicum* + irrigation at moisture stress (at 50% field capacity) must have rendered enough availability of soil moisture, which is reported to be detrimental for the growth and multiplication of fungus. Kendig *et al.* (Kendig *et al.*, 2000). Wokocha (2000) have also reported that high soil moisture levels were unfavourable for the growth and pathogenicity of *M. phaseolina*, while low soil moisture levels favoured the growth and pathogenicity. Almeida *et al.* (2003) have reported that the charcoal rot of soybean can be controlled by conserving moisture through no-tillage.

Application of Zn + B and Zn + Fe along with *T. viride* and *B. japonicum* seed treatment led to reduction in the charcoal rot incidence up to 75 per cent as compared to control. Zn and B when singly applied along with *T. viride* and *B. japonicum* seed treatment, the reduction in disease was to the extent of 66.3 per cent over control only, whereas, on application of Fe, the reduction was 50 per cent. These bio-agents when applied in combination Zn + B the disease

reduction was 75 per cent as compared to control. This brings out that the Zn and B have synergistic effect but when combined with Fe, there was reduced effect. Grewal (2001) has found that application of Zn has increased yield and reduced leaf drops against some disease. B, Cu, Mn and Zn inhibited the growth of *M. phaseolina* and reduced the disease in groundnut (Murugesan and Mahadevan, 1988). Pareek and Pareek (1999) found that all micronutrients were effective in reducing the charcoal rot incidence in Maize induced by *M. phaseolina*. Whereas, Sarkar *et al.* (2000) observed that application of different levels of B, Zn, and Fe alone showed no significant difference however, most of the interactions between the micronutrients reduced the disease over the control. With regards to yield the highest (3, 164 kg/ha) was recorded in (ST with *B. japonicum* and Vitavax power) and minimum in (1, 859 kg /ha) in control.

Up to 50 per cent disease incidence can be reduced by ST with *B. japonicum* and *T. viride* and applying irrigation at the time of moisture stress. Additional reduction (60-80 %) can be achieved by soil application of micronutrients especially Zn and B. Both B and Zn inhibited the growth of fungus. It was found that high soil moisture levels were unfavourable for the growth and pathogenicity of the fungus, and hence adequate soil moisture at the time of stress must be maintained to contain this disease.

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Accelerating Economic Development in South East Rajasthan through Soybean Farmers

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ABSTRACT

The body of work identifies the opportunities for value creation and the challenges affecting various stages of the soybean value chain in South East Rajasthan. Our research shows that both domestic and international demand for soy, soy oil and de-oiled cake is robust. However, low productivity and weak market linkages have constrained the growth of the soybean subsector in India, in general, and Rajasthan in particular.

For the soybean subsector in Rajasthan to flourish, farm productivity must increase, marketing costs must be reduced, and quality standards must be established and adhered to. Expansion of domestic production requires targeting other markets, including the soybean oil and soy foods where demand is growing.

Finally, there is a need for a policy framework that would (i) enhance strategic linkages between government, corporations and NGO for farm extension and to promote scientific package of agronomy practices, (ii) promote producer group marketing strategies to ensure consistent supply of soybean and to strengthen the market power of small producers (iii) develop measures that promote and support contract farming and align incentives for regular and consistent supply of quality soybean crop, and (iv) promote models that can promote financing of agriculture value chain.

This work is based on a detailed research and grass root level work done over a two year period. 'TechnoServe' undertook a comprehensive value chain analysis starting with demand and working through the supply of soybean to processors, marketing and ultimately the constraints at the production level. For the research, our team interviewed over 325 value chain participants in the soybean sector. We have created a strategic plan that quantifies the potential demand, identifies major constraints in the soy value chain and articulates the various points of intervention.

Keywords: Market linkages, productivity, value chain

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Soybean is increasingly becoming one of the important agricultural produces. It is a hardy crop that requires minimal care and water, has robust demand and provides a good return on investment for farmers. The beans are a good source of protein and edible oil and have the potential to support the healthy growth of humans as well as livestock (Badal *et al.*, 2000).

About 85 per cent of the world's soybean crop is processed or crushed. This results in the extraction of oil and de-oiled cakes (DOC), also called soybean meal. Around 95 percent of oil is consumed as edible oil; the rest is used for the manufacture of industrial products such as fatty acids, soaps and biodiesel (FAO Statistics Report, 2009). Approximately 98 percent of the soybean meal that is crushed is further processed into animal feed with the balance used to make soy flour and proteins.

World soybean production has increased by over 500 per cent in the last 40 years, and it is expected to continue to grow on strong demand for animal feed and for other soy-products (FAO Statistics Report, 2009). Significant demand growth for biodiesel feedstock is also seen; soybeans will continue to be one of the primary such feed stocks in the near term.

Soybean is also extremely versatile in its usage for human consumption. Many food items like soy-milk, miso (soy-paste), tempeh (soy-cake), tofu (soy-*paneer*), soy-flour, soy-sauce, soy-*namkeen* and soy-flakes are

prepared from soybeans. Soybeans are also sometimes added to foods like breads, cereals, and meat products, and used as a meat substitute in products such as soy-burgers and soy-hot dogs. Foods that contain whole soybeans are good source of protein for vegetarians because they provide essential amino acids, a type of nutrient that people need to stay healthy.

Soybean in India

Over the last 20 years, soybean production, in India, has increased by over 300 per cent. The production which was 2.6 mt in 1991 has crossed 10 million tonnes in 2009. It is estimated that the area under the crop has been 9.79 million hectares with production of 10.05 million tonnes in *khari* 2009 (http://dacnet.nic.in/eands/Advance_Estimate/1st_Advance_English%282010-11%29.pdf). Our research shows that there is robust market demand of soybean and its products. Demand for soybean oil in India is increasing @ 9 per cent per year. The domestic production meets only 49 per cent of this demand.

Indian and global demand for soya products has been and is expected to continue to grow faster than supply. Indian processors have invested in 2.2 times more capacity than current soya production (Ramesh Chand, 2007), creating a competitive demand market for limited soybean production. Progressive

multinational and Indian companies are eager to work with farmers to increase soybean farm yield and the area under cultivation. DOC is India's second largest agricultural export item for the last five years and its demand is growing at 1% per year (<http://dacnet.nic.in/eans/pdf%20files/tb13.3FU.pdf>).

At the same time, soya yields in India currently average 1.1 tons per hectare, which is less than half the average productivity of other large soybean producing countries (2.5 t/ha). Basic interventions at farmer's level in India have seen yields more than double, benefiting both farmer and processors. Soya is also farmed on a large scale across three of India's states, namely Madhya Pradesh, Maharashtra, and Rajasthan and has proved to be a popular crop among small farmers due to its relatively low investment requirements, hardy nature, and comparatively high profit margins (Dupare *et al.*, 2006). Out of 4.5 million farmers engaged in soy cultivation, more than one half or about 2.4 million farming families, are small and marginal farmers each of them owning less than two hectares of land (http://dacnet.nic.in/eands/Book_Setup_7.pdf).

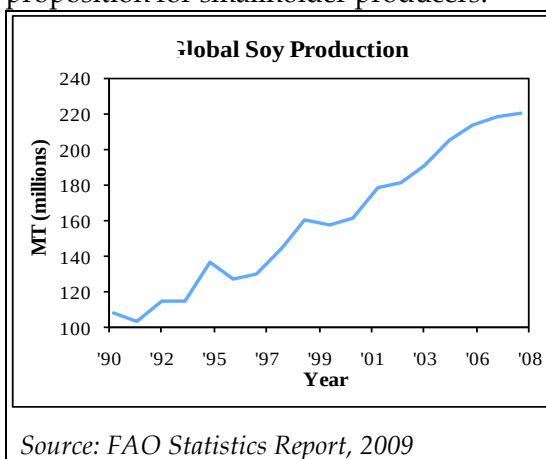
Moreover, edible soya has not gained traction in India to date, but there is immense opportunity to explore soya as a vegetarian protein source to combat malnutrition in India. Some soya products, such as soya protein and flour have started to gain traction, and companies continue to research opportunities to build the market.

At the processing level, soya crushing is a commodity process with little

value addition. Industry players tend to treat the soya sector like traders, not investors. There is a need to shape their mindset and create an economic case to get them to invest in farmers. This will not only help farmers but will also help strengthen the supply chain of the processor leading to greater competitive advantage in hypercompetitive auction commodity environment.

Soybean prospects

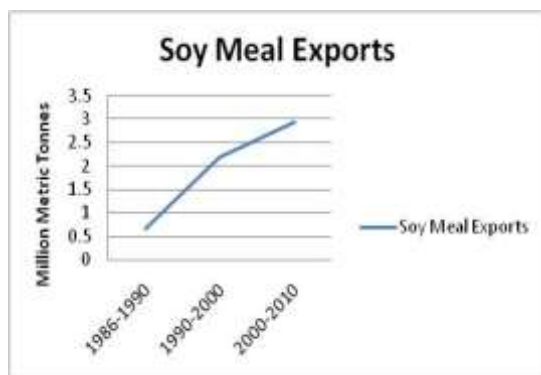
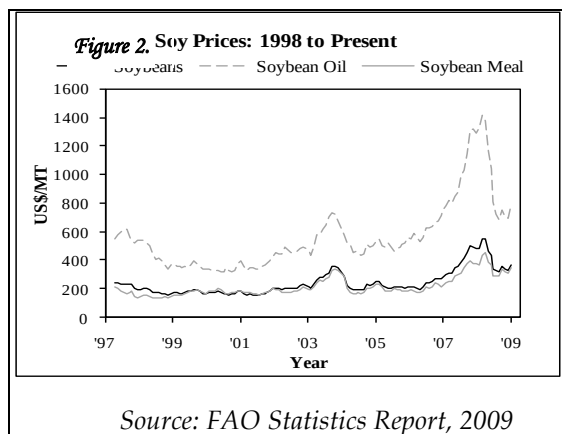
Steady growth in the poultry/livestock feed and oil industries are the primary drivers of local soy production and processing. Soy's increasing use in human food products is another driver that will likely play a larger role over time. The strong projected growth in demand supports a compelling long-term income proposition for smallholder producers.



According to the FAO, in 2008, 220 million MT of soybeans were produced, of which 82 per cent came from the US, Brazil and Argentina. Over the past decade, soy production has increased by

nearly 35 per cent and the overall price trend has been upwards. Soybeans are the world's second largest grain cash crop, after corn (maize).

While it is impossible to accurately predict the future market price of soy, a number of trends support stable, if not increasing, price levels. Due to increasing global consumption of meat, demand for livestock is expected to grow at 7 per cent per annum over the next decade. U.S. production is likely to be constrained over the next ten years by incentives causing farmers to shift to corn for ethanol production. The USDA projects global trade in soybeans to increase by 33 per cent in the next decade. China already accounts for one-half of all imports. Its continuing robust demand growth is expected to account for 80 per cent of this growth in global trade.



Source: <http://www.sopa.org/statindex.htm>

In the national trade scenario, the export of soybean meal from India has grown by 600 per cent since 1985. Approximately 70 per cent of the soybean cake produced in India is exported. Annual exports reached 4.88 M MT in 2008/09 before falling by more than 20 per cent in 2009/10. Projections for next year (2010/11) anticipate significant recovery, with exports to reach 4 – 4.5 M MT (<http://dacnet.nic.in/eands/pdf%20files/tb13.3FU.pdf>).

On the production front, of the total 2008 production of soybean in India, MP was the largest producer with 5480 thousand tonnes in 5024 thousand hectare followed by Maharashtra and Rajasthan (Table 1). There is significant difference in the yield levels of the top three soybean producing states in India.

Table 1. Area (000 ha), production ('000 tonnes) and productivity (kg/ha) of soybean major states of India

Location/year	2006			2007			2008		
	Area	Yield.	Prod- uction	Area	Yield.	Produ- ction	Area	Yield	Prod- uction
M.P	4255.3	1058	4500.7	4756.6	1006	4784.9	5024.4	1091	5480.5
Maharashtra	2347.0	1077	2527.0	2521.0	1147	2892.0	2664.0	1492	3976.0
Rajasthan	744.3	1150	856.3	641.1	1203	771.3	797.6	1343	1071.2
India	7705.5	1073	8273.5	8328.7	1063	8850.8	8881.7	1235	10968

Source http://dacnet.nic.in/eands/StateData_12years

Objectives of Study

There is lack of empirical data and information to formulate strategies to strengthen the soybean value chain and to increase its competitiveness on small farms. A systematic analysis of value chains is therefore needed to understand the various factors inhibiting the growth of value in soybean crop.

In spite of being the third largest producer in India, yield levels of soybean in Rajasthan are 10 per cent lower than the Maharashtra. However, the area under soybean in Rajasthan has been increasing at a rate of 5 per cent every year since 2004 (http://dacnet.nic.in/eands/StateData_12years.htm).

Consistent increase in area under soybean and presence of large number of small farm holders (98%) offers an excellent opportunity to increase the income of farmers and the areas under soybean production, through various interventions at farm and post farm levels. Rajasthan with a potential of

increasing the area under soybean by 200% and the yield by 33% can result in an increase in annual production by 300% (<http://dacnet.nic.in/eands/pdf%20files/tb14.1U.pdf>).

This paper employs a value chain approach and provides a critical overview of the soybean subsector in Rajasthan. The paper transcends the usual subsector analysis to identify the existing soybean value chain and assesses the pre-farm, on-farm and post-farm aspects affecting the growth of soybean crop.

The specific objectives of the study are to (i) map the various factors behind the low productivity levels of soybean crop in Rajasthan, (ii) map the value chain and understand the structure, conduct and performance of soybean markets in Rajasthan, and (iii) Identify priority interventions that strengthen value chains and facilitate commercialization to harness the full potential of the soybean subsector.

MATERIAL AND METHODS

The value chain analysis focuses on the chain of activities and value created at each stage. The concept has now been extended to whole supply chains and distribution networks in the form of the integrated value chain, which is a dynamic integration of enterprises and their suppliers and customers to determine, create, fulfil and communicate value in the global environment. This approach analyzes the flow of resources, materials and information within the chain of activities from initial point to final consumption. It pays particular attention to linkages between different intermediaries. The technique makes it possible to breakdown the costs involved in the value chain process for specific products. The findings of the analysis make it possible to determine the greatest impediments to cost competitiveness and develop remedial policy actions, institutional changes and other corrective measures that deserve priority (Bayson *et al.*, 2006).

In general, an in-depth value chain analysis considers the following:

- What are the economic costs along the value chain?
- Where is the most value added in the value chain?
- Who are the most important actors within the value chain?
- What is the institutional framework of the value chain?
- Where are the bottlenecks in the value chain?

For this study we adopt a broader concept of a value chain to assess the structure and functioning of all the actors along the chain till final product and try identifying the key constraints and weak linkages that determine the overall competitiveness of the soybean subsector. We deal with marketing conditions where linkages among the players are underdeveloped, and asymmetric information and mistrust are pervasive.

Empirical Methods

The study entailed a detailed review of literature together with collation and analysis of secondary data. The secondary data comprised of FAO aggregate data on national output, data on export volumes of soybean from India obtained from various published documents and district level production data from major soybean producing regions in India.

Information from these secondary sources was augmented with collection and analysis of post-farm level marketing data. The post-farm level data included information from 325 value chain actors in India in 2009. These value chain actors included farmers, commission agents, brokers, traders, oil millers, solvent extraction unit owners, oil wholesalers and retailers.

Marketing costs were taken to include both transaction costs and standard marketing costs (eg, transport, assembly, grading/sorting). Measurable transaction costs includes the reported costs of finding a buyer/seller, costs of monitoring/inspecting the quality of grain

being traded, and the costs of negotiating prices. The standard marketing costs considered in the study included the costs of assembling the produce, grading/sorting, labour, transportation and storage among others. The estimation of participants net marketing margins was therefore stated as marketing margin less total cost, i.e.:

$$\text{Net Marketing Margin} = \text{Marketing Margins} - \text{Total Costs} \quad (1)$$

$$\text{Marketing Margin} = \text{Selling Price} - \text{Buying Price} \quad (2)$$

$$\text{Total Cost} = \text{Standard Marketing Costs} + \text{Transaction Costs} \quad (3)$$

The standard marketing costs included transport costs incurred during buying and selling activities, i.e. transport from seller to store and from store to buyer. In addition, marketing costs included costs paid for labor to clean the grain, storage costs, loading and offloading costs, grading costs, processing costs, packaging costs, market fee, custom fee and other implicit costs.

Soybean Production constraints and opportunities

India's unusually rapid development of soybean is based on a highly area-specific expansion. The states of Madhya Pradesh, Maharashtra and Rajasthan have been consistently increasing the area under soybean from 1985 onwards and have achieved a multiple fold increase in production. However, the yield levels have been less than 50% of the world soybean average

and have failed to gain any significant increase.

Though high yields are usually constrained by complex interaction of genetic, physiologic and climatic factors, knowhow of recommended package of practices and access to inputs also play a major role in constraining the potential yield of the crop.

During 2008-09 a pilot program was conducted by 'TechnoServe' in two major soy producing districts (Jhalawar and Bundi) of Rajasthan and data on farming practices from 2600 soybean farmers were collected and analyzed. Data from a mixture of large and small farmers was collected for better understanding of the possible reasons and their correlation with the land holdings.

This program involved an in-depth research around the practices being followed by the farmers and the plausible reasons behind not following some of the recommended package of practices. The research was done around the practices being followed at three stages of farming- Pre-Farm, On-Farm and Post Farm.

RESULTS AND DISCUSSIONS

Lack of adequate knowledge and access to quality inputs were two of the biggest reasons behind the low adoption of recommended "package of practices." Among the elements of the package of practices that are not being followed – seed treatment and targeted pesticide application were not followed by close to 85% of the farmers. Other aspects of the package seed replacement and composting were practiced by only 10% of the farmers in the region.

Access to higher quality inputs is usually dependent on factors such as access to credit and availability of quality inputs in the region. Often the farmers access credit from the local money lenders, who also acts in collusion with the existing supplier of agri-inputs. These money lenders usually charge exorbitant interest rates (30-56%), while making it mandatory for the farmer to buy agri-inputs from their recommended shops. These recommended agri-inputs are usually of inferior quality manufactured by the unorganized market players. This, in turn, results in lack of effective demand, which prevents large agri-input companies from operating in the region, thereby, preventing progressive farmers from accessing quality inputs. Therefore, it is important to generate effective demand, by tackling hindrance factors such as access to financial institutions, etc.

There is also a need to increase the know-how about the recommended package of practices and the associated benefits to the farmer community at large. Most of the farmers lack understanding of the associated benefits in following a particular set practices and hence do not follow it. Increasing the awareness and knowledge of the crop can be helpful in promoting a scientific approach to farming.

Usage of water along with the pesticide is another major practice that is not being followed as per the recommendation. While the scientists recommend that around 500 to 700 litres of water per hectare should be used while

pesticide spraying, farmers usually use 180-240 litres of water while spraying with pesticides. Water harvesting facilities need to be developed to ensure sufficient usage of water in pesticide application. This kind of an intervention will also be beneficial in tackling issues such as irrigation at critical times.

Fertilizer application is major practice with low awareness levels. Farmers usually tend to apply fertilizers without any knowledge of the soil nutrient status; this kind of an approach can lead to excess application or under application of particular set of nutrients. Farmers are usually dependent on government agriculture officers who have a mandate to provide this service but rarely do so. As a result, Farmers lack information on the nutrient levels in their soil and cannot choose the most appropriate set of fertilizers.

It should also be noted that land holding does not influence follow up of package of practices. Though the ability to experiment with the new practice is high among the large farmers, the farmers usually lack know-how about the right "package of practices". However, it's been observed that small and marginal farmers usually tend to learn from the experiments done by the large farmers. Hence targeting the large farmers to increase the adoption of recommended "package of practices" might result in large scale replication.

An account off 2600 farmers on practices being followed by the farmers against the recommended practices is given in table 2.

Table 2. Package of practices

Practices	Current practices	Implication
<i>Pre farm practices</i>		
Seed treatment	Seldom practiced, as farmers tend to trust the quality of seeds they purchase, rather than testing it themselves. Only around 15% of the farmers have done seed treatment.	Quality of seeds remains unchecked and farmers can suffer huge losses due to low seed germination resulting in below normal plant populations in the field and subsequent lower yields
Soil testing	Farmers are dependent on government agriculture officers who have a mandate to provide this service but rarely do so. Around 16.6% of the farmers had undertaken seed testing.	Farmers lack information on the nutrient levels in their soil and cannot resort to adequate and balanced nutrient management.
Deep ploughing	Few farmers are aware of the need for deep ploughing, which kills deeply burrowed pests and weeds by exposing them to sunlight. Around 53% of the farmers had done deep ploughing.	Pests remain hidden deep in the soil and emerge upon sowing of a new crop
Organic composting	Inadequate, unbalanced and skewed approach to fertilizers without following integrated approach. Close to 62% of the farmers follow this kind of an approach.	In the absence of integrated nutrient management soil health and sustainability of products is adversely affected.
<i>On farm practices</i>		
Seed replacement	Very low, with only 10% of farmers purchasing new seeds each year	Poor seed replacement can result in lower yields. Farm-saved seed lacks quality and purity.

Row spacing	Current practice is planting at below 30 cm space between rows, which is insufficient. Almost 80% of the farmers maintain narrow row spacing.	Narrow row planting hampers desired growth, adequate resource utilization and increase in biotic stresses.
Usage of pesticides	Non use of pest-specific pesticide in recommended quantities and with desired spray volume. Only 10% of the farmers used using pest-specific pesticide.	Either poor pest management or provision of opportunities for acquiring resistance by pests against particular pesticide.
Post-farm practices		
Clearing the Field	Burning of crop residue after harvest of 'rabi' crop to facilitate cultivation of subsequent soybean crop. Close to 80% of the farmers indulged in this practice.	Burning of crop residues after harvest is a very harmful practice and leads to harm soil biota and reduce the organic carbon content in the soil. This may ultimately lead to deterioration of soil quality.

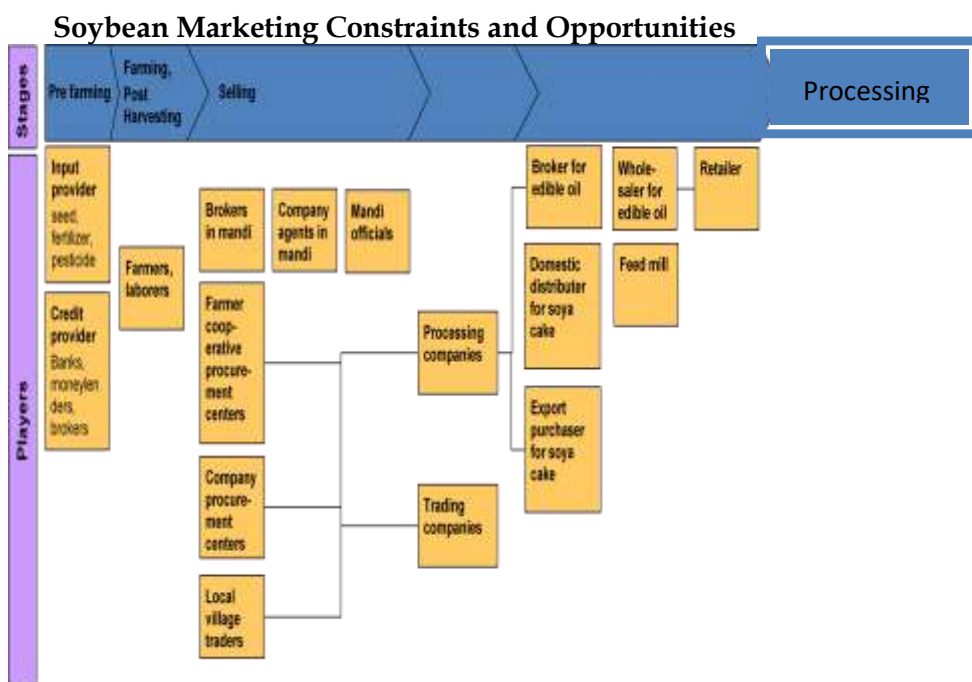


Figure 3. Soybean marketing channel in Rajasthan

Source: Anonymous Report, 2009

The soybean marketing channel in Rajasthan (Fig 4) comprises of producers, middlemen, traders, exporters, and processors. Farmers usually sell soybean to middlemen, co-operatives, traders and agri-business companies. Middlemen and traders are aggregators who usually pass on the commodity to the processors or other large middle men, without any value addition.

The presence of middlemen between the farmer and processor not only increases the cost at the customers end but also decreases the efficiency along the chain leading to lowering of the farm gate prices.

Traders are mainly large-scale buyers who purchase soybean for retail and wholesale purposes whereas company procurement buyers and cooperatives are buyers who buy soybean mainly for processing and export. The traders buy from farmers and middlemen and subsequently sell to processors. The main difference between traders and middlemen is in the scale of operation and connectivity. The traders are like middlemen but they operate on a larger scale and are mostly situated at the block/district level. In a year, a trader usually trades in approximately 60MTs of soybean.

Whereas middle men operate at a village level and operate at a relatively smaller scale. A middle man trades in approximately 15 MTs of soybean in a year. The other buyers are usually company appointed agents and farmer

cooperatives. Farmers also sell the produce at Mandis. Often the produce at mandis is either picked by large traders or company appointed agents.

The next stage of marketing usually involves agri-processors. Soybean processing has many players with large, medium and small scale operations. These companies are involved in crushing the whole soybean for soy oil and DOC. The soy oil produced then goes to the retailer through the vegetable oil wholesalers.

The de-oiled cake, on the other hand, is usually sold to the poultry feed market or exported. There is high demand for DOC in the export market.

Many companies are also involved in the trading of the whole soybean. This soybean is often utilized in the domestic food industry. However, most of the trading companies are usually involved in the export marketing of the whole soybean.

The processing cost of soybean is usually 6.5% at of the final price at Rs.1600 (Table 3). As per market research, involving 325 value chain actors in India, conducted by TechnoServe during 2008-09, access to improved technologies along with integration of crushing and refining technologies has helped lower the cost of processing. Many of the processing plants add silica to the de-oiled cake obtained from the crushing and processing of soybean. The addition of silica usually aids the process of digestion in poultry.

The packaging and transportation of the soybean oil and DOC is usually around 6.2% of the final produce (Table 3). The packaging of the DOC is usually cheap and consists of around 20% of the total packaging cost. The packaging of soy oil on the other hand is highly mechanized and is relatively more expensive. For soy meal, 70% of the produce is marketed while 30% is used internally. For soy oil, 90% of the oil is transported within Rajasthan while the rest is transported outside.

There are different ways through which the price of soybean can be determined. In the past, the government determined the price of soybean. However, with liberalization, prices are now increasingly determined by players in the market. This has resulted in spatial and temporal price variation. The price is usually determined by the prevailing plant price on the particular day which in turn is determined by the price of DOC in the international market.

Table 2. Price Spread of Soybean in Rajasthan

Steps	Cost (per ton of output produced)	Amount (INR/MT)	Facts
Seed procurement	Price offered to the farmers after accounting variable seed quality and contaminations	17,460	<i>Mandi</i> price of Rs 18000
	Additional surcharge paid by processor as agent commission, <i>mandi</i> tax, brokerage, etc	1400	Transaction cost
Industrial processing	Fixed costs (maintenance of the machinery, payment of permanent employees)	700	Standard marketing cost
	Variable cost (electricity costs, fuel costs, etc)	650	
	Improving de-oiled cakes by adding silica	250	Adding silica aids the process of digestion in poultry
Packaging and transportation	Total packaging cost (standard marketing costs)	1102	Packaging of DOC is a simple and cheap process. Packaging of soya oil is a highly mechanized and relatively expensive

	Transportation cost (meal + oil)(transaction costs)	340	For Soy meal 70% of the produce is exported while 30% is used internally. For soy oil, 90% of the soy oil is transported within Rajasthan while the remaining 10% is transported outside
Totals costs to processor	Includes all the above costs factors	21,902	
	Revenues	Amount	
Sale of soybean products	Sale of DOCs per ton of soybean	18,800	30% of the DOC is sold locally at 19,500 per ton, while 70% of the DOC is sold in the International Market at 18,500 per ton.
	Sale of soy oil per ton	50,760	Oil sells 2.5 times the DOC on an average
Total revenues	Sales of DOC + oil per ton of soybean	24,553	0.18 ton of soy oil and 0.82 ton of DOC is produced per ton of soybean
Net profits	Revenue-Costs	2,651	

Source: Anonymous Report 2009

Most of the small farm holders usually sell the produce on the day of the harvest. Lack of storage facilities and credit facilities are some of the most important reasons for the immediate sale of the produce in the market. Also, farmers usually face challenges in accessing market information and delivering the produce to markets due to deteriorating infrastructure. Few private transporters were willing to risk

travelling to remote areas due to high fuel costs and poor roads; farmers had no choice but to participate in unprofitable local sales to institutions, small businesses, and traders at the farm gate.

In contrast, Indian processors have 127% (Ramesh Chand, 2007) more capacity than is met by the current production of soybean in India and they continue to invest in new infrastructure

as international demand for soybean cakes grows. A persistent shortage of produce has provided smallholder farmers with an important opportunity. Many companies are being forced to rethink their strategies for securing raw materials and show interest in the smallholder farming sector.

However, this can only happen when there are clearly defined roles and linkages among all the value chain actors viz, farmers, warehouses, agri-input companies, agri-business and processing firms and financial institutions.

One of ways to promote these linkages could be through contract farming, where the procurement firms are in constant touch with the farmers throughout the season rather than the harvest time. Contract farming arrangements between companies and smallholder farmers can be advantageous to both partners because they reduce the risk of transactions at the informal marketplace – farmers without secured markets face the risk of selling produce at a loss due to market oversupply whilst companies without guaranteed supply may not be able to keep their factories running. Farmers may also benefit from embedded services supplied by the company including access to input loans and credit, provision of extension and technical advice, use of appropriate technology and company management systems.

However, contract farming as such is not free from the demerits and

would need adequate policy level interventions to ensure free and fair transactions at all levels.

Policy and Institutional Overview

For the soybean subsector to remain competitive and to take advantage of the growing demand for soy food market and remain stable in the oil and DOC market, productivity needs to increase, marketing costs must be reduced and quality, grades and standards must be established. These policy recommendations fall within the realms of different stakeholders (national government, private sector, researchers, extension workers and traders), and suggest a need for greater collaboration. Currently, many of these stakeholders are acting largely independent of each other.

Linkage in Extension System

Increase in area, adoption of recommended package of practices and introduction of new seed varieties have often been seen as the possible solutions to increase the production and meet the supply shortfall. However, lack of an effective extension system working towards spreading the knowhow of soybean farming techniques has been one of the most important bottlenecks in soybean farming in India.

It's been observed that following the recommended "package of practices" itself

can increase the yield by 25%-30%. Linking up with various stakeholders viz, NGOs, corporate and civil society can increase effectiveness of extension system and help increase the yield. Partnering with various NGOs in designing and implementing of area based extension system can help in having a targeted approach.

Corporate on the other hand can work along with other stakeholders in providing quality inputs at a lower cost through an effective distribution system

Credit and Market Linkages

The international soybean market is dominated by the demand for DOC use, while the domestic market is driven by demand for soybean oil and DOC. In the short term, the demand for soybeans may be driven by DOC demand, while in the medium term expansion of the soybean subsector will depend on the exploitation of the export market, soy oil and soy food markets.

Poor and underdeveloped infrastructure along with poor access to information remains the major reasons for high marketing costs in India. Reducing marketing costs through a more integrated approach across the value chain can greatly lower the transactions costs and spur commercialization. Transaction and marketing cost along the soybean value chain can be lowered by shortening the

length of the marketing chain. Reducing marketing cost can lower the domestic prices and make soybean competitive in the international market. Participation in a well structured and dynamic supply chain can also improve chances of obtaining financing.

Another way of minimizing the marketing costs and hence lowering the domestic prices may entail utilizing forward contracts. Such contracts could help shorten the supply chain, reduce inspection costs and thereby increase farmer's margin. There are a few attempts being made in this direction (Madhya Pradesh), however their success is yet to be seen.

Key Policy Issues

- Develop strategic linkages between government, corporations and NGOs to increase the effectiveness of the extension system and promote increase in yield through follow up of recommended package of practices
- Develop policies and legal frameworks that promote and support contract farming and improve incentives for regular and consistent supplies of quality soybean crop. Future strategies should include promotion of forward market contracts between farmer groups, traders and other market participants along a shortened commodity value chain.

- Enhance strategic linkages among the researchers, farmers, extension agents and traders/processors and also promote collective marketing of soybean. Fostering group marketing activities will require public and/or private sector investment in strengthening rural institutions for mobilizing farmers into groups/associations, enhancing their agribusiness skills, and developing forward and backward linkages. Support in establishing institutional infrastructure and enabling policies to strengthen farmer organizations.
- Develop value chain financing: Models promoting agriculture value chain financing needs to be developed in collaboration with different stakeholders.

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Marketing Practices Followed by Soybean Processors in Punjab

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ABSTRACT

The soybean is a species of legume native to East Asia. The plant is classed as an oilseed rather than a pulse. Fat-free (defatted) soybean meal is a primary, low-cost, source of protein for animal feeds and mostly pre-packaged. Soy vegetable oil is another valuable product obtained from processing of the soybean crop. Soybean is a source of complete protein that contains significant amounts of all the essential amino acids that must be provided to the human body because of the body's inability to synthesize them. For this reason, soy is a good source of protein, especially for vegetarians. Although soybean and its products have huge health and economic benefits but it does not have commensurate market or customers. Companies are not putting many efforts to promote and market soy products or to create consumer awareness. The present research was under taken with the objectives of analyzing the marketing practices of the selected soybean processors in Punjab and identifying the problems involved in marketing of soybean products in Punjab. A sample of 10 soybean processors was selected from the list of soybean processors in Punjab obtained from the American Soybean Association, Delhi on random basis. It was found that 90 per cent of the processors get their raw material from other state of India i.e. Madhya Pradesh, 80 per cent of the processors sell their products under a brand name and 70 per cent of the processors follow marginal cost pricing and cost plus pricing techniques. All processors are using pamphlets and hoarding for product promotion. Further, lack of technical staff was the major problem in processing of soybean and lack of knowledge was the major problem in marketing of soybean products.

Keywords: Soybean, processors, marketing practices

Soybean [*Glycine max* (L.) Merrill] is a high value crop with multiple food, feed and industrial uses. It is often referred to as 'miracle crop' because it contains about 40 per cent protein, 20 per cent oil rich in polyunsaturated fatty acid, 6-7 per cent total minerals, 5-6 per cent crude fibers and 17-19 per cent carbohydrates (Chauhan *et al.*, 1988). This is a source of complete protein which contains significant amount

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of all the essential amino acids that must be provided to the human beings as the body is unable to synthesize them. Majority of soybean carbohydrates belong to dietary fiber and soy- proteins are relatively heat stable storage protein. It is this heat stability of the soy protein that enables soy food products requiring high temperature cooking. Besides being the cheapest source of vegetable protein it also contains good amount of salts and vitamins. Soybeans were also referred as *Cinderella crop* and later as *Golden bean* (Sharan and Valhalla, 2007).

Consumption of soybean products helps in maintaining good health. The various health benefits (Gill, 2010) of soybean intake as food are: (i) soy-based infant formula is salutary for lactose-intolerant infants; (ii) regular consumption of soy foods selectively reduces total cholesterol and LDL (bad) cholesterol, and maintains HDL (good) cholesterol levels (iii) content of phytoestrogen type of isoflavones (genistein and daidzein) are considered to be useful in the prevention of cancer; (iv) contents of both soluble and insoluble fiber and lower fat that helps in lowering serum cholesterol and control blood sugar; (v) contained insoluble fiber increases stool bulk and provides relief from symptoms of some digestive disorders; and (vi) protects from osteoporosis—by restoring bone health. Manickam (2001) and Kulkarni (2004) studied the medicinal properties of soy and soy-based products. It helps to control diabetes and has the power to defend our system against cancer. While

analyzing the effect of soybean protein on blood pressure, it was reported (Jaing *et al.*, 2005) that increased intake of soybean protein may play an important role in preventing and treating hypertension.

Soybean food industry is expected to grow by 20 per cent over next few years (Singh *et al.*, 2005). The increasing awareness about the benefits of soybean products is evident from the fact that sale of soy milk has increased by 50 per cent in Punjab region. Russell *et al.* (2006) interpreted analytical chemistry results and identified specific ingredient applications and marketing strategies. Singh *et al.* (2009) studied the efficacy of defatted soy flour mix levels in *Gulabjamun* and revealed that protein content was increased to 20.66 per cent from 18.24 per cent and fat content lowered to 12.09 per cent from 16.36 per cent. Kumar *et al.* (2009) studied the acceptance and attitude of soy-foods among consumers and found that consumers had a positive attitude towards soy-foods, especially soy-milk and soy-*paneer*.

Soybean requires proper processing to be made suitable for use as food, feed or industrial products. Largely, soybean is processed to get oil and meal. Major products obtained after processing soybean are green vegetable soybeans, hydrolyzed soy protein, soy-based infant formulas, meat analogues, soy fibre, soy flours, soymilk, soy grits, soy protein concentrate, soy-protein isolates, soybean oil, soy-sauce, soy-nuts, soy-sprouts, soy-nut butter and tofu.

Although soybean and its products have numerous health and economic benefits, but it does not have commensurate market or customers. Companies are not putting many efforts to promote and market soy products or to create consumer awareness. Enhanced and improved marketing practices can not only increase productivity but also increase the marketing efficiency of soybean and its products. As very little research work has been done in this area, the present research aims to understand the marketing practices undertaken by the Soybean processors and to identify the problems relating to the marketing mix. The specific objectives of the study undertaken are (i) to analyze the marketing practices of selected soybean processors in Punjab, and (ii) to identify problems relating to the marketing mix faced by selected soybean processors.

MATERIAL AND METHODS

The population of the study consisted of all soybean processors in Punjab. A sample of 10 soybean processors was selected from list of soybean processors in Punjab obtained from the American Soybean Association, Delhi on random basis. The selected processors were contacted and interviewed through a structured and non-disguised questionnaire. Data was collected regarding production, pricing policies, basis of pricing, promotional activities, distribution channels and various problems relating to product, pricing, promotion and distribution.

After collection of data, master tables were drawn and analysis of collected data was done using percentage method and other suitable statistical techniques like mean scores, rank scores etc.

RESULTS AND DISCUSSION

Profile of Respondents

The analysis of the profiles of respondents (Table 1) revealed that 60 per cent of them belonged to graduate, 30 per cent to higher secondary and 10 per cent to matric category. On the basis of age, 40 per cent of the respondents were above 40 years of age, 30 per cent each were from

Table 1. Profile of the respondents (N = 10)

Category	Frequency	Percentage
<i>Education</i>		
Metric	1	10
Higher secondary	3	30
Graduate	6	60
Post graduate	0	0
Total	10	100
<i>Age</i>		
20-30	3	30
30-40	3	30
More than 40	4	40
Total	10	100
<i>Investment</i>		
Up to 5 lakh	3	30
Up to 10 lakh	2	20
Up to 15 lakh	2	20
Up to 20 lakh	2	20
More than 20 lakh	1	10
Total	10	100

age group 20-30 years and 30-40 years. As far as the investment in plant is concerned, 30 per cent respondents have invested up to 5 lakhs, 20 per cent each up to 10 lakhs, 15 lakhs and 20 lakhs, while 10 per cent have invested more than 20 lakhs. Hence, all of them were small scale manufacturers.

Marketing practices

The out- come of the study on various marketing practices like production, pricing policies, basis of pricing, promotional activities, distribution channels and various problems relating to product, pricing, promotion and distribution is as stated in the following text.

Types of soy product: The respondents revealed that all of them processed soybean for milk and tofu. The milk produced by these respondents was with variety of flavours (chocolate, strawberry, butterscotch, *kesar-elaichi* and mango). Soy flour and soy-*namkeen* were prepared by 80 per cent of them while only 40 per cent were engaged in making soy flakes. None of these respondents were involved in oil extraction form soybean (Table 2).

Table 2. Types of soy products (N=10)

Product	Frequency	Percentage
Soymilk	10	100
Tofu	10	100
Soy flour	8	80
Soy flakes	4	40
Soy- <i>namkeen</i>	8	80

**Multiple Responses*

Variety of tofu produced: All the respondents’ produced plain tofu. The variation as spicy or salted tofu was imparted by 70 per cent of them (Table 3)

Table 3. Variety of tofu produced by respondents (N = 10)

Variety of tofu	Frequency	Percentage
Spicy	7	70
Salted	7	70
Plain	10	100

**Multiple responses*

Availability of products in different sizes: Responses from respondents on size of packaging of their soy products (Table 4) clearly brought out that all of them packaged soy-milk in medium sized and 40per cent and 20 per cent, respectively

Table 4. Availability of different sizes of various products (N = 10)

Availability of size of packaging	Packaging					
	Large	Percentage	Medium	Percentage	Small	Percentage
Soy milk	2	20	10	100	4	40
Tofu	1	10	10	100	3	30
Soy flour	6	60	5	50	-	-
Soy flakes	-	-	1	10	1	10
Soy <i>namkeen</i>	1	10	5	50	-	-

**Multiple Responses*

in small and large sized packages. In case of tofu, all packages were in medium followed by small (30 %) and large (10 %) sizes. Soy-flour was packaged in large (60 %) and medium (50 %) packages only. Only one respondent each packaged soy-flakes in medium (10%) and small (10 %) packages. Most of the soy-*namkeen* was packaged in medium (50 %) and large (10 %) sized packages.

Source of raw material: Most of the raw material (90 %) for processing various soy-products was procured from states other than Punjab, particularly from Madhya Pradesh. Only 50 per cent procurement was from producers of Punjab while 10 per cent resorted for self production (Table 5).

Table 5. Source of raw material (N=10)

Source of raw material	Frequency	Percentage
Own production	1	10
Producers from Punjab	5	50
Producers from other states	9	90

**Multiple responses*

Information displayed on packaging: Enquiry from respondents on information displayed on the label of product revealed that all of them invariably display price of the product and the expiry date. Ninety per cent of them are practicing display of nutrient content in the products as well as precautionary storage conditions (Table 6). Thus, majority of them abide to display required information on the label of products processed by them.

Table 6. Information displayed on packaging by the respondents (N= 10)

Information displayed	Frequency	Percentage
Price	10	100
Nutrient information	9	90
Proper storage condition	9	90
Expiry date	10	100

**Multiple Responses*

Branding of the products: Eighty per cent of the processors marketed the products processed by them in the brand name. Only 20 per cent of them are not branding their processed products (Table 7).

Table 7. Branding of the products by the respondents (N=10)

Branding of the products	Response	Percentage
Yes	8	80
No	2	20
Total	10	100

Pricing methods: The respondents resort to different methods for pricing of their processed products. Seventy per cent of processors go for marginal cost pricing (direct cost covered), whereas equal number (70%) follow cost plus pricing (a standard mark up to the cost of product). Only 50 per cent of them follow competition based pricing (Table 8).

Table 8. Pricing method followed by the respondents (N=10)

Pricing method	Frequency	Percentage
Marginal cost pricing	7	70
Cost plus pricing	7	70
Competition based	5	50

**Multiple Responses*

Response to decrease in price: In response to slashing prices by competitors, the respondents do not appear change prices of their processed products; rather they maintain the prices set by them. Fifty percent of them respond to the change and slash down prices of some products. Ten per cent of them combat the situation by improving the product price with increase in price. Same number of respondents (10%) switch on to launching of lower priced new product (Table 9).

Table 9. Response to decrease in price by the respondents (N=10)

Response to decrease in price	Frequency	Percentage
Maintain price	10	100
Decrease price	5	50
Increase price & improve quality	1	10
Launch same/low priced new product	1	10

**Multiple Responses*

Drivers of the price in future: Responses of respondents on driving forces of future pricing of their processed products brings out that quality conscious customers and making variety of products available to consumers are likely to be primary driving forces for deciding future prices of products followed by increasing competition for processed products (Table 10).

Table 10. Drivers of price in future (N=10)

Drivers of the price	Frequency	Percentage
Increasing competition	9	90
Quality conscious customer	10	100
Increasing variety of products	10	100

**Multiple Responses*

Distribution channel followed: All the processors follow company-retailer-consumer and company-consumer distribution channels for taking their processed products to consumers. In 70 per cent cases, company utilizes whole sailors and through retailers the product is made available to consumers (Table 11).

Table 11. Distribution channel followed by respondents (N=10)

Distribution channel followed	Frequency	Percentage
Company-Wholesaler-Retailer-Consumer	7	70
Company-Retailer-Consumer	10	100
Company-Consumer	10	100

**Multiple Responses*

Factors influencing location of outlets: Scoring for factors influencing the location of outlets for processed products brought out that non-similar outlets followed by approachability, growth of households and low rent are the factors in order of their importance (Table 12).

Table 12. Factors affecting location of outlets (N=10)

Factors	Overall Rank Score
Non- similar outlet	1
Approachability	2
Growing households	3
Low rent	4

Extent of distribution of products: Enquiry from respondents on the extent of distribution of products processed by them indicated that none of their products is being made available to consumers outside the state of Punjab. All of them distribute their products in the city of their establishment and 60 per cent of them are making their products available in other cities of Punjab state (Table 13).

Table 13. Extent of distribution of products by the respondents (N=10)

Extent of distribution	Frequency	Percentage
Within city	10	100%
Within state (Punjab)	6	60%

**Multiple Responses*

Mode of transportation: Responses of respondents on mode of transport of processed products revealed that all of them resort to road transportation and 20 per cent% of them utilize rail transport for making products available to consumers.

Table 14. Mode of transportation used by the respondents (N=10)

Mode of transportation	Frequency	Percentage
Road	10	100
Rail	2	20

**Multiple Responses*

Availability of products on bakery and grocery stores: Of the 10 processors, nine make their processed products available to consumers through bakery and grocery stores. Only one processor is selling its processed products directly to the consumers from their own outlets (Table 15).

Table 15. Availability of Products on Bakery/Grocery Stores (N=10)

Availability of products on bakery/grocery stores	Response	Percentage
Yes	9	90
No	1	10
Total	10	100

Provision of home delivery: Only 40 per cent of processors are providing home delivery service for products processed by them (Table 16).

Table 16. Provision of home delivery by respondents (N=10)

Provision of home delivery	Response	Percentage
Yes	4	40
No	6	60
Total	10	100

It is clear from Table 16 that only 40 per cent of selected processors have provision of home delivery while 60 per cent don't deliver their products directly at customer's home.

Means of promotion: Advertising their processed products to create awareness and boost up their sales, the processors have been resorting to various means of promotion (Table 17). Majority of them preferred to promote their products by distributing pamphlets and through erecting hoardings at prominent places. Wall paintings and advertisement in news papers were other medium utilized by respondents. About 50% processors utilized advertising products through broadcasting on radio and only one of ten respondent advertised by telecasting (Table 17).

Table 17. Means of promotion used by the respondents (N=10)

Means of promotion used	Frequency	Percentage
TV	1	10
Radio	5	50
Wall painting	7	70
Pamphlets	10	100
Hoardings	10	100
Newspaper	7	70

**Multiple Responses*

Discount schemes for promotion: To promote sales, only one out of 10 processors banked on sale promotional schemes whereas remaining nine did not make this effort (Table 18). This showed that their products are being sold to their

satisfaction without opting for any such scheme.

Table 18. Discount schemes for promotion given by respondents (N=10)

Discount schemes for promotion	Response	Percentage
Yes	1	10
No	9	90
Total	10	100

Problems faced by Soybean Processors; After going through the marketing practices of processed soy products, following problems in soybean processing and marketing have been identified.

Problems faced in processing: The problems faced by the respondents in processing of soy-products identified in order were shortage of technical staff, shortage of labour, inadequate power supply, obsolete of labour, difficulty in availability of raw material and lack of infrastructural facilities (Table 19). This call for some promotional policy for processors so that more and more soy-products can be consumed as food to mitigate wide spread energy-protein malnutrition and renders advantage of health benefits of inclusion of soybean in routine diet of masses.

Table 19. Problems faced by respondents in processing of products (N = 10)

Problems faced in processing	Rank score
Shortage of technical staff	1
Shortage of labour	2
Shortage of power supply	3
Obsolete of labour	4
Non availability of raw material	5
Lack of infrastructural facilities	6
Lack of financial help	7

Problem faced in marketing: The problems narrated respondents by respondents while marketing soy-processed food products in order were lack of awareness among lack of awareness among consumers, credit / discount offered by

Table 20. Problems of marketing (N=10)

Problems faced in marketing	Rank score
Lack of awareness	1
More credit/discount given by competitors	2
Poor infrastructure	3
Stiff competition	4
Lack of distribution network	5
Government regulation and control	6
High taxes	7

competitors, poor infrastructural facilities, stiff competition, lack of

efficient distribution network, unfavourable government regulations and control, and higher taxes (Table 20). Facilitating the curbing of these marketing constraints may help in diverting more and more of nutritious food from soybeans for consumers. It was also brought forth that there was no promotion by way of subsidy by the government for venturing, establishing and running of soy-food processing units.

Soybean is a source of complete protein which contains significant amount of all the essential amino acids that must be provided to the human beings as the body is unable to synthesize them. For this reason, soy is important to many vegetarians. The study revealed that majority of the processors included in the study were well educated and running their units in a planned manner. All the soybean-processing units were conscious about the quality of products their brand image. These soybean processors of Punjab are operating through small scale units and producing variety of quality products and adopting various marketing means to make their products available to customers at reasonable price. Major problems faced by the units/respondents in processing of soy products were lack of technical staff and shortage of labour and problems faced by them in marketing are of low awareness of people about the soy products and poor infrastructure facilities. The study further brings out that government support to soy-processors is non-existent. This is the right time to promote soy-food processing industries so as to combat wide spread energy-protein malnutrition and extend the health benefits of these products to general masses.

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Heterosis Study for Yield, its Components and Quality Characters in Soybean [*Glycine max* (L.) Merrill]

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A careful choice of the parents in any breeding program is the utmost important step in the development of the high yielding cultivars. Beside *per se* performance, multivariate, heterosis, diallel cross analyses, creation of variability and selection of the best recombinants possessing desirable characteristics have been shown to be useful in any breeding program. Exploitation of hybrid vigour in autogamous crop species like soybean is useful in improving yield potential of existing cultivars by identifying potential cross combinations on the basis of heterosis and the extent of inbreeding is aimed at isolating gene combinations (recombinants) which possess promising genotype. Knowledge of gene effect operating in expression of a character and extent of heterosis for yield and its components help the plant breeder in making correct decision about material selection method, type of variety and extent of testing. Since the research work in soybean has been initiated in late

sixties in India, additional generations of knowledge is required for the genetic improvement in soybean. Therefore, the present study was undertaken with the objective to examine the manifestation of heterosis in soybean crosses.

The present investigation was carried out during *kharif*, 2006 at the Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. The experimental material consisted of 27 parental lines including one check/ standard parent, PS 1092 and 35 F₁ crosses. Considering each genotype as one treatment, the experiment was conducted in a Randomized Complete Block Design with two replications. Each parental plot had three rows, whereas one row of F₁s, with 1.5 m length, spaced at sixty cm apart, and plant to plant distance was maintained at 5-7 cm, and each F₁ plot was filled and guarded with two border rows of PS 1347 on either side. The standard agronomic package of practice was followed to raise a normal crop. Five representative plants from each parental line and all F₁s were selected from each

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replication and tagged. The data for plant height, basal pod height, number of primary branches per plant, number of nodes per plant, number of pods per plant, number of seeds per pod, grain yield per plant, dry matter weight per plant and harvest index were recorded on these selected plants. Whereas, observations for days to fifty per cent flowering and days to maturity were recorded on whole plot basis, and hundred seed weight, oil and protein content were calculated from composite seeds of selected plants. The average values for these characters were calculated and used for statistical analysis.

For estimation of oil content the standard for running NMR was prepared using Soxhlet apparatus (Ranganna, 1977) and nitrogen was estimated by Micro Kjeldahl method (Ranganna, 1977). The value of heterosis over mid parent, better parent and standard parent for each character in each cross was estimated and its significance was worked out with *t*-test.

The analysis of variance (ANOVA) revealed significance differences among the genotypes for all the characters studied indicating the presence of variability in the material studied. The most promising crosses showing mid parent, better parent and standard parent heterosis either alone or in combination are presented in table 1.

For days to fifty per cent flowering, Ankur x JS 335 showed significant negative mid parent heterosis. Three cross combinations, *viz.* PK 515 x PK 1225, Bhatt x PK 416 and MACS 450 x Hardee showed

highly significant negative heterosis over mid parent for days to maturity. From these cross combinations, it also appears that the early parents contributed genes for early maturity and gene interactions. For plant height four F₁s showed positive mid, better and standard parent heterosis of which PS 1241 x PS 1347 showed highest mean value (129). Thus it appears that in these crosses, the combination of parents did not produce such reduced gene effects for decreased plant height. Perez *et al* (2009b) also observed positive mid parent heterosis for plant height. The heterosis for basal pod height was exhibited by four cross combinations with PK 472 x JS 71-05 exhibiting highly significant values of heterosis over mid, better and standard parent. Similar results for days to fifty per cent flowering, days to maturity, plant height and basal pod height were obtained by Guleria *et al.* (2000) and Massey *et al.* (2007).

Five F₁s *viz.* PS 1029 x AGS 129, PS 1241 x PS 1330, PS 1241 x PS 1347, MACS 450 x Hardee and MACS 450 x PS 1024 expressed significant positive heterosis over mid parent, better parent and standard parent for number of primary branches per plant. Most of the crosses showed significant positive heterosis over mid parent for number of nodes per plant. Cross PS 1029 X AGS 129 showed maximum mid parent (380.55), better parent (280.22) and standard parent (217.43) heterosis for number of pods per plant. Maximum amount of positive standard parent heterosis for seeds per pod was found in cross PK 327 x PS 1042. Similar results were also obtained by Ramana and Satyanarayana (2006).

JS 335 x DS 98-14 was promising cross exhibiting significant heterosis over respective mid, better as well as standard parent for hundred seed weight. The results were similar with that of Sood (1999) who reported that additive as well as dominance variance works behind seed weight and which indicates the presence of epistatic effects and complexity of genetic architecture of hundreds seed weight. There were twenty promising F₁s which showed significant positive heterosis over mid parent, better parent and standard parent for grain yield per plant. Among these, five F₁s viz. PS 1241 x PS 1330, PS 1241 x PS 1347, PS 1241 x PS 1428, PS 1029 x

AGS 129 and PS 1241 x Hardee showed highest positive values of heterosis for grain yield per plant. Here the non-additive type of gene action is responsible for high heterosis. These five F₁s also showed high values of mid, better and standard parent heterosis for dry matter weight per plant. For harvest index, Bragg x PS 1042 and JS 335 x EC 389148 showed highly significant positive heterosis over mid parent and standard parent while MACS 450 x PS 1347 exhibited significant positive heterosis over better parent and standard parent. The results are in conformity with the results as reported by Zhang and Yang (2000) and Woodworth (1933).

Table 1. Promising cross combinations showing heterosis (%) over mid parent, better parent and standard parent (PS 1092)

Characters	Cross combinations	Mean of F ₁	Heterosis (%)		
			MP	BP	SP
Days to 50 % flowering	Ankur x JS 335	44.00	-12.00**	-8.33	-3.29
	JS 335 x EC 389148	44.80	-8.71*	-2.19	-2.19
	MACS 450 x PS 1024	45.00	-10.45**	-1.09	-1.09
Days to maturity	PK 515 x PK 1225	95.00	-5.24*	-5.00	-0.52
	Bhatt x PK 416	96.00	-7.02**	-3.03	0.52
	MACS 450 x	96.50	-5.16*	-3.98	1.05
	Hardee				
Plant height	PS 1029 x AGS 129	93.00	52.46**	26.18*	112.81**
	PS 1241 x PS 1330	94.50	47.54**	26.51**	116.25**
	PS 1241 x PS 1347	129.00	123.76**	72.69**	195.19**
	PS 1347 x PK 327	70.60	67.10*	60.82**	61.55**
Basal pod height	PK 472 x JS 71-05	3.50	-72.65**	-71.77**	-63.54**
	PS 1241 x PS 1347	6.70	-42.06*	-31.12	-29.68**
	Ankur x JS 335	8.30	-53.23**	-47.46**	-13.54
	TGX 1681-3S x PK 472	6.80	-47.28*	-45.16*	-29.16**
Number of primary branches/plant	PS 1029 x AGS 129	6.50	271.40**	225.00**	85.71**
	PS 1241 x PS 1330	10.60	202.85**	165.00**	202.86**
	PS 1241 x PS 1347	8.50	183.33**	112.50**	142.86**

	MACS 450 x	8.00	166.66**	128.57**	128.57**
	Hardee	6.50	85.71*	85.71*	85.71**
	MACS 450 x PS 1024				
Number of nodes/plant	PK 472 x JS 71-05	20.00	40.35*	37.93*	37.93*
	PS 1241 x PS 1347	24.00	74.54**	45.45**	65.52**
	Bhatt x PK 416	22.50	36.36**	12.50	55.17**
Number of pods/plant	PK 472 x JS 71-05	94.00	155.78**	116.09**	72.48**
	PS 1029x AGS 129	173.00	380.55**	280.22**	217.43**
	PS 1241 x PS 1330	103.00	128.88**	121.51**	88.99**
	PS 1241 x PS 1347	132.50	237.58**	184.94**	143.92**
	MACS 450 x Hardee	97.50	95.00**	50.00**	78.89**
Number of seeds/pod	PK 327 x PS 1042	2.80	17.89	14.28	19.14**
	PS 1241 x PS 1330	2.60	7.21	1.96	10.63
	PS 1241 x PS 1347	2.60	6.12	1.96	10.63
100-seed weight	PS 1029 x AGS 129	12.36	59.17**	40.45**	3.08
	Ankur x JS 335	13.55	47.84**	39.97**	13.01
	JS 335 x DS 98-14	14.18	71.25**	46.48**	18.26*
Grain yield/plant	PS 1029 x AGS 129	57.00	418.18**	395.65**	200.00**
	PS 1241 x PS 1330	74.00	326.51**	289.47**	289.47**
	PS 1241 x PS 1347	73.70	442.27**	369.74**	288.16**
	PS 1241 x PS 1428	46.50	219.58**	196.17**	144.74**
	MACS 450 x Hardee	45.00	215.78**	200.00**	136.84**
Dry matter weight/plant	PS 1029 x AGS 129	134.00	458.33**	436.00**	182.11**
	PS 1241 x PS 1330	160.50	316.88**	286.75**	237.89**
	PS 1241 x PS 1347	145.00	371.54**	308.45**	205.26**
	PS 1241 x PS 1428	113.00	286.98**	218.31**	137.89**
	MACS 450 x Hardee	96.00	182.35**	174.28**	102.11**
Harvest index	Bragg x PS 1042	50.60	20.31*	17.14	27.71**
	JS 335 x EC 389148	48.00	25.39**	0.39	21.05*
	MACS 450 x PS 1347	48.90	9.80	7.89*	23.33**
Oil content	JS 335 x EC 389148	20.70	15.93**	9.98*	3.34
	JS 335 x DS 98-14	20.88	10.50**	10.07*	4.24
Protein content	PS 1241 x JS 90-41	40.40	5.83*	5.62	0.82
	JS 90-41 x PS 1241	40.70	6.61*	6.41*	1.57

MP- Mid Parent; BP- Better Parent; SP- Standard Parent; * Significant at 5% level of probability; **Significant at 1% level of probability

Oil content is an important quality character in soybean. PK 515 x EC 389148 and JS 335 x DS 98-14 exhibited positive heterosis over mid parent and standard parent. Only one F₁ i.e. JS -90-41 x PS 1241 showed significant mid and better parent heterosis for protein content. Similar results were obtained by Sabbouh *et al.*, (1998). Perez *et al.*, (2009a) also observed heterosis over mid parent for protein content.

From the present study it can now be predicted that some promising F₁s which showed high value of heterosis in PS 1241 x PS 1330, PS 1241 x PS 1347, PS 1241 x PS 1428, PS 1021 x AGS 129, JS 335 x DS-98-14, PK 472 x JS 71-05, PK 515 x EC 389148 and MACS 450 x Hardee for yield and its components to get better segregants in advanced generations in soybean for selection.

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Genetic Diversity in Black-seeded Soybean from NW Himalayan Regions of Uttarakhand

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Black-seeded soybean [*Glycine max* (L.) Merr.], known as *Bhat*, is an important *kharif* pulse crop of Uttarakhand hills. The protein- and oil-rich grains are used whole or after grinding coarsely for preparation of a variety of traditional dishes. The grains and the protein-rich crop residue make nutritious feed for the cattle. In the state of Uttarakhand, Bhat is grown over an area of 5, 559 ha with a total production and productivity of 4972 t and 894.4 kg/ha, respectively (Anonymous, 2010). The crop is also grown on a small scale in Himachal Pradesh, eastern Bengal, the *Khasi* Hills, Manipur, the *Naga* Hills, and parts of central India covering Madhya Pradesh. The bean is referred to locally as *Bhat*, *Bhatman*, *Bhatmas*, *Ramkulthi*, *Garakalay*, and *Kalitur* (Singh, 2006). The low yields of the traditional cultivars and the high price fetched by the crop on account of its nutritional qualities and characteristic

flavour and aroma, call for initiation of breeding programmes for developing high yielding cultivars of *Bhat*. Assessment of genetic diversity in a population is an essential pre-requisite for initiating a crop improvement programme as it enables the breeders to determine appropriate strategy for accomplishing genetic enhancement in a crop. Precise information on nature and degree of genetic diversity also helps breeders in identifying potential donors and selecting appropriate parents for hybridization to develop high yielding cultivars. Since published information on genetic diversity in black-seeded soybean in India is scanty, the study was undertaken to ascertain the nature and magnitude of genetic diversity and the characters contributing to diversity in 50 genotypes of soybean from NW Himalayan regions of Uttarakhand.

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The study involved 47 diverse accessions of black-seed soybean, two yellow-seeded checks, PS 1092 and VLS 47, and one black-seeded check, VLS 65. Of the 47 accessions, 35 were collected from various regions of Uttarakhand and 12 accessions were supplied by NBPGR Regional Station, Bhowali, Nainital (Uttarakhand). The set comprising of 50 entries was evaluated in a completely randomized design with three replications during *kharif* 2007 at GBPUA&T, Agriculture Research Station, Majhera (Uttarakhand). The material was planted in 3 m long two-row plots spaced at 40 cm and plant to plant distance was maintained at 10 cm. The trial was grown in organic mode under rain-fed conditions. Observations were recorded for nine traits on five randomly selected plants in each plot. Genetic diversity analysis was carried out using

Mahalanobis D^2 statistics. The genotypes were grouped into clusters as per Tocher's method following the formula cited by Singh and Chaudhary (1979). All the statistical analysis was performed using BIOSTAT Computer software.

The analysis of variance showed highly significant differences between the genotypes for all the nine characters studied (Table 1). On the basis of D^2 values, the 50 soybean genotypes were grouped into five clusters. Cluster I contained highest number of genotypes (17) followed by cluster IV (15), cluster V (10), cluster II (5) and cluster III (3). The average intra- and inter-cluster distances are presented in table 2 and the diversity pattern of the genotypes is presented in fig. 1. The inter cluster distances were higher than the average intra cluster distances, which indicated wide distance

Table 1. Analysis of Variance for yield and yield contributing characters in black-seeded soybean

Source of variation	Degree of freedom	Mean squares								
		Days to 50% flowering	Days to maturity	Plant height	Primary branches	Pods/ Plant	Pod length	Seeds/ Pod	100 - seed weight	Yield/ plant
Replication	2	0.74	30.36	123.24	6.22	437.66	0.18	0.02	1.82	29.10
Treatment	49	4.82*	91.64*	2012.75*	4.88*	1392.94*	0.44*	0.16*	49.13*	166.12*
Error	98	0.71	9.83	57.86	0.88	85.66	0.03	0.04	1.00	9.69
C.D. at 5%		1.36	5.08	12.32	1.52	14.99	0.31	0.31	1.62	5.04
C.V.(%)		1.66	2.58	8.14	17.57	20.73	5.51	8.11	9.35	26.52

* Significant at 5 % level of probability

Table 2. Average intra (bold) and inter-cluster distance of 50 black and white seeded soybean genotypes

Clus- ters	I	II	III	IV	V
I	24.97	52.89	72.26	80.65	168.18
II		21.50	163.38	95.76	149.08
III			32.63	112.73	239.96
IV				47.43	117.41
V					52.50

between cluster III and V (239.96), followed by the inter-cluster distance between cluster I and V (168.18). The lowest inter-cluster distance was found between cluster I and cluster II (52.89). The highest intra-cluster distance was observed for cluster V (52.5) and minimum for cluster II (21.5). The two yellow-seeded checks, VLS 47 and PS 1092, were placed in cluster V together with the black-seeded check, VLS 65, and

eight other black-seeded accessions (Table 3). PS 1092 involves exotic germplasm (yellow-seeded variety Semmes from USA) in its parentage, VLS 47 is a selection from

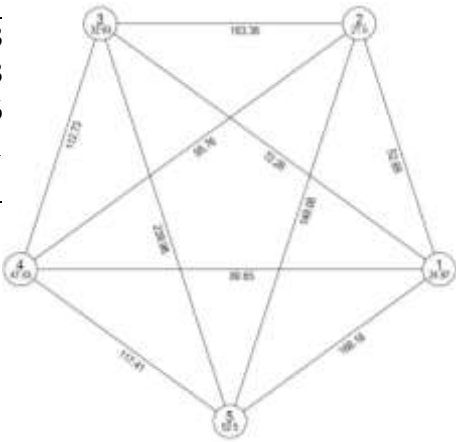


Fig. 1. Diagrammatic representation of diversity pattern of 50 genotypes of black- and white-seeded soybean

Table 3. Distribution of 50 black- and white-seeded soybean genotypes in the five clusters

Cluster	Genotypes
I (17)*	PCPGR 7857, IC-419823, IC-419842, PCPGR 7861, PCPGR 7870, IC-419847, PCPGR 7875, IC-469767, PCPGR 7886, IC-469833, PCPGR 7890, PCPGR 7894, IC-538042, IC-524256, PCPGR 7897, PCPGR 7898 and IC-436967
II (5)	PCPGR 7880, IC-444241, IC-444248, PCPGR 7891 and PCPGR 7895
III (3)	IC-419815, IC-444239 and PCPGR 7902
IV (15)	PCPGR 7858, PCPGR 7860, PCPGR 7862, PCPGR 7863, PCPGR 7864, PCPGR 7867, PCPGR 7868, PCPGR 7871, PCPGR 7873, PCPGR 7879, PCPGR 7884, PCPGR 7888, PCPGR 7893, PCPGR 7899 and PCPGR 7901
V (10)	VLS 47, PCPGR 7865, PCPGR 7866, PS 1092, PCPGR 7872, PCPGR 7876, PCPGR 7877, PCPGR 7878, VLS 65 and PCPGR 7883

*Figures in parentheses denote number of genotypes in the cluster

Table 4. Clusters means for 9 characters in 50 black- and white-seeded soybean genotypes and contribution of characters to diversity

Characters	Clusters					Contribution of characters (%)
	I	II	III	IV	V	
Days to 50% flowering	49.69	50.53	49.33	51.96	50.80	2.2
Days to maturity	123.10	118.40	118.78	123.24	118.33	8.24
Plant height	108.02	66.52	150.27	94.22	63.54	28.16
Primary branches	5.35	5.31	5.50	6.27	3.92	2.04
Pods/plant	30.79	43.13	41.64	65.97	37.86	17.39
Pod length	3.37	3.46	3.33	3.34	4.01	5.71
Seeds/pod	2.34	2.22	2.44	2.41	2.46	1.8
100-seed wt	7.39	7.01	8.32	11.65	17.41	33.14
Seed yield/plant	5.42	6.71	8.99	17.92	16.56	1.31

KHSF 3-1-1 (yellow-seeded material from Karnataka), and VLS 65 is a selection from local germplasm. The occurrence of yellow-seeded checks and the black-seeded check as well as local accessions in the same cluster points to genetic relatedness between black- and yellow-seeded genotypes despite their diverse origins. Non-correspondence between genetic and geographic diversity in soybean has also been reported by Chen and Nelson (2005) and Malik *et al.* (2009). On the basis of cluster means (Table 4), cluster IV and V emerged important for seed yield/plant and 100-seed weight. Cluster IV also showed highest mean for pods/plant, days to maturity and primary branches. Cluster V was important for pod length and seeds/pod also. For plant height, the mean was

lowest in cluster V and highest in cluster III. The contribution of characters towards diversity of the genotypes revealed maximum contribution (33.14%) by 100-seed weight and minimum contribution (1.8%) by seed yield/plant (Table 2). Over 80 per cent of the diversity among the genotypes was accounted for by 100-seed weight, plant height and pods/plant, suggesting the scope for yield improvement by exploiting variability for these traits. Further, the accessions with higher 100-seed weight from cluster V and accessions with higher pods/plant from cluster IV may be selected as parents in hybridization programme for developing high yielding genotypes of black-seeded soybean.

The present study revealed existence of ample genetic diversity in the local germplasm, which may be exploited by using them as parents in breeding programmes for developing high yielding varieties of black-seeded soybean.

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Productivity Enhancement of Soybean [*Glycine max* (L.) Merrill] through Improved Technologies in Farmers Field

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During past four decades of its commercial exploitation, soybean has established itself as a major rainy season oilseed crop in India, particularly in central part of the country. Madhya Pradesh has its major share in area of 5.51 million hectares (59.3 %) with production of soybean of 6.10 mt (60.2 %) in India (www.sopa.org), to grace the state as "Soya State". Although, the soybean research and development system in the country has generated viable production technology to raise the productivity to more than 80 per cent from the present level of around 1 t per hectare, it appears that there are impediments in reaching to end users creating a technological gap (Bhatnagar, 2009). To convince the soybean growers on effectiveness of technology and to motivate them for adoption, laying out of demonstrations is one of the proven methods. In view this, frontline demonstrations financed by

Department of Agriculture, Government of India through Indian Council of Agricultural Research, New Delhi were organized by *Krishi Vigyan Kendra* (Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalyaya, Gwalior) in the Shajapur District of Madhya Pradesh for consecutive five years. This district is one among major soybean districts of Madhya Pradesh and covers an area of 3, 32, 800 hectares under soybean crop with average productivity of 1049 kg per ha (Agriculture Statistics, 2009) and needed intervention to enhance the productivity

A total of 60 frontline demonstrations were organized by the *Krishi Vigyan Kendra* in the Shajapur district of Madhya Pradesh to demonstrate the impact of research emanated production technology on soybean productivity over five years during *kharif* 2004 - 05 to 2008 - 09. Each year 12

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demonstrations were laid out covering villages namely Rampura Mewasa (2004-05), Satgaon (2005-06), Jaloda (2006-07), Ragbel (2007-08) and Batavada (2008-09) of the Shajapur district. The improved package of practices included short/medium duration improved varieties (JS-335, NRC-7, JS 93-05 and JS 95-60), seed treatment with fungicides (thiram + carbendazim in 2:1 ratio @ 3 g/kg seed) and inoculated with bio-fertilizer (*Bradyrhizobium japonicum* and phosphorus solubilizing bacteria cultures, recommended dose of fertilizer (20:26.6:16.6:20 N:P:K:S), weed management (Imazethapyr @ 800 ml/ha) and pest management (One Spray of Endosulphon at 15 DAS + one spray of Trizophos at 35 DAS). The performance of soybean under these demonstrations were compared with the farmers' practice which included (farm-saved seed + 50 kg DAP + 50 kg SSP/ha). The results were economically evaluated in terms of C: B ratio and net returns to re-establish the viability.

The soil of the demonstrations belonged to Vertisols with low to medium fertility and grown to soybean-wheat/chick pea cropping system. Each frontline demonstration was laid out on 0.4 ha area adjacent 0.4 ha was considered as control for comparison (farmers' practice). The demonstrations were planted between 25th June and 7th July in 2004-05, July 2nd and 5th in 2005-06, June 28th and 30th in 2006-07, July 7th-9th in 2007-08 and July 3rd and 5th in 2008-09 with seed rate 80 kg/ha. Recommended dose of N and P through DAP, K through

MOP and S through gypsum @ 20:26.6:16.6:20 kg/ha, respectively, was applied as basal. The selection of cultivators was done on the basis of Participatory Rural Appraisal (PRA) action plan and care has been taken to lay out the demonstrations on road side to facilitate the dissemination of technology.

The results of front line demonstrations conducted on farmers' fields for 5 years (2004-05 to 2008-09) under real farm conditions in Shajapur district indicated that the imparted technology could lead to average seed yield levels in the range of 1, 115 to 1, 670 kg per ha as compared to 838 to 1, 450 under farmers practice. The highest level of yield in these demonstrations was in the range of 1, 480 to 2, 250 kg per ha. Mean yield of 60 demonstration worked out to 1, 480 kg per ha from demonstration where as the average yield obtained in case of farmers practice was 1, 138 kg per ha. This reveals that the adoption of improved production technologies of soybean cultivation is capable to enhance the productivity by 30.05 per cent over farmers practice. Bhatnagar (2001) reported that the research emanated production technologies are capable of increasing the productivity of soybean by 32.26 percent through front line demonstration on farmers' field.

There has been year to year variation in average yield of soybean which varied from 1, 115 - 1, 670 kg per ha in case of improved practices and 838 - 1, 450 kg per ha farmers' practice (Table 1). It could partly be accounted for the interaction between quantum of rainfall and nature of soybean variety. The minimum yield of 1, 115 kg per ha (Improved technology) and 867 kg per ha

Table 1. Performance of improved technologies of soybean cultivation on production through front line demonstrations

Year	Variety	Seed yield (kg/ha)		Farmers' practice	Additional yield over farmers practice(kg/ha)	Increase over farmers' practice (%)
		Improved technology				
		Maximum	Mean			
2004-05	JS 335	1, 800	1, 589	838	751	89.62
2005-06	JS 335	2, 250	1, 670	1, 450	220	15.17
2006-07	NRC 7	1, 480	1, 115	867	248	28.60
2007-08	JS 93 05	1, 550	1, 391	1, 183	208	17.58
2008-09	JS 95 60	1, 850	1, 633	1, 350	283	20.96
Mean	-	-	1, 480	1, 138	342	30.05

Note: The number of trials during each year was 12

(farmers' practice) was recorded in case of NRC 7, an early maturing variety in 2006-07, when the rainfall was almost double (1800 mm) as compared to other years (724-946 mm). During 2006-07, the excessive rainfall in the season must have suppressed the performance of the variety.

In economic evaluation (Table 2), the per hectare gross returns of Rs. 22,

200/- were obtained in demonstration plots while Rs. 17, 070/- in farmers' practice resulting in additional returns of Rs. 5, 130/-. The average net return of Rs.17, 613/- was obtained in demonstrations which was 20.01 per cent higher than farmers' practice (Rs 13, 248/-). The B:C ratio under improved practices (3.83) was 10.37 per cent higher over farmers' practice (3.47).

Table 2. Economic evaluation of improved technologies of soybean cultivation

Particulars	Farmers practice	Improved technology	Actual increase over farmers' practice	Increase over farmers' practice (%)
Average yield (kg/ha)	1, 138	1, 480	342	30.05
Gross return (Rs/ha)	17, 070	22, 200	5, 130	30.05
Cost of cultivation (Rs/ha)	3,822	4,587	765	20.01
Net return (Rs/ha)	13, 248	17, 613	4, 365	32.95
B:C ratio	3.47	3.83	0.36	10.37

Price of Soybean (Average of 2004-05 to 2008-09) Rs 15/kg

It is concluded from these demonstrations spread over five years that the yield levels of soybean can be increased profitably provided the

available production technology is adopted by the soybean growers in the potential district of Shajapur, Madhya Pradesh.

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