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Early Generation Selection for Pods per Plant and Dry Matter Yield in Interspecific Crosses of Soybean

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ABSTRACT

The effectiveness of number of pods per plant and dry matter yield per plant as independent selection criteria in early generations F_3 and F_4 generations of two inter specific crosses of soybean viz., (PK 472 x Glycine soja*) x PK 472 and (Bragg x* Glycine soja*) x Bragg were evaluated for yield improvement. Twenty top ranking plants, out of 200 visually selected plants from F_3 generation each for number of pods per plant and dry matter yield were independently evaluated in F_4 generation from both the crosses. Mean of the selected progenies for dry matter (88.45 and 82.58 g) and for pods per plant (255 and 200) were higher as compared to the bulk (77.6 and 60.59 g) and (194 and 172) in respective crosses. Selected progenies showed 15.18 and 45.17 per cent yield superiority in (PK 472 x* Glycine soja*) x PK 472 whereas, in second cross it was 36.31 and 45.65 per cent superior in yield in dry matter and pods per plant selection, respectively. Both the yield components showed significant positive correlation with seed yield. Whereas, high broad sense heritability and high genetic advance was also observed for number of pods per plant, dry matter and for their respective yield in the selected progenies in both the crosses. Proportions of significantly superior progenies over the better parents were also substantially higher in selected progenies as compared to respective bulks.*

Key words : Selection, soybean, yield components

Rejection of soybean crosses based on visual evaluation for overall agronomic traits in early generations followed by pedigree method has been the most common practice in soybean breeding programmes. For maximum efficiency and progress in breeding for any character it is advantageous if effective selection could be carried out in early generations so that the a limited number of superior lines could be retained for further testing. Visual selection for seed yield in soybean in early generation has not been very successful (Reaber and Weber, 1953; Torrie, 1958; Kwon and Torrie, 1964; Schapaugh Jr and Wilcox, 1980). Seed yield being a complex trait depends upon large number of component characters and therefore,

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selection based on seed yield *per se* has not been very effective but when selection was based on its component characters it was more effective (Singh *et al.*, 1998). Usually single plant selection in early generations is reported to be effective because of large environmental variations in common yield components (Wilcox and Schapaugh Jr, 1980). St Martin and Geraldi (2000) suggested F_2 derived families for maximum genetic gain for yield while avoiding desirable changes in lodging in early generation test programme. It is, therefore, necessary to look for alternative traits having high heritability and positive correlation with yield in soybean. Dry matter yield and number of pods per plant were found to be such characters that tend to increase parallel seed yield (Pushpendra and Ram, 1987). The present investigation was, therefore, carried out to evaluate the potential of selection in early germination for dry matter yield and pods per plant for yield improvement in inter-specific crosses of soybean.

MATERIAL AND METHODS

Two inter specific crosses viz. (PK 472 x *Glycine soja*) x PK 472 and (Bragg x *Glycine soja*) x Bragg were used as experimental material. These crosses were developed to generate pre-breeding material for soybean improvement programme at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar though conventional breeding approach (modified back cross) for this study. *Glycine soja* (Shib & Zucc) is a wild relative of cultivated soybean and has indeterminate plant growth habit with small dull black seeds. It is resistant to yellow mosaic virus and hairy caterpillar. Based on visual observations, 200 random F_3 plants from each of the two crosses were scored for dry matter, pods per plant and yield *per se* in rainy season crop (2002). Out of these, ten top ranking plants were selected on the basis of dry matter and pods per plant from F_3 progenies of respective crosses for further evaluation in F_4 generations. A total of 38 single plant progenies from (PK 472 x *Glycine soja*) x PK 472 and 36 from (Bragg x *Glycine soja*) x Bragg along with respective parents and random F_4 bulks were grown in randomized block design replicated twice in rainy season of 2003. Each progeny was grown in a single row plot of 3 m length, spaced 60 cm a part and with in rows plant to plant distance was 5 cm. Observations were recorded on ten random plants from each progeny and 20 from random bulk of both the crosses. Heritability (broad sense) was calculated as the ratio of genotypic variance to the phenotypic variance (Allard, 1960). Genetic advance was calculated by the formula as suggested by Sarafi (1978).

$$Hb = \frac{6^2g}{6^2P} \times 100$$

6^2g = Genotypic variances; 6^2p= Phenotypic variance

$$\text{Genetic advance} = \frac{\bar{S} - \overline{MP}}{\overline{MP}} \times 100$$

Where,

$\bar{S}$ = Pooled mean of selected families
$\overline{MP}$ = Mid-parental value.

RESULTS AND DISCUSSION

Mean values of plants selected in F_3 generation and their corresponding F_4 progenies crosswise are presented in tables 1 and 2. Significant differences were observed for yield components among the F_4 progenies selected for pods per plant, dry matter and for their respective grain yield in both the inter-specific crosses.

(PK 472 x *Glycine soja*) x PK 472.

Selection for dry matter: Plants selected in F_3 generation for dry matter yield and their F_4 progenies had higher mean dry matter yield compared with mean dry matter yield in bulk (93.0 g against 65.0 g in F_3 and 88.45 g against 77.06 g in F_4). Dry matter had a range of 60.0-180.0 g and 41.77 to 116.75 g in F_3 and F_4 generations, respectively. Whereas, corresponding mean yield of selected progenies was 29.41 g against 19.0 g in F_3 and 30.34 g against 26.20 g in F_4 as compared to bulk. Dry matter selected F_4 progenies overall exhibited 15.18 per cent mean yield superiority over the bulk. The proportions of significantly superior progenies recovered in F4 were 20 per cent for dry matter and 25 per cent for the corresponding seed yield (Table 1 and 2).

Table1. Mean values of parents, F_3 progenies derived from selected F_2 plants for dry matter (g) and number of pods per plant

Particular	(PK 472 x *G. soja*) x PK 472				(Bragg x *G. soja*) x Bragg			
	Dry matter (g)	Yield/ plant (g)	Pods/ plant (No)	Yield/ plant (g)	Dry matter (g)	Yield/ plant (g)	Pods/ plant (No)	Yield/ plant (g)
Mean of selected progenies	93.00	29.41	200	28.92	91.25	26.72	183	27.36
Random bulk	65.00	19.0	183	19.90	69.50	20.20	170	21.20
% superiority	43.07	54.78	9.28	45.32	31.29	32.27	7.64	29.05
Range	60-180	10.83-68.05	136-420	15.33-68.05	75-155	16.13-54.00	139-324	17.15-54.73
PK 472/ Bragg	80.00	29.10	294.0	29.10	45.00	16.10	145	16.10
Glycine soja	8.00	2.31	204. 0	2.31	8.00	2.96	263	2.96
No. of progenies superior to better parent	11	8	2	8	19	12	8	10

Table 2. Mean values of parents, F_4 progenies derived from selected F_3 plants for dry matter and number of pods per plant

Particular	(PK 472 x *G. soja*) x PK 472				(Bragg x *G. soja*) x Bragg			
	Dry matter (g)	Yield/ plant (g)	Pods/ plant (No)	Yield/ plant (g)	Dry matter (g)	Yield/ plant (g)	Pods/ plant	Yield/ plant (g)
Mean of selected progenies	88.45	30.34	255	29.79	82.58	25.30	200	24.12
Random bulk	77.06	26.20	194	20.52	60.59	16.56	172	16.56
% superiority	14.78	15.18	31.46	45.17	36.29	36.31	16.25	45.65
Range	41.77-116.75	15.62-50.72	131-378	15.62-50.73	54.00-117.6	16.08-41.00	152.45-342.1	16.79-41.01
PK 472/ Bragg	79.99	25.69	262.50	25.69	42.06	15.65	155.0	15.65
Glycine soja	7.25	2.49	227.00	2.49	7.57	2.50	244.9	2.50
CD (p = 0.05)	**29.18**	**11.03**	**35.10**	**9.0**	**20.49**	**10.38**	**21.83**	**10.38**
CV (%)	20.70	22.35	19.39	22.35	14.52	23.07	19.55	23.07
%age of progenies significantly superior to better parent	20	25	40	65	90	40	25	50

Table 3. Correlation coefficient (with yield/plant), per cent heritability and genetic advance for yield and yield contributing characters in F_4 generation in inter-specific crosses

Character	(PK 472 x *G. soja*) x PK 472			(Bragg x *G. soja*) x Bragg		
	Correlation coefficient	Heritability (%)	Genetic Advance	Correlation coefficient	Heritability (%)	Genetic Advance
Days to flowering	-0.335**	92.67	17.02	-0.369*	92.13	17.94
Days to maturity	-0.101	67.51	3.94	-0.369*	36.71	1.84
Dry matter	0.834**	67.44	48.89	0.787**	74.63	44.34
Plant height	-0.170	89.99	48.65	0.515*	85.36	31.84
No. of primary branches	-0.118	85.57	29.34	0.281	79.96	22.39
Pods/ plant	0.698**	66.50	45.91	0.598**	59.26	37.40
Test weight (g/100 seeds)	0.318	94.44	38.26	0.228	94.65	53.68
Harvest index	0.371**	60.16	25.51	0.431**	54.63	23.39
Yield/plant	-	67.30	54.19	-	46.00	29.85

Selection for pods per plant: Fairly large variation for number of pods per plant was observed in this cross ranged of 136-420 in F_3 and 131-378 in F_4 generation. The mean of selected plants for number of pods per plant was 200 against 183 the bulk in F_3 where as, in F_4 selected progenies, pods per plant exhibited higher mean pods per plant (255) as compared with the mean of bulk (194) and their grain yield was 29.79 g and 20.52 g, respectively. These progenies have shown 45.17 per cent yield superiority over the bulk. In F_3, twelve per cent plants were superior for pods per plant and eight progenies in grain yield over the better parent. Whereas in F_4, the proportion of significantly superior progenies was 40 per cent for pods per plant and 65 per cent for seed yield over the better parent i. e. PK 472 (Table 1 and 2). Genetic advance for pods per plant was 45.91 per cent and for seed yield it was 54.19 per cent in F_4 generation (Table 3).

(Bragg x *Glycine soja*) x Bragg

Dry matter per plant: Dry matter selections gave higher mean dry matter yield (91.25 g *vs* 69.50 g and 82.58 g *vs* 60.59 g/plant) in F_3 and F_4 over the respective bulks. Mean seed yield of selected progenies was 26.72 and 25.30 g per plant as compared to the bulk i. e. 20.20 and 16.56 g per plant in F_3 and F_4 respectively and, overall 52.78 per cent mean yield superiority over the bulk was recorded in F_4 progenies. Ninety per cent progenies were recovered in F_4 which were significantly superior over the best parent for dry matter and forty per cent for seed yield (Table 1 and 2). The genetic advance for dry matter yield was 44.34 per cent and for grain yield it was 29.85 per cent (Table 3).

Number of pods per plant: The range number of pods per plant in bulks was comparatively wider, as compared to selected progenies. The mean of selected plants for pods per plant was 183 in F_3 and their selected progenies in F_4 it was 200 pods per plant. Whereas, the mean of respective bulks was 170 and 172, pods per plant, respectively in F_3 and F_4 generation (Table 1 and 2). In F_4 the proportion of significantly superior progenies over the better parent was 25 per cent for pods per plant. Whereas, selected progenies exhibited 45.65 per cent yield superiority over the bulk. Genetic advance for pods per plant was 37.40 per cent and for seed yield it was 29.85 per cent in F_4 generation. Fifty per cent progenies under selection group exhibited significantly higher seed yield over the better parent i.e. Bragg in F_4.

As evident from table 1 and 2, selections for dry matter yield and pods per plant in F3 have shown worth superiority in terms of mean over the bulks and their corresponding yield. These selected progenies were 15.18 and 45.17 per cent superior in yield over the bulk in (PK 472 x *Glycine. soja*) x PK 472 cross for dry matter yield and pods per plant selection. Whereas in (Bragg x *Glycine soja*) x Bragg cross selected progenies were 36.31 and 45.65 per cent superior in yield respective selection over the bulks. Simple correlation between yield and yield components in the selected progenies for both the selections criterion, dry matter and pods per plant, cross-wise (Table 3) indicated that dry matter per plant, pods per plant and harvest index showed highly significant positive correlation with seed yield in both the crosses. Plant height showed positive significant correlation with seed yield in (Bragg x *Glycine soja*) x Bragg, however this relationship was negative but non-significant in F_4 generation. However, for number of primary branches per plant and hundred seed weight exhibited in consistent correlation coefficient with seed yield in both these eases.

Highest broad sense heritability estimate reported for test weight in both the crosses was 94.44 and 94.65 per cent followed by days to flowering and plant height. Whereas, for pods per plant, dry matter and yield per plant moderate estimates of heritability were observed.

Highest genetic advance 54.19 per cent was recorded for seed yield followed by dry matter (48.89%) plant height (48.65 %), pods per plant (45.91 %) and test weight (38.26 %) in (PK 472 x *Glycine soja*) x PK 472, whereas, it was lowest for days to maturity i.e. 3.94 per cent. In (Bragg x *Glycine soja*) x Bragg hundred seed weight exhibited highest genetic advance (53.68 %) followed by dry matter (44.34 %), pods per plant (37.40 %) and plant height (31.84 %) and was lowest (1.84 %) for days to maturity. If the selection in a population is to be effective, the relative performance of a group of genotypes must remain stable over the years and locations. From this point view of seed yield was shown to be highly unstable in contrast with mature plant weight in soybean (Schapaugh Jr and Wilcox, 1980). This may be the reason why dry matter is better selection criteria over seed yield *per se*. Wilcox and Schapaugh Jr (1980) reported that visual selection for superior plants from heterogeneous populations in soybean had no effect on seed yield. Hussain (1990) also reported that selections for high pod number in F_2 gave increased biomass per plant which may lead to high yield. Considering the high mean of F_3 selected plants and their progenies in F_4 for number of pods per plant and dry matter and their corresponding yield was higher as compared to the bulks, proportion of superior or significantly superior progenies over the better parents PK 472/ Bragg, and high genetic advances, positive relationship with seed yield both the selections viz. pods per plant and dry matter yield were considered effective for yield improvement in early generation in inter specific crosses of soybean.

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Isoflavones Concentration in Popular Soybean Genotypes of *Malwa* Region in Central India

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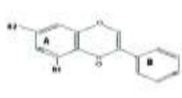
ABSTRACT

Nine popular soybean genotypes of the Malwa *region were grown in the fields in* kharif *2007. The seeds of different genotypes were harvested at their respective maturity and subjected to estimation of isoflavones using High Performance Liquid Chromatography (HPLC). Genotypic variability was observed for daidzein, glycitein, genistein and total isoflavones contents and the range for these were: 95.5-624.4; 154.5-517.1, 79.7-817, 477.9-1731.4 µg/g soy flour, respectively. 'Samrat' and 'NRC 7' exhibited the lowest levels of daidzein and total isoflavones while 'JS 97 52' exhibited the lowest value for genistein. Genotypes 'JS 80 21', 'JS71 05' and 'MAUS 61 2' were the top 3 cultivars for total isoflavones content. Correlation studies indicated that breeding soybean genotypes with early maturity as well as with low isoflavones content may be easier.*

Key words: Daidzein, genistein, glycitein, *Malwa* region, soybean

Isoflavones are flavonoids compounds, with two benzyl rings joined by three-carbon chain (C_6-C_3-C_6). They differ from flavones in the site of attachment of second benzyl ring (B) which is joint at position 3 instead at position 2 (Fig 1). Soybean owes much of its 'functional food' sobriquet to the versatility of isoflavones present in its seeds. Isofavones as antioxidant compounds reduce the risk of prostrate and colon cancer (Sarkar and Li, 2004) and cardiovascular diseases (Clarkson *et al.*, 2002); and as estrogen-like compounds mitigate the post-menopausal blues and prevent the incidence of osteoporosis and hormone-related breast, ovarian and uterine cancers. Specially designed dietary supplements with soy isoflavones concentrate have already arrived in the market for this purpose. However, concerns have been raised about the possible adverse effects of isoflavones on foetal development and infants fed on soy-based formulae (Mendez *et al.*, 2002 and Chen and Rogan, 2004) so much so that some



Daidzein : R1 = H;
Genistein : R1 = OH ; R2 = H
Glycitein : R1 = H ; R2 = OCH_3

Fig 1. Structure of isoflavones

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countries have recommended safe upper limit for daily intake of isoflavones (Morandi *et al.,* 2005). Besides, high level of isoflavones in certain genotypes is considered to be responsible for astringency associated with soy products (Kudou *et al.,* 1991). Therefore, the development of soybean genotypes with low as well as high levels of isoflavones is important breeding objective to meet the requirement of different end users. The isoflavones in soybean exist as free aglycones (daidzein, glycitein, genistein, daidzein), as β glucoside (genistin, daidzin and glycitin) when sugar is conjugated to aglycones and as malonyl and acetyl derivatives of glucoside (Griffth and Collison, 2001). However, free alglycone forms, *i. e.* daidzein and genistein are stable and have physiological activities superior to other isoflavones (Akiyama *et al.,* 1987).

Soybean is being increasingly sought as health food across the globe, going beyond the traditional expanses of China, Japan and Southeastern countries. In India too, the dismal scenario of soybean in food uses has been constantly improving as people are becoming increasingly aware of the health benefits of soybean. *Malwa* is the hub of soybean cultivation in India and the seeds and defatted meal of the soybean genotypes grown by the farmers in this region reach soy food processing units located in the regions and neighbouring states as well. Therefore, isoflavones levels in the seeds of soybean cultivars of the region would also help to indicate the concentration of isoflavones in different soy-products processed in the region. Recently, genotypic variability for isoflavones concentration has been reported in the major soybean growing countries (Seguin *et al.,* 2004 and Craig *et al.,* 2005); however, the investigation of Indian soybean genotypes for isoflavone concentration has not yet been conducted. Therefore, it was felt pertinent to analyze the popular soybean genotypes of the *Malwa* region for isoflavones content.

MATERIAL AND METHODS

Nine soybean cultivars, *viz.* 'JS 335', 'JS 93 05', 'NRC 7', 'JS 71 05', 'JS 97 52', 'JS 80 21', '*Samrat*', 'MAUS 61 2' and 'NRC 37'of *Malwa* region were raised in the fields of National Research Centre for Soybean, Indore, in *kharif* 2007 following recommended agronomic practices. Barring '*Samrat*', which is a farmers' selection, remaining all 8 genotypes are released varieties. Standards of the isoflavones (daidzein, glycitein and genistein) were procured from Sigma Aldrich.

The days-to-flower (DF) and the days-to-maturity (DM) of each of the 9 genotypes were recorded. The harvested seeds were ground into fine flour with metallic pestle and mortar and passed through a sieve of 500µ. The finely ground soy-flour was used subsequently for the extraction of the isoflavones.

Extraction of isoflavones: 125 mg of the finely ground soy flour was extracted with 80 per centethanol (8 ml) and concentrated hydrochloric acid (2 ml) for 2 hr in a boiling water bath (Vyn *et al.* 2002), which relies on acid hydrolysis of

12 endogeneous isoflavones isomers to their respective aglycone form, *i.e.* daidzein, glycitein and genistein. The suspension resulted after the extraction was centrifuged at 10, 000 rpm.

HPLC analysis of isoflavones: The supernatant obtained after centrifugation was passed through the PTFE syringe filter (Whatman 0.5 micron, 13 mm diameter) before loading into the HPLC system. A 20 µl of the syringe-filtered sample was injected into a Shimadzu chromatographer (LC-10AT *VP*), equipped with a UV detector (SPD 10AT VP) and oven (CTO-10) housing a C-18 silica column (Phenomenex; 5 µM with dimension of 250 mm x 4.6 mm), which was preceded by a guard column (Phenomenex 4.0 mm x 3.0 mm). The column was maintained at 40^{o}C. The separation and elution of isoflavones was accomplished by employing binary gradient mode with solvent A (10 % Acetonitrile) and solvent B (38% Acetonitrile) at a flow rate of 0.8 ml per minute for 25 minutes. The solvent system was run as follows: [(% solvent A/solvent B; 0 min (0/100), 5 min (10/90), 20 min (0/100) and 25 min (0/100)]. The isoflavones were detected at a wavelength of 260 nm. Standard curves for daidzein, glycitein and genistein were prepared by injecting varying concentrations of isoflavones standards into the HPLC system. The relative concentration of individual isoflavone in the sample was calculated by Spinco software CSW version 1.7 after superimposing the chromatograph of the sample on the standard curve. Individual isoflavone concentration was expressed as µg per gram of soy flour on dry weight basis (*db*). Concentrations of aglycones were summed up to compute the total isoflavone concentration.

RESULTS AND DISCUSSION

Concentration of individual isoflavones in 9 soybean cultivars was determined by HPLC (Table 1.). Individual and total isoflavones were expressed as µg per gram soy-flour. Daidzein concentration ranged from 95.5 ('*Samrat*') to 624.4 ('NRC 37') with mean value of 344.7 µg per gram soy-flour. The ratio between the lowest and the highest value of daidzein was computed to be 1:6.5. Glycitein concentration ranged from 154.5 ('*Samrat*') to 517.1 ('JS 335') with mean value of 361.1 µg per gram soy-flour. The ratio between the lowest and the highest was 1:3.3. Genistein concentration ranged from 79.7 ('JS 97 52') to 817 ('JS 71 05') with mean value of 506.5 µg per gram soy-flour. The ratio between the lowest and the highest value was 1:10.3. Total isoflavones concentration ranged from 478 ('*Samrat*') to 1731.2 ('JS 80 21') with a mean value of 1212.3 µg per gram soy-flour. The ratio between the lowest and the highest value of total isoflavones worked out to 1:3.62. Of the 9 genotypes analyzed, 4 genotypes exhibited total isoflavones concentration more than 1500 µg per gram soy-flour, 1 cultivar between 1000-1500 µg per gram soy-flour and 2 cultivars each for 500-1000 and less than 500µg per gram soy-flour. Eldridge and Kwolek (1983) reported that total isoflavone concentrations in soybean seeds

Table 1. Isoflavone concentration* in 9 popular soybean genotypes of *Malwa* region with their respective days-to-flowering (DF) and days-to-maturity (DM)

Genotype	DF	DM	Daidzein	Glycitein	Genistein	Total Isoflavones
'JS335'	47	105	317.6 ± 10	517.1 ± 13	615.2 ± 19	1449.9
'JS93-05'	47	95	236.3± 15	252.3 ± 18	398.4 ± 22	887.2
'NRC7'	36	88	97.2 ± 12	240.0 ±11	153.2 ± 27	490.4
'JS71-05'	45	95	377.4 ± 9	493.6 ± 10	817.0 ± 21	1688.0
'JS97-52'	48	96	417.9 ± 12	378.0 ± 10	79.7 ± 24	875.6
'JS80-21'	51	110	452.5 ± 8	507.9 ± 15	770.8 ± 21	1731.2
'*Samrat*'	35	87	95.5 ± 12	154.5 ± 16	228.0 ± 15	478.0
MAUS61-2	57	103	484.0 ± 18	436.8 ± 14	757.3 ± 13	1678.1
NRC37	53	115	624.4 ± 10	270.0 ± 14	739.0 ± 36	1633.4

**μg/g ± SD of soy flour (dry weight basis); the value given are the mean values of duplicate samples*

Table 2. Significant correlations among isoflavones, total isoflavones, days-to-flowering (DF) and days-to-maturity (DM)

	Glycitein	Genistein	Total isoflavones	DF	DM
Daidzein	-	0.655*	0.829**	0.750*	0.897**
Glycitein		-	0.773*	-	-
Genistein		-	0.938***	0.658*	0.676*
Total isoflavones		-	-	-	0.822**
DF		-	-	-	-
DM		-	-	-	-

, **, * indicate the significance for $p < 0.05$, < 0.01 and < 0.001, respectively*

ranged from 1160 to 3090 μg per gram in 4 soybean cultivars in 4 environments. Wang and Murphy (1994) analyzed total isoflavone concentration in 3 Japanese cultivars and 8 American cultivars. In Japanese cultivars, total isoflavones concentration ranged from 1261 to 1417 μg per gram soy-flour while in 7 American cultivars, it ranged from 2053 to 4216 μg per gram soy-flour. Hoeck *et al.* (2000) studied the influence of genotype on isoflavone concentration in 6 cultivars grown at 6 different locations for 2 consecutive years. Genotypic variation was observed for total isoflavones at all 6 different locations. Lee *et al.* (2003)

evaluated 15 Korean soybean cultivars in 3 consecutive years and observed a range of 188.4-483.0 mg per 100 grams in 1998; 218.8- 948.9 mg per 100 grams in 1999 and 293.1-483.0 mg per 100 grams in 2000. Seguin *et al.* (2004) reported isoflavone concentration in 20 soybean cultivars grown in eastern Canada region across two years ranging from 360 to 2241 µg per gram of soy-flour. Recently, Craig *et al.* (2005) analyzed isoflavones concentration in the seeds of 17 soybean cultivars and found that the total isoflavone concentration ranged from 2038 to 9514 µg per gram with an average value of 5644 µg per gram of the soy flour.

A negative correlation between oil content and isoflavones concentration has earlier been reported (Craig *et al.,* 2005). In the present study, 'NRC 7' which exhibited the lowest concentration of genistein and also ranked second lowest for daidzein concentration and total isoflavones concentration has earlier been reported for high oil content (Kumar *et al.,* 2007). In addition, 'NRC 7' and '*Samrat*', which exhibited comparatively low level of individual isoflavones and total isoflavones in the study, are both early maturing genotypes. This is in consonance with the earlier study (Wang *et al*., 2000) that indicated a lower isoflavones concentration in early maturing varieties of soybean.

Significant correlations were observed among individual isoflavones, total isoflavones, days-to-flowering (DF) and days-to-maturity (DM) of the different soybean genotypes (Table 2). Both daidzein and genistein exhibited significant ($p < 0.05$) positive correlation with DF. DM was significantly correlated with daidzein, genistein and total isoflavones, with daidzein exhibiting the strongest ($r = 0.897$; $p = 0.001$) followed by total isoflavone ($r = 0.822$, $p = 0.005$) and genistein ($r = 0.676$; $p = 0.041$). All the three individual isoflavones exhibited significant correlations with total isoflavones; however, highly significant correlation ($p < 0.001$) was observed between genistein and total isoflavones content. Furthermore, significant correlation was observed between individual isoflavones, *i.e.* between daidzein and genistein, which was expected as the isoflavones are synthesized *de vovo via* a common phenylpropanoid pathway.

Conclusively, among the major soybean genotypes grown in *Malwa* region, soy-food industries located in the region and interested to manufacture foods with low levels of isoflavones may select 'NRC 7 'and '*Samrat*' as raw seed material for processing into soy-foods while seeds of 'JS 80 21' and 'JS 71 05' would constitute ~~be~~ suitable raw material for pharmaceutical industries to realize maximum isoflavones extraction. Correlations presented in the study also suggest the convenience to develop soybean varieties with early maturity and low isoflavones levels by the plant breeders.

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Field Evaluation of *Bradyrhizobium*, PSB and AM Fungus on Nodulation, Nutrient uptake, Growth and Yield of Soybean

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ABSTRACT

A field experiment was conducted to study the effect of Bradyrhizobium japonicum*, PSB and AM fungus (AMF) on nodulation, N, P content and uptake, growth and yield of soybean variety PK 416 in Mollisol. Maximum number of nodules per plant (25.66) was obtained with inoculation of* B. japonicum *alone at 30 days after sowing (DAS), which was at par with application of 60 kg P_2O_5/ha. However, at 60 and 90 DAS maximum nodule number per plant (80.0 and 141.3, respectively) was recorded by application of 60 kg P_2O_5/ha, which was significantly more than microbial inoculation alone or in combination. The application of 60 kg P_2O_5/ha produced maximum dry weight of nodules at all the growth stages of soybean and was significantly more than microbial inoculation alone or in combination, whereas lowest values were associated with uninoculated control. At 30 and 90 DAS, maximum shoot dry weight was recorded with the application of 60 kg P_2O_5/ha, but at 60 DAS* B. japonicum + *40 kg P_2O_5/ha gave maximum dry weight (28.10 g), which was significantly higher than inoculation with* B. japonicum *alone. Maximum N uptake (66.01 kg/ha) by shoot was obtained with AMF inoculation + 40 kg P_2O_5/ha, which was significantly higher than* B. japonicum *inoculation alone. The highest N content of 1.73 per cent in shoot was recorded by co-inoculation of AM + PSB with 40 kg P_2O_5/ha and lowest with uninoculated control (1.20%). The maximum P content (0.46 %) was found with the treatment of* B. japonicum + *PSB + 40 kg P_2O_5/ha, which was significantly more than microbial inoculation alone or in combination. The highest grain yield (2296 kg/ha) was obtained with* B. japonicum + *60 kg P_2O_5/ha, which was 197 kg/ha more than* B. japonicum *inoculation alone.*

Key words: *B. japonicum,* inoculation, mycorrhiza, PSB, soybean

Soybean being a legume host fixes atmospheric nitrogen in symbiotic relationship with *Bradyrhizobium japonicum*. Phosphorous plays a key role in the biological nitrogen fixation. Soybean crop require more phosphorous because of its high energy requirement for N_2 fixation and protein synthesis (Havelka *et al.*, 1982). *Rhizobium* requires phosphorus for its growth and survival in soil, rhizospheric colonization, nodule development and energy transformation

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during N_2 fixation in root nodules. Dual inoculation of *B. japonicum* and Psuedomonas help the plant to acquire both N and P for growth (Zaidi and Singh, 2001). Mycorrhizal fungi have widely recognized value for the plant survival and nutrient cycling in the ecosystem. AM Fungus (AMF) greatly improves phosphate supply to the host plant, which results in increased nodulation and nitrogen fixation in legumes (Schenck and Hinson, 1973). Therefore, the study was undertaken to evaluate the influence of inoculation of *B. japonicum*, PSB (*Psuedomonas striata*) and AM fungus (*Glomus lamellosum)* on soybean with applied phosphorous.

MATERIAL AND METHODS

A field experiment was conducted at the Crop Research Centre (CRC) of Pantnagar, during the rainy season of 2004 to study the effect of PSB and AMF inoculation on soybean *Bradyrhizobium* symbiosis on silty clay loam soil having organic carbon 0.75 per cent, available nitrogen (N) 295.62 kg/ha, available phosphorous 19.71 kg P/ha, available potash 140.12 kg K/ha and pH 7.2. Treatments consisted of inoculation of *B. japonicum,* PSB (*Psuedomonas striata*) and AM fungus (*Glomus lamellosum)* either alone or in combinations with 40 and 60 kg P_2O_5/ha applied as basal through SSP and unicoculated control treatment with three replications. The experiment was laid out in Randomized Block Design in plots of 3m x 4m size. Soybean (*cv*. PK 416) seed was treated with 20 g inoculant of *B. japonicum,* PSB (*Psuedomonas striata*) and AM fungus (*Glomus lamellosum)* per kg seed at the time of sowing.

Three plants from each plot were randomly uprooted along with soil core at 30, 60 and 90 days after sowing (DAS). Soil cores with plant roots were placed in sieve, washed off with water jet and nodules were separated and counted. Dry weight of nodules and plants, was determined after drying to constant weight at 70°C. Grain and straw yields were recorded at final harvest. Nitrogen and phosphorus content in plant was determined by modified Kjedahl and vandomolybdo phosphoric yellow color method in nitric acid system (Jackson, 1973) after grinding the sample to 40 mesh and total N and P uptake were calculated.

RESULTS AND DISCUSSION

Nodulation

The inoculation of tested microorganisms increased nodules number, nodule dry weight and shoot dry weight per plant (Table 1). Maximum nodule number (25.66) per plant was recorded with inoculation of *B. japonicum* alone at 30 DAS, which was at par with 60 kg P_2O_5/ha, while at 60 and 90 DAS maximum nodule number was recorded with 60 kg P_2O_5/ha. It might be due to more availability of phosphorous for the formation of nodules (Singh and Singh, 1993). The minimum number of nodules per plant was recorded with uninoculated control treatment at all the growth stages of soybean. *B. japonicum* inoculation showed 57.0 per cent more nodules per plant than PSB alone inoculation and 24.2 per cent more than

Table 1. Effect of *B. japonicum*, PSB and AMF inoculation with applied phosphorus on nodule number, nodule dry weight and shoot dry weight of soybean at 30, 60 and 90 DAS

Treatment	Nodule number per plant (No.)			Nodule dry weight per plant (mg)			Shoot dry weight per plant (g)		
	30 DAS	60 DAS	90DAS	30 DAS	60 DAS	90DAS	30 DAS	60 DAS	90DAS
Uninoculated control	13.33	29.33	38.66	50.66	142.10	172.33	2.56	10.30	25.30
B. japonicum alone	25.66	57.00	57.33	136.33	241.11	285.83	3.10	17.94	40.67
AMF alone	20.66	54.66	55.00	114.00	253.33	280.33	3.03	17.43	34.81
PSB alone	16.33	56.33	56.66	113.33	273.06	353.33	3.50	26.19	37.87
B. japonicum + AMF	16.66	56.33	67.00	149.66	276.55	352.66	3.60	20.06	46.86
B. japonicum + PSB	14.33	51.66	66.66	164.00	297.66	346.50	3.60	17.76	46.25
AMF + PSB	18.00	61.00	56.66	172.66	381.66	370.83	3.66	17.06	45.90
B. japonicum + SSP@60 kg P_2O_5/ha	24.66	66.66	76.00	168.00	268.55	457.33	3.96	27.28	49.56
B. japonicum + SSP@ 40 kg P_2O_5/ha	24.00	59.00	69.66	182.66	282.66	384.43	3.36	28.10	47.94
AMF + SSP@ 40 kg P_2O_5/ha	23.00	60.66	105.33	185.66	293.99	363.01	3.96	24.80	46.89
PSB + SSP@ 40 kg P_2O_5/ha	21.66	64.66	108.66	164.66	277.55	336.73	3.20	20.65	49.07
B. japonicum + AMF +SSP@ 40 kg P_2O_5/ha	20.66	51.33	123.33	185.00	282.44	366.16	3.10	22.99	47.07
B. japonicum + PSB + SSP@ 40 kg P_2O_5/ha	17.66	56.66	125.00	189.66	296.95	362.00	3.33	23.44	50.35
AMF + PSB + SSP@ 40 kg P_2O_5/ha	17.33	75.00	125.00	188.66	364.55	335.83	2.96	20.56	49.28
SSP@40kg P_2O_5/ha	18.66	71.33	135.00	165.00	281.55	356.83	3.96	24.34	46.29
SSP@60kg P_2O_5/ha	23.66	80.00	141.33	257.33	420.77	447.83	4.20	25.27	55.57
SEm (±)	1.84	3.47	3.64	4.78	8.49	14.58	0.229	1.41	2.09
CD (P = 0.05)	**5.31**	**10.03**	**10.51**	**13.80**	**24.53**	**42.11**	**0.66**	**4.07**	**6.05**

AM fungus inoculation at 30 DAS, it might be due to the effectiveness of inoculated *B. japonicum* for formation of nodules on roots. Vijayapriya *et al.* (2003) also found increasing nodulation in soybean by the seed inoculation with *B. japonicum* over the control. All the treatments significantly increased nodule dry weight per plant at all the stages of growth of plant over the control. Maximum nodule dry weight (257.33, 420.77 and 447.83 mg, respectively) per plant was recorded with the application of 60 kg P_2O_5 /ha at 30, 60 and 90 DAS, while lowest in uninoculated control. It may be due to more availability of phosphorus for synthesis of nodular tissue (Taiwo and Adebite, 2001). Co-inoculation of *B. japonicum*, PSB and AM fungus performed significantly better than their individual inoculation. It may be because of synergistic effect of inoculated organisms on nodulation in which *B. japonicum* fixed atmospheric N, PSB solubilized insoluble phosphorus and AM fungus mobilized P to the plant roots. The above observation is in conformity with Singh *et al.* (1995).

Shoot dry weight

The increases of 21.0 and 18.3 per cent (Table 1) in shoot dry weight with the inoculation of *B. japonicum* and AM fungus over uninoculated control at 30 DAS were possibly due to the effect of nitrogen fixed by *B. japonicum* and supply of phosphorus to the plant by AM fungus. Sreenivasa *et al.* (1995) also found increase in shoot dry weight by the application of *B. japonicum* and AM fungi over the control. The maximum shoot dry weight of 4.20 and 55.57 g per plant was recorded with the application of 60 kg P_2O_5/ha at 30 and 90 DAS, respectively. It may be due to the synthesis of more plant tissue by elevated supply of phosphorous. Singh (1985) reported that increasing phosphorus rate increased shoot dry weight of soybean. *B. japonicum* inoculation with 60 kg P_2O_5/ha gave significantly higher shoot dry weight at all the growth stages than inoculation *with B. japonicum* alone. It may be because of the combined effect of phosphorus and nitrogen fixed by *B. japonicum* which helped in the synthesis of plant tissue. The results corroborate the findings of Dadson and Acquatt (1994), who found that the inoculation of *B. japonicum* along with phosphorus application increased shoot dry weight of soybean plant.

N and P content and uptake

Application of phosphorus increased plant nitrogen content because phosphorus is required for nodular tissue formation and as a source of ATP for activation of nitrogenase enzyme. Singh *et al.* (2001) reported similar results in soybean and found that nitrogen content was significantly more with the application of 60 kg P_2O_5/ha. The highest N content of 1.73 per cent (Table 2) was recorded by co-inoculation of PSB and AMF along with application of 40 kg P_2O_5/ha and lowest in uninoculated control (1.20%), which may be due to more availability of energy in the form of ATP to nitrogenase enzyme for N_2 fixation. Inoculation of AMF and PSB

Table 2. Effect of *B. japonicum*, PSB and AM fungi inoculation with applied phosphorus doses on N, P content and uptake at harvest and yield of soybean

Treatment	Nutrient content in shoot (%)		N and P uptake at harvest (kg/ha)		Grain yield (kg/ha)
	N	P	N	P	
Uninoculated control	1.20	0.29	36.35	5.61	1827
B. japonicum alone	1.61	0.30	41.55	8.25	2099
AMF alone	1.21	0.37	51.21	6.51	1994
PSB alone	1.42	0.35	49.85	9.58	1976
B. japonicum + AMF	1.66	0.34	59.83	7.31	2116
B. japonicum + PSB	1.64	0.38	57.48	7.28	2138
AMF + PSB	1.63	0.31	56.21	6.29	2074
B. japonicum + SSP@60 kg P_2O_5/ha	1.55	0.34	62.03	7.51	2296
B. japonicum + SSP@ 40 kg P_2O_5/ha	1.52	0.38	46.95	8.69	2184
AMF + SSP@ 40 kg P_2O_5/ha	1.68	0.45	66.01	10.51	2044
PSB + SSP@ 40 kg P_2O_5/ha	1.42	0.38	48.58	8.21	2034
B. japonicum + AMF +SSP@ 40 kg P_2O_5/ha	1.57	0.31	60.36	7.48	2155
B. japonicum + PSB + SSP@ 40 kg P_2O_5/ha	1.59	0.46	60.69	10.51	2106
AMF+ PSB + SSP@ 40 kg P_2O_5/ha	1.73	0.31	63.23	9.05	2261
SSP@40kg P_2O_5/ha	1.56	0.34	58.42	7.77	2130
SSP@60kg P_2O_5/ha	1.59	0.37	59.82	8.42	2184
SEm (±)	0.140	0.21	6.01	1.23	97.09
CD (P = 0.05)	**NS**	**0.06**	**17.38**	**NS**	**281**

significantly increased phosphorus content in plant over uninoculated control treatment probably due to phosphorus solubilizing action of PSB and P mobilizing effect of AM fungus which increased availability of P to the plant roots. Sreenivasa *et al.* (1995) also found significant increase in phosphorus content of plant with dual inoculation of *B. japonicum* + *Glomus fasciculatum*. Inoculation of *B. japonicum* + AMF recorded significant increases of 64.6 and 43.9 per cent in total N uptake, respectively, over uninoculated control and *B. japonicum* alone inoculation. It seems the combined effect of both organisms on the availability of N to plant through more supply of phosphorus by AMF needed for more fixation of nitrogen by *B. japonicum*. Similarly, Singh and Singh (1993) reported that maximum uptake of N was obtained by the combined inoculation of *B. japonicum* + *Aspergillus awamori* in soybean. The highest P uptake of 10.51 kg/ha (Table 2) was shown by AMF inoculation with 40 kg P_2O_5/ha which was similar to that obtained by combined inoculation of *B. japonicum* and PSB with 40 kg P_2O_5/ha possibly because of increased amount of available phosphorus by fertilizer, PSB and AMF to the plant and N supply by *B. japonicum*. Similar results were reported by Bardet et *al.* (1986) who found that superphosphate fertilization along with *B. japonicum* inoculation significantly increased P uptake by soybean plant.

Grain yield

An increase of 14.9 per cent in the grain yield of soybean (Table 2) over uninoculated control was obtained with inoculation of *B. japonicum.* Praharaj and Dhingra (2001) also reported that *B. japonicum* inoculation significantly enhanced the seed yield of soybean by 10.4 per cent over uninoculated control. However, when *B. japonicum* was inoculated with AM fungus or PSB yield increased significantly showing the combined effect of nitrogen and phosphorus availability to the plant due to combined action of these organisms. These finding are in corroboration with the results reported by Kumarawat *et al.* (1997) who observed that interaction between *Rhizobium* and PSM significantly increased seed yield of soybean. The highest grain yield of 2296 kg/ha was recorded with *B. japonicum* inoculation plus 60 kg P_2O_5/ha which was 9.4 and 5.1 per cent more than *B. japonicum* inoculation alone and 60 kg P_2O_5/ha, respectively, because of more availability of phosphorus supplied through chemical fertilizer along with N fixed by *B. japonicum.* Mausumi *et al.* (1997) also reported that *Rhizobium* and phosphorus interaction significantly increased grain yield of soybean.

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Influence of Balanced Nutrition on Productivity of Soybean

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ABSTRACT

In a field experiment conducted at National Research Centre for Soybean, Indore during 2003 and 2004, thirteen combinations of NPK were tried in randomized block design to assess the impact of balanced fertilization on productivity of soybean. The maximum productivity and profitability was obtained with the application of N, P_2O_5 and K_2O in the proportion of 20:60:40 kg/ha (with soil test values of organic carbon 0.39%, available P 10.5 kg/ha and available K 280 kg/ha), as it resulted in maximum mean soybean seed yield, net returns and B: C ratio. The maximum mean straw yield was recorded with 40:80:40 kg N:P_2O_5:K_2O per hectare. Overall consideration of data suggested that the present recommendation for soybean needs to be modified to the extent of doubling the level of potassium to ensure balanced nutrition, achieve maximum benefit: cost ratio without compromising on productivity.

Key words: Balanced nutrition, productivity, net returns

Soybean [*Glycine max* (L.) Merrill)] is one among the most important oilseed crops of India. It is estimated that the crop has been sown in 8.85 million hectares and is likely to produce 9.47 million tonnes of soybean in *kharif* 2007 (Anonymous, 2007). The performance of crop during past few years revealed that the national productivity is hovering around one tonne per hectare, however, it was linked with the quantity and distribution of rainfall during those years (Joshi *et al.,* 2006). Although, national R&D system has developed varieties with much higher yield potentials (3.5 to 4.0 t/ha) and national level demonstrations have established an average yield level of 1.8 tonnes per hectare under real farm conditions, but the major constraint of low soybean productivity is unbalanced nutrition (Anonymous, 1981 and 2000; Jain, 1986; Tiwari, 2001; Joshi and Bhatia, 2003). Unless soybean is provided with required nutrient input to produce sufficient biomass it does not yield high (Singh *et al*., 2006). The present NPK levels under recommendation were based on the agronomic experiments with the initiation of commercial cultivation and are subjected to review on account of changed varietal scenario and soil nutrient status due to continuous cropping over the years. A need, therefore, has aroused to assess the impact of balanced nutrient levels in terms of N, P and K to break the productivity plateau and harvest optimum yield of soybean.

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MATERIALS AND METHODS

Field experiment was conducted during *kharif* 2003 and 2004 at experimental farm of National Research Centre for Soybean, Indore. The soil of experimental site is medium black and belonged to Sarol series (Fine montmorillonitic, iso-hyperthermic family of Typic Haplusterts). Pre-experimental analysis revealed that it is clayey having pH 7.82, EC 0.15 dS/m, organic carbon 0.39 per cent, available P 10.5 kg per hectare and available K 280 kg per hectare. Thirteen treatments combinations comprising of N, P_2O_5 and K_2O viz. 20:40:20, 20:40:40, 20:60:20, 20:60:40, 20:80:20, 20:80:40, 40:40:20, 40:40:40, 40:60:20, 40:60:40, 40:80:20, 40:80:40 and control were replicated thrice in randomized block design. The carriers utilized for the supply of nutrients were urea, single super phosphate and muriate of potash as basal application. The soybean variety JS 93-05 was sown on 27th June and 29th June during 2003 and 2004, respectively.

RESULTS AND DISCUSSIONS

Effect on growth and yield attributes

In general, application of any of the nutrient combination resulted in numerical increase in plant height over control (Table 1). Maximum mean height of soybean plant (57.0 cm) was recorded with the application of N: P_2O_5: K_2O per hectare in combination of 40:80:40 closely followed by 40:60:40 (56.9 cm) which were significantly higher over control, 20:40:20, 20:40:40 and 20:60:20 but at par with rest of the treatments.

Application of different combinations of nutrients showed a numerical increase in number of mean branches per plant as well as pods per plant over control; however the differences in pods per plant were statistically non-significant (Table 1). Maximum number of branches per plant was associated with the application 40:40:40 combination followed by 40:80:20 of N: P_2O_5: K_2O and differed significantly over control. There was a significant effect of combinations of nutrients on seed index. The maximum mean seed index (14.00 g/100 seed) was recorded with the combination of 20:60:20, which was significantly superior over rest of the treatments.

The effect of fertilizer application on the growth parameters of various crops is well documented in the literature. The differential growth response with combination of major nutrients appears to be on account of interactive effect of nutrients. The correlations worked out between the seed and straw yield and the yield attributing factors (branches/plant, pods/plant and seed index) showed positive values, but only pods/plant showed significant relationship for seed (r = 0.757**) and straw yield (r =0.813**). The results are in agreement with Rosalind *et al.* (2001) and James *et al.* (1999).

Effect on yield and harvest index

Application of any combination of N: P_2O_5: K_2O per hectare resulted in significant seed yield enhancement to the extent of 20.2 to 51.2 per cent over control (Table 1). Maximum mean soybean seed yield (2311 kg/ha) was recorded with the application of 20:60:40 kg of N: P_2O_5: K_2O per hectare which was significantly higher over control, 20:40:20, 20:40:40, 40:40:20 and 40:40:40 kg N: P_2O_5: K_2O per hectare. The extent of increase was 51.2, 25.8, 16.6, 19.7 and 13.1 per cent, respectively.

Straw yield of soybean also recorded numerical increase (5.0 to 32.0%) over control consequent upon application of various combinations of major nutrients, however, significant differences as compared to control were associated with most of the combinations except application of 20:40:20 and 20:40:40 kg N: P_2O_5: K_2O per hectare. The maximum straw yield was observed with 40:80:40 combination (Table 1).

In general, application of different combinations of nutrients enhanced the harvest index (HI) of soybean. The maximum mean HI was recorded with 20:40:40 (49.2%) which was significantly higher than control (44.8 %) along with other combinations except 20:40:20 (45.7 %), 40:40:40 (46.97 %) and 40:80:40 (46.45 %).

The yield expression by different combinations is a result of combined effect of yield attributing parameters like branches per plant, pods per plant and the seed index. In the present set of experimentation, although the pods per plant (r= 0.757** and 0.813**) appear to have played major role, the out come in

Table 1. Effect of nutrient levels on yield attributes, yield, harvest index, net returns and B: C ratio (pooled 2 years data)

Treatment (N: P_2O_5: K_2O kg/ha)	Plant height (cm)	Branches (No./ plant)	Pods (No./ plant)	Seed Index (g/100 seeds)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Net returns (Rs./ha)	B:C ratio
Control	46.0	3.0	49.3	11.5	1528	1868	44.80	12721	2.78
20:40:20	49.4	4.2	59.6	13.2	1837	1982	45.67	15671	2.91
20:40:40	50.8	4.1	54.7	12.6	1981	2126	49.15	17422	3.09
20:60:20	50.6	3.7	57.3	14.0	2172	2310	48.17	19704	3.31
20:60:40	52.7	4.1	58.8	13.3	2311	2462	47.64	21389	3.47
20:80:20	51.3	4.2	55.5	13.5	2213	2366	48.04	19915	3.25
20:80:40	51.8	3.9	53.2	12.0	2172	2290	48.80	19259	3.15
40:40:20	52.8	3.6	53.6	12.7	1931	2252	47.75	16610	2.96
40:40:40	52.0	4.5	61.1	13.2	2043	2290	46.97	17936	3.08
40:60:20	54.7	3.9	54.7	13.5	2292	2390	47.53	20980	3.38
40:60:40	56.9	3.9	54.8	13.7	2292	2424	48.04	20981	3.35
40:80:20	52.3	4.3	58.5	13.0	2216	2463	48.56	19676	3.16
40:80:40	57.0	4.1	55.2	11.4	2145	2466	46.45	18617	3.01
SEm (±)	1.60	0.33	3.04	0.03	46.94	73.13	0.68	345.09	0.03
CD (P=0.05)	**6.06**	**1.23**	**NS**	**0.11**	**177.3**	**276.2**	**2.57**	**1303.4**	**0.113**

terms of yield is the cumulative effect. These yield attributing characters might have been triggered by balanced application of fertilizers leading to overall biomass production and enhanced yield (Lamond and Wesley, 2001; Hegde and Sudhakara Babu, 2004 and Singh *et al.,* 2006). The results obtained in the present studies also gain support from the findings under the long term fertilizer experiments on soybean based cropping system (Anonymous, 1988-89).

Economic evaluation

The economic evaluation, in general, revealed that the mean net returns by adopting any of the combinations of major nutrient employed in the study (Rs. 15671 to 21389/ha) increased substantially over control (Rs.12721/ha). The maximum mean net returns were associated with the treatment 20:60:40 kg N: P_2O_5: K_2O per hectare, which was significantly higher than rest of the treatments except 20:60:40, 40:60:20 and 40:60:40 (Table 1). Similarly, the maximum mean B: C ratio (3.47) was associated with the combination of 20:60:40 kg N: P_2O_5: K_2O per hectare.

Overall examination of the results of the study brings out that the maximum advantage can be obtained by resorting to application of N: P_2O_5: K_2O per hectare in the combination of 20:60:40 for soybean cultivation on Vertisols and associated soils without compromising the productivity. In view of above, the present recommendation of combination of 20:60:20 kg N: P_2O_5: K_2O per hectare is required to be modified to the extent of doubling the recommended quantities of potassium.

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Effect of Herbicidal Weed Control on Weed Dynamics and Yield of Soybean [*Glycine max* (L.) Merrill]

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ABSTRACT

Field experiments were conducted at Research Farm of National Research Centre for Soybean, Indore (Madhya Pradesh) during kharif *seasons of 1999 and 2000 to study the efficacy of herbicidal weed control in soybean. The total density of weeds as well as their total dry biomass was minimum at 30 days after sowing (DAS) under pre-emergence application of metolachlor (750 ml/ha) but at 60 DAS, the post-emergence application of imazamox + imazethethapyr (800 ml/ha) was found more effective. Among the post-emergence herbicides, quizalofop ethyl and quizalofop-p-tefuril significantly reduced the growth of monocots while imazamox and imazamox + imazethapyr paralyzed the dicot weeds. The seed and straw yields were higher under imazamox + imazethapyr (800 ml/ha) and quizalofop ethyl (50 g/ha) being comparable to two hand-weeding. The increase in seed yield on account of containing weeds recorded was 56 per cent.*

Key words: Herbicidal, soybean, weed dynamics

Soybean [*Glycine max* (L.) Merrill] is a predominantly rainy season crop in Central India and particularly in Madhya Pradesh. The annual loss in agricultural production due to weeds is around 45 per cent in India (Mukhopadhayay, 1992) but in soybean the yield losses ranged between 35 and 77 per cent (Tiwari and Kurchania, 1990; Chandel and Saxena, 1988 and Billore *et al*, 1999) depending on type of weeds, intensity and duration of crop-weed competition during crop season. The critical period of crop-weed competition in soybean is reported to be first 45 days after sowing (Prabhakar *et al.*, 1992). Therefore, it is necessary to keep the crop weed free during this period for achieving the optimum yield. Since the information on the efficacy of new herbicides is very meager, therefore, the present investigation was undertaken.

MATERIAL AND METHODS

Field experiments were conducted at Research Farm of National Research Centre for Soybean, Indore (Madhya Pradesh) for two consecutive years during *kharif* seasons of 1999 and 2000. The experimental soils belonged to Typic Haplusterts and analyzed: pH 8.2,

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available N (232 kg/ha), available P (10.85 kg/ha) and available K (404 kg/ha). A total of 10 treatments comprised of alachlor @ 2.0 kg /ha as pre-emergence (PE), S-metolachlor @ 0.50 kg/ha as PE, S-metolachlor @ 0.75 /ha as PE, quizalofop ethyl @ 37.50 g/ha as post-emergence (POE), quizalofop ethyl @ 50 g/ha as POE, quizalofop-p-tefuril @ 50 g/ha as POE, imazamox @ 40 g/ha as POE, imazamox + imazethapyr @ 800 ml/ha as POE, two hand weeding at 3rd and 6th weeks after sowing and weedy check were replicated thrice under randomized block design. Soybean *cv* JS 335 was sown on 26th and 29th June and harvested on 22nd and 16th October during 1999 and 2000, respectively. The crop received recommended level of fertilization (20:26.6:17 kg NPK/ha). Species-wise weed count and their dry biomass were recorded at 30 and 60 days after sowing (DAS).

RESULTS AND DISCUSSION

Weed density and their dry biomass

Euphorbia geniculata, *Digera arvensis*, *Aclypha indica*, *Eclipta alba* and *Physalis minima* among dicot while *Echinocloa* spp., *Cynodon dactylon* and *Cyperus rotundus* among monocot were dominant weed species in soybean. Weed management was most efficient in cultural control by way of two hand-weeding at 3rd and 6th week after sowing as indicated by weed count as well as total weed dry biomass (Table 1). At 30 DAS, the POE application of mix formulation of imazamox plus imazethapyr, imazamox, quizalofop-p-tefuril and both the levels of quizalofop ethyl failed to contain the dicot weeds. While both the PE applied herbicides namely alachlor and s-metolachlor were found effective against both dicot as well as monocot weeds. The trend visualized in case of weed count was further confirmed when dry biomass of weeds was considered. Better weed control by PE herbicides was reported earlier (Rao, 2000) and can be attributed to the limited or no options of POE herbicides available to soybean growers. Moreover, the POE herbicides were applied only 20 days after sowing and the time gap between application and expression of effect at the time of observation was limited. This may be the reason for better control of weeds by POE herbicides at observations recorded at 60 days after sowing.

At 60 days, the scenario was different than observed at 30 days after sowing. Among herbicides applied as POE, imazamox and imazamox plus imazethapyr significantly reduced the dicot and monocot weeds (Table 2). The remaining two herbicides *i.e.* quizalofop ethyl at both the levels and quizalofop-p-tefuril applied as POE were confined to the control of monocots only. The effect of herbicides applied as pre-emergence was subdued at this belated stage, which may possibly be on account of longer period after application and restricted effective residual period. In general, the performance of PE applied herbicides to contain monocot weeds was relatively lower than all the POE applied herbicides. These results have further been confirmed by Meena (2004) and Singh (2005) in

Table 1. Effect of different weed management treatments on weed count (no./m²) and dry biomass (g/m²) of dicot and monocot weed species at 30 days after sowing in soybean

Treatment	Dicot weeds												Monocot weeds					
	Euphorbia geniculata		*Digera arvensis*		*lypha indica*		*Eclipta alba*		*Physalis minima*		**Other dicot**		*Echinocloa spp.*		*Cyperus rotundus*		*Cynodon dactylon*	
	No/m²	**g/m²**	**No/m²**	**g/m²**	**No/m²**	**g/m²**	**No/m²**	**g/m²**	**No/m²**	**g/m²**	**No/m²**	**g/m²**	**No/m²**	**g/m²**	**No/m²**	**g/m²**	**No/m²**	**g/m²**
Alachlor @ 2 kg/ha as pre-emergence	33.3	10.8	17.2	12.7	5.3	6.0	9.3	7.8	7.8	6.5	12.5	10.4	9.3	8.6	7.8	4.2	12.5	8.4
S-Metolachlor @ 500 g/ha as pre-emergence	37.2	12.0	17.5	13.3	5.3	6.0	9.8	8.2	7.3	6.1	10.8	9.0	9.8	8.8	7.3	5.1	10.8	9.4
S-Metolachlor @ 750 g/ha as pre-emergence	33.7	10.9	19.3	12.6	4.7	5.2	8.8	7.4	7.5	6.3	11.3	9.4	8.8	7.5	7.5	4.2	11.3	8.2
Quizalofop ethyl @ 37.5 g/ha as post-emergence	53.7	17.3	24.3	18.5	13.3	14.8	14.3	12.0	15.2	12.6	17.8	14.9	14.3	34.2	15.2	18.2	17.8	18.4
Quizalofop ethyl @ 50.0 g/ha as post-emergence	49.8	16.1	22.7	17.7	13.5	15.0	15.0	12.5	15.2	12.6	17.7	14.7	15.0	34.8	15.2	18.0	17.7	17.5
Quizalofop-p-tefuril @ 50.0 g/ha as post-emergence	54.0	17.4	22.2	17.8	14.0	15.6	14.3	11.9	15.8	13.2	18.2	15.1	14.3	34.2	15.8	19.8	18.2	17.7
Imazamox @ 40 g/ha as post-emergence	50.3	16.2	22.0	16.6	13.3	14.8	15.0	12.5	15.7	13.1	19.0	15.8	15.0	33.8	15.7	18.2	19.0	19.0
Imazamox + Imazethapyr @ 800 ml/ha as post-emergence	53.8	17.4	14.3	18.4	13.8	15.4	14.5	12.1	15.2	12.7	18.0	15.0	14.5	33.0	15.2	19.4	18.0	19.0
Two hand weeding	5.0	1.6	14.0	3.0	2.5	2.8	2.2	1.8	2.5	2.1	4.2	3.5	2.2	6.1	2.5	2.9	4.2	4.4
Weedy check	54.7	17.6	37.0	18.4	13.8	15.4	14.7	12.2	15.0	12.5	19.7	16.4	14.7	32.1	15.0	19.4	19.7	20.0
CD (P=0.05)	**7.1**	**1.5**	**3.4**	**2.1**	**1.8**	**1.7**	**2.1**	**1.4**	**1.9**	**1.6**	**2.3**	**1.5**	**2.1**	**2.6**	**1.9**	**2.1**	**2.3**	**2.3**

Table 2. Effect of different weed management treatments on weed count (no./m²) and dry biomass (g/m²) of dicot and monocot weed species at 60 days after sowing in soybean

Treatment	Dicot weeds												Monocot weeds					
	Euphorbia eniculata		*Digera arvensis*		*Aclypha indica*		*Eclipta alba*		*Physalis minima*		Other dicot		*Echinocloa spp.*		*Cyperus rotundus*		*Cynodon dactylon*	
	No/m²	**g/m²**	**No/m²**	**g/m²**	**No/m²**	**g/m²**	**No/m²**	**g/m²**	**No/m²**	**g/m²**	**No/m²**	**g/m²**	**No/m²**	**g/m²**	**No/m²**	**g/m²**	**No/m²**	**g/m²**
Alachlor @ 2 kg/ha as pre-emergence	48.5	15.5	20.5	15.8	9.8	11.2	15.8	12.6	13.0	11.2	18.5	15.7	14.3	18.0	12.5	15.7	14.7	18.4
S-Metolachlor @ 500 g/ha as pre-emergence	50.7	15.9	20.2	15.5	10.0	11.8	15.7	13.1	13.5	11.6	19.7	16.7	14.8	18.6	12.8	16.1	15.0	18.8
S-Metolachlor @ 750 g/ha as pre-emergence	47.8	15.3	19.5	15.0	9.3	10.9	15.3	12.1	12.5	10.8	19.5	15.6	13.5	16.9	12.5	15.6	14.0	17.5
Quizalofop ethyl @ 37.5 g/ha as post-emergence	54.0	16.9	24.5	18.4	15.7	17.4	19.7	16.9	19.2	16.2	23.2	19.3	8.8	12.4	8.3	11.3	9.5	12.6
Quizalofop ethyl @ 50.0 g/ha as post-emergence	54.0	16.9	22.7	17.6	14.3	16.0	19.3	16.2	19.2	15.9	22.2	18.8	6.7	11.4	5.8	10.6	7.8	10.9
Quizalofop-p-tefuril @ 50.0 g/ha as post-emergence	54.0	16.9	24.7	18.0	16.2	18.0	21.2	17.5	20.8	17.4	24.3	20.3	8.2	12.1	7.8	11.5	7.7	11.7
Imazamox @ 40 g/ha as post-emergence	16.2	5.2	15.0	11.3	7.5	7.2	8.0	6.1	9.2	7.4	9.5	7.9	6.5	8.1	6.7	7.9	7.0	8.0
Imazamox + Imazethapyr @ 800 ml/ha as post-emergence	7.7	2.5	9.5	7.3	5.0	5.6	6.2	5.3	5.0	4.2	7.5	6.3	4.7	5.9	4.0	5.4	6.3	7.1
Two hand weeding	5.2	1.7	7.0	5.4	4.7	5.2	4.3	4.3	4.0	3.3	7.3	6.1	4.5	5.7	3.8	5.2	5.8	6.7
Weedy check	65.5	21.1	32.5	25.0	23.8	26.5	25.7	20.6	27.2	22.6	31.0	25.8	37.7	47.1	26.5	33.2	26.0	32.5
CD (P=0.05)	**5.2**	**1.6**	**3.1**	**1.6**	**2.0**	**2.2**	**2.2**	**1.6**	**2.2**	**1.7**	**3.7**	**1.9**	1.9	**1.9**	2.0	**1.8**	1.9	**1.8**

Table 3. Effect of different weed management treatments on seed yield, straw yield and harvest index of soybean

Treatment	Seed yield (kg/ha)			Straw yield (kg/ha)			Harvest index (%)		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
Alachlor @ 2 kg/ha as pre-emergence	2160	1527	1844	2726	2689	2708	44.20	36.21	40.50
S-Metolachlor @ 500 g/ha as pre-emergence	2198	1585	1892	2676	2583	2630	45.09	38.02	41.84
S-Metolachlor @ 750 g/ha as pre-emergence	2401	1439	1920	2841	2750	2796	45.80	34.35	40.71
Quizalofop ethyl @ 37.5 g/ha as post-emergence	2315	1690	2003	2981	2884	2933	43.71	36.95	40.58
Quizalofop ethyl @ 50.0 g/ha as post-emergence	2259	1842	2051	3549	3487	3518	38.89	34.57	36.83
Quizalofop-p-tefuril @ 50.0 g/ha as post-emergence	2272	1640	1956	3232	3096	3164	41.28	34.63	38.20
Imazamox @ 40 g/ha as post-emergence	2062	1662	1862	3382	3297	3340	37.88	33.51	35.79
Imazamox + Imazethapyr @ 800 ml/ha as post-emergence	2278	1728	2003	3856	3783	3820	37.14	31.36	34.39
Two hand weeding	2407	1953	2180	4019	3901	3960	37.45	33.36	35.50
Weedy check	1704	1083	1394	2247	2187	2217	35.26	35.02	35.14
CD (P=0.05)	**435**	**254.6**	**345**	**790.9**	**702**	**510**	**NS**	**2.71**	**2.01**

subsequent experimentation.

The effective weed management, particularly within first 40 to 45 days is most critical and later the crop canopy by and large keeps the weed count low in soybean, can work out to be a tool to curtail the substantial losses in yield due to weed infestation. The variation in efficiency in weed management related to mode and time of application of herbicides and the selectivity of herbicides to control specific group or species of weeds provides adequate opportunity to contain weed infestation in soybean fields.

Seed and straw yield and harvest index

All the pre- and post-emergence herbicides and two hand weeding significantly enhanced the soybean seed and straw yield as well as harvest index (Table 3) as compared to control. The average highest seed yield (2180 kg/ha) was recorded in two hand-weeding which remained at par with all other herbicidal treatments (1844 to 2051 kg/ha). All the weed management treatments were significantly superior (yielding 32 to 56%) higher than control (1394 kg/ha). In general, use of POE herbicides led to comparatively higher seed yield levels than PE herbicides. Similar was the trend observed in case of straw yield also. However, the higher harvest index was recorded in case of PE herbicides and quizalfop ethyl (@ 37.5 g/ha) as POE. Enhanced seed yield of soybean has been recorded when weed management was done with alachlor (Jadhav *et al.*, 2003 and Singh, 2004) and quzalafop ethyl (Meena, 2004 and Johnson *et al.*, 1998).

Based on the results accumulated over two years, it can be concluded that (i) the pre-and post-emergence herbicides were effective in weed management in soybean, (ii) post-emergence herbicides were more effective than pre-emergence ones, (iii) POE applications of imazamox and imazamox plus imazethapyr were effective against monocot as well as dicot weeds whereas quazalofop ethyl and quizalofop-p-tefuril were effective in control of monocot weeds only, and (iv) The increase in seed yield on account of containing weeds recorded was 56 per cent.

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Phytotonic and Phytotoxic Effects of Some Novel Insecticides on Soybean, *Glycine max* (L.) Merrill

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ABSTRACT

Field experiments were conducted during kharif *2004 and 2005 at Rajasthan College of Agriculture, Udaipur, for testing the phytotonic and phytotoxic effects of some newer insecticides on soybean plants. All the insecticidal treatments produced phytotonic effects and did not show any phytotoxic lesions on soybean plants. Indoxacarb and lambda-cyhalothrin had highly boosting/phytotonic effect on soybean plants in increasing the plant height, average number of trifoliate leaves, average length of tap root, number of pods per plant and number of grains per plant and followed by triazophos 40 EC.*

Key words: Soybean, phytotonic, phytotoxic, phytotoxicity

Soybean, *Glycine max* (L.) Merrill, is an important *kharif* oilseed crop grown in the southeast part of Rajasthan. The crop is attacked by many field insects due to its luxuriant growth and green foliage with high nutritive value. The liquid formulations of chemical insecticides against the soybean insect-pests are used extensively. The chemical insecticides besides controlling the target pests also induce direct or indirect effects on growth and development of crop plant. Earlier, Thirumala Rao *et al*. (1964) reported increased vegetative growth of brinjal and okra plants treated with DDT. The study was, therefore, conducted to quantify the phytotonic effects of some newer groups of insecticides in soybean plants.

MATERIAL AND METHODS

The effect on plant health of some newer insecticides *viz*., triazophos 20 EC, triazophos 40 EC, lambda-cyhalothrin 5 EC, indoxacarb 14.5 EC, acetamiprid 20 SL each at two doses with endosulfan 35 EC as standard check were tested on soybean crop.

The experiments were conducted at two locations *i.e.* Agronomy Farm, Rajasthan College of Agriculture, Udaipur and Agricultural Research Station, Banswara during *kharif* 2004 and 2005 in

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a randomized block design with 12 treatments (Table 1) replicated 3 times and individual plot measuring 12 m^2. Ten plants were randomly selected from each plot and observation were recorded 90 days after germination (DAG) in both years on average height of plant (cm), numbers of trifoliate leaves, length of tap root (cm), numbers of pods, numbers of grains of each plant.

The phytotoxicity, the burning symptoms and lesion, produced on the plant, were observed and classified as recommended by Kavadia and Gupta (1986) as under.

Mild (+)	:	Few lesions on leaflets or less than 20 per cent leaflets of plant showing burning symptoms
Moderate (++)	:	Between 20-50 per cent leaflets of the plant showing burning symptoms
Severe (+++)	:	More or less all the leaflets of the plant showing burning symptoms (50-100%)
Most severe (++++)	:	Complete mortality of the plant

RESULTS AND DISCUSSION

The results revealed that all the parameters of plant growth showed significant differences between treated and untreated plots (Table 1 and 2). The plants treated with indoxacarb @ 100 a.i./ha during *kharif* 2004 showed maximum plant height (62.74 cm) which was statistically at par with lambda-cyhalothrin @ 20 g a.i./ha (60.20 cm), lambda-cyhalothrin @ 40 g a.i./ha (61.54 cm) and endosulfan (59.72 cm). The similar results were also observed during *kharif* 2005, where indoxacarb @ 100 g a.i./ha was found superior and gave 61.96 cm height to soybean plants. Maximum number of trifoliate leaves (26.67 and 26.67) was recorded in indoxacarb 100 g a.i./ha during *kharif* 2004 and 2005, respectively and was at par with its lower dose indoxacarb 50 g a.i./ha (24.33 and 24.87) and lambda-cyhalothrin @ 40 g a.i./ha (24.20 and 25.40) during 2004 and 2005, respectively. Minimum number of average trifoliate leaves (16.67 and 15.87) was found in control plots in both the years.

Maximum average length of tap root was recorded in lambda-cyhalothrin @ 40 g a.i./ha 12.40 and 14.40 cm during *kharif* 2004 and 2005, respectively. The treatments triazophos 20 EC, acetamiprid, triazophos 40 EC and endosulfan were found *at par* in average length of tap root during both the experimental years. In control plots 8.10 and 9.70 cm length of tap root was observed in both the years. Maximum numbers of pods 62.13 and 63.33 per plant were recorded at two doses of lambda-cyhalothrin at 20 and 40 g a.i./ha, respectively which was statistically similar to indoxacarb at 50 and 100 g a.i./ha with 64.60 and 62.20 pods per plant, respectively during *kharif*, 2004. These treatments were also found superior during 2005 as well.

During *kharif* 2004 and 2005 maximum numbers of grains per plant

Table 1. Phytotonic effects of some insecticides on soybean

Treatments	Dose (g a.i./ ha)	Average plant height (cm)		Average trifoliate leaves (No)		Average length of tap root (cm)		Pods per plant (No)		Grains per plant (No)	
		2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Lambda-cyhalothrin 5 EC	20	60.20	60.07	22.40	23.53	11.30	13.50	62.13	64.67	147.67	150.13
Lambda-cyhalothrin 5 EC	40	61.54	61.71	24.20	25.40	12.40	14.40	63.33	66.80	149.80	152.53
Indoxacarb 14.5 EC	50	59.12	59.52	24.33	24.87	10.40	11.30	64.60	64.53	144.20	149.60
Indoxacarb 14.5 EC	100	62.74	61.96	26.67	26.67	11.20	13.60	62.20	65.07	145.33	152.40
Triazophos 20 EC	150	53.46	54.10	18.00	19.33	10.20	11.50	58.13	59.13	132.00	136.87
Triazophos 20 EC	300	54.18	54.39	21.80	21.00	10.50	12.10	59.40	60.60	134.53	136.93
Acetamiprid 20 SL	40	56.10	57.85	22.40	21.20	10.10	11.50	59.67	58.80	137.73	142.20
Acetamiprid 20 SL	80	57.34	59.20	23.67	23.93	11.10	12.87	58.80	60.20	138.67	144.27
Triazophos 40 EC	150	54.15	55.22	21.27	20.00	10.50	11.90	59.13	61.40	139.40	146.53
Triazophos 40 EC	300	55.22	56.02	22.93	21.27	10.60	12.30	60.40	63.33	142.60	150.13
Endosulfan 35 EC	350	59.72	57.48	23.33	25.73	10.30	11.50	54.33	57.13	130.67	133.67
Untreated control	---	49.21	47.34	16.67	15.87	8.10	9.70	44.20	46.13	97.27	101.13
S Em (±)		1.19	1.06	1.24	0.98	0.38	0.84	1.68	1.36	2.74	2.42
CD (P = 0.05)		**3.50**	**3.11**	**3.65**	**2.87**	**1.11**	**2.48**	**4.93**	**4.00**	**8.05**	**7.10**

(149.80 and 152.53) were observed in the treatment lambda-cyhalothrin @ 40 g a.i./ha, respectively which was at par with its lower dose (147.67 and 150.53), indoxacarb 50 g a.i./ha (144.20 and 149.60) and indoxacarb at 100 g a.i./ha (145.33 and 152.40), respectively. In untreated control, 97.27 and 101.13 grain per plant were observed in 2004 and 2005, respectively. Thus, in the present investigation, indoxacarb and lambda-cyhalothrin had boosting effect on plant growth which was very well realized through increase in plant height, length of tap root, average number of trifoliate leaves, number of pods per plant and number of grains per plant.

Similar phytotonic effects have been reported by Bhattacharya *et al*. (1989) on mustard crop by the use of aldicarb 10 G applied at 3 kg a.i./ha. Patel and Srivastava (1990) observed the phytotonic effect on cowpea and green gram and revealed that carbofuran and carbosulfan significantly improved plant growth as compared to phorate and mephosfolan. Chander and Singh (1993) also reported that monocrotophos, dimethoate and chlorphriphos had boosting effect on green gram. This finding was also supported by Yein and Nath (1995) on green gram, Mandal *et al*. (1999) on brinjal and Prasanna *et al*. (2004) on cotton crop.

In present investigation, no visual phytotoxic effect in the form of burning symptoms and lesions were observed from any of the insecticidal treatments. Even indoxacarb and lambda-cyhalothrin at their higher dose of 100 g and 40 g a.i./ha, respectively did not produce any lesions or burning effects on leaflets. Wilson and Trevenna (1986) reported that lambda-cyhalothrin caused no phytotoxicity on vegetables and fruits. Choudhary (1990) also reported that normal doses of endosulfan, monocrotophos, fenvalerate and cypermethrine did not cause any phytotoxic effects while very high abnormal doses produce mild phytotoxic symptoms on soybean plants.

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Soybean Research, 5 : 38-42 (2007)

Studies on the Biology of Pulse Beetle, *Callosobruchus maculates* (Fab.) (Coleoptera: Bruchidae)[1]

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ABSTRACT

The studies on the biology of Collosobruchus maculatus *Fab. on the grains of soybean variety JS 335 revealed oviposition period of 4-7 days (av. 5 days), larval plus pupal period of 33-37 days (av. 35.2 days) and total developmental period of 40-50 days (av. 43.9 days). A single female laid 65-72 eggs (av. 59.5) on soybean seeds. The longevity of male and female (unmated) ranged between 10 to 15 days (av. 13 days) and 8 to 14 days (av. 11.5 days), respectively.*

Key words: Biology, pulse beetle, soybean

Soybean [*Glycine max* (L.) Merrill] has emerged as number one oil seed crop of India. However, the crop suffers heavily by a number of insect-pests, both during pre- and post-harvest stages. Bruchids are known to inflict heavy quantitative and qualitative losses to pulses during storage. *Callosobruchus maculatus* (Fab). is a major storage pest of pulses and is also known to damage soybean as well (Jay *et al.*, 1973). The life cycle of *C. maculatus* has been studied on various pulses (Raina, 1970 and Dhepe *et al.*, 1993) but information on its development on soybean seeds is lacking.

In order to combat loss of pulse grains due to pulse beetle infestation, the knowledge of the life-history is necessary to have a thorough understanding of the conditions favourable to the pest. The knowledge of the weaker links in its life-history could be taken advantage of, in the effective management of the pest. Thus, it was considered imperative to study the biology of *C. maculatus* on most popular soybean variety JS 335.

MATERIAL AND METHODS

A nucleus culture of *Callosobruchus maculatus* (Fab.) was obtained from National Research Centre for Soybean, Indore and stock culture of test insect was maintained in the laboratory to get a regular supply of adults for experimentation. The biology of *C. maculatus* was studied on soybean variety

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JS 335 in the laboratory of Zoology Department, Government College, Kota in the month of August-September during 2002 and 2003 at ambient room temperature. The observations on the fecundity, incubation period, larval and pupal period, total development period, sex ratio and longevity of adults were recorded.

Ten pairs of newly emerged adults (0-24 hr old) from the stock culture were released in each of the three jars containing 100 g grains of variety JS 335. The eggs laid were counted daily with the help of lens and egg laid grains were taken out and kept separately in vials and marked accordingly till the date of last oviposition to record the oviposition period. The dates of egg laying and hatching were recorded to find out the incubation period. Hatched eggs were identified by the presence of larval frass which caused the eggs to turn into a white spot as larvae bore into the seed (Giga *et al.,* 1993). The larvae remained inside the grain and appearance of a capped exit hole on the grain showed the pupal stage. The dates of adult emergence were noted to work out the larval plus pupal period. Daily observations were recorded on the emergence of adults. The average period for complete development was calculated by taking the weighted means of the time required for egg hatching, larval plus pupal period. Longevity of male and female adults (unmated) was determined by recording the date of their emergence from pupae till the date of normal death.

RESULTS AND DISCUSSION

The observations revealed that newly emerged adults mated after a few hours of their emergence from the seeds. The adults came on the surface layers of grains for mating which might be perhaps in order to get larger free area. This corroborates with the findings of Pandey and Singh (1997), Singh and Kumari (2000) and Vyas and Motka (2005). The mating period ranged from 3 to 7 minutes. The adults mated several times in their life span. The female laid oval (planoconvex) and translucent eggs singly glued to the surface the grain. The oviposition was at random; sometimes 3 to 4 eggs were laid on a single seed, out of which normally only one hatched. Similar observations reported by Raina (1970) on mung and Dick and Credland (1984)) on cowpea seeds, support the present findings.

The newly laid eggs were shiny, creamy white in colour which turned darker with the lapse of time. After hatching, the eggs looked like opaque white spots due to presence of larval frass. Giga *et al*. (1993) too reported change in colour of eggs with passage of time and finally the white spot indicated the presence of larval frass.

The oviposition period of *C. maculatus* ranged from 4 to 7 days with an average of 6.5 days in the present investigation (Table 1). The findings are in conformity with those of Gokhale and Srivastava (1975) and Singh and Pandey (1994) who reported average oviposition period of 5 and 4 to 6 days, respectively.

The data presented in table 1 indicated that a female of *C. maculatus* laid 42-72 eggs (av. 59.5) on soybean seeds. The present findings corroborate with those of Pandey and Singh (1997) and Singh and Kumari (2000) who noted an average of 70 to 74 eggs on different pulses. On the contrary, Dwivedi and Sharma (1993) reported 22 eggs on soybean seeds. This difference may probably be due to the change in substrate, varietal difference, and climatic conditions of the locality. The incubation period of *C. maculates* on soybean seeds ranged from 3 to 6 days with an average of 4.5 days. Similarly, incubation period of 4 days on green gram (Raina, 1970), 4.6 days on red gram (Dhepe *et al.*, 1993), 4-5 days on urd and chickpea seeds (Pandey and Singh, 1997) and 5.6 days on soybean (Singh, 1962) have been reported which support the present investigation.

Table 1. Biology of *C. maculatus* on soybean seeds under laboratory condition during 2002 and 2003

Parameters examined*	***2002***		**2003**	
	Range	*Mean + SEm*	*Range*	*Mean + SEm*
Number of eggs laid/female (fecundity)	45-70	57.5 + 1.69	48-72	61.6 + 1.72
Oviposition period (days)	4-7	6.5 + 0.71	4-7	6.1 + 0.67
Incubation period (days)	3-5	4 + 0.64	3-6	4.9 + 0.71
Combined larval and pupal period (days)	33-35	34.5 + 0.16	34-37	35.9 + 0.12
Total development period (egg to adult) (days)	40-47	43.22 + 0.85	41-50	44.4 + 0.74
Longevity of adults (days)				
a. Male	10-15	13.6 + 0.37	11-15	12.5 + 0.31
b. Female	8-13	11.3 + 0.76	9-14	11.7 + 0.83
Sex ratio (Male : Female)	1:0.7	-	1:0.8	-

**Data based on 10 pairs of adults.*

In the present study, the larval and pupal periods took 33 to 37 days (average 35.2 days), while total development of *C. maculatus* took 40 to 50 days (average 43.85 days) on soybean seeds. Singh (1962) recorded 35.2 days larval and pupal periods of *C. chinensis* on soybean seeds, which corroborate the present findings. Dwivedi and Sharma (1993) noted average development period of 37 days for *C. chinensis* on soybean seeds, while Kim and Choi (1987) recorded development period averaged, 46 and 34 days on soybean and black soybean, respectively, which partially confirms the present findings.

The longevity of (unmated) male and female ranged between 10 to 15 days (average 13 days) and 8 to 14 days (average 11.5 days), respectively. It is evident that the life span of male beetle was longer in comparison to that of female which was endorsed by Singh and Borah (2001).

It is, therefore, concluded that despite the inhibiting influence of saponins (Applebaum *et al.*, 1965), *C. maculatus* successfully survives and completes its life cycle on soybean and thus considered as most serious insect-pest under storage conditions. It also warrants proper and suitable management measures to be implemented to prevent losses due to *C. maculatus*.

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Soybean Research, 5 : 43-49 (2007)

Profitability and Input Use Efficiency in Cultivation of Soybean in *Malwa* Plateau of Madhya Pradesh

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ABSTRACT

Madhya Pradesh is designated as the 'Soya State' as it has major share in area (67%) and production (57%) of soybean in India. In this study, an effort is made to examine the profitability and input use efficiency in cultivation of soybean at different size of farms in soybean producing district (Ujjain) of Malwa *plateau agro-climatic zone of Madhya Pradesh which is selected purposively having maximum area under cultivation of soybean in the state. The sampling unit comprised of randomly selected 240 farm holdings (110 small, 70 medium and 60 large). The required primary data related to agricultural year 2004-05 were collected through survey method using pre-tested interview schedule. It is observed from the analyzed data that the total cost of cultivation was maximum on large (Rs 8574.80/ha) as compared to medium (Rs 8538.19/ha) and small (Rs 7680.73) size of farms revealing that soybean production involves high expenditure on purchased inputs viz., seed, fertilizers, insecticides and hired mechanical power. The maximum gross income was found on medium (Rs 13400/ha) followed by large (Rs 12969.50/ha) and small (Rs 11813.00/ha) size of farms. As far as the cost benefit ratio is concerned, it was found to be maximum on medium (1: 1.57), followed by small (1: 1.54) and large (1: 1.51) size of farms. The use of human labour showed positive and significant contributions towards yield of soybean on all sizes except large size of farms. The use of fertilizer and plant protection chemicals showed positive and significant impact on yield on all sizes of farms except large. The other factors of production did not show any positive response towards yield revealing that these factors were not used efficiently by the soybean growers or the quality of the inputs was not up to the mark. The sum of the regression coefficients indicated constant return to scale in all the category of farms. This implies that the further increase in soybean production is possible only through up-gradation of existing production technology either through seed (varietals) replacement coupled with superior inputs, balanced use of fertilizers and judicious farm management practices. This will not only enhance the input use efficiency but will also help to reduce the cost per unit of production of soybean.*

Key words: Soybean, profitability, resource use efficiency

Madhya Pradesh is designated as the 'Soya State' as it has remarkable share in area (67%) and production of soybean (57%) in India. It is a prospective crop in terms of income and export potential and ensures the highest profit among major *kharif* crops of the State (Gautam and Nahatkar, 1993). The adoption of the crop

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has resulted in economic and industrial revolution and has dramatically improved the living standard of farming community that was the worst sufferer of poverty. The major problem in soybean production is stagnant/declining trend in productivity in the country in general and Madhya Pradesh in particular (Nahatkar *et al.*, 2005). This trend may be accounted for poor resource base of the farmers, inefficient use of available resources and non-adoption of improved production techniques for soybean. In the wake of technological advancements and WTO obligations in agriculture, the endeavours are to increase productivity, profitability, adoptability, stability, sustainability and competitiveness of the farm business. Soybean, being the major commercial crop in farm business of the state with high-marketed surplus, needs special attention due to stagnating productivity. In this study, efforts have been made to examine the profitability and input use efficiency in production of soybean at different scales of operation. The results of the study can fruitfully be used for diagnosis of the problem and providing suggestive measures for reducing production cost and increasing profitability from soybean.

MATERIAL AND METHODS

The present study is confined to *Malwa* plateau agro-climatic zone of Madhya Pradesh, which was selected purposively looking to the major revolutions that took place in soybean production in this plateau. Out of nine districts (Ujjain, Indore, Dhar, Shajapur, Dewas, Ratlam, Mandsaur, Nimach and Rajgarh), Ujjain was selected purposively for the study as it accounts for maximum area under soybean in the plateau. Out of seven blocks (Badnagar, Mahidpur, Tarana, Ujjain, Ghatiya, Khachrod and Nagda) in the district, Badnagar was selected purposively on the basis of same criteria. From the list of all the villages along with total number of operational holding and area under soybean, 5 top most soybean growing villages viz.; Palduna, Amla, Kharsod Kalan, Jahangeerpur and Dangwara were selected for the study. Ten per cent of the soybean growers listed was selected randomly from each land holding size groups. Thus, the sampling unit comprised of 240 soybean growers (110 small, 70 medium and 60 large). The cost of cultivation, cost of production, net profit, and cost-benefit ratio were worked out using standard cost and profitability concepts. Input use efficiency in soybean production was worked out using Cobb-Douglas production function. The data was collected from the respondents for the agricultural year 2004-05 through survey method using pre-tested interview schedule.

RESULTS AND DISCUSSION

Cost of cultivation

On an average, growers spend Rs. 5400.96 per hectare on the operational inputs (Cost A_1) in the cultivation of soybean (Table 1). Cost of cultivation was highest on large (Rs 5922.25/ha) followed by medium (Rs 5716.44/ha) and small (Rs

4564.18/ha) size of farm, revealing that it increased with increase in size of holding (Table 2). This implies that the medium and large farmers due to their strong resource base and purchasing power use more inputs especially seed of improved variety as compared to the small ones. Cost A_1 and A_2 are identical on all the farm sizes since none of the farmer lease in the land for soybean cultivation. Cost B_1 was Rs 4923.56, Rs 6148.22 and Rs 6390.07 per hectare, respectively on small, medium and large size of farms and at aggregate level, it was Rs 5820.60 per hectare. Similarly Cost B_2 was Rs 6123.55, Rs 7348.25 and Rs 7590.07 per hectare, respectively on small, medium and large size of farms. The Cost C_1 was found to be highest (Rs 6595.27/ha) on large as compared to medium (Rs 6561.97) and small (Rs. 5782.48/ha) size of farms. Cost C_2 was Rs 6982.48, Rs 7762.00 and Rs 7795.27 per hectare on small, medium and large size of farms, respectively. Cost C_3 (overall total cost) was Rs 7680.73, Rs 8538.19, Rs 8574.80 and Rs 8264.57 per hectare, respectively for small, medium, large and at aggregate level (Table 2). This indicated that soybean production is capital intensive as compared to other *kharif* crops like maize, sorghum etc. The trend of increasing cost with the increase in size of holding reflected towards the capacity of soybean growers to invest more on technological inputs with the increase in size of farms and thus, the general trend of large scale economics does not stand true in case of soybean production. The cost of production also revealed a similar trend indicating that the cost incurred on purchase inputs did not reflect in yield of soybean on different size of holdings. This may be due to managerial problems, quality aspects of inputs, and other soil health and biotic factors which need to be examined in-depth.

Profitability

On an average gross income of Rs 12727.50 per hectare was obtained from cultivation of soybean in the study area. The gross income was found to be maximum on medium (Rs 13400.00/ha) followed by large (Rs 12969.50/ha) and small (Rs.11813.00/ha) size of farms which follows the productivity trend since the sale price of soybean is more or less identical (about Rs 12.40/kg) irrespective of size of holdings. This also reflected towards tendency of sale of produce just after harvesting due to poor hording capacity of the farmers and shortage of storage facilities. The maximum farm investment income was Rs 7683.56 per hectare on medium followed by small (Rs 7248.82/ha) and large (Rs 7047.25/ha) size of farms. Higher family labour income was noted on medium (Rs 6051/ha) as compared to the small (Rs 5689.45/ha) and large (Rs 5379.43/ha) size of farms revealing that the use of family labour was higher on these farms. Due to small holdings, the family labour were employed to other off farm activity in case of small farms and family members of large holding are either engaged in other occupations or for pursuing higher education in urban areas. The maximum net income from cultivation of soybean was found to be more on medium (Rs 4861.81/ha) followed by large (Rs 4394.10/ha) and small (Rs. 4394.70/ha) size of farms, although the differences were insignificant. The maximum cost-benefit ratio was observed on medium (1:1.57) followed by small (1:1.54) and large (1:1.51) size of farms. At aggregate level it was 1:1.54 (Table 3) in the study area revealing that soybean production is cost effective even on consideration of the operational and fixed cost.

Resource Use Efficiency

Efficiency of input use in production of soybean was estimated using Cobb-Douglas production function (Table 4). The values of R^2 (coefficient of multiple determination) ranged between 68 to 82 per cent, which indicated that the Cobb- Douglas production function was best fitted to the dependent and independent variables on yield per hectare (dependent variable). The coefficient of expenses on human labour was observed to be positive and significant. The expenses on fertilizer and insecticides and pesticides were also positive and significant revealing that these inputs contributed significantly towards productivity of soybean in the study area and there is a further scope of increasing productivity by increasing use of these inputs ensuring that the productivity and fertility of soils will be enhanced accordingly along with judicious and balanced use of chemicals. The expenditure on bullock labours, seed, machine labours were positive but insignificant irrespective of size of holding revealing that either these inputs are presently used in excess or the quality and management aspects of these inputs were poor. Use of human labour and insecticides and pesticides on small size of farms and use of fertilizer, insecticides and pesticides on large size of farms showed positive and significant impact on the productivity of soybean. The sum of regression coefficient was about unity irrespective of size of holdings revealing that the constant returns to scale prevailed in soybean production in the study area. This indicated that for increasing soybean production by one per cent, farmers will be required to increase level of all the inputs by one per cent. From the efficiency point of view this is not an economically viable preposition nor technically feasible venture without upgradation of technology in a right way and manner after identifying the managerial, biotic and soil health related constraints (Sharma *et al.,* 2005) because the vast potential exists for increasing soybean production in the State (Gautam *et al.*, 1994; Nahatkar and Mishra, 2004).

In soybean production area, special attention is needed on seed/varietals replacement since at present use efficiency of seed is found to be insignificant. Application of purchased inputs especially seed, fertilizers and insecticides did not reflect towards soybean yield enhancement in the study area, which needs to be analyzed from the quality and managerial point of view.

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Table 1. Details of Cost (Rs/ha) concepts and break-up of cost of cultivation of soybean on different size of farms

Particulars	**Size of Farms**			
	Small	**Medium**	**Large**	**Average**
Hired labour	711.54	1171.05	1243.82	1042.14
Bullock labour	817.98	562.83	346.72	575.84
Machine labour	990.26	1563.08	1689.53	1414.29
Seed	1109.78	1118.76	1301.48	1176.67
Fungicide	8.07	13.40	15.20	12.22
Bio-fertilizer	4.67	11.40	10.32	8.80
Fertilizer and Manure	240.47	420.19	426.51	362.39
Weedicide	121.58	124.08	152.28	132.65
Insecticide	101.81	114.38	125.50	113.90
Depreciation	184.17	274.29	260.56	239.67
Interest on working capital @12%	273.85	342.98	350.33	322.39
Cost A_1	**4564.18**	**5716.44**	**5922.25**	**5400.96**
Rental value of leased land	00.00	00.00	00.00	00.00
Cost A_2	**4564.18**	**5716.44**	**5922.25**	**5400.96**
Interest on fixed capital	359.38	431.78	467.82	419.66
Cost B_1	**4923.56**	**6148.22**	**6390.07**	**5820.62**
Rental value of owned land	1200.00	1200.00	1200.00	1200.00
Cost B_2	**6123.56**	**7348.22**	**7590.07**	**7020.62**
Imputed value of family labour	858.92	413.75	205.20	492.60
Cost C_1	**5782.48**	**6561.97**	**6595.27**	**6313.22**
Cost C_2 (Cost B2 + Family labour)	**6982.48**	**7762.00**	**7795.27**	**7513.25**
Cost C_3 (10% of Cost C2)	**7680.73**	**8538.19**	**8574.80**	**8264.00**

Table 2. Cost (Rs/ha) of cultivation of soybean at different size of farms

Cost concepts	**Size of farms**			**Average**
	Small	**Medium**	**Large**	
Cost A_1	4564.18	5716.44	5922.25	5400.96
	(4.28)	(4.97)	(5.32)	(4.88)
Cost A_2	4564.18	5716.44	5922.25	5400.96
	(4.28)	(4.97)	(5.32)	(4.88)
Cost B_1	4923.56	6148.22	6390.07	5820.62
	(4.67)	(5.39)	(5.83)	(5.31)
Cost B_2	6123.55	7348.22	7590.07	7020.62
	(5.98)	(6.57)	(7.05)	(6.55)
Cost C_1	5782.48	6561.97	6595.27	6313.22
	(5.61)	(5.80)	(6.03)	(5.82)
Cost C_2	6982.48	7762.00	7795.27	7513.25
	(6.92)	(6.97)	(7.25)	(7.05)
Cost C_3	7680.73	8538.19	8574.80	8264.00
	(7.68)	(7.73)	(8.04)	(7.82)

Figure in parenthesis shows cost per kg

Table 3. Profitability (Rs/ha) of soybean at different size of farms

Particulars	Size of farms			
	Small	Medium	**Large**	Average
Quantity of grain (kg/ha)	915	1020	985	973
Price (Rs/kg)	12.20	12.50	12.55	12.42
Quantity of straw material (kg/ha)	1000	1000	935	978
Price (Rs/kg)	6.50	6.50	6.50	6.50
Total value of grain (Rs/ha)	11163.00	12750.00	12361.00	12091.58
Total value of straw materials (Rs/ha)	650.00	650.00	607.75	635.92
Gross income	11813.00	13400.00	12969.50	12727.50
Farm investment income	7248.82	7683.56	7047.25	7326.54
Family labour income	5689.45	6051.78	5379.43	5706.88
Net farm income	4132.27	4861.81	4394.70	4462.93
Cost-benefit ratio at Cost C_3	1:1.54	1:1.57	1:1.51	1:1.54

Table 4. Estimate of Production Function Coefficient on yield of Soybean at different size of farms

Particulars	**Size of farms**			
	Small	**Medium**	**Large**	**Average**
Constant (a)	5.262	2.667	1.176	3.516
Independent Variables				
Human labour (X_1)	0.664**	0.668**	0.198	0.490*
	(0.210)	(0.198)	(0.229)	(0.201)
Bullock labour (X_2)	-0.047	0.030	0.098	0.058
	(0.140)	(0.221)	(0.063)	(0.064)
Seed (X_3)	0.074	0.090	0.703	0.034
	(0.373)	(0.754)	(0.237)	(0.341)
Machine labour (X_4)	0.022	0.085	-0.117	0.016
	(0.070)	(0.170)	(0.170)	(0.66)
Fertilizer (X_5)	0.002	0.063**	0.023*	0.059*
	(0.036)	(0.020)	(0.010)	(0.026)
Insecticides and Pesticides	0.379**	0.006	0.085**	0.070**
(X_6)	(0.078)	(0.071)	(0.023)	(0.026)
Return to scale (Sum of bi)	1.094	0.940	0.990	0.727
Coefficient of multiple determinations (R^2 %)	82	68	74	72

*Figures in parenthesis indicate the standard error of regression coefficient; *Significant on 5% level, * *Significant on 1% level*

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Suitability of Reclaimed Land for Soybean Based Cropping System

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ABSTRACT

Studies conducted between 2003 and 2005 on black soils of Malwa *region brought out that deep tillage plays a vital role in increasing the productivity of the crops through reduced infestation of weeds and increased water retention capacity of soil consequent upon improvement in its physical environment as indicated by lower values in bulk density of soil. This not only led to increasing productivity of soybean but also made the planting of* rabi *crops feasible without pre- sowing irrigation. The studies further revealed that the waste land reclaimed by spreading excavated soil from tank can immediately be brought under cultivation for soybean based cropping system. Successful raising of rainfed soybean (*kharif*) followed by gram (*rabi*) has been demonstrated on such reclaimed land.*

Key words : Soybean, reclaimed land, cropping system

The state of Madhya Pradesh has nearly 7.2 million hectares as waste land (Gupta and Sharma, 2001). An effort to convert a part of this waste land, wherever feasible, to cultivable land will lead to horizontal expansion and increased production of crops. The land covered by Vertisols and associated soils in *Malwa* region of Madhya Pradesh typically encompasses interrupted slopes of the large fields, which are considered to develop erodible velocities of runoff, resulting in severe splash, rill and gully erosion. It has been documented that these black soils are highly prone to water erosion (Sharda, 2007). The loss of soil by erosion and water through runoff also leads to water stress, particularly towards the termination of monsoon needing supplemental irrigation for sustaining crop yields. Similarly the dry-spells during one or other stage of crop growth in *kharif* adversely affect the yields in spite of optimum rainfall. It has been experienced that deep tillage is another viable option to increase the productivity of crops (Anonymous, 1988; Frederick *et al.*, 1998; Wesley and Smith, 1991; Wesley *et al*., 1993; Busscher *et al.,* 2000). This operation may provide better *in situ* moisture conservation in addition to providing the salutary condition for crop growth. The additional advantage of the

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operation is to contain weeds, which are instrumental in lowering the productivity of crops by way of offering severe competition to crop plants for natural resources (Muniyappa *et al*., 1986 and Tiwari *et al*., 1997). Deep tillage also helps in management of certain dominant weeds like *Sacharum spontaneum* (*Kans*), which otherwise uncontrollable even by using herbicides. Deep tillage paves the way for eradication of offshoots of roots of trees on boundary of fields and facilitates smooth tillage operations and avoids the competition with crop plants leading to enhanced productivity. College of Agriculture, Indore, has been putting concerted efforts to demonstrate appropriate technologies of rainfed agriculture to substantiate production of crops in the Indore district under Operational Research Project and ICAR funded ad-hoc research project on rainwater management. The stated site specific problems can be resolved by managing natural resources, increasing *in-situ* soil conservation (Malik *et al*., 1988), through deep tillage operations (Vittal *et al*., 1983 Shrimali *et al*., 2002) and by reclaiming the gullied portion in order to increase the overall productivity in the affected fields. Keeping the above site specific problems in view, the present study was carried out in for four years (2003-05).

MATERIAL AND METHODS

Two villages namely Barlai and Jaitpura (Tehsil Sanver, District Indore) were considered for the study. The soils of these villages belonged to broad group "Vertisols". These soils are characterized by swell-shrink property during wetting and drying. During hot summer months due to high evaporation rate, the cracks of about 5 to l5 cm width and l to 2 m deep are formed. These cracks serve as site for inversion of surface soil layer exposing lower surface for weathering. These cracks vanish on wetting during rainy season.

The study on bringing new area under cultivation was organized at Barlai village. For facilitating the reclamation, the soil from created water harvesting tank was utilized. The soil of this location belonged to Baloda series and classified as clayey, montmorillonitic, non-calcareous, hyperthermic family of typic Haplusterts. This site was utilized for reclaiming waste land by spreading the excavated soil from tank constructed simultaneously for water harvesting. In another study a 4.86 ha area, infested mainly by deep rooted weeds were identified and deep tillage operations were carried out using crawler drawn MB plough and reversible plough. The soil of the area also belonged to Baloda series

To ascertain the effect of tillage to contain weeds on production of crops, studies were under taken at Jaitpura. The soil of the site belonged to Panchderia series and classified as clayey, non-calcareous, hyperthermic family of typic Ustorthent.

The predominant weeds encountered in these villages are *Saccharum spontaneum* (Kans), *Cyperus rotundus* (Motha), *Xanthium strumarium* (Gokharu), *Convolvulus arvensis* (Hirankhuri), *Parthenium hysterophorus* (Gajar ghas), *Sonchus arvensis* (Bawachi), and *Euphorbia geniculata* (Bari Dhudi) *etc.*

Table 1. Physico-chemical properties of different soil series found in these villages

Soil Series	Sub group	Clay %	pH (1:2.5)	EC (1:2.5) (dSm^{-1})	OC (%)	CEC (C mol)	$CaCO_3$ (%)
Baloda	Typic Haplusterts	44.0	8.1	0.20	0.52	40.0	1.0
Panchderia	Vertic Ustorthent	33.0	7.3	0.10	0.82	30.0	-

RESULTS AND DISCUSSION

Bringing new area under cultivation

A suitable site was selected at Barlai village for the construction of a water-harvesting tank utilizing crawler tractor based on various hydro-geo morphological characteristics of each micro watershed. It was ensured that the tank area to be developed lies in the natural drainage lines having depressions. In the adjoining fields, an undulating strip lying barren for decades due to severe erosion was selected for reclamation. The excavated soil (approx. 450 m^3) of the tank area was transported and was spread over the fallow undulating area (120m x 6m) in the month of May-June 2003. Subsequently from the following season onwards, this reclaimed area was brought under cultivation. In *kharif* soybean (JS 335) intercropped with sorghum (JJ 938) and in *rabi* gram (JG 218) was cultivated under rainfed conditions during 2003-04 and 2004-05 on reclaimed area successfully. The soybean equivalent yield during first year was 4330 kg/ha during 2003-04, which increased by 8 per cent during subsequent year. The operation involving the excavation, spreading of soil and leveling in reclaiming the 0.072 ha area involved an amount of Rs 16,450/-. Working out net return (Rs 3754) from crops raised, the cost of reclamation can be met out in 4.38 years (Table 2).

The successful reclamation of waste land not only added newer area for cultivation for future but also turned out to be the regular source of income for the

Table 2. Crop productivity from the reclaimed land

Year	Yield (kg/ha)			Soy Equivalent Yield (kg/ha)
	Soybean	Sorghum (SEY)	Gram (SEY)	
2002-03	No crop was feasible on undulated waste land.			0
2003-04	1190	3000 (1200)	1455 (1940)	4330
2004-05	1350	2800 (1120)	1657 (2210)	4680

Prevailing selling price of soybean @ Rs 15/kg, Sorghum @ Rs 6/kg and gram @ Rs 20/kg

Table 3. Comparison of income accrued with reclamation cost

Reclamation cost (Rs) for 120 m x 6 m = 0.072 ha area			
Excavation of earth for spreading (450 cu m) @ Rs 25/cu m		11250	
Transportation and spreading by tractor trolleys (@ Rs 10/cu.m.		4500	
Spreading and leveling of fields by tractor leveler		700	
Total		16450	
Accrued income (Rs) in 2003-04			
Particulars	***Kharif***	***Rabi***	**Total**
Actual Cost of cultivation (Rs)	468	446	914
Gross Income (Rs)	2581	2088	4669
Net return (Rs)	2113	1641	3754
Years required to recover the cost		4.38	

targeted farmer. In addition, the reclamation process reduced the further chances of gully development and restricted the erosion loss of top fertile soil. The success of present attempt paves the way for bringing such waste land under cultivation and enhancing income of farmers.

Eradication of sub-surface lateral roots by deep ploughing

In village Barlai, several farmers' field had peripheral planting of trees like Babool (*Acacia nilotica*), Ber (*Zyzyphus jujuba*) and Hingot (*Balanitis roxburghii*). Since these trees existed for a long time, their lateral roots penetrated into the fields' even up to 100 m inside and were interfering with the cultivation operations. These lateral roots use to further develop suckers after the on-set of monsoon and were turning out competitor for soybean, which is the main crop of the area. Consequently the productivity of the crop was affected. To address this problem, 4.86 ha area in such problematic field was identified. This area was ploughed in April 2003 employing a crawler tractor drawn mould board plough which turned the soil up to 45-50 cm. This deep ploughing destroyed the lateral roots which amounted to 6 tonnes per hectare. Hingot (*Balanitis roxburghii*) has the major share (> 90%) of the root mass, which were removed from the area. This area was put to soybean cultivation during *kharif* 2003-04 and yielded 1560 kg per hectare as compared to 1150 kg per hectare harvested prior to eradication of lateral roots. This amounted to 36 per cent increase in soybean yield. The total expenditure involved in eradication operation amounted to Rs 11,400/- i.e. Rs 2345/- per hectare. The increment in yield by the first vary crop (soybean) over pre-operation could fetch Rs 6000/- per hectare and possibly expenditure incurred may be made within the first year itself.

Effect of tillage on the development of weeds and crop yields

The predominant weed *Sacchaurum spontaneum* (*kans*) is difficult to manage utilizing common weed management practices. Infestation of land with this weed along with others in Jaitpura fields was limiting the soybean yield to 600-800 kg/ha and making it difficult to raise *rabi* crops. To contain this weed, the deep tillage operation through crawler tractor drawn MB plough, tractor drawn MB plough and tractor drawn cultivator separately in three independent identical fields (100m x 100m each) was carried out and compared in January 2005. Among the three implements tried, it was observed that the use of crawler tractor drawn mould board plough could eradicate 10 times *Saccharum spontaneum* biomass (10 t/ha) as compared to tractor drawn mould board plough (1 t/ha) and 100 times to tractor drawn cultivator (0.1 t/ha). This is mainly on account of higher working depth of crawler tractor drawn mould board plough (45-60 cm) as compared to 8-20 cm in case of other two. The bulk density as an indicator of soil environment is also lowest (1.29 mg/m^3) as compared to tractor drawn mould board plough (1.37 mg/m^3) and tractor drawn cultivator (1.42 mg/m^3). These results indicated that crawler tractor drawn mould board plough is most effective in managing this notorious weed (Table 4).

During *kharif* 2005, two plots (0.8 and 0.2 ha) from the land cleared of *Saccharum spontaneum* using crawler tractor drawn mould board plough were cropped with soybean (JS 335) to compare its performance as compared to infested land. The yield levels achieved was 39 per cent higher in treated plots (1420 kg/ha) as compared to infested land (1020 kg/ha). This enhanced yield could be accounted for better soil environment for crop growth as indicated by lower bulk density and higher moisture retention in

Table 4. Performance evaluation of different tillage equipments

Observations	Equipment		
	Tractor drawn MB plough	**Tractor drawn cultivator**	**Crawler tractor drawn MB plough**
Removed weed biomass of *Saccharum spontaneum* (*Kans*) (t/ha)	1	0.1	10
Working depth (cm)	15-20	8-11	45-60
Bulk density (Mg/m^3)	1.37	1.42	1.29
Soil moisture content (% Θv) in surface soil layer (0-15 cm) on 07-10-2005	0.31	0.22	0.35
Soil moisture content (% Θv) in surface soil layer (0-15 cm) at the time of *rabi* planting on 22-10-2005	0.25	0.16	0.28

surface soil (Table 4). Further, on account of improved moisture retention even after harvest of soybean, the treated area could be used for rainfed cultivation of gram (JG 412) which revealed successful germination on residual moisture. The rainfed gram recorded 1461 kg/ha yields from the treated plots as compared to no crop from untreated fields.

From the above, it may be concluded that the deep tillage operation carried out not only eradicates the notorious weeds like *Saccharum spontaneum* but also takes care of lateral roots of plants grown on periphery penetrating into the fields' and interfering with the cultivation operations. This also improves the soil environment for crop growth and also ensures better germination of even rainfed crops. Similarly, a gullied area can be reclaimed and brought under cultivation immediately if the tank excavated soil is spread to make it leveled.

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A Database Management System for Agronomy Trials under All India Coordinated Research Project on Soybean

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ABSTRACT

A database management system developed at National Research Centre for Soybean for multi-location agronomic experimentation under All India Coordinated Research Project on Soybean provides routine processing of data and report generation in easy, efficient and user-friendly mode. The system and database has been developed using Visual Basic (6.0) and MS-Access, respectively. The reports are generated in the form of EXCEL worksheets. The functioning of the system catering to the needs of the end-user is discussed.

Keywords: Agronomy, data management, software, soybean

A Database Management System is a software programme that controls the organization, storage, management and retrieval of data in a database. In agriculture, Database Management Systems have successfully been used as a very effective tool for managing experimental trials data. An exercise done earlier for the data management of plant breeding trials (Kolhe and Karmakar, 2005) is being successfully utilized.

Soybean in India, not only occupies a coveted position among oilseeds grown, but also plays an important role in national economy by way of saving expenditure on import of edible oil (soy oil supplements about 13% of edible oil produced annually) and export earnings to the tune of average Rs 20, 000 million through export of soy meal (Chauhan and Joshi, 2005; Joshi 2005). Realizing the potentials of soybean, the Indian Council of Agricultural Research took a visionary decision before the commercial exploitation of soybean in India to establish a multi-location inter-disciplinary All India Coordinated Research Project on Soybean (AICRPS) in 1967 which functions through a network of 7 main-, 13 sub-centres and 8 need-based locations representing different agro-climatic regions of the country at present. The coordinating unit for AICRPS is located at National Research Centre for Soybean, Indore. Under the AICRPS, every year a sizeable quantum of data of agronomic experiments is generated by each cooperative centre and use to be manually processed in the form of annual report leading to a high level of drudgery with a possible component of manual error. Moreover, the practice uses to make

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it cumbersome to lay hands on data generated over the years. The report is quite handy in taking decisions on location specific recommendations on production technology for soybean growers. In view of above, a data management and report generation system, which is simple, easy-to-handle, user-friendly, accurate and efficient, was developed at NRC for Soybean. Similar efforts on data management systems have earlier been documented (Wallach and Rellier, 1987; Martiniello, 1988; Bayles *et al*., 1995 and Kolhe and Karmakar, 2005). This present paper describes the data management system for AICRPS agronomic trials.

Aims of the system developed

The AICRPS data management and report generation system was developed with the following twin objectives.

- To ensure that the present manual system of processing of sizable data from agronomic trials from cooperative centres of AICRPS and report generation could be replaced with an efficient, effective and user friendly computerized system to eliminate drudgery and component of manual error.
- To allow safe storage of data including that of previous years and easy retrieval for assessing sustainable performance of generated technology and further to get feed back for their refinement.

MATERIAL AND METHODS

Data Collection

The research on development and refinement of production technology with time and space is a continuous process. The data acquisition from the cooperative centres located in five agro-climatic regions of the country (North hill, North plain, Central, Southern and North east zones) and processing it for report generation is a cumbersome and time consuming process. The cooperative centres of AICRP on Soybean undertake a number of trials on different aspects of production technology and agronomic evaluation of improved varieties. On the basis of consistent performance over years, the location specific technology/variety is made available to extension agencies for disseminating among farmers. To take the benefit of the technology developed through experimentation, the annual report is generated at NRC for Soybean. The data collected by each cooperative centre received at the coordinating unit at NRC for Soybean can conveniently be fed to the developed data management system to generate the report on findings/recommendations. The database size without insertion of data is nearly 2MB and with insertion of the data from all the locations gains the size of 170MB or more depending on the number of varieties/technology evaluated during the reporting year.

Description of the system

The said computerized system developed using Visual Basic 6.0 is user-friendly and interactive. It has been designed to enable a person even with limited computer skills to handle it. A person familiar with the Windows Graphical User Interface can handle the system conveniently. The system requires a Windows NT operating system with MS-Office installed on the Pentium II or an advanced computer for its proper functionality. The database at back end is designed using MS-ACCESS. The reports are generated in the form of EXCEL worksheets. Since the present system is specifically developed for management of agronomic trial data and its report generation for All India Coordinated Research Project on Soybean, it is of immense use to the agronomists. The main user-interface is provided in the form of Menu-bar with menu options viz., 'Master', 'Data-entry', 'Report', 'User-settings', 'Backup', 'Help' and 'Exit' as shown in fig. 2. Each of these menu options contains a few sub-menu options that on click will open a particular form to perform certain task. The logical operation of the system can be described with the help of data flow diagram (Fig. 1). A sample statement showing the report in generated format is given (Fig. 3.)

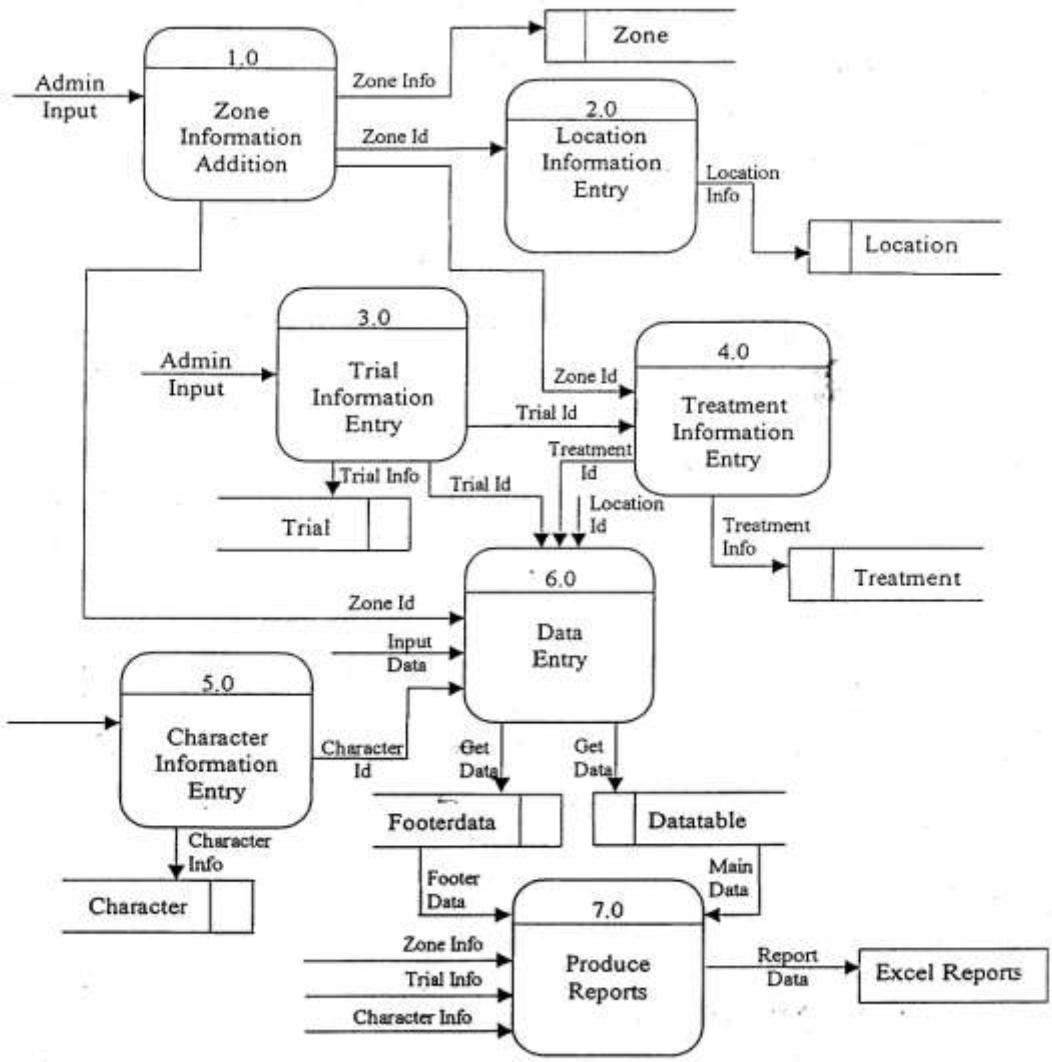

Fig.1. Data flow diagram (DFD) of the System

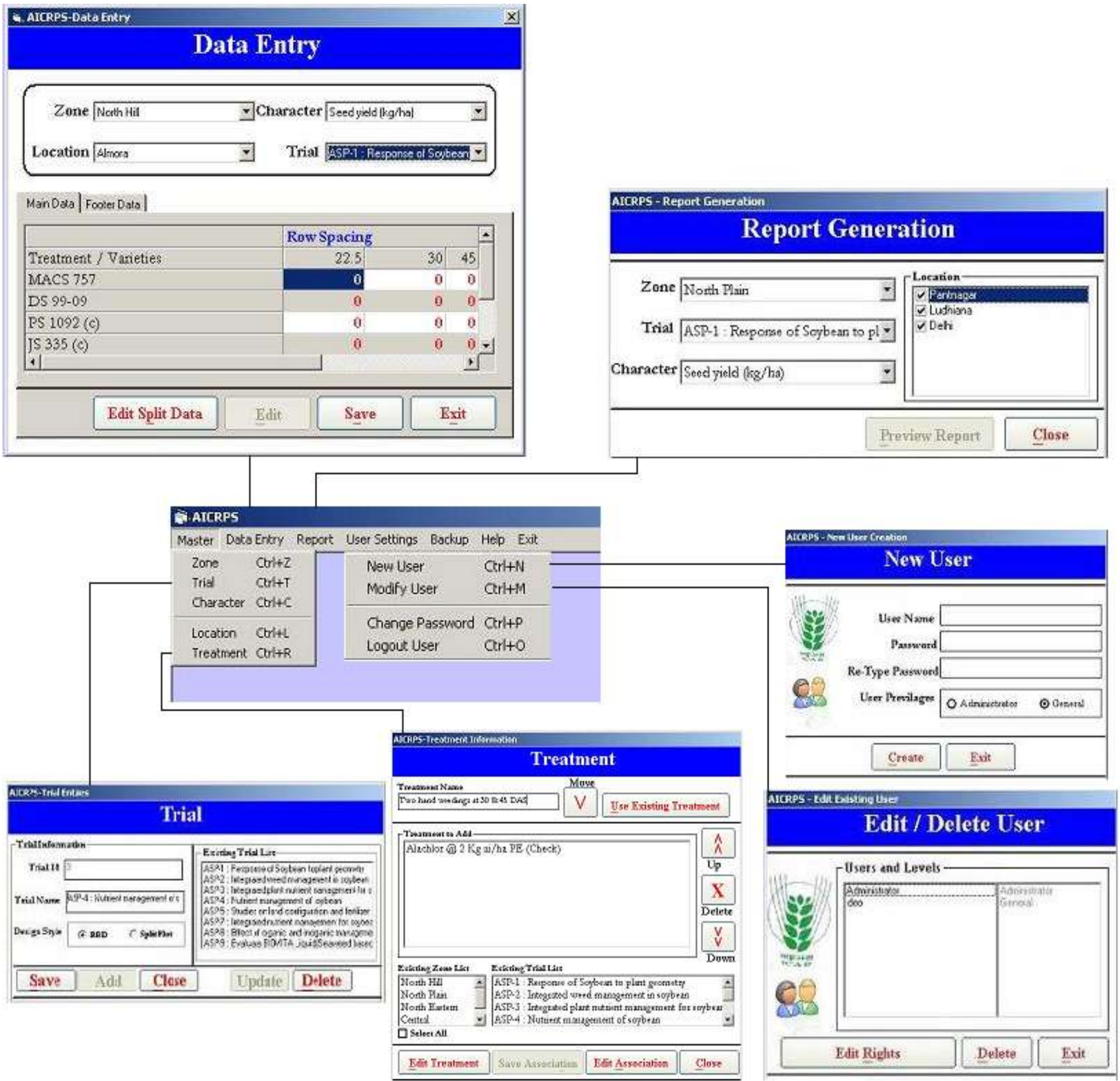

Fig. 2. Detailed design of the Graphical User Interface of the system

Table 2.4

ASP-1: Evaluation of AVT II entries for optimum plant population

Zone: Central
Character: Seed yield (kg/ha)

Treatment	Parbhani				Sehore				Zonal mean			
	Plant population (m/ha)											
Entry	0.3	0.4	0.5	Mean	0.3	0.4	0.5	Mean	0.3	0.4	0.5	Mean
JS 98-63	1561	1667	1406	1541	1301	1403	1915	1540	1431	1535	1661	1540
RKS 24	971	1165	1085	1074	1403	1515	1472	1463	1187	1340	1279	1269
JS 97-52	982	1280	1314	1192	1420	1373	1452	1415	1201	1327	1383	1304
RKS 21	914	1257	1280	1150	1456	1324	1363	1381	1185	1291	1322	1267
NRC 67	982	1257	1131	1123	1312	1568	1439	1440	1147	1413	1285	1282
MAUS 158	1561	1771	1817	1716	1302	1359	1601	1421	1432	1565	1709	1569
MRSB 345	1188	1394	1302	1295	1367	1416	1497	1427	1278	1405	1400	1361
NRC 66	1256	1348	1474	1359	1258	1493	1856	1536	1257	1421	1665	1448
JS 335 (C)	1005	983	1223	1070	1227	1299	1586	1371	1116	1141	1405	1221
Mean	1158	1347	1337	1281	1338	1417	1576	1444	1248	1382	1456	1362
CD(P=0.0-5)												
Entry				248				NS				-
Plant Population				137				89				-
Interaction				NS				268				-

Fig. 3. Report for ASP-1 trial, central zone and seed yield (kg/ha) character

The "administrator" can input the data into the master tables for feeding basic information viz., "Zone information", "Location information", "Trial information", "Treatment information" and "Character information" (Fig. 1). Then the master tables are ready to serve the basic data required for final data-entry by the data entry operator. After the complete agronomic trial data is entered for the particular year, final summary table reports can be generated in the form of Excel worksheets.

Stages for operating the system

Preparation of the system as per the technical programme: The system needs to be prepared to get it ready before starting data entry and report generation as follows.

- Initially name of zones, trials, characters and location are to be entered using the "Master" menu-option of the main interface (Fig. 2).
- Each year the treatment list is entered based on zone and trial by using "Treatment" option of "Master" main menu-option (fig. 2).

Thus, all the master tables of the database are made ready for subsequent functionality of the package.

Zone-wise and trial-wise data compilation and manual data entry: Each year, after the cropping season, the trial data in printed sheets from all the cooperative centres of AICRP on Soybean is received at the Coordinating Unit, NRC for Soybean, Indore. These data sheets compiled zone-wise and are utilized by the data-entry operator to feed to the system. The operator has a liberty to resort to new data-entry, change the existing data or delete the data by using different forms provided in the said package.

Processing of data files: Subsequent to the process of data-entry, correction of erroneous data, validation of the final data and before the generation of reports, the data files are processed at the system level for calculation of location-wise mean and zonal mean for individual treatment. Based on these means, each treatment is given an increasing rank (I onwards) from highest mean value to the lowest. The ranks assigned paves the way to decide the suitability of a particular treatment(s) specific to location/zone, which can be indicated in the final report generated.

Data analysis and Report generation: Having completed the above steps, the summary table reports for each zone and trials for all the characters are printed out for verification by the concerned staff to ascertain errors that might have incurred at the data-entry level. The erroneous data are edited and submitted for rerunning of the system. After repeated corrections at different levels, final reports are generated in formats specified by the AICRP on Soybean system. The developed system has versatility for incorporation of more complex and non-standard reports using a combination of MS word and MS Excel.

Creating history database files: The provision incorporated for creating the history database in the system provides easy access to the accumulated data over years for viewing earlier year-wise information. The complete database with all the tables in it is storable in the form of backup files that can be restored and linked to the system for future reference.

Monitoring all the phases of the system

The system administrator has given the rights to provide username and password at different user-levels – administrator and data-entry-operator. The administrator monitors every phase of the system from master table data-entry as per the technical programme up to final report generation.

RESULTS AND DISCUSSION

The developed flexible and user-friendly system is an out come of rigorous time consuming analysis, planning, discussions, designing, programming and user efforts. The introduction of the projected system in place of system prevailed earlier has lead to saving of manpower, accuracy and flawlessness of the presented results, prompt retrieval of data for past years for generation of allied information, and reduced cost of processing. The data compilation for multi-location agronomy trial has successfully been utilized for the generation of report in 2005, 2006 and 2007. The system uses efficient procedures for rapid calculation of mean and rank, so that users get accurate results. The reports generated earlier through typewriters were not uniform. Now, the agronomists are happy to get uniform reports with same fonts and style thus making the overall summary table report attractive and occupying less space thus reducing the overall cost of printing (Fig. 3). With the help of thorough training to all the users, the system was rapidly accepted and successfully implemented for agronomy trial data handling and report generation. The system is very specific to the agronomic experimental trials and paves the way for development of similar system for multi-location trials conducted under other disciplines. To make the system more versatile with respect of receipt of data, it will be possible to modify and develop an on line data-entry system.

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Residual Heterosis for Yield and Yield Contributing Traits in Soybean [*Glycine max* (L.) Merrill]

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Key words: *Glycine max*, residual heterosis, soybean, yield, yield contributing traits

With the cropped area of above 8.0 million hectare and estimated production of over 7.5 million tones in 2006, Soybean [*Glycine max* (L.) Merrill] has occupied an important place in agriculture and oil economy of India and it is projected that by 2025, production of soybean in India may progressively increase to 18 million tonnes and then may stabilize (Chauhan, 2007). The primary objective of plant breeding programme is to create variability and to select the best recombinants possessing desirable characteristics. The chances of getting better recombinants are more in parental combinations which show hybrid vigour or heterosis. The hybrid vigor in soybean has very well been established. Shanti *et al.* (2003) reported heterosis over mid parent and standard parent for 1000 seed weight, seed yield per plant, plant height, days to maturity and number of pods per plant. Pandini and Vello (2002) reported highly significant and positive heterosis for seed yield per plant, 100 seed weight, pods per plant, seeds per pod and harvest index. In soybean, high magnitude of heterosis and male sterility system is available (Brim and Young, 1971). However, the exploitation of hybrid vigour of existing cultivars in soybean is difficult because of its flower being cleistogamous in nature. In these circumstances, the residual heterosis i.e. the extent of heterosis which remains in the F_2 and later generations, may be used to isolate recombinants which are superior to either of the parents and existing cultivars and thus can be used for enhancing the productivity in soybean The present study was therefore undertaken to ascertain the manifestation of residual heterosis in F_2 generations.

The present investigation was carried out during *kharif* 2004 at the Crop Research Centre of Govind Ballabh Pant Uuniversity of Agriculture and Technology,

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Pantnagar, Uttarakhand, India. The experimental material in the present study consisted of five parental lines *viz*. JS 335, PK 327, PK 472, PK 416 and PS 1024 and F_2 generations of ten crosses generated from these lines by crossing them in a diallel cross combination system namely JS 335 × PK 327, JS 335 × PK472, JS 335 × PS 1024, JS 335 × PK 416, PK 327 × PK 472, PK 327 × PS 1024, PK 327 × PK 416, PK472 × PS 1024, PK 472 × PK 416 and PS 1024 × PK 416. The experiment was laid in randomized complete block design with a spacing of 60cm x 5cm in three replications. All the recommended package of agronomic practices was followed during the course of experimentation to grow a healthy normal crop. Characters considered under the following study include days to maturity, plant height (cm), number of primary branches per plant, number of pods per plant, number of seeds per pod, basal pod height (cm), number of nodes per plant, dry matter weight per plant (g), seed yield per plant (g), hundred seed weight (g), harvest index (%) and seed yield efficiency (%).The observations were recorded on five randomly selected competitive plants from each parental line and thirty randomly chosen plants from each F_2 cross combinations. Residual heterosis over mid parent (MP), better parent (BP) and standard parent (SP) was calculated as the deviation of F_2 mean from MP, BP and SP value and expressed in percent.

The analysis of variance exhibited significant differences among the different cross combinations for all the characters studied except for the number of seeds per pod. This indicated that there was sufficient variability among the treatments included in the study. Among the F_2 generations, for days to maturity, the maximum significant negative residual heterosis over BP and SP was recorded in PK 472 × PS 1024 (-1.87) and in JS 335 × PK 416 (-5.78), respectively. Other crosses exhibiting significant residual heterosis over SP are JS 335 × PS 1024, JS 335 × PK 327 and JS 335 × PK 472. It indicated that parent JS 335, PK 416 and PS 1024 contributed genes for early maturity and this is due to gene interaction. Dogney *et al.* (1998) also reported negative and significant heterosis over BP for days to maturity. Guleria *et. a!.* (2000) studied thirty F_1 and F_2 soybean hybrids and reported heterosis for days to maturity and other yield contributing traits. Residual heterosis over mid parent, better parent and standard parent (PK 472) and mean performance of specific cross combinations are presented in table 1. For plant height, all the crosses except PS 1024 x PK 416, JS 335 x PS 1024 and PK 327 x PS 1024 showed positive residual heterosis over mid parent and better parent. A significant increase in plant height was reported in JS 335 x PK 416 over MP, BP and SP. This is due to the exposure of certain alleles in the recombinants which led to enhanced plant height. Zhang and Yang (2000) also reported heterosis for increased plant height in soybean. For number of pods per plant, per cent residual heterosis over BP ranged from -44.00 to 41.17 with five crosses (PK 327 × PK 416, JS 335 × PK 416, PK 472 × PS 1024, PK 327 × PK 472, PS 1024 × PK 416) significantly

Table 1. Specific cross combinations showing significant residual heterosis (%) over mid parent (MP), better parent (BP) and standard parent (SP i. e. PK 472)

Character	Cross combinations	Mean of F_2 generations of specific crosses	Residual heterosis over		
			MP	BP	SP
Days to maturity	JS 335 × PK 416	114.00	-2.35 **	-0.86	-5.78**
	PK 472 × PS 1024	117.50	-2.48**	-1.87 *	-2.68**
Plant height (cm)	JS 335 × PK 416	89.00	20.88**	16.34**	28.05**
	PK 327 × PK 416	85.50	12.83**	5.85**	23.02**
	PK 327 × PK 472	83.75	11.44**	3.65*	20.50**
Number of primary branches/plant	JS 335 × PK 416	8.25	17.85**	10.00*	57.14**
	JS 335 × PK 472	7.25	23.40**	11.53*	38.09**
	PK 327 × PK 472	6.30	26.00**	20.00**	20.00**
Number of pods/plant	JS 335 × PK 416	83.50	73.95**	38.01**	33.60**
	PK 327 × PK 472	76.50	34.80**	22.40**	22.40**
	PK 327 × PK 416	72.00	66.47**	41.17**	15.20**
	PK 472 × PS 1024	80.00	35.02**	28.08**	28.00**
	PS 1024 × PK 416	68.50	49.72**	22.32**	9.60*
Number of seeds/pod	JS 335 × PK 416	2.28	4. 11**	1.78*	0.88
	PK 472 × PK 416	2.30	2.22	1.76*	1.77*
Basal pod height (cm)	JS 335 × PK 416	14.30	-2.22	-14.40**	17.21**
	PS 1024 × PK 416	14.83	0.40	-15.85**	21.55**
Number of nodes/ plant	JS 335 × PK 327	17.15	12.67 **	10.64**	3.97*
	JS 335 × PK 416	18.50	30.05**	23.74**	12.12**
	PK 327 × PK 472	17.61	10.06**	6.72*	6.72*
	PK 327 × PS 1024	18.00	19.63**	16.12**	9.12*
Dry matter weight/plant (g)	JS 335 × PK 416	64.00	61.00**	49.70**	56.09**
	PS 1024 × PK 416	62.44	53.22**	37.53**	52.29**
	JS 335 × PK 472	60.89	45.40**	42.43**	48.51**
Seed yield/plant (g)	JS 335 × PK 416	31.20	128.23**	103.25	38.66**
	PK 472 × PS 1024	29.97	42.72**	33.19	33.22**
	PK 327 × PK 472	28.75	57.51**	27.74	27.77**
	JS 335 × PK 472	26.31	52.50**	16.90	16.93**
Hundred seed weight (g)	PK 472 × PK 416	15.50	25.81**	16.98**	34.96**
	JS 335 × PK 472	13.50	12.97**	8.00**	18.42**
	JS 335 × PK 416	14.16	9.98**	6.86*	24.21**
	PK 327 × PK 472	12.75	9.91**	8.05*	11.84**
Harvest index (%)	PK 472 × PS 1024	58.19	18.22**	6.03*	6.03*
	JS 335 × PK 416	48.75	39.64**	16.73**	-11.16**
	JS 335 × PK 327	41.32	29.69**	15.87**	-24.70**
Seed yield efficiency (%)	PK 472 × PS 1024	139.32	39.96**	14.34**	14.34**
	JS 335 × PK 416	95.12	71.78**	32.60**	-21.93**
	JS 335 × PK 327	70.42	49.10**	26.99**	-42.20**

** Significant at 5% level of significance; **Significant at 1% level of significance* superior to BP and SP. The maximum residual heterotic response over BP was shown by PK 327 × PK 416. The range of residual heterosis over SP was from -44.00 (PK 472 × PK 416) to 33.60 per cent (JS 335 × PK 416). Significant positive residual heterosis for number of pods per plant was also reported by Bhartiya (2004). In case of number of seeds per pod, range of per cent residual heterosis over BP was from -4.54 to 1.78 with two crosses (JS 335 × PK 416 and PK 472 × PK 416) significantly superior over BP and four crosses exhibited significant positive residual heterosis over SP and maximum heterotic response for number of seeds per pod over SP was shown by PK 472 × PS 1024. Pandini and Vello (2002) reported highly significant and positive heterosis for number of seeds per pod. For 100 seed weight, four crosses (PK 472 × PK 416, PK 327 × PK472, JS 335 × PK 472, JS 335 × PK 416) showed significant positive residual heterosis over BP and maximum heterosis was observed in PK 472 × PK 416 (16.98). Six crosses exhibited significant positive residual heterosis over SP with maximum heterotic response exhibited by PK 472 × PK 416 (34.96). The range of per cent residual heterosis for seed yield per plant over BP was from -37.79 to 103.25 and six crosses were found to be significantly superior to BP and SP. Highest significant positive residual heterosis for seed yield per plant (103.25 %) was noted in JS 335 x PK 416, followed by JS 335 x PK 327 and PK 327 x PK 472. The non-additive type of gene action is responsible for high heterosis (Bruno, 1997 and Ponnuswamy and Harer, 1998). In case of harvest index and seed yield efficiency three crosses (JS 335 × PK 327, JS 335 × PK 416 and PK 472 × PS 1024) showed positive significant residual heterosis over BP and PK 472 × PS 1024 showed positive significant residual heterosis over SP. Availability of residual heterosis can be manipulated for the genetic improvement and thus can be used for enhancing productivity in soybean. Importantly, residual heterosis in soybean is specific to certain cross combinations. Therefore to overcome this specificity, multiple cross combination or biparental crosses of identified genotypes for specific traits could be implemented for the genetic improvement of productivity in soybean.

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Evaluation of Soybean Genotypes against *Macrophomina phaseolina* (= *Rhizoctonia bataticola*) Causing Charcoal Rot in Soybean

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Key words: Charcoal rot, resistance, *Macrophomina phaseolina, Rhizoctonia bataticola***,** soybean

Soybean [*Glycine max* (L.) Merrill] is the premier largest oilseed crop in India. It is a cheap source of high quality protein and edible oil. In India, soybean is grown in more than 8.0 million hectares, with production of more than 8.0 million tonnes. The major area is confined largely to the states of Madhya Pradesh, Maharashtra, and Rajasthan in that order. The crop use to be relatively free of biotic stresses during initial years of its establishment, but its continuous cultivation and change in climatic conditions during past few years has caused a number of epidemics in different regions. In the year 1997, an epiphytotic of charcoal rot occurred in Guna district of Madhya Pradesh at seedling stage, which had caused substantial loss to plant stand and yield. Charcoal rot caused by *Macrophomina phaseolina* (Tassi) Goid [=*Rhizoctonia bataticola* (Taubenh) E. J. Butler] is a seed as well as soil borne disease, predominantly occurring in Madhya Pradesh , Maharashtra, Rajasthan, and Delhi and have potential to cause yield losses up to 77 per cent by killing the plants at early reproductive stage (Wyllie, 1976). Dry conditions, relatively low moisture and nutrients and temperature ranging from 25 to 35 ^{0}C are favourable for the disease especially at pod formation and filling stages, when demand for water and nutrient absorption is high (Wyllie, 1976). So far no resistant variety and effective management methods are available to manage the disease. Hence, an attempt was made to evaluate the field resistant / tolerant soybean genotypes to be utilized in future breeding programme.

A total of 126 elite genotypes were screened under natural field condition in *kharif* 2004 and 2005 seasons. The crop was sown in the last week of June and one line each of 5 meter length was sown for each genotype, the recommended package and practices were followed.

Per cent disease incidence was recorded on 0 - 9 scale at the time of late reproductive stage, which is considered to

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Table 1. Reaction of Soybean genotypes against Charcoal rot

Category	Scale	Genotypes
Immune or absolutely free	0	Nil
Highly Resistant (1)	0.1 to 1.0% mortality	JS 335 (0.1), G 213 (0.2), Birsa Soya 1(0.2), GS 1 (0.2), GC 175320(0.3), G 9 (0.2), G 688 (0.3), NRC 37 (1.0), DSb 6-1 (1.0), RSC 14 (1.0)
Moderately Resistant (3)	1.1 -10.0% mortality	JS 76-205 (1.57), LSB 1(1.58), Bragg (1.69), NRC 48 (2.00), Pusa 16 (2.09), HIMSO 1602 (2.10), G 205 (2.22), Pusa 24 (2.29), Lee (2.29), JS 97-52 (2.50), Pusa 37 (2.70), NRC 67 (2.80), JS 98-63 (3.00), EC 175324 (A) (3.03), JS 2 (3.06), NRC 69(3.12), JS 90-41(3.20), EC 216376 (3.22), RAV 5 (3.22), RKS 24 (3.49), NRC 66 (3.50), MAUS 158 (3.60), Coimbatore 1 (3.61), MAUS 68 (3.80), RKS 21 (3.80), SL 682 (3.80), MAUS 47 (3.92), MACS 58 (3.95), MAUS 187 (4.00), EC 37656 (4.08), MACS 993 (4.12), Pusa 22 (4.16), PK 471(4.16), MAUS 161(4.30), JS 71-05 (4.38), JS 80-21(4.44), EC 398484 (4.87), JS 98-68 (5.00), Pusa 40 (5.06), JS (SH) 99-14 (5.10), NRC 12 (5.26), G 21-29 (5.35), MAUS 1(5.40), Pusa 416 (5.40), MACS 40 (5.51), NRC 2 (5.55), JS 72-280 (5.88), Pellican Soya (5.88), Cockerstuart (6.06), Fukuyukutaka (7.69), EC 39488 (7.69), MAUS 32 (7.69), G 76 (8.06), JS 72-44 (8.57), G 11(8.75), Akiyoshi (9.09), Indira Soya 9 (9.09), Shilajeet (9.30), JS 79-81(9.63), NRC 38 (9.67)
Moderately Susceptible (5)	10.1 -25% mortality	Pusa 564 (10.56), EC 175330 (10.71), EC 57043 (10.81), Hongyoku (11.11), EC 39490 (11.11), LX 2 (11.62), AGC 191 (12.0), Bhatt yellow (12.08), AGS-2 (12.50), JS 93-06 (12.93), Boiling type (13.04), G 214 (13.20), G 288 (13.79), EC 175322 (14.81), T 49 (14.96), JS 93-05 (15.00), EC 216379 (15.15), NRC 8 (15.84), Akisholgyyoku (17.64), EC 39486 (17.64), PK 1029 (17.88), PK 308 (18.18), DS 2101(18.18), Improved Pellican (18.78), Samarat (19.35), Bhowali bold (19.44), Monetta (19.64), Kalitur (22.22), Enrei (22.72), MACS 998 (23.07), EC 216374 (23.25)
Susceptible (7)	25.1-50% mortality	DS 1394 (25.63), SH 40 (27.20), AGS 386 (27.27), JS(SH) 99-02 (31.05), NRC 7 (32.65), Hyunga (33.33), PK 262 (33.54), EC 216384 (38.09), GS 2 (38.37), Harasoya (38.63), PI 542044 (40.90), Kogne (44.00), G 52 (44.92)
Highly Susceptible (9)	More than 50% mortality	Ankur (54.79), EC 210380 (58.53), VLS 1(60.00), VLS 47(60.86), BAUS 40 (61.00), DS 1392 (62.50), MACS 985(66.75), EC 216385 (80.00), TS 40 (86.00)

**Value given in parenthesis is the average percent mortality* be the susceptible phase of the plant and 10 days later after first observation (Smith and Carvil, 1997). The data were pooled and total mortality was calculated. The reactions categorized were: 0, immune or absolutely free (no mortality); 1, highly resistant (1% mortality); 3, moderately resistant (1.1 – 10.0 % mortality); 5, moderately susceptible (10.1 – 25.0 % mortality); 7, susceptible (25.1 – 50.0% mortality) and 9, highly susceptible (more than 50.0 % mortality) (AICRPS, 2005).

Data presented in table 1 revealed that none of the genotypes showed immune reactions, while 11 genotypes showed highly resistant reaction and the mortality was up to 1 per cent. The highly resistant genotypes were JS 335 (0.1), G 213 (0.2), Birsa Soya-1(0.2), GS 1 (0.2) GC 175320 (0.3), G 9 (0.2), G-688 (0.2), G-688 (0.3), NRC 37 (1.0), DSb 6-1 (1.0), RSC 14 (1.0). Sixty lines showed moderate resistance, 32 were moderately susceptible and the rest were found susceptible to the disease. Genotype JS 335 (matures in 99-102 days), which was found to be the best in all the resistant lines, is a dominant variety and occupied more than 80% area among the cultivated varieties/genotypes. NRC 37 (Ahilya 4) is another genotype matures in 99-105 days also showed resistant reaction against charcoal rot. Thus the resistant genotypes may be used in hybridization programme for generating high yielding charcoal rot resistant materials.

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Development of Soybean Lines Resistant to Yellow Mosaic Virus

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Yellow mosaic disease caused by *Mungbean yellow mosaic virus* is one of the important diseases of soybean in India. It is most severe in Kangra region of Himachal Pradesh, *tarai* region of Uttarakhand, plains of Delhi, Punjab, Haryana, and parts of Madhya Pradesh and Uttar Pradesh (Gupta and Chauhan, 2005). Yellow mosaic resistant cultivars of soybean fitting into the most advantageous cropping systems are the best solution for such regions. Though, the disease can be minimized by the application of thiamethoxam (Gupta *et al*., 2006), considering cost-benefit ratio and chemical hazards involved, most desirable approach would be to capitalize on the genetic resistance (Ramteke and Gupta, 2005). Hence, it is imperative to screen for resistance genes and transfer them in susceptible but agronomically superior varieties.

Though, some YMV resistant cultivars are available in India, their resistance level is slowly diminishing and are mostly adapted to Northern plain zone only. Therefore, a study was taken up to revalidate the resistance status of earlier known lines and cultivars so as to develop lines having good resistance, wider adaptability and desirable agronomic characters.

Earlier known resistant lines and cultivars as well as breeding material developed at NRC for Soybean, Indore were evaluated at YMV hot spots at Jabalpur, New Delhi and Ludhiana under field condition in *kharif* 2003 to 2006. The scoring of the disease was done at pod-fill stage, using standard 0-9 scale based on the per cent area of leaf infected, where 0 denotes no disease and 9 denotes >90 per cent area covered due to yellow mosaic. Mean score over the locations and years were considered for assigning resistance categories.

Results indicated that lines NRC 20, SL 328 and SL 603 were highly resistant, and cultivars SL 295

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Table 1. Reaction of the genotypes of soybean to yellow mosaic virus at hot spots

Genotype	Yellow mosaic virus rating (0 to 9 scale)								Mean
	Ludhiana				Delhi		Jabalpur		
	Kharif 2003	*Kharif* 2004	*Kharif* 2005	*Kharif* 2006	*Kharif* 2003	*Kharif* 2004	*Kharif* 2003	*Kharif* 2004	
A. Cultivars									
JS 335	9	9	8	7	9	7	9	6	**8.0**
JS 93-05	-	-	3	1	-	-	-	3	**2.3**
Malav King	-	-	5	4	-	-	-	3	**4.0**
NRC 37	9	9	9	-	9	-	9	7	**8.7**
PK 1024	3	3	2	-	-	-	3	1	**2.4**
PK 1029	3	3	2	-	-	-	3	3	**2.8**
PK 416	1	3	1	-	3	-	3	3	**2.3**
PK 564	5	4	-	-	3	-	3	-	**3.7**
Samrat	8	8	-	-	9	-	9	-	**8.5**
SL 295	1	1	-	-	1	-	-	-	**1.0**
SL 525	1	1	1	-	2	-	-	1	**1.2**
B. Lines									
SL 328	1	1	-	-	2	-	-	-	**1.3**
SL 428	3	3	-	-	3	-	-	-	**3.0**
SL 459	1	1	-	-	3	-	-	-	**1.7**
SL 517	5	4	-	-	3	-	-	-	**4.0**
SL 603	1	1	-	-	1	-	-	-	**1.0**
NRC 20	1	1	2	-	3	1	-	1	**1.5**
UPSM 534	3	3	3	1	3	-	-	2	**2.7**

– denotes that the line was not screened

Table 2. Reaction of breeding material of soybean to yellow mosaic virus at hot spots

Line	Pedigree	Yellow mosaic virus rating (0 to 9 scale)					Mean
		Jabalpur		Ludhiana			
		Kharif 2004	*Kharif* 2005	*Kharif* 2004	*Kharif* 2005	*Kharif* 2006	
A1	NRC 37 x PI 230970	4	3	9	8	8	**6.4**
A2	PK 416 x PI 459024s	4	3	9	9	7	**6.4**
A3	Ankur x PK 1024	1	3	3	2	4	**2.6**
A4	Ankur x PK 1024	1	3	3	1	-	**2.0**
A5	Ankur x PK 1024	1	3	3	3	5	**3.0**
A6	JS 335 x PK 1024	1	3	4	1	5	**2.8**
A8	JS 335 x PK 1024	2	3	3	6	3	**3.4**
A9	JS 335 x PK 1024	1	3	5	8	4	**4.2**
B1	NRC 37 x PK 1024	1	3	7	5	6	**4.4**
B2	NRC 37 x PK 1024	1	3	9	-	5	**4.5**
B3	NRC 37 x PK 1024	-	3	7	3	5	**4.5**
B4	NRC 37 x PK 1024	-	3	7	-	-	**5.0**

B5	NRC 37 x PK 1024	-	3	3	-	-	**3.0**
B6	NRC 37 x PK 1024	-	3	7	5	-	**5.0**
B7	PK 416 x Samrat	-	3	7	-	8	**6.0**
B8	PK 416 x Samrat	-	7	7	7	-	**7.0**
B9	PK 416 x Samrat	-	7	5	-	7	**6.3**
B10	PK 416 x Samrat	-	3	5	-	7	**4.3**
B11	PK 416 x Samrat	-	3	3	3	2	**2.7**
B12	PK 416 x Samrat	-	3	3	3	3	**3.0**
B13	PK 1024 x Ankur	-	3	4	4	1	**3.0**
B14	PK 1024 x Ankur	-	3	3	2	1	**2.3**
B15	PK 1024 x Ankur	-	3	3	4	2	**3.0**
B16	PK 1024 x Ankur	-	3	3	-	2	**2.7**
B17	PK 1024 x PK 564	-	7	3	-	1	**3.7**
B18	PK 1029 x JS 80-21	2	3	7	-	7	**4.7**
B19	PK 1029 x JS 80-21	4	3	5	-	7	**4.7**
B20	PK 1029 x JS 80-21	1	3	9	-	9	**5.5**
B21	Ankur x PK 1024	-	7	-	-	8	**7.5**
B22	Ankur x PK 1024	-	7	-	-	7	**7.0**
B23	Ankur x PK 1024	1	3	3	-	6	**3.2**
B24	Ankur x PK 1024	-	3	-	2	5	**3.3**
B25	Ankur x PK 1024	1	3	5	-	6	**3.7**
B26	Ankur x PK 1024	1	3	5	6	5	**4.0**
B30	Ankur x PK 1024	1	3	7	6	3	**4.0**
B31	Ankur x PK 1024	1	3	3	-	4	**2.7**
B32	Ankur x PK 1024	-	3	-	3	7	**4.3**
B33	Ankur x PK 1024	1	3	3	-	5	**3.0**
B34	Ankur x PK 1024	-	3	-	3	6	**4.0**
B35	Ankur x PK 1024	3	3	3	-	-	**3.0**
B36	Ankur x PK 1024	1	3	4	4	4	**4.0**
B37	Ankur x PK 1024	1	3	7	7	6	**4.8**
B38	NRC 37 x JS 80-21	1	3	5	6	8	**4.6**
B39	NRC 37 x JS 80-21	4	3	9	5	8	**5.8**
B40	NRC 37 x JS 80-21	2	3	3	8	6	**4.4**
B41	NRC 37 x JS 80-21	4	-	9	-	6	**6.3**
B42	NRC 37 x JS 80-21	1	7	5	8	5	**5.2**
B43	NRC 37 x JS 80-21	4	7	9	-	8	**7.0**
B44	NRC 37 x JS 80-21	1	7	5	6	6	**5.0**
B45	NRC 37 x JS 80-21	-	3	-	6	-	**4.5**
B46	NRC 37 x JS 80-21	-	7	-	6	4	**5.6**
B47	NRC 37 x JS 80-21	-	3	-	7	3	**4.3**
B48	NRC 37 x JS 80-21	4	3	7	6	-	**5.0**
B49	NRC 37 x JS 80-21	-	3	-	8	8	**6.3**
B50	NRC 37 x JS 80-21	-	3	-	5	6	**4.6**
B51	NRC 37 x JS 80-21	-	3	-	**7**	**3**	**4.3**
B54	NRC 37 x JS 80-21	5	9	3	-	1	**4.5**

and SL 525 were still maintaining their "highly resistant" status. Lines UPSM 534 and SL 428 were resistant and cultivars JS 93-05, PK 1024, PK 1029 and PK 416 could maintain their resistant status, line SL 517 and cultivars PK 564 and '*Malav* King' were moderately resistant, while cultivars JS 335, NRC 37, 'Samrat' were highly susceptible at all three the locations (Table 1).

Amongst breeding lines developed at NRC for Soybean, Indore A3, A4, A5 (derived from Ankur x PK 1024), B5 (derived from NRC 37 x PK 1024), B11, B12, B13, B14, B16 (derived from PK 416 x Samrat), were found resistant while B33, B35 (derived from Ankur x PK 1024) were moderately resistant at Jabalpur and Ludhiana (Table 2).

The study made it clear that cultivars SL 295 and SL 525 (highly resistant) and PK 1029, PK 1024, PK 416 and JS 93-05 and line UPSM 534 (resistant) can be used in crossing programmes as one of the parents. New identified sources of resistance viz. lines, NRC 20, SL 328, SL 603 and SL 428, and breeding materials A3, A4, A5, B5, B11, B12, B13, B14 and B16, which are at present in F_7 generation can be considered as homozygous pure, and be utilized in further crossing programme.

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Evaluation of Soybean Genotypes for Multiple Disease Resistance

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Soybean is one of the important oilseed crops of the country. Presently it is cultivated over an area of 8.85 million hectares with an annual production 9.47 million tonnes. In Karnataka also the area under soybean cultivation is consistently increasing and has reached to 0.16 million hectares with a production of 0.15 million tones (Anonymous 2007). The state (950 kg/ha) and national (1070 kg/ha) productivity are low in comparison with world average (2206 kg/ha). Apart from other factors, diseases are known to play a major role in yield reduction. Resistant genotypes are important component in of disease management involving integrated approach. Hence, an attempt was made to screen 204 soybean genotypes against 10 major diseases (Table 1), both under field and glass house conditions during 2005 and 2006 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad.

For screening against rust, each genotype was sown in a row of one metre length with a row spacing of 30 cm. Severity of rust was scored at 75-90 days after sowing (DAS) based on per cent leaf area infected using scale given by Mayee and Datar (1986). For purple seed stain, each genotype was sown in a single row of three metre length. At maturity, total number of harvested seeds and number of purple stained seeds were counted and per cent disease incidence (PDI) was calculated. Genotypes were categorized as highly resistant (0 PDI), resistant (0.1 to 1.0 PDI), moderately resistant (1.1 to 3.0 PDI), susceptible (3.1 to 5.0 PDI) and highly susceptible (>5 PDI).

Screening against anthracnose, Myrothecium leaf spot, Rhizoctonia aerial blight and Alternaria leaf spot was under taken during July, 2006 in growth chamber. Seeds of each genotype were sown with 3-4 seed per Styrofoam cups of 7.5 cm x 7.5 cm. Two cups were maintained for each genotype. Fifteen day old seedlings with 3 to 4 leaves were inoculated with ten day old culture of the above fungi multiplied on potato dextrose broth (10^5 spores/ (10^5 spores/ ml water) by

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Table 1. Soybean genotypes showing resistant reaction against major diseases of soybean

Resistant against	Genotypes	Total genotypes
Rust	EC 241778 and EC 241780	2
Purple seed stain	AMS 2001-1, Birsa soya 1, Co Soya 2, DS 98-14, DS 2001, EC 245988, EC 325100, EC 325115, Hardee, Himso 1598, Himso 1599, Improved Pelican, JS 76-205, JS 81-1625, JS 148-22, JS (SH) 98-22, KHSb 2, Lee, MACS 57, MACS 58, MACS 708, MACS 756, NRC 65, Palamsoya, PS 364, PS 564, PS 1347, RAUS 5, RKS 18, RSC 5, Shivalik, SL 96, SL 794, SL 813, TNAUS 7, TS 3, TS 17, TS 29, VLS 2, VLS 62, VLS 64, VLS 65, VLS 2108, VLS 2127 and VLS 2173	45
Anthracnose	Birsasoya 1 , Durga , JS (SH) 98-22 and Lee	4
Myrothecium leaf spot	Nil	0
Rhizoctonia aerial blight	Nil	0
Alternaria leaf spot	Nil	0
Collar rot	Nil	0
Powdery mildew	B 1664, Birsa soya 1, DS 98-14, DS 2001, DSB 6-1, EC 24460, EC 34115, EC 109541, EC 241756, EC 241778, EC 241780, EC 245988, EC 251348, EC 325100, Himso 1599, IC 1005, IC 15992, IC 24541, Indira Soya 9, JS 335, JS 71-05, JS 80-21, JS 95-56, JS 95-60, JS 97-51, JS 97-52, JS 98-61, JS 98-63, JS 98-68, JS 99-71, JS 99-72, JS 99-75, JS 99-77, JS 99-79, JS 99-81, JS 99-82, JS 148-22, JS (SH) 98-22, Kalitur, KB 261, KHSb 2, MACS 124, MACS 708, MACS 746, MACS 757, MACS 869, MACS 871, MAUS 2, MAUS 30, MAUS 32, MAUS 47, MAUS 61, MAUS 71, MAUS 81, MAUS 86, MAUS 128, MAUS 144, MAUS 158, MAUS 162, MAUS 164, MAUS 681, MAUS 61-2, NRC 7, NRC 12, NRC 59, PK 1337, PK 262, PK 472, PK 673, PS 364, PS 564, PS 1024, PS 1241, PS 1347, PS 1370, Pusa 37, Pusa 40, RAUS 5, RKS 12, RKS 15, RKS 18, RSC 5, Samrat, SL 295, SL 518, SL 525, SL 633, SL 744, SL 797, SL 812, SL 813, SL 814, SL 815, SL 817, SL 818, TS 3, TS 17, TS 29, UPSM 534, VLS 2, VLS 47, VLS 57, VLS 60, VLS 61, VLS 62, VLS 63, VLS 64, VLS 65, VLS 495, VLS 2108, VLS 2121, VLS 2127, VLS 2165, VLS 2166, VLS 2169, VLS 2173 and VLS 2174	117
Collar rot	Nil	0
Bacterial pustule	Bragg, EC 245988, Hardee, Himso 1597, Lee, MACS 450, MAUS 681, NRC 2, NRC 12, PK 472, PS 1092, PS 1347 and SL 518	13
Indian bud blight	AGS 12, DS 2001, DS 228, DSb 6-1, EC 241756, EC 242093, JS 80-21, MAUS 61-2, JS (SH) 98-22, MACS 58, PK 471, PK 472, PS 564, PS 1370, Punjab 1, SL 637, SL 813, SL 815, SL 818, VLS 64 , VLS 2169, AMSS 36, Ankur, CoSoya 2, DS 98-14, EC 24460, EC 251348, EC 325100, EC 333874, EC 333905, Himso 1597, Himso 1598, Himso 1601, IC 1005, IC 15992, IC 24541, JS 71-05, JS 93-05, JS 95-56, JS 98-66, JS 99-71, JS 99-82, JS (SH) 96-31, KHSb 2, MACS 124, MACS 450, MACS 708, MACS 754, MACS 757, MACS 871, MAUS 2, MAUS 128, MAUS 681, Monetta, NRC 7, NRC 65, PK 13-37, PK 262, PK 308, PK 416, PS 1092, PS 1241, Pusa 37, RSC 5, SL 525, SL 797, SL 814, SL 817, TS 17, VLS 47, VLS 59, VLS 63, VLS-2121 and VLS 2165	74

Table 2. Soybean genotypes showing multiple disease resistance during 2005 and 2006

Resistant against	Genotypes	Total genotypes	Resistant to number of diseases
Rust and powdery mildew	EC 241780	1	2
Powdery mildew and purple seed stain	Birsa soya 1, DS 98-14, DS 2001, EC 245988, EC 325100, JS 148-22, JS (SH) 98-22, KHSb 2, MACS 708, PS 364, PS 564,PS 1347, RAUS 5, RKS 18, RSC 5, SL 813, TS 3, TS 17, TS 29, VLS 2, VLS 65, VLS 2108, VLS 2127 and VLS 2173	24	2
Powdery mildew and bacterial pustule	EC 245988, Himso 1597, NRC 12 and PK 472	4	2
Powdery mildew and bud blight	DS 98-14, DSb 6-1, EC 24460, EC 241756, EC 251348, EC 325100, Himso 1597, IC 1005, IC 15992, IC 24541, JS 71-05, JS 80-25, JS 95-56, JS 99-71, JS 99-82, JS(SH)98-22, KHSb 2, MACS 124, MACS 708, MACS 757, MACS 871, MAUS 2, MAUS 128, MAUS 681, PK 1337, PK 262, PK 472, PS 564, PS 1241, PS 1370, Pusa 37, RSC 5, SL 525, SL 797, SL 813, SL 814, SL 815, SL 817, SL 819, TS 17, VLS 2, VLS 47, VLS 63, VLS 64, VLS 2121, VLS 2165 and VLS 2169	47	2
Purple seed stain and bacterial pustule	EC 245988, Hardee, Lee and PS 1347	4	2
Purple seed stain and bud blight	CoSoya 2, DS 98-14, EC 325100, Himso 1598, JS (SH) 98-22, MACS 708, NRC 65, PS 564, RSC 5, SL 813, TS 17 and VLS 64.	12	2
Bacterial pustule and bud blight	MACS 450, MAUS 681 and PS 1092	3	2
Anthracnose, powdery mildew and purple seed stain	Birsasoya 1 and JS (SH) 98-22	2	3
Anthracnose, purple seed stain and bacterial pustule	Lee	1	3
Powdery mildew, purple seed stain and bud blight	DS 98 14, DS 2001, EC 325100, KHSb 2, MACS 708, PS 564 and VLS 64	7	3
Powdery mildew, bacterial pustule and bud blight	Himso 1597 and PK 472	2	3
Anthracnose, powdery mildew, purples seed stain and bud blight	JS (SH) 98-22	*1*	*4*

spraying uniformly on foliage during evening hours. Inoculation was repeated twice at 10 min intervals to ensure infection. Inoculated seedlings were transferred to the growth chamber maintained at 25°C and 95% relative humidity. Disease reaction was recorded five days after inoculation using 0-9 scale given by Mayee and Datar (1986). Similar procedure was followed for bacterial pustule. JS 335 was used as a susceptible check while screening the genotypes against rust, anthracnose, *Myrothecium* leaf spot, *Rhizoctonia* aerial blight, *Alternaria* leaf spot, purple seed stain and collar rot and Punjab 1 against bacterial pustule.

Field experiment was carried out during the *rabi*/summer season of 2005 for evaluation of 204 soybean genotypes against powdery mildew and Indian bud blight (thrips transmitted viral disease). All the genotypes were sown in a row of 5 m length with a row spacing of 30 cm. Observations for powdery mildew were recorded at 75-85 days after sowing using the scale given by Mayee and Datar (1986) and for Indian bud blight by counting the plants showing the typical symptoms of bud blight and calculated the per cent disease incidence (PDI). Genotypes were categorized as highly resistant (0-5 PDI), resistant (6-10 PDI), moderately resistant (11-25 PDI), moderately susceptible (26-50 PDI), susceptible (51-75 PDI) and highly susceptible (76-100 PDI). JS 335 was used as susceptible check against Indian bud blight and DSb 1 against powdery mildew.

Susceptible check JS 335 indicated susceptible reaction to anthracnose, *Myrothecium* leaf spot, *Rhizoctonia* aerial blight, *Alternaria* leaf spot, purple seed stain and bud blight and highly susceptible reaction to rust and collar rot. Punjab 1 showed susceptible reaction to bacterial pustule and DSb 1 to powdery mildew. Among the 204 genotypes, two genotypes (EC 241778 and EC 241780) against rust, 45 against purple seed stain, 117 against powdery mildew, 13 against bacterial pustule, 74 against bud blight exhibited resistant reaction. However, none of the genotypes showed resistant reaction against *Myrothecium* leaf spot, *Rhizoctonia* aerial blight, *Alternaria* leaf spot and collar rot (*Sclerotium rolfsii*) (Table 1). Further, genotypes with multiple disease resistance are categorized and given in table 2. One genotype (JS (SH) 98-22) was resistant to four diseases, 12 exhibited resistance against three diseases while 95 against two diseases. There are few earlier reports on multiple disease resistance in soybean (Chandra *el al.,* 1987; Zaostrovnykh and Vaschenko, 1991).

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Persistence of Fungicides in the Soybean Seeds and Their Effect on Field Emergence after Storage

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Key words: Fungicides persistence, *Fusarium moniliforme,* soybean

Seed treatment is the cheapest, convenient and most popular technology for quality seed production. It not only contains the seed deterioration on account of microbes but also ensures good field stand and seed yield. Although considerable information is available regarding efficacy of seed dressing fungicides, the information on their residual efficacy and biological behavior is limited. There is very little information available on the retention of fungicidal activity of fungicides deposited on the seeds during the storage period. In view of the above, the present study was undertaken to assess the period for which the effect of seed dressing fungicides is retained during storage under ambient conditions.

Seeds of six popular and promising cultivars of soybean viz. Pusa 16, Pusa 20, Pusa 22, JS 335, JS 75-46 and JS 80-21, having about 8 per cent moisture content were treated with thiram, carbendazim and a combination of thiram + carbendazim in the ratio of 1:1 w/w (mixed mechanically) @ 3g/kg of seed. However, in case of hexaconazole, seeds were sprayed with 0.3 per cent solution using an atomizer followed by the drying of seeds in shade. Proper controls were also maintained in each case. The hot air oven method was used for the determination of moisture content. Each treatment was further divided into two equal sub-lots; one lot was kept in cloth bag and the other in 700 gauge polythene bag and with an electric sealer. Both, the cloth bags and polythene bags were stored in the seed cabinets under ambient conditions from December to May and subsequently the persistence of the chemical fungicides at 45 and 135 days of storage and field emergence were evaluated. The data on field emergence was subjected to analysis of variance by completely randomized design

A smear of spore suspension of *Fusaruim moniliforme,* having 10^5 spores / ml was spread twice on the PDA plate and

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one seed from each treatment in five replications was kept in the centre of the plate. The plates were then incubated at a temperature of 20 ± 1°C under alternating cycle of 12 hours darkness/ light (ISTA, 1976). After 3-4 days, the inhibition developed around the seeds was measured.

One hundred fifty seeds were drawn separately from each treatment and were evaluated for the field emergence. Fifty seeds were sown in each of the three rows (2.5 m long) for each treatment. The emergence of the plumule was recorded on the 8th day of sowing and was expressed as per cent field emergence.

Persistence of fungicides during storage: In the present study, storing the seeds in polythene bag resulted in better retention of fungicidal effect as compared to that stored in cloth bags (Table 1). In the seeds treated with thiram + carbendazim, an inhibition zone of 40 and 30 mm was developed after the storage of 45 and 135 days respectively, in polythene bags indicating a decrease in the efficacy of the chemical on the seed surface. Similarly, inhibition zones of 20 and 25 mm were observed in the seeds treated with thiram and carbendazim, individually after 45 days of storage (Table 1). These inhibition zones were further reduced to 12 and 10 mm diameter after 135 days of storage. Hexaconazole does not appear to be effective in either cloth bag and polythene bag storage.

On the contrary, seeds treated with thiram + carbendazim, thiram and carbendazim when stored for 45 days in cloth bags, inhibition zones of 25, 18 and 20 mm diameter respectively were obtained, while with the storage of 135 days, the respective inhibition zone were of 16, 8 and 10 mm. According to Vyas and Nene (1971), Thiram is reported to degrade on seed during storage. Further, Raju and Chatrath (1978) reported that the process of degradation of fungicide is influenced by the storage conditions. Similarly, Gupta and Chatrath (1983) observed that the quantity of thiram on the soybean seeds decreased gradually with the increase in the storage period and fungicide degradation was maximum when the seeds were stored in cloth bags.

Table 1. Inhibition zones in different treatments (dia. in mm)

Days of storage/ Treatments	Cloth bag		Polythene bag	
	Storage (days)		Storage (days)	
	45 d	135 d	45 d	135 d
Control	-	-	-	-
Thiram	18	8	20	12
Carbendazim	20	10	25	10
Thiram + Carbendazim	25	16	40	30
Hexaconazole	-	-	8	-

Field emergence: The initial germination for different cultivars was found to be in the range of 87-97% viz. Pusa 16 (87%), Pusa 20 (89 %), Pusa 22 (92 %), JS 335 (91 %), JS 75-46 (97 %) and JS 80-21(96 %). All the untreated seeds failed to meet the minimum certification standards of 70% germination except Pusa 22 when stored in polythene bags (Table 2). In case of cultivar Pusa 16, only seeds treated with thiram and stored in polythene bags could meet the certification standards. In the remaining cultivars, seeds treated with thiram irrespective of the container could meet the certification standards. The seeds treated with carbendazim and stored in polythene bags in all the cultivars except Pusa 16 were able to meet the certification standards of 70% germination.

Seed treatment with thiram + carbendazim, irrespective of the container could meet the minimum certification standards in case of Pusa 20 and Pusa 22, while JS 335, JS 75-46 and JS 80-21 could meet the certification requirements only when stored in polythene bags. In case of hexaconazole treated seeds, cultivars Pusa 20, Pusa 22 and JS 80-21 were able to meet the certification standards only when stored in polythene bags. In case of cloth bags, there was a greater loss in the activity of chemical fungicides and consequently the viability of the seeds also declined. These chemicals do not play a direct role in the process of seed germination but somehow give protection to the seed both against fungal invasion and physiological ageing. Similar trend was also observeed earlier by Gupta (2002).

Significant differences were observed between different treatments, storage containers as also between the different cultivars. However, all the fungicides were biologically active against *Fusarium*

Table 2. Field emergence (%) of seeds of different soybean cultivars after storage period of five months

Cultivars/ Treatment	Pusa 16		Pusa 20		Pusa 22		JS 335		JS 75-46		JS 80-21	
	C	P	C	P	C	P	C	P	C	P	C	P
Control	58	62	64	68	64	70	62	67	60	66	62	68
Thiram	66	70	72	76	73	76	70	76	71	75	72	77
Carbendazim	62	67	68	73	66	72	66	71	65	70	66	74
Thiram + Carbendazim	64	69	70	75	71	74	68	73	66	73	65	76
Hexaconazole	58	64	66	70	65	72	65	68	65	69	65	70
(P=0.05)	**Container**		**=**	**0.87**	**Treatment**		**=**	**1.37**	**Varieties**		**=**	**1.50**
	Interactions		**=**	**NS**								

moniliforme, except hexaconazole as they retained fungicidal properties even after 135 days of storage in both the containers. Polythene bag was a better container as compared to that of cloth bag and the bioassay revealed that thiram + carbendazim proved to be the best followed by carbendazim, thiram and hexaconazole against *Fusarium moniliforme*. The seeds stored in polythene bags after pre-storage seed treatment with thiram and thiram + carbendazim yielded highest seedling emergence in the field in all the cultivars as compared to seeds treated with the same fungicides and stored in cloth bags.

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Potential of Naturally Occurring Bio-control Agents of Lepidopteran defoliators Infesting Soybean

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Key words : Bio-control agents, defoliators

Soybean [*Glycine max* (L) Merrill] is attacked by half a dozen of lepidopteran defoliators. The lion's share is taken by green semiloopers (*Chrysodeixis acuta* and *Diachrysia orichalcea*) and tobacco caterpillar (*Spodoptera litura*) (Sharma, 1999). They account for about 60 per cent of total losses caused by the insect-pests. Usually chemical control methods are resorted to for the management of these defoliators. In nature, several bio-control agents (BCAs) viz. parasitoids, predators and insect pathogens (Lorenzato and Corseuil, 1982 and Singh and Singh, 1988), influence the populations of defoliators. However, activity of such naturally occurring bio-control agents is hampered due to indiscriminate use of chemical insecticides. Present study was undertaken to establish the potential of naturally occurring bio-control agents, especially insect pathogens, larval parasitoids and spiders. Effect of insecticide spray and seed treatment on parasitoidation and spider population was also studied.

A study was undertaken during *kharif* (rainy) seasons of 2001, 2002 and 2003 to identify potential BCAs and to quantify their potential in suppressing the defoliators' population. Twenty larvae (green semiloopers and/or tobacco caterpillar) were collected from untreated field at weekly interval during the season and kept in 500 ml glass jars covered with muslin cloth. All the jars were placed in an environmental chamber maintained at 27 $\pm$ 1^0 C and 80 $\pm$ 5 per cent RH. The larvae were observed for mortality due to *Beauveria bassiana* and/or *Nomuraea rileyi*. Larval parasitoidation by dipteran *Sturmia* spp. was recorded form the field population of defoliators. Observations on parasitoidation and spider's population were also recorded from experiments laid out for evaluating spray and seed dressing formulations. Data are presented in table 1 and meteorological data of corresponding weeks in table 2.

The mean larval population in soybean field showed an increasing trend up to 3rd week of August, which declined

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Table 1. Larval population, larval mortality due to insect pathogen(s) *Beauveria bassiana* and/or N*muraea rileyi* and larval parasitoidation due to *Sturmia* spp. observed during the month of August

Year	Larval population of defoliators (per m) in week				Larval mortality (%) due to insect pathogen(s) in week				Larval parasitoidation (%) due to *Sturmia* spp. in week			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
2001	2.6	9.0	1.7	5.0	10.0	30.0	45.0	70.0	8.0	12.0	8.0	8.0
2002	1.8	2.3	3.1	0.5	10.0	40.0	70.0	80.0	10.0	30.0	20.0	20.0
2003	4.3	2.8	1.5	1.6	3.3	13.3	20.0	26.6	13.6	16.7	13.3	16.7
Mean	**2.9**	**4.7**	**5.4**	**2.3**	**7.8**	**27.8**	**45.0**	**58.9**	**10.5**	**19.6**	**13.8**	**14.9**

Table 2. Weather parameters during the month of August

Year	Weeks			
	1	**2**	**3**	**4**
		Relative Humidity (%)		
2001	94.57	95.71	94.00	93.80
2002	93.80	95.50	94.00	95.00
2003	66.14	71.43	69.00	69.57
Mean	**84.83**	**87.55**	**85.67**	**86.12**
		Min. – Max. Temperature (^{o} C)		
2001	24.7 – 30.7	24.4 – 29.6	23.1 – 28.2	23.2 – 29.6
2002	24.4 – 30.7	24.7 – 30.7	23.4 – 28.1	23.0 – 29.2
2003	24.1 – 31.7	22.8 – 28.0	22.3 – 26.4	22.5 – 28.1
Mean	**24.4 – 31.0**	**24.0 – 29.4**	**22.9 – 27.6**	**22.9 – 29.0**

sharply during fourth week (Table 1). The study indicated that the period during the month of August provided most congenial conditions for activity of BCAs as well. The average larval mortality due to *B. bassiana* and/or *N. rileyi* ranged form 7.7 per cent in larvae collected during first week of August to 58.9 per cent in those collected during fourth week of August. Singh and Singh (1988) reported 93.6 per cent mortality in gray semilooper (*Rivula* spp.) population infesting soybean. Larval parasitoidation due to dipterous *Sturmia* spp. was found maximum (19.6 %) during second week of August. Perusal of weather data clearly indicated that high relative humidity (>80 %) and temperature ranging between 23 to 31 ^{0}C prevailing during August provided most congenial conditions for fast multiplication of BCAs, especially *B. bassiana* and *N. rileyi* (Table 2). Sosa-Gómez and Alves, (2000) have also reported influence of temperature and RH on conidiogenesis of *B. bassiana*.

Use of chemical insecticides appeared to have definite effect on the extent of parasitoidation and on predators' population. In untreated soybean field, 37 per cent larval parasitoidation and 2 predatory spiders per m row were observed. In the soybean crop sprayed with chemical insecticides (monocrotophos, triazophos and methomyl), larval parasitoidation was only 11.3 per cent with no predatory spiders. However, when soybean was planted after treating the seeds with chemical insecticide (thiamethoxam), parasitoidation (16.7 %) and spider population (1.8 per m row) was higher than the sprayed fields.

In view of these facts, it will be desirable to exploit the potential of naturally occurring BCAs. Pre-sowing seed treatment with suitable insecticide should be preferred and the crop should be sprayed with microbial insecticides containing *B. bassiana* or *N. riely* during first week of August to augment the efficacy of the naturally occurring BCAs.

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Effect of New Insecticides against the Control of Major Insect Pests and Yield of Soybean [*Glycine max* (L.) Merrill)]

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Key words: Insecticides, insect-pests

In Marathwada region of Maharashtra, about 16 different species of insect-pests have been reported on soybean. The important ones are leaf miner [*Aproaerema modicella*, (Deventer)], jassid [*Empoasca kerri (Pruthi)*] and white fly [*Bemisia tabaci, (*Gen.)], stem fly [*Melanagromyza sojae,* (Zehnter)] and girdle beetle [*Obereopsis brevis*, (Swed.)]. These insect are causing appreciable loss to the crop and one of the effective methods is the use of insecticides to manage them. Since new chemicals are being introduced in the market, it becomes imperative to test them. Hence, the present investigation was carried out to study the efficacy of some newer insecticides against the major insect-pests, their effects on yield and economic feasibility.

A field experiment was conducted during *kharif* 1999-2000 at the farm of Marathwada Agricultural University, Parbhani under All India Coordinated Research Project on Soybean. The experiment was comprised of ten treatments (Table 1) replicated thrice under randomized block design. The plot size for each treatment was 5.0m x 3.15m in which seven rows of soybean variety MAUS-32 (Prasad) was grown following standard package of practices. Seed treatment of carbosulfan 25 DS, thiamethoxam 70 WS and chlorpyriphos 20 EC was done before sowing and soil application of phorate 10 G and carbofuran 3G was done by drilling at the time of sowing. In case of imidecloprid 200 EC, thiamethoxam 25 WG and chlorpyriphos 20 EC two sprayings, first on 28th and second on 48th day of sowing, were given by using hand knapsack sprayer using 500 liter of spray material per hectare.

The incidence of major pests was recorded on five randomly selected plants from each plot at weekly intervals. Observations on leaf miner larvae per plant and number of leaflets infested, jassids and white flies on 3 compound leaves (upper, middle and lower)

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per plant, length of stem tunneling by stem fly and girdle beetle from each plot were recorded. The grain yield was converted to per hectare basis and statistically analyzed.

The data on overall effect of different insecticides on the incidence of major insect pests, yield of soybean and economics are presented in table 1. All the treatments were significantly superior over control in respect of incidence of various pests.

Leaf miner

The incidence and per cent leaf damaged due to leaf miner varied significantly amongst the different treatments ranging from 1.82 to 4.17 larvae per plant and 19.28 to 27.82 per cent, respectively. The treatments with chloropyriphos 20 EC @ 1.5 l / ha, thiamethoxam 25 WG @ 100 g/ ha and phorate @ 10 kg/ ha had significantly lower incidence and per cent leaf damage of leaf miner except imidacloprid 200 EC @ 100 ml/ ha and were at par with each other. The treatments of carbosulfan 3 G soil application and carbosulfan 25 DS seed treatment were significantly superior to rest of the treatments. Taware *et al.* (2000) reported chloropyriphos 20 EC spray @ 1.5 l/ ha at 8-10 days after germination to be most effective against leaf miner.

Jassid and white fly

The incidence of jassid and white fly varied from 0.81 to 1.75 and 0.58 to 1.50 adults per 3 leaves, respectively. All the insecticidal treatments were significantly superior over untreated control. The seed treatment with carbosulfan and thiamethoxam, in general, significantly reduced the number of jassid and whitefly as compared to other treatments. Sharma *et al.* (1994) reported that the seed dressing of soybean with carbsulfan 25 STD controlled jassid and white fly. Solunke (1999) also reported thiamethoxam 70 WS @ 3 g/ kg seed and carbsulfan 25 WS @ 3 g/ kg seed as effective against incidence of jassid and white fly.

Stem fly

The per cent stem length tunneled by stem fly ranged from 4.20 to 18.42 per cent. Tunneled stem length was significantly less in the treatment with soil application of phorate 10 G followed by in carbofuran , seed treatment with thiamethoxam 70 WS (6g/kg) and spraying of thiamethoxam 25 WG (100g/ha). Gain and Kundu (1988) and Bagle and Verma (1991) also reported that phorate 10 G was most effective in reducing the stem tunneling by *M. sojae*.

Girdle beetle

The girdle beetle damage ranged between 9.65 and 28.49 per cent in various treatments. The treatments with soil application of phorate showed significantly less damage as compared to other treatments which is followed by carbofuran soil application (30 kg/ ha), imidacloprid spray (100 ml/ha) and chlorpyriphos (1.5 l/ha). Rajput *et al.* (1996) reported that a specified number of plants were damaged by girdle beetle when phorate was applied at 10 and 15 kg per ha in the furrows at the time of sowing. Solunke (1999) observed lowest infestation of girdle beetle with carbofuran @ 30 kg/ha followed by phorate 10 G @ 10 kg/ha.

Yield

The yield of soybean varied from 1194 to 2231 kg per ha in different treatments. The treatment with phorate had highest seed yield of 2231 kg per ha which was followed by thiamethoxam spray (2018 kg/ha). Seed treatments with chlorpyriphos @ 4 ml per kg seed, carbosulfan @ 30 g per kg seed and thiamethoxam @ 3 g per kg seed yielded significantly low than all other chemical treatments. Highest cost benefit ratio was observed in the treatment with soil application of phorate followed by thiamethoxam spray @ 100 g per ha, chlorpyriphos spray, imedacloprid spray and cholorpyriphos seed treatment. It is

Table 1. Efficacy of some new insecticides against major insect-pests and their effect on soybean seed yield

Treatments	Leaf miner (No/plant)	Leaf miner (% leaf damage)	Jassid (No/three leaves)	White fly (No/three leaves)	Stem fly (% Stem length tunneled)	Girdle beetle (% Stem length tunneled)	Yield (kg/ha)	ICBR Ratio
Carbosulfan 25 DS @ 30 g/kg seed	2.27 (1.66)*	22.20 (28.10)**	0.81 (1.14)*	0.58 (1.04)*	10.54 (18.93)**	20.46 (26.89)**	1694	1: 2.32
Thiamethoxam 70 WS @3 g/ kg seed	2.75 (1.80)	23.23 (28.81)	0.85 (1.16)	0.75 (1.11)	11.11 (19.45)	20.74 (27.08)	1712	1: 0.80
Thiamethoxam 70 WS 6 gm/kg seed	2.83 (1.82)	22.99 (28.64)	0.84 (1.16)	0.65 (1.07)	8.65 (17.10)	21.10 (27.33)	1833	1: 0.49
Chlorpyriphos 20 EC @ 4 ml/kg seed	3.12 (1.90)	23.47 (28.96)	0.87 (1.17)	0.75 (1.07)	13.29 (21.37)	23.30 (28.85)	1657	1: 9.48
Thiamethoxam 25 WG @100 g/ha	1.89 (1.54)	20.69 (26.77)	1.06 (1.24)	1.24 (1.32)	9.73 (18.17)	19.88 (26.46)	2018	1: 11.15
Imidacloprid 200 EC @ 100 ml/ha	2.03 (1.59)	21.54 (27.65)	1.24 (1.31)	1.30 (1.34)	12.12 (20.36)	15.29 (23.01)	1906	1: 10.20
Chlorpyriphos 20 EC @ 1.5 lit/ha	1.82 (1.52)	19.28 (26.04)	1.05 (1.24)	1.18 (1.29)	12.51 (20.70)	17.80 (24.99)	1916	1: 10.66
Phorate 10 G @ 10 kg/ha	1.92 (1.55)	20.97 (27.05)	0.95 (1.20)	0.96 (1.20)	4.20 (11.86)	9.65 (18.07)	2231	1: 14.44
Carbofuran 3 G @ 30 kg/ha	2.27 (1.66)	22.57 (28.36)	0.96 (1.20)	1.13 (1.27)	5.74 (13.86)	11.85 (20.13)	1814	1: 2.51
Control (untreated)	4.17 (2.16)	27.82 (31.83)	1.75 (1.50)	1.50 (1.41)	18.42 (25.41)	28.49 (32.25)	1194	--
S Em (±)	(0.017)	(0.41)	(0.028)	(0.015)	(0.35)	(0.43)	(0.33)	
C.D. (P = 0.05)	**(0.052)**	**(1.24)**	**(0.084)**	**(0.046)**	**(1.06)**	**(1.29)**	**(0.99)**	

** Figures in parenthesis are square root values; ** Figures in parenthesis are arcsine values.*

surprising to note that though the seed treatment with thiamethoxam 3 and 6 g per kg seed gave good protection and yielded high, it gave lowest cost benefit ratio owing to its high cost. Hence it is not economical. Singh and Singh (1989) tested phorate and carbofuran at different conditions and timing on soybean and obtained maximum grain yield and cost benefit ratio (1:2.28) from the treatment with phorate 10 kg/ha, 25 days after sowing. Kundu and Shrivastava (1991) reported that the furrow application of phorate 10 G @ 1.5 kg a.i. per ha before sowing followed by one spray of monocrotophos (0.04%) 20 days after germination or phorate 10 G @ 1.5 kg a.i. per ha alone to soybean at sowing, increased the grain yield from 11.0 to 17-18 q per ha.

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