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Transgressive Segregation for Yield Traits in F_2 and F_3 Generation of Soybean [*Glycine max* (L.) Merrill] Crosses

***J P ADITYA*[1], *ANURADHA BHARTIYA*[1], *PUSHPENDRA*[2] *and KAMENDRA SINGH*[2]**
Department of Genetics and Plant Breeding, College of Agriculture, GBPUA&T, Pantnagar 263 145, Uttarakhand, India
(Email: jayprakashaditya@gmail.com)

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ABSTRACT

*In the present study 15 F_2 and F_3 generation of soybean crosses evaluated in a randomized block design along with their 16 parents for prediction and isolation of transgressive segregants for seven quantitative characters. The cross PK 416 × VLS 47 and T49 × PK 472 showed high frequency of transgressive segregation for plant height in F_2 (30 %) and F_3 (25 %) generations, respectively. The cross PK 1029 × PK 1162 showed highest frequency of transgressive segregation for number of primary branches per plant in F_2 generation whereas, (*G. soja *× PK 262) × PK 1029) showed highest frequency of transgressive segregation for the same character in F_3 generation. For number of pods per plant, frequency of transgressive segregants was high and equal in cross PS 1241 × PK 317 and T49 × PK 472 in F_2 generation whereas, cross T49 × PK 472 showed high frequency of transgressive segregants in F_3 generation. For hundred seed weight and seed yield per plant, the frequency of transgressive segregants was highest in cross PK 1029 × PK 1162 in F_2 generation. The promising parents and crosses for yield and other economic traits may be used for future breeding programme.*

Key words: Soybean, transgressive segregants, yield components

Soybean [*Glycine max* (L.) Merrill] often rightly designated as a miracle crop, ranks first among the oilseeds in the world as well as in India. Globally, this crop accounts 101.81 mha area with production of 253.38 mt and 2,490 kg per ha productivity. In India, it is grown in 10.27 m ha area with 11 mt production and an average yield of 1 071 kg per ha (Anonymous, 2011-12). Transgressive breeding aimed in isolating gene combinations (recombinants) which

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[1] *Scientist (VPKAS, Almora, Uttarakhand),* [2] *Professor (G.B.P.U.A&T, Pantnagar, Uttarakhand)*

posses promising genotype *i.e.*, superior to either parents and also to existing of local cultivar. For a successful plant breeder, development of high yielding genotypes is the main objective and transgressive breeding is a useful approach for attaining this goal as it improves yield and yield contributing traits through transgressive segregation. It is also referred to as "assembling productive genes". The appearance of transgressive progenies in F_2 and F_3 is the function of favourable genetic situations associated with the parents. The production of extreme or `transgressive' phenotypes in segregating hybrid populations has been speculated to contribute to niche divergence of hybrid lineages. Here, we assess the frequency of transgressive segregation in hybrid populations and describe its genetic basis. Quantitative genetic studies of plant hybrids consistently point to the action of complementary genes as the primary cause of transgression, although over-dominance and epistasis also contribute. Complementary genes appear to be common for most traits, with the possible exception of those with a history of disruptive selection.

MATERIAL AND METHODS

The present investigation was carried at the Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar (Udham Singh Nagar), Uttarakhand. The experimental material consisted of F_2 generation of 15 soybean crosses which were grown with their sixteen parental lines and evaluated for yield and its components. Again in next year, F_3 generation of these crosses was evaluated along with their parents for yield related traits in randomized block design (RBD) with two replications. The crosses were grown in ten row and parents were grown in two row of four meter length per replication. Row to row and plant to plant distance was maintained at 60 cm and 5 cm, respectively. The recommended package of agronomic practices was followed during the course of experimentation to grow a normal crop. Forty individual plants from each F_2 and F_3 crosses and ten individual plants from each parent were randomly selected from each replication and the data were recorded for seven quantitative characters. Percentage of transgressive segregation in the F_2 and F_3 generations was obtained by defining extreme progeny as significantly transgressive segregates (the lines that exceeded their better parent mean and L.S.D. at 0.05 probability). Analysis and comparisons were made based on the value of individual plants. The transgressive segregants were calculated in favourable direction only.

RESULTS AND DISCUSSION

Frequency of transgressive segregants in different crosses for yield and its components in the F_2 and F_3 generation

(Table 1) revealed that the cross PK 416 x VLS 47 and T49 × PK 472 showed high frequency of transgressive segregation for plant height in F_2 (30 %) and F_3 (25 %) generations, respectively, which indicated the accumulation of the genes from both the parents, as a consequence of recombination, which led to the increased plant height. Similar results have been reported by Kant and Singh (1998) in F_2 and F_3 generation in lentil crosses.

The highest frequency of transgressive segregation for dry matter weight per plant was observed in the cross Kalitur × PS 1024 and PK 1029 × PK 1162 in F_2 and F_3 generations, respectively. Cross Kalitur × PK 317 showing equal frequency (17 %) of transgressive segregation in both generations indicated that the involvement of additive gene, which is fixed.

The cross PK 1029 × PK 1162 showed highest frequency of transgressive segregation for number of primary branches per plant in F_2 generation whereas, (*G. soja* × PK 262) × PK 1029) showed highest frequency of transgressive segregation for the same character in F_3 generation. The highest frequency of transgressive segregants in F_3 generation of cross (*G. soja* × PK 262) × PK 1029 may be due to involvement of additive and additive × additive epistatic effects along with the dominance effects. Similar finding was reported by Bahl (1980) in chickpea crosses and Kant and Singh (1998) in lentil crosses.

For number of pods per plant, high and equal frequency of transgressive segregants in cross PS 1241 × PK 317 and T 49 × PK 472 in F_2 generation indicated the accumulation of favourable genes from the parents as a consequence of recombination, which led to the increased number of pods per plant. Cross T49 × PK 472 also showed high frequency of transgressive segregants in F_3 generation. Similar result were also reported by Miku and Damaskin (1984) in soybean; Reddy and Singh (1989) in green gram and black gram crosses; Raina *et al.* (1994) in wide cross of pigeonpea; Kant and Singh (1998) in lentil.

In F_2 generation, cross PS 1241 × PK 317 and Kalitur × PK 317 and in F_3 generation, cross PS 1241 × Jupiter gave higher and equal number of transgressive segregants for harvest index. Similar results have been reported by Lawrence and Frey (1975) in interspecific oat crosses.

For hundred seed weight and seed yield per plant, the frequency of transgressive segregants was highest in cross PK 1029 × PK 1162 in F_2 generation. The cross PS 1241 × PS 1042 exhibited equal frequency of transgressive segregation for hundred seed weight and seed yield per plant in both F_2 and F_3 generation. Reddy and Singh (1990) reported higher transgressive segregants for 100-seed weight and yield in mungbean. Lawrence and Frey (1975), Cox and Frey (1984) and Mishra and Verma (1985) reported transgressive segregants for higher grain yield in oats.

Table 1. Percentage of transgressive segregants for yield and yield components in the F_2 and F_3 generations of soybean crosses

Crosses	Gene-ration	Plant height	Dry matter (weight/ plant)	Primary bran-ches (No/ plant)	Pods (No/ plant)	Har-vest Index	Hun-dred seed weight	Seed yield (weight/ plant)
PK 416 × VLS 47	F_2	30	38	30	22	57	0	45
	F_3	0	39	29	6	45	3	69
PS 1024 × G 2121	F_2	0	60	45	65	18	7	45
	F_3	3	57	47	58	22	45	42
PK 1029 × PK 1024	F_2	0	45	30	55	22	57	57
	F_3	8	39	25	47	13	43	30
PK 1029 × PK 1162	F_2	10	87	80	77	75	92	90
	F_3	6	82	20	77	52	45	45
PK 1029 × G2115	F_2	3	35	77	65	22	55	42
	F_3	8	25	33	77	16	17	13
PS1241 x PK 1162	F_2	3	40	47	80	77	25	60
	F_3	0	34	42	77	72	29	55
PS 1241 × PK 317	F_2	8	67	30	90	85	42	82
	F_3	13	60	26	18	77	42	85
PS 1241 × PS 1042	F_2	10	37	30	50	72	65	55
	F_3	8	30	35	55	45	65	55
PS 1241 × Jupitor	F_2	5	52	47	77	80	37	70
	F_3	8	47	60	40	85	17	87
UPSM 534 × PK 472	F_2	0	77	32	67	32	3	80
	F_3	11	66	35	75	28	0	77
Kalitur × PK 317	F_2	3	17	35	32	85	5	60
	F_3	0	17	26	56	26	13	40
Kalitur × PK 472	F_2	3	30	30	45	52	10	52
	F_3	0	20	39	32	60	0	47
Kalitur × PS 1024	F_2	18	90	60	85	37	13	82
	F_3	13	78	57	82	45	18	78
T49 × PK 472	F_2	5	82	22	90	70	25	77
	F_3	25	75	17	85	77	5	85
(*G. soja* × PK 262) × PK 1029)	F_2	0	22	65	60	23	0	5
	F_3	0	50	100	50	76	25	80

Table 2. Parent and cross combination showing maximum transgressive segregants for seven qualitative characters in soybean crosses

Characters	Generation	Best parents	Best cross combination	Transgressive segregation in desired direction (%)
Plant height	F_2	VLS 47	PK 416 × VLS 47	30
	F_3	PK 472	T 49 × PK 472	25
Dry matter/plant	F_2	PS 1024	Kalitur × PS 1024	90
	F_3	PK 1029	PK 1029 × PK 1162	82
Primary branches (No/plant)	F_2	PK 1162	PS 1029 × PK 1162	80
	F_3	PK 1029	*G. soja* × PK 262 × PK 1029	100
Pods (No/plant)	F_2	PS 1241; PK 472	PS 1241 × PK 317 and T49 × PK 472	90
	F_3	T 49	T 49 × PK 472	-
Harvest index	F_2	PK 317; Kalitur	PS 1241 × PK 317 and Kalitur × PK 317	85
	F_3	Jupiter	PS 1241 × Jupiter	85
Hundred seed weight	F_2	PK 1162	PK 1029 × PK 1162	92
	F_3	PS 1042	PS 1241 × PS 1042	65
Seed yield/plant	F_2	PK 1029	PK 1029 × PK 1162	90
	F_3	Jupiter	PS 1241 × Jupiter	87

Miku and Damaskin (1984) reported higher number of transgressive segregants for yield in soybean. Kant and Singh (1998) also reported transgressive segregation for yield and yield components in the F_2 and F_3 generation of lentil.

Transgressive segregants in the F_2 may arise due to dominance and dominance interactions in addition to additive x additive interaction which is fixable or due to recombination of genes with positive effects and responsible for the production of transgressive segregants in the F_3 generation. The findings, therefore, also revealed that the parents differed for many genes and introgression of genes from germplasm lines created large amount of genetic variability for yield and yield components in some of the crosses suggested the scope to use these materials and the crosses.

The crosses which gave high frequency of transgressive segregants for seed yield per plant and number of pods per plant in both the generations may be preferred over the other crosses in an on-going breeding programme.

The promising parents and crosses were identified (Table 2) for various economic traits which can be further used for future breeding programme. Some of these parents and crosses are being utilized in the breeding programme.

It can be concluded that in order to generate high frequency of transgressive segregants in desired direction it would be imperative to execute the potential parental lines *viz*., PS 1024, VLS 47, PK 1162, PK 1029, PK 472 and PK 317 in crossing programme for improvement of yield and its components in soybean.

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Sustainability and Stability of Yield of Soybean Varieties under Various Planting Time in Different Agro-climatic Regions of India

S D BILLORE[1] and S K SRIVASTAVA[2]
Directorate of Soybean Research, Indore, Madhya Pradesh 452 001
E-mail: billsd@rediffmail.com

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ABSTRACT

A multi-location trial was conducted in diverse agro-ecological zones of India during 2009-2011 to optimize the planting date for newly released soybean varieties. Results accrued over three years revealed that the early planting of soybean increased the soybean yields by 23.83 to 26.13 per cent in North Plain, 30.29 to 57.23 per cent in Central, 36.61 to 71.14 per cent in North East and 43.09 to 99.36 per cent in South zones as compared to late sowing. The regression analysis showed that the soybean yields declined by 7 kg per ha per day in North Plain, 9 kg per ha per day in Central, 20.5 kg per ha per day in North East and 25.47 kg per ha per day in South zones. The planting of soybean on 5 July in North Plain and Central zones, 15 or 30 June in North East and South zones showed maximum sustainability yield index. Soybean varieties namely, SL 744 in North Plain, JS 95 60 in Central, JS 97 52 in North East and MACS 450 in South zones were found to be the most productive with highest sustainability yield index (SYI) as compared to other varieties. The high yielding varieties showed sharp decline in seed yield with delayed planting and variation in yield over years as compared to low yielders. Per day decrease in seed yield in SL 744 in North plain (25.6 kg/ha/day), JS 97 52 in Central zone (12.45 kg/ha/day), JS 335 in North East (24.0 kg/ha/day) and South zone (46.19 kg/ha/day) was recorded.

Key words: Agro-climatic regions, planting date, regression, stability, sustainability yield index, soybean, yield

Soybean is premier oil yielding legume crop of India as well as the world. Soybean can provide complete protein, containing 8 amino acids essential for human beings (Asadi and Faraji, 2009). Soybean is basically a rainfed crop; water stress being a major constraint to production in rainfed areas (Chinh *et al.*, 2001) and farmers are unable to exploit/harness full yield potential of the

[1]*Principal Scientist (Agronomy);* [2]*Director*

crop. Owing to global climate change, there is uncertainty of monsoon and its distribution which leads to staggered sowing. Sowing date is considered to affect growth stages significantly and is one of the important factors in determining the harvest of maximum cultivar yield in one or another region. Appropriate planting date causes optimal utilization of the climatic resources such as temperature, humidity, day length and also anthesis time adaptation with proper temperature (Hashemi, 2001). An early planting date of soybean was invariably found to be more productive than later ones (Buehring *et al.*, 2003 and Shafigh *et al.*, 2006). The delayed planting due to high sensitivity of soybean to photo-period and prevailing temperature affect yield negatively by curtailing the duration of vegetative and reproductive growth and drop in yield components (Kazemi *et al.*, 2005). Temperature is the most crucial factor for achieving the optimum plant population; the temperatures lower than 8°C and higher than 38°C are not suitable for performance of soybean (Arshi, 2001). In view of above, the present investigation at multilocations was initiated to study the effect of different planting dates on productivity potential of various new genotypes of soybean under different agro-climatic conditions of India.

MATERIAL AND METHODS

The field experiments were conducted at 9 locations of four agro-ecological zones namely, North Plain (Ludhiana and Delhi), North East (Ranchi, Imphal and Raipur), Central (Amravati) and South (Pune, Coimbatore and Adilabad) zones under All India Coordinated Research Project on Soybean during 2009 to 2011. Four sowing date (5 June, 20 June, 5 July and 20 July for North Plain and Central zones; and 15 June, 30 June, 15 July and 30 July for North East and South zones) as a main plot and varieties (PS 1347, SL 525, DS 98 14, Bragg and SL 744 in North Plain, JS 95 60, JS 97 52, MAUS 71 and JS 335 in Central, RKS 18, JS 97 52, JS 335, RAUS 5, BSS2 and JS 93 05 in North East and RKS 18, MAUS 61, MACS 450, JS 335, LSb1 and Co3 in South zones) as a sub-plots were laid out in split plot design with three replications. The recommended dose of fertilizers applied was 20 N: 60 P_2O_5:20 K_2O:30 S kg per ha for North Plain, 20 N: 80 P_2O_5:40 K_2O:40 S kg per ha for North East, 20 N: 60 P_2O_5:40 K_2O:20 S kg per ha for Central and 20 N: 80 P_2O_5:20 K_2O:30 S kg per ha for South zones. Soybean yield data were collected from all the locations and grouped under different zones and then statistically analyzed using years as replications. Based on the three years data, the various parameters like sustainability yield index- SYI (Singh *et al.*, 1990) and stability coefficient (Finlay and Wilkinson, 1963) were determined. Treatment-wise coefficient was also worked out. The variety-wise yield data were regressed over sowing date for the determination of rate of yield reduction due to per unit change in sowing date.

RESULTS AND DISCUSSION

North Plain zone

Soybean yield was found to be influenced significantly by the variation in sowing dates (Table 1). The planting of soybean on 5 June gave highest yield and remained at par with later two planting dates (20 June and 5 July) and all these three sowing dates were found to be significantly superior to late planting (20 July). Early planting of soybean (from 5 June to 5 July) produced higher yield to the tune of 23.83 to 26.13 per cent as compared to 20 July sowing (late). The regression equation y = -100.9x + 1801 (R^2 = 0.636) revealed that the delay in planting from 5 June caused a reduction of 101 kg per ha per fortnight or 7 kg per ha per day (Table 5). Early planting of soybean indicated a higher variation in soybean yield, which was linearly decreased with delayed planting. The maximum value of SYI (0.54) was associated with 5 July planting closely followed by 20 June or July plantings.

Soybean varieties differed significantly with respect to yielding ability. The maximum yield was recorded with SL 744 (57.33 %) followed by SL 525 (19.80 %), Bragg (18.34 %) and PS 1347 (5.53 %) as compared to lowest yielding DS 9814 (1,303 kg/ha). Among the varieties, Bragg showed least yield reduction (4.7 kg/ha/ fortnight or 0.3 kg/ ha /day) over the sowing dates and closely followed by PS 1347 (91 kg/ ha/ fortnight or 6 kg/ha/day). While the highest yield

Table 1. Effect of sowing date on yield of soybean varieties in North plain zone*

Variety	Date of sowing					SD	SYI
	05 June	20 June	05 July	20 July	Mean		
PS 1347	1456	1336	1391	1134	1375	96.73	0.55
SL 525	1702	1564	1591	1230	1561	224.96	0.58
DS 9814	1140	1174	1481	1415	1303	96.37	0.52
SL 744	2503	2302	2106	1290	2050	375.57	0.72
Bragg	1429	1704	1582	1454	1542	-	-
Mean	1646	1616	1630	1305	1566		
SD	519	435	278	132			
SYI	0.45	0.47	0.54	0.47			
Significance level	Sowing date (D)	Variety (V)	D x V				
SEm (±)	55.27	61.79	123.58				
CD (P=0.05)	**159.76**	**173.79**	**346.04**				

**Mean of 2 locations (Ludhiana and Delhi)* reduction was noted with SL 744 (384 kg/ha/ fortnight or 25.6 kg/ha/day). The results clearly showed that the high yielding varieties were more sensitive to planting dates as compared to low yielding ones. Variety SL 744 and SL 525 showed higher yield variation over the years and also indicated higher SYI values as compared to PS 1347 and DS 9814 which showed lower yield variation as well as SYI values.

Central zone

The seed yield was significantly influenced by sowing dates as well as varieties and their interaction also (Table 2). Significantly highest soybean yield was recorded with 20 June planting followed by 5 July planting. The lowest yield was associated with late planting (20 July). The early (5 June) and delayed planting (5 and 20 July) of soybean resulted in reduction of soybean yield by 17.14, 3.40 and 36.40 per cent as compared to 20 June planting. However, early plantings showed yield enhancement to the extent of 30.29, 57.23 and 51.89 per cent over late planting (20 July). The maximum SYI was associated with 5 July planting followed by 20 June planting. However, the variation in yield was the maximum with 20 June planting followed by 20 July planting. The yield regressed over sowing dates [Y = -129.3x + 2139 (R^2 = 0.227)] which indicated that the soybean yield declined at rate of 129 kg per ha per fortnight or 9 kg per ha per day (Table 5).

The yielding ability of JS 95 60 and JS 97 52 was on par, however, former produced 2.54 per cent higher yield along with higher year-wise variations and

Table 2. Effect of sowing date on yield of soybean varieties in Central zone

Variety	**Date of sowing**					**SD**	**SYI**
	05 June	**20 June**	**05 July**	**20 July**	**Mean**		
JS 95 60	1879	2279	2112	1471	1935	370.58	0.70
JS 97 52	1872	2217	2132	1278	1887	212.14	0.75
MAUS 71	1506	1538	1754	1620	1604	120.21	0.77
JS 93 05	1761	2437	2187	1020	1769	-	-
Mean	1755	2118	2046	1347	1799		
SD	174	397	197	259	148		
SYI	0.65	0.71	0.76	0.45	0.68		
Significance level	Sowing date (D)	Variety (V)	D x V				
SEm (±)	66.02	66.02	132.04				
CD (P=0.05)	**190.83**	**184.86**	**369.73**				

Table 3. Effect of sowing date on yield of soybean varieties in North East zone*

Variety	Date of sowing					SD	SYI
	15 June	**30 June**	**15 July**	**30 July**	**Mean**		
RKS18	1647	1609	1314	1035	1401	221.11	0.48
JS 97 52	1936	1999	1673	1339	1737	145.08	0.65
JS 335	1874	1815	1343	830	1341	195.07	0.47
RAUS 5	2641	2637	2327	1856	2365	275.86	0.76
BSS 2	2487	2455	2117	1542	2150	313.96	0.69
JS 93 05	2409	2724	1790	1134	2014	-	-
Mean	2166	2206	1761	1289	1835		
SD	399	462	407	371			
SYI	0.65	0.64	0.50	0.34			
Significance level	Sowing date (D)	Variety (V)	D x V				
SEm (±)	73.30	89.78	179.57				
CD (P=0.05)	**211.88**	**251.39**	**502.82**				

Mean of three locations (Ranchi, Imphal and Raipur)

Table 4. Effect of sowing date on yield of soybean varieties in South zone*

Variety	Date of sowing					SD	SYI
	15 June	**30 June**	**15 July**	**30 July**	**Mean**		
RKS18	2997	2732	2298	1762	2447	690.06	0.54
MAUS 61	1973	1880	1460	1136	1612	233.21	0.43
MACS 450	3230	2858	2578	1702	2592	371.09	0.68
Lsb 1	1142	1373	802	293	903	501.78	0.43
JS 335	2771	2592	1419	852	1908	75.24	0.29
Co 3	1168	1082	947	899	1024	95.21	0.54
Mean	2214	2086	1584	1107			
SD	923	752	715	557			
SYI	0.40	0.41	0.27	0.17			
Significance level	Sowing date (D)	Variety (V)	D x V				
SEm (±)	112.81	138.17	276.34				
CD (P=0.05)	**326.09**	**386.89**	**773.78**				

Mean of three locations (Pune, Coimbatore and Adilabad)

Table 5. Linear regression between sowing dates and varieties under different zones

Zone/ Variety	Regression equation	Zone/ Variety	Regression equation
North plain		*North East*	
PS 1347	y = -91x + 1556 (R^2 = 0.715)	RKS 18	y = -213.1x + 1933 (R^2 = 0.925)
SL525	y = -138.8x + 1868 (R^2 = 0.777)	JS 97 52	y = -211.9x + 2266 (R^2 = 0.827)
DS 9814	y = 113.2x + 1019 (R^2 = 0.732)	JS 335	y = -360.2x + 2366 (R^2 = 0.917)
SL 744	y = -383.5x + 3009 (R^2 = 0.865)	RAUS 5	y = -266.5x + 3031 (R^2 = 0.864)
Bragg	y = -4.7x + 1554 (R^2 = 0.002)		
Mean	y = -100.9x + 1801 (R^2 = 0.636)	Mean	y = -307.5x + 2624 (R^2 = 0.861)
Central		*South*	
JS 95 60	y = -139.0x + 2283 (R^2 = 0.262)	RKS 18	y = -414.0x + 3482 (R^2 = 0.978)
JS 97 52	y = -186.8x + 2341 (R^2 = 0.323)	MAUS 61	y = -293.1x + 2345 (R^2 = 0.950)
MAUS 71	y = 55.8x + 1465 (R^2 = 0.424)	MACS 450	y = -486.4x + 3808 (R^2 = 0.931)
JS 93 05	y = -129.3x + 2139 (R^2 = 0.227)	Lsb1	y = -311.8x + 1682 (R^2 = 0.736)
		JS 335	y = -692.9x + 3641 (R^2 = 0.935)
		Co3	y = -94.26x + 1259 (R^2 = 0.971)
Mean	y = -307.5x + 2624 (R^2 = 0.861)	Mean	y = -382.1x + 2703 (R^2 = 0.949)

lower SYI over JS 97 52. The regression analysis revealed that the rate of yield decline (186.8 kg/ha/fortnight or 12.45 kg/ha/day) was higher with variety JS 97 52 [Y = -186.8x + 2341 (R^2 = 0.323)] as compared to JS 95 60 [y = -139.0x + 2283 (R^2 = 0.262)], which showed the 139 kg per ha per fortnight or 9.27 kg per ha per day yield decline (Table 5).

North East zone

Early plantings (June) of soybean showed non-significant differences between them and thereafter planting indicated a drastic reduction in soybean yield (Table 3). The magnitude of yield improvement due to early planting was to the tune 68.04, 71.14 and 36.61 per cent as compared to 30 July planting (1,289 kg/ha). Planting of soybean in the second fortnight of June showed maximum SYI while the 30 June and July plantings possessed maximum and minimum yield variations in yield over years. The regression analysis [Y = -307.5x + 2624 (R^2 = 0.861)] indicated that the yield reduction due to late planting of soybean was to be 307.5 kg per ha per fortnight or 20.5 kg per ha per day (Table 5).

The highest soybean yield was recorded with variety RAUS 5, which was closely followed by BSS 2 as compared to remaining varieties and also possessed maximum SYI and variation in yield over years. Soybean yield regressed over sowing dates (Table 5) indicated that the rate of yield decline was highest in JS 93 05

(475.8 kg/ha/fortnight or 31.72 kg/ha/day) and followed by JS 335 (360.2 kg/ha/fortnight or 24 kg/ha/ day), BSS 2 (317.3 kg/ha/fortnight or 21.15 kg/ha/day), RAUS 5 (266.5 kg/ha/fortnight or 17.77 kg/ha/day), RKS 18 (213.1 kg/ha/fortnight or 14.21 kg/ha/day) and JS 97 52 (211.9 kg/ha/fortnight or 14.13 kg/ha/day).

South zone

Soybean yield as well as variation in yield across the years linearly decreased with delayed planting from 15 June (Table 4). The maximum yield was recorded when soybean was planted on 15 June. The early planting of soybean improved the yield by 99.36, 88.43 and 43.09 per cent over 30 July planting. The maximum SYI was associated with 30 June planting closely followed by 15 June planting. The regression analysis between yield and sowing date [$Y = -382.1x + 2703$ ($R^2 = 0.949$)] revealed that the yield declination rate was 382.1 kg per ha per fortnight or 25.47 kg per ha per day (Table 5).

The yielding ability of soybean variety MACS 450 was maximum and closely followed by RKS 18 and JS 335 along with higher SYI and produced the higher yield to the tune 187.04, 170.98 and 111.29 per cent, respectively as compared to LSb 1. However, the varieties with high yield potential showed higher variation in yield over years. All the varieties of soybean indicated a drastic reduction in yield due to delayed sowing. The magnitude of yield reduction as evidenced from regression equation was 692.9 (46.19 kg/ha/day) in JS 335, 486.4 (32.43 kg/ha/day) in MACS 450, 311.8 (20.79 kg/ha/day) in LSb1, 293.1 (19.55 kg/ha/day) in MAUS 61 and 94.2 (66.28 kg/ha/day) in Co 3.

Early planting (most preferably first two plantings on 5 June and 20 June, and 15 June and 30 June) of soybean was found to be optimum for maximization of soybean yield as evidenced from the yield levels achieved with higher sustainability index and stable performance in different agro-ecological regions of India. This might be due to appropriate planting date, which caused optimal utilization of the climatic resources such as temperature, humidity, day length and also anthesis time adaptation with proper temperature (Hashemi, 2001; Rezai-Zadeh, 2004; Azizi *et al.*, (2005); Shafigh *et al.*, 2006)) and had the impact on plant vegetative and reproductive growth that in turn increased efficiency of photosynthesis, photo-assimilates transport and their storage in the seed and caused improved performance (Azari and Khajepour, 2003). General delay in planting resulted in reduction of potential crop yield, since part of solar radiation is not received by the shadow picture (Jose *et al.*, 2004), the growth, the plant does not achieve its potential ability and so this leads to reduced yield. Billore *et al.* (2000) also reported similar results for *Malwa* conditions of Madhya Pradesh. Bastidas *et al.* (2008)

Stipulated that delayed planting led to significant linear seed yield declines of 17 kg per ha per day in 2003 and 43 kg per ha per day in 2004, denoting the importance of optimally early planting for capturing the yield potential available in soybean production, when moisture supply is not limiting.

The differences in yielding ability of soybean genotypes may be due to differences in their genetic makeup. These results are in agreement with the findings of Billore *et al.* (2000). Buehring *et al.* (2003) reported that all soybean cultivars obtained more yield from early planting date than two delayed planting dates. With delay in planting, due to high sensitivity of soybean to photo-period duration and temperature affects yield negatively by reducing the duration of vegetative and reproductive growth and yield components drop (Kazemi *et al.*, 2005). Egli and Bruening (2000) indicated that planting date effects on yield of soybean cultivars and with respect to time delay, reduces the desired yield; considering that soybean is a short day plant, so if exposed to short day length it flowers. Longer day increases the flowering delay with the delay in planting, because, plants exposed to earlier days get a short height, shorter, fewer branches and weak growth period before flowering and get a shorter flowering period that all these factors cause the formation of fewer pods and fewer transfer material to the sheath and the photosynthetic performance is reduced (Azizi *et al.*, 2005). Truyen *et al.* (2004) also concluded that the soybean varieties significantly differed when planted in different sowing dates and early planting were found to be better for soybean.

On the basis of aforesaid results in could be concluded that the early planting of all the soybean genotypes was found to more productive than late planting. The optimum planting time of soybean was 20 June to 5 July for North plain zone, 20 June to 5 July for Central zone, 15 to 30 June for North East and South zones.

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Productivity, Nutrients Uptake and Economics as Influenced by Integrated Nutrient Management in Rainfed Soybean of Bundelkhand Region of Uttar Pradesh

NARENDRA SINGH[1] and H S KUSHWAHA[2]
Department of Natural Resource Management, Faculty of Agriculture, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna 485 780, Madhya Pradesh
(Email: kushwaha_hs@rediffmail.com)

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ABSTRACT

*A field experiment was conducted at Krishi Vigyan Kendra, Ganivan Chitrakoot (Uttar Pradesh) during 2006 and 2007 to assess the optimum doses of fertilizers along with organic manures on soybean [*Glycine max *(L.) Merrill]. Integrated use of chemical fertilizers (100 % NPK) with FYM @ 5 tonnes per ha recorded significantly higher nodules per plant, yield attributes namely, pods per plant, seeds per pod, seed index and seed yield (2,470 and 2,547 kg/ha), straw yield (2,408 and 2,658 kg/ha) and harvest index. Significantly higher uptake of N (209.7 and 223.0 kg/ha), P (34.7 and 34.7 kg/ha) and K (88.0 and 91.0 kg/ha) by soybean were recorded under 100 per cent NPK through fertilizer + FYM @ 5 tonnes per ha. Net returns (Rs 40,432 and Rs 42,241) and returns per rupee (Rs 5.20 and 4.76) was estimated maximum in 100 per cent NPK through fertilizer + FYM @ 5 tonnes per ha.*

Key words: Economics, FYM, nutrient uptake, productivity, soybean, vermicompost

Soybean [*Glycine max* (L.) Merrill] - wheat (*Triticum aestivum* Lenend., Fiori & Pao) system has emerged as a predominant cropping system of Bundelkhand region under both irrigated and rainfed conditions.. Soybean is an important crop for Bundelkhand region in respect of economic returns. Farmers prefer to grow soybean as a cash crop followed by wheat as a high yielding food grain crop. In Bundelkhand region of Uttar Pradesh, soybean was grown over an area of 16,906 ha with production 21, 166 tonnes and productivity of 1,252 kg per ha in year 2011-12 (Anonymous, 2011-12). The producti-vity of soybean and wheat ranged from 0.7 to 0.9 tonnes per ha and 1.5 to 2.2 tonnes per ha, respectively in the past (Jain *et al.,* 2004). The productivity of

[1]Subject Matter Specialist (Agronomy), Krishi Vighyan Kendra, Gonda (Uttar Pradesh); [2] Senior Lecturer (Agronomy)

these crops has been stagnated or even showing a slightly declining trend. Imbalanced nutrition is one of the important constraints of low soybean productivity in north Indian plains. Continuous use of chemical fertilizers has led to problem of soil degradation, which is proving detrimental to soybean production. Application of organic material along with inorganic fertilizers into the soils leads to increase in productivity of the system and sustain the soil health for longer period (Manna *et al.,* 2007). Hence, an experiment was conducted to study the performance of soybean with different organic and inorganic source of nutrients in terms of productivity, nutrients uptake and economics.

MATERIAL AND METHODS

The field investigation was conducted at Tulsi Krishi Vigyan Kendra, Ganivan, Chitrakoot (Uttar Pradesh) during *kharif* - *rabi* season in 2006-07 and 2007-08. In *kharif* season, soybean crop was taken and subsequent wheat was grown in *rabi* season. The experiment was conducted at same site during both the years, where each treatment was allocated in same plot. Geographically the experimental farm is situated at the 24°52′ N latitude and 80°40′ E longitude and about 132.98 meter above mean sea level. The soil of experimental site was heavy textured (Inceptisols), poor in nitrogen (125.09 kg/ha), medium in phosphorus (19.96 kg/ha) and rich in potassium (328.22 kg/ha) with pH of 7.3. The experiment consisted 13 treatments namely, control (no fertilizer), 50 per cent recommended dose of fertilizers (RDF), 75 per cent RDF, 100 per cent RDF, 50 per cent RDF + FYM @ 10 tonnes per ha, 50 per cent RDF + vermicompost @ 5 tonnes per ha, 50 per cent RDF + cow pat pit (CPP) @ 3.75 kg per ha, 75 per cent RDF + FYM @ 5 tonnes per ha, 75 per cent RDF + vermicompost @ 2.5 tonnes per ha, 75 per cent RDF + CPP @ 1.875 kg per ha, 100 per cent RDF + FYM @ 5 tonnes per ha, 100 per cent RDF + vermicompost @ 2.5 tonnes per ha and 100 per cent RDF + CPP @ 1.875 kg/ha), which were tested in randomized block design with 3 replications. The RDF for soybean was 20:80:40 kg N: P_2O_5:K_2O per ha. However, the succeeding wheat crops was provided considering recommended dose of NPK (120:60:40 kg N: P_2O_5:K_2O/ha) as detailed in tables. The N, P and K fertilizer were applied through urea, diammonium phosphate (DAP) and muriate of potash (MOP). According to treatment combination, the required quantity of FYM and vermicompost were added during land preparation. The cow pet pit was applied in the furrow at the time of sowing. The FYM, vermicompost and CPP were prepared at KVK, Ganivan. CPP is a biodynamic field preparation and strong soil conditioner. The NPK content in FYM was 0.42:0.28:0.75 and 0.44:0.30:0.71 per cent; vermicompost

1.30:0.23:0.78 and 1.41:0.22:0.85 per cent and CPP 1.65:0.32:0.85 and 1.71:0.30:0.84 per cent in 2006 and 2007, respectively. Fertilizers and seeds of soybean @ 80 kg per ha inoculated with *Bradyrhizobium japonicum* culture @ 200 g per 10 kg seed were drilled manually in open furrow. The row to row distance was maintained at 45 cm and plant to plant spacing (10 cm) was maintained by thinning at 20 DAS. The soybean variety JS 335 was sown on 14th July, 2006 and 15th July, 2007 and was harvested on 22nd October and 24th October in respective years. The rainfall of 450.0 and 438.5 mm was received from July to October in 2006 and 2007, respectively (Table 1). The data on crop growth and yield were recorded. The N, P and K uptake of soybean (seed and straw) were analyzed by Kjeldahl digestion and distillation method (Jackson, 1971), Olsen's method (Olsen *et al*., 1954) and ammonium acetate method (Jackson, 1971), respectively. The cost of cultivation and gross return were calculated as per the prevailing market price of seed.

RESULTS AND DISCUSSION

Nodulation

Number of nodules per plant was significantly higher under 100 per cent NPK + FYM 5 t per ha at 60 DAS (Table 2).

Table 1. Meteorological data for the experimental period

Month	Meteoro-logical week (No)	2006-07					2007-08				
		Rain-fall (mm)	Temperature (^{0}C)			Relative humi-dity (%)	Rain-fall (mm)	Temperature (^{0}C)			Relative humi-dity (%)
			Mini-mum	Maxi-mum	Aver-age			Mini-mum	Maxi-mum	Aver-age	
July	27	12	24	39	31.5	62.71	-	24	37	30.5	62.57
July	28	79	25	34	29.5	73.43	20	26	39	32.5	60.14
July	29	117	24	27	25.5	84.0	25.5	24	37	30.5	66.43
July	30	36.5	25	34	29.5	80.86	16.5	24	34	29.0	77.86
August	31	23	25	31	28.0	64.57	91.5	25	32	28.5	81.28
August	32	-	25	35	30.0	70.29	60.5	25	35	30.0	70.29
August	33	12	25	35	30.0	78.29	18	25	35	30.0	74.57
August	34	93	25	36	30.5	78.14	65.5	26	35	30.5	68.86
September	35	42	25	33	29.0	77.15	42.5	26	35	30.5	67.00
September	36	11	25	34	29.5	77.28	31	24	34	29.0	85.85
September	37	-	26	37	31.5	63.86	-	26	35	30.5	63.28
September	38	10.5	24	34	29.0	77.57	38.5	24	35	29.5	71.71
September	39	-	22	34	28.0	73.46	20.5	22	34	28.0	80.14
October	40	-	23	37	30.0	46.29	8.5	21	34	27.5	60.14
October	41	-	21	37	29.0	37.00	-	19	34	26.5	46.71
October	42	7	18	36	27.0	45.43	-	17	35	26.0	45.42
October	43	19	16	32	24.0	65.86	-	16	35	25.5	37.28

It might be due to availability of abundant organic matter and effective microbial activities because of sufficient supply of feeding material for rhizobium bacteria in the form of humus (Prakash *et al*., 2001). It also ensured healthy soil environment and better aeration for higher nodulation. This finding closely supports the results of Mishra *et al*. (2005).

Yield attributes

Yields attributes namely, pods per plant, seeds per pod, pod length and seed index of soybean were recorded significantly greater with the application

Table 2. Effect of integrated nutrient management on nodulation and yield attributes of soybean

Treatment Soybean	Wheat	Nodule at 60 DAS (No/plant)		Pods (No/plant)		Seeds (No/pod)		Pod length (cm)		Seed index (g/100 seeds)	
		2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Control	Control	14.6	14.4	35.3	35.0	1.9	1.9	2.9	2.9	6.88	6.82
50 % NPK	100 % NPK	26.1	26.8	43.7	44.0	2.4	2.4	3.3	3.3	7.45	7.45
75 % NPK	75 % NPK	34.8	34.9	46.3	46.7	2.6	2.7	3.6	3.6	7.54	7.55
100 % NPK	75 % NPK	52.4	55.7	54.1	56.4	3.0	3.1	4.3	4.3	7.71	7.68
50 % NPK + FYM @ 10 t/ha	75 % NPK	44.1	46.0	51.5	51.5	2.9	2.9	4.0	4.5	7.62	7.61
50 % NPK + VC @ 5 t/ha	75 % NPK	40.8	43.0	48.5	48.6	2.8	2.9	3.9	3.9	7.57	7.60
50 % NPK + CPP @ 3.75 kg/h	75 % NPK	39.8	41.9	44.2	45.1	2.6	2.6	3.6	3.6	7.54	7.58
75 % NPK + FYM @ 5 t/ha	75 % NPK	61.6	63.3	60.0	59.0	3.3	3.3	4.4	4.4	7.79	7.81
75 % NPK + VC @ 2.5 t/ha	75 % NPK	54.3	56.6	55.3	56.3	3.2	3.3	4.3	4.3	7.71	7.79
75 % NPK + CPP @ 1.875 kg/ha	75 % NPK	51.7	51.1	48.7	50.0	2.8	2.9	3.9	3.9	7.60	7.65
100 % NPK + FYM @ 5 t/ha	100 % NPK	70.9	72.8	62.7	63.0	3.3	3.3	4.7	4.7	8.03	8.03
100 % NPK + VC @ 2.5 t/ha	100 % NPK	68.1	67.2	60.7	61.7	3.2	3.2	4.5	4.5	7.91	7.92
100 % NPK + CPP @ 1.875 kg/ha	100 % NPK	66.9	64.6	58.3	59.3	3.1	3.1	4.4	4.4	7.91	7.91
SEm (±)		0.6	2.4	1.6	0.7	0.1	0.1	0.07	0.07	0.14	0.01
CD (P = 0.05)		**1.9**	**7.1**	**4.8**	**2.1**	**0.4**	**0.4**	**0.3**	**0.1**	**0.41**	**0.03**

FYM – Farmyard manure; VC – Vermicompost; CPP – Cow pat pit of RDF (100 % NPK) + FYM @ 5 tonnes per ha during 2006 and 2007 than most of the other treatments (Table 2). This might be due to supplementation of balanced dose of NPK as well as organic matter through FYM. The nitrogen supplied in inorganic form was properly utilized due to more microbial activities in the soil with organic matter (Prakash *et al*., 2001). This led to better physiological development owing to facilitating in formation of chlorophyll and photosynthates. Thus, healthy and timely develop-ment of crop plants resulted in higher yield attributes. The results are in line with the findings of Raut *et al*. (2004) and Khutale *et al*. (2005). Similarly, balanced dose of phosphorus and potassium through fertilizer might have promoted better root development and root activity for absorption of nutrients. (Fageria *et al*., 1997) In addition to this, use of organic manures through FYM increases the microbial activities as well as number of nodules per plant (Prakash *et al*., 2001), which pilot the continuous availability of essential elements to crop plants. Jointly, these factors positively enhanced the nutrients uptake and photosynthesis process and ultimately soybean crop produced higher yield attributes (Mehasen and Saeed, 2005).

Yield

Seed yield (2,470 and 2,547 kg/ha) of soybean was significantly higher obtained under 100 per cent NPK + FYM @ 5 tonnes per ha during both the years (Table 3) than all other treatments except 75 per cent NPK+ FYM @ 5 tonnes per ha, 75 per cent NPK+ VC @ 2.5 tonnes per ha and 100 per cent NPK + FYM @ 5 tonnes per ha and 100 per cent NPK + VC @ 2.5 tonnes per ha in 2006 and 2007. Straw yield was also recorded evidently higher (2,658 kg/ha) under the same fertilizer management in 2007, while in 2006, the straw yield (2,408 kg/ha) was found significantly greater under 100 per cent NPK + vermicompost @ 2.5 tonnes per ha over rest of treatment combinations except 100 per cent NPK + FYM @ 5 tonnes per ha and 100 per cent NPK + CPP @ 1.875 kg per ha. Obviously maximum seed yield of soybean could be ascribed due to higher values of yield components like pods per plant, seeds per pod, pod length and 100 seed weight and greater harvest index (Khutale *et al*., 2005). Optimum quantity of NPK and organic manures promotes the bio-physical activities of crop plants that convert proteins and carbohydrates in the form of grains (Raut *et al*., 2004; Mengel *et al*., 1974). Organic manures like FYM and vermicompost are the best examples to supply micronutrients and catalyse the microbial activities in the soil. These nutrients are in available form for longer period of crop life. These biophysical and biological interactions have lead to additional pod and seed setting (Mehasen and Saeed, 2005). Similarly, significantly greater straw yield (2,408 and 2,658 kg/ha) in 2006 and 2007 was because of higher values of growth characters under these treatments with the application of

100 per cent NPK + FYM @ 5 tonnes per ha or vermicompost @ 2.5 tonnes per ha. Moreover, the synergistic effect of NPK and FYM/vermicompost promoted the growth parameters and ultimately gave higher straw yield. Highest grain yield and straw yield of soybean with integrated nutrient management was also reported by Khutale *et al.* (2005), Tenguria and Menaria (2006) and Prakash *et al.* (2007).

Harvest index

Harvest index of soybean calculated was significantly higher under 100 per cent NPK + FYM @ 5t per ha over rest of treatment during 2006. However in 2007, the pattern was almost same (Table 3). This trend was ascribed due to

Table 3. Effect of Integrated Nutrient Management on yield and harvest index of soybean

Treatment		Yield (kg/ha)				Harvest Index (%)	
Soybean	Wheat	Seed		Straw			
		2006	2007	2006	2007	2006	2007
Control	Control	713	700	858	876	45.38	44.43
50 % NPK	100 % NPK	1288	1211	1378	1392	48.31	46.52
75 % NPK	75 % NPK	1568	1538	1593	1690	49.60	47.64
100 % NPK	75 % NPK	1956	2002	1978	2131	49.76	48.44
50 % NPK + FYM @ 10 t/ha	75 % NPK	1920	1963	1980	2125	49.24	48.01
50 % NPK + VC @ 5 t/ha	75 % NPK	1847	1924	1882	2065	49.53	48.40
50 % NPK + CPP @ 3.75 kg/h	75 % NPK	1496	1484	1573	1626	47.79	47.72
75 % NPK + FYM @ 5 t/ha	75 % NPK	2101	2195	2108	2322	49.91	48.60
75 % NPK + VC @ 2.5 t/ha	75 % NPK	2033	2171	2045	2285	49.85	48.56
75 % NPK + CPP @ 1.875 kg/ha	75 % NPK	1696	1737	1818	1907	48.16	47.66
100 % NPK + FYM @ 5 t/ha	100 % NPK	2470	2547	2405	2658	50.66	48.93
100 % NPK + VC @ 2.5 t/ha	100 % NPK	2406	2462	2408	2612	49.97	48.53
100 % NPK + CPP @ 1.875 kg/ha	100 % NPK	2108	2195	2258	2357	48.28	48.22
SEm (±)		160	170	60	90	0.24	0.17
CD (P = 0.05)		**470**	**460**	**170**	**270**	**0.49**	**0.48**

FYM – Farmyard manure; VC – Vermicompost; CPP – Cow pat pit

Table 4. Effect of integrated nutrient management on total nutrient uptake (seed + straw) of soybean

Treatment		Total nutrient uptake (kg/ha)					
Soybean	Wheat	Nitrogen		Phosphorus		Potassium	
		2006	2007	2006	2007	2006	2007
Control	Control	67.3	57.0	14.3	13.3	34.0	32.3
50 % NPK	100 % NPK	111.3	114.3	22.7	21.7	57.3	57.7
75 % NPK	75 % NPK	146.7	152.0	26.3	25.7	67.3	68.3
100 % NPK	75 % NPK	182.0	189.5	28.6	29.3	80.2	81.5
50 % NPK + FYM @ 10 t/ha	75 % NPK	172.5	190.0	29.3	29.6	80.2	81.5
50 % NPK + VC @ 5 t/ha	75 % NPK	168.0	179.8	28.0	29.3	79.6	79.5
50 % NPK + CPP @ 3.75 kg/ha	75 % NPK	137.8	141.5	25.0	25.0	65.3	62.4
75 % NPK + FYM @ 5 t/ha	75 % NPK	183.0	184.7	29.7	30.3	75.7	76.3
75 % NPK + VC @ 2.5 t/ha	75 % NPK	182.0	182.3	29.3	29.0	74.0	76.0
75 % NPK + CPP @ 1.875 kg/ha	75 % NPK	168.7	170.3	28.0	27.3	70.3	70.7
100 % NPK + FYM @ 5 t/ha	100 % NPK	209.7	223.0	34.7	34.7	88.0	91.0
100 % NPK + VC @ 2.5 t/ha	100 % NPK	205.0	211.7	34.0	34.3	86.3	88.7
100 % NPK + CPP @ 1.875 kg/ha	100 % NPK	187.7	191.0	31.0	30.3	82.0	83.7
SEm (±)		1.5	1.4	0.3	0.3	0.7	0.8
CD (P = 0.05)		**4.3**	**4.0**	**0.9**	**1.0**	**2.0**	**2.4**

FYM – Farmyard manure; VC – Vermicompost; CPP – Cow pat pit

direct correlation of seed and straw yield of soybean in both the year. These findings are in agreement with those of Kumar *et al.* (2006).

Nutrient uptake

Total nitrogen, phosphorus and potassium uptake of soybean (seed + straw) was significantly greater with 100 per cent NPK + organic manures (FYM @ 5 t/ha or vermicompost @ 2.5 t/ha) during 2006 and 2007 than the other treatments (Table 4). Significantly higher uptake of nitrogen (209.7 and 223.0 kg N/ha),

Table 5. Effect of integrated nutrient management on economics of soybean

Treatment		Economics					
Soybean	Wheat	Cost of cultivation (₹/ha)		Net returns (₹ /ha)		Returns / rupee invested	
		2006	**2007**	**2006**	**2007**	**2006**	**2007**
Control	Control	5964	6836	8309	7878	2.39	2.15
50 % NPK	100% NPK	6994	7850	15773	17574	3.68	3.24
75 % NPK	75 % NPK	7506	8374	23861	23917	4.18	3.85
100 % NPK	75 % NPK	8021	8889	31159	33162	4.89	4.73
50 % NPK + FYM @ 10 t/ha	75 % NPK	10221	11641	28176	29572	3.79	3.54
50 % NPK + VC @ 5 t/ha	75 % NPK	12611	14347	24339	26061	2.89	2.82
50% NPK + CPP @ 3.75 kg/h	75 % NPK	8991	9879	20926	21289	3.33	3.15
75 % NPK + FYM @ 5 t/ha	75 % NPK	9119	10255	32914	35841	4.61	4.49
75 % NPK + VC @ 2.5 t/ha	75 % NPK	10255	11616	30412	33989	3.97	3.92
75 % NPK + CPP @ 1.875 kg/ha	75 % NPK	8367	9433	25566	27037	4.06	3.86
100 % NPK + FYM @ 5 t/ha	100 % NPK	9635	11239	40432	42241	5.20	4.76
100 % NPK + VC @ 2.5 t/ha	100 % NPK	10491	12132	37342	39563	4.59	4.27
100 % NPK + CPP @ 1.875 kg/ha	100 % NPK	9080	9949	33087	36146	4.64	4.63
SEm (±)		-	-	473	277	0.05	0.03
CD (P = 0.05)		**-**	**-**	**360**	**797**	**0.15**	**0.08**

FYM – Farmyard manure; VC – Vermicompost; CPP – Cow pat pit

phosphorus (34.7 and 34.7 kg P/ha) and potassium (88.0 and 91.0 kg K/ha) of soybean were recorded under 100 per cent NPK + FYM @ 5 tonnes per ha during the two consecutive years. It might be due to addition of FYM, which played an important role in solublization of insoluble phosphorus and potash, leading to higher availability of plant nutrients. The availability of nitrogen and phosphorus increased by addition of FYM, thus total uptake of NPK increased (Kumar *et al.*, 2006). Further, integrated fertilizer management might have ensured higher uptake of NPK because of increased cation exchange capacity of roots. Mahajan *et al.* (2002) also reported similar findings.

Economics

Net monetary returns (₹ 40,432 and ₹ 42,241/ha) was found superior due to application of 100 per cent NPK + FYM @ 5 tonnes per ha in 2006 and 2007 (Table 5). The higher values of economic returns are directly related to higher grain and straw yield under this treatment combination during both the years. Billore *et al*. (2005) have also reported similar findings. Significantly higher returns per rupee invested was obtained with 100 per cent NPK + FYM @ 5 tonnes per ha over all other treatment combinations during 2006 and 2007.

It was concluded that application of 100 per cent NPK through fertilizer supplemented with FYM 5t per ha was found most appropriate nutrient combination for improving productivity of soybean in Bundelkhand region of Uttar Pradesh.

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Response of Soybean to Sulphur and Boron Nutrition in Acid Upland Soils of Jharkhand

A K SINGH [1], C S SINGH [1] and J P YADAVA [2]
Department of Agronomy, Birsa Agricultural University,
Ranchi 834 006, Jharkhand
E mail: aksbau@gmail.com

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ABSTRACT

A field experiment was conducted at Agricultural Farm, Birsa Agricultural University, Ranchi, Jharkhand to study the effect of sulphur and boron fertilization on yield attributes, yield and nutrient uptake of soybean (variety JS 335) during kharif *2007 and 2008. The experiment was conducted under factorial randomized block design with sulphur as a first factor at five levels (0, 10, 20, 30 and 40 kg /ha) and boron as a second factor at five levels (0, 0.5, 1.0, 1.5 and 2.0 kg /ha) and replicated thrice. Results indicated that increasing doses of sulphur and boron significantly enhanced the soybean seed yield. Application of sulphur @ 30 kg per ha recorded significantly higher seed yield (2,730 kg/ha), net returns (₹ 19 953) and B: C ratio (1.98) than its lower levels, but it remain at par to 40 kg S per ha. Similarly application of 1.5 kg B per ha significantly enhanced the yield attributes and seed as well as haulm yields of soybean. The results revealed that basal application of 30 kg S per ha and 1.5 kg B per ha proved to be the best for higher productivity and profitability of soybean in acid upland soil of Jharkhand.*

Key words: Boron, nutrient uptake, soybean, sulphur, yield

Soybean [*Glycine max* (L.) Merrill] is recognized as 'Golden Bean' due to its high nutritional value such as high quality protein (40-45 %), oil (18-20 %), mineral nutrients like calcium, iron and glycine. Apart from these, it is a good source of isoflavone which helps in preventing heart disease, cancer and HIVs. In India, the area under soybean cultivation was 10.18 m ha and the production was 12.28 m t with productivity level of 1.21t per ha (http://eands. dacnet.nic.in/Publication 12-12-2012/ Agriculture_ at _ a _Glance % 202012/ Pages85-136.pdf), though the crop has potential productivity of nearly 2,500 – 3,000 kg per ha (Anonymous, 2012).

Sulphur is involved in synthesis of

[1]*Junior Scientist- cum-Assistant Professor;* [2] *M Sc(Ag) Student*

fatty acid and also increased protein quality through the synthesis of certain sulphur containing amino acid such as cystine, cystein and methionine (Havlin *et al.*, 1999). Boron deficiency occurs in highly leached sandy soils, acidic soils and soils low in organic matter and it plays an important role in nodulation, flowering, pollen germination, fruiting, seed setting and synthesis of protein and oil (Malewar *et al.*, 2001). In Jharkhand, presently the area under soybean cultivation is 850 ha with a production of 521 tones and productivity of 509 kg per ha. The total geographical area of state is 79.7 lakh ha, of which 49 per cent soils are extremely acidic to strongly acidic (pH < 5.5) and about 36 per cent are moderate to slightly acidic (pH 5.6 to 6.5). Likewise 38 per cent soils are low in available sulphur and 45 per cent soils are deficient in available boron. Intensive cropping, indiscriminate use of fertilizers and limited use of organic matter are the reasons for occurrence of sulphur and boron deficiency in the state which limits soybean yield. However, very meager information is available on response of soybean to sulphur and boron nutrition. Hence a field experiment was conducted to investigate the effect of sulphur and boron nutrition on soybean yield in acid upland soils of Jharkhand.

MATERIAL AND METHODS

A fields experiment was carried out during *kharif* 2007 and 2008 at the Birsa Agricultural University, Ranchi situated at an altitude of 625 m above MSL, 23^{o}17′ North latitude and 35 ^{o} 19′ East longitudes. The soil of the experimental field was sandy loam, acidic in reaction (pH 5.8), low in organic carbon (0.37 %), available nitrogen (213.24 kg N/ha), phosphorus (14.54 kg P_2O_5/ha), available sulphur (6.8 mg/kg), available boron (0.45 mg/kg) and medium in available potassium (180 kg K_2O/ha). The experiment was laid out in factorial randomized block design with three replications. Twenty five treatment combinations were compared comprising of five levels of sulphur (0, 10, 20, 30 and 40 kg S/ha) and five levels of boron (0, 0.5, 1.0, 1.5 and 2.0 kg B/ha). Soybean variety JS 335 was grown at a row spacing of 45 cm. Crop received recommended basal dose of nutrients @ 20:60:40:: kg N:P_2O_5:K_2O per ha through di-ammonium phosphate and muriate of potash, respectively. Sulphur and boron were applied as per treatment details through gypsum (18 % S) and borax (11 % B) as basal. Soybean seed were inoculated with *Bradyrhizobium japonicum* culture @ 5 g per kg seed. The rainfall received during *kharif* 2007 and 2008 was 1,160 mm and 1,210 mm, respectively. Other crop management practices were perfo-rmed as per recommended package of practices. The seed samples were digested in nitric-perchloric acid to determine S and B. Sulphur was determined turbidimetrically (Page *et al.,* 1989) and boron by cramine method (Hatcher and Wilcox, 1950). Protein content (%) in seed was worked out by multiplying the nitrogen content in grain by the factor 5.71 (Sadasivam and Manickam, 1996). Oil content was estimated by Soxhlet extraction method. The observations on growth parameters/ attributes like plant height, branches per plant, pods per plant, seeds per plant and dry matter per plant was taken on five randomly selected plants from each treatment at harvest. Observation on seed index was taken and expressed as g per 100 seed. Since data followed the homogeneity test, pooling of data was done over the seasons and mean data was statistically analyzed and presented here under.

RESULTS AND DISCUSSION

Growth parameters

Among growth parameters, plant height was numerically maximum with application of 40 kg S per ha and 2.0 kg B per ha, respe-ctively. However, the differences were non-significantly statistically. Maxi-mum branches were associated with the application of 40 kg S per ha, which was at par with 30 kg S per ha, but was significantly superior over 20, 10 kg S per

Table 1. Effect of sulphur and boron fertilization on growth and yield attributes of soybean (Pooled data of 2 years)

Treatment	Plant height (cm)	Branches (No/plant)	Dry matter (g/plant)	Pods (No/ Plant)	Seeds (No/ Pod)	Seed index (g/100 seeds)
S level (kg/ha)						
0	68.40	3.80	67.42	68.30	2.86	10.45
10	68.87	3.83	71.40	70.93	2.95	10.71
20	69.83	3.92	71.55	74.13	3.06	11.11
30	70.00	4.37	74.00	77.43	3.17	11.48
40	70.51	4.40	74.90	78.49	3.24	11.74
SEm (±)	0.98	0.08	0.84	0.83	0.04	0.30
CD (P=0.05)	**NS**	**0.23**	**2.38**	**2.36**	**0.13**	**0.85**
B level (kg/ha)						
0	68.39	3.94	68.94	71.90	3.04	11.01
0.5	68.97	4.01	70.93	74.06	3.08	11.15
1.0	69.68	4.09	72.15	74.33	3.08	11.18
1.5	70.06	4.12	73.28	74.47	3.08	11.15
2.0	70.52	4.17	73.98	74.51	3.01	11.00
SEm (±)	0.98	0.08	0.84	0.83	0.04	0.30
CD (P=0.05)	**NS**	**NS**	**2.38**	**2.36**	**NS**	**NS**

Table 2. Effect of sulphur and boron fertilization on yield and economics of soybean (Pooled data of 2 years)

Treatment	Seed yield (kg/ha)	Haulm yield (kg/ha)	Harvest index (%)	Net returns (₹/ha)	B:C ratio
S level (kg/ha)					
0	2095	2638	45.70	14094	1.57
10	2449	2755	46.72	17612	1.89
20	2625	2847	47.61	19178	1.97
30	2730	2939	47.83	19953	1.98
40	2779	2996	47.76	20115	1.92
SEm (±)	29	25	0.35	323	0.03
CD (P=0.05)	**83**	**70**	**0.99**	**916**	**0.09**
B level (kg/ha)					
0	2225	2676	46.80	15226	1.65
0.5	2491	2758	47.04	17923	1.89
1.0	2586	2850	47.15	18751	1.92
1.5	2671	2933	47.23	19460	1.95
2.0	2704	2959	47.39	19591	1.92
SEm (±)	29	25	0.35	323	0.03
CD (P=0.05)	**83**	**70**	**NS**	**916**	**0.09**

ha and control. Whereas boron levels did not significantly influence the branches per plant, numerically highest value was recorded with application of 2 kg B per ha and the lowest number of branches per plant was recorded in control (0 kg B/ha). Dry matter production per plant was maximum with application of 40 kg S per ha which was significantly superior over 20, 10 kg S per ha and control. Application of 2.0 kg B per ha recorded the maximum dry matter at harvest, which was significantly superior to application @ 0.5 kg B per ha and control (Table 1). This might be due to high accumulation of net photosynthates. The results obtained are consistent with findings reported by Meena *et al.* (2011).

Yield attributes and yield

Yield attributes like number of pods per plant, seeds per pod and seed index showed a significant variation for different sulphur and boron levels. Application of 40 kg S per ha resulted into higher values for number of pods per plant, seeds per pod and seed index, which was significantly superior to all the sulphur levels except 30 kg S per ha. Except pods per plant, remaining yield attributes were not influenced by B application. Boron @ 2.0 kg per ha recorded significantly higher pods per plant over control and was on par with all other levels of boron (Table 1). The above results are in conformity with the results of Joshi and Billore (1998) who reported a gradual increase in yield attributes of soybean with increasing level of sulphur.

Application of sulphur and boron significantly influenced seed and haulm yield of soybean (Table 2). Application of 40 kg S per ha recorded maximum seed and haulm yield, which was on par with 30 kg S per ha and significantly superior to 0, 10 and 20 kg S per ha. Higher seed and haulm yield of soybean with sulphur application might be the result of its favorable effect on the yield attributing characters and plant metabolism. Harvest index showed maximum value with application of 40 kg S per ha, which was on par with other sulphur levels but significantly superior over control. The results obtained are in accordance with the findings of Sarkar *et al.* (2002) who reported that sulphur application @ 30 kg per ha increased the seed and haulm yield of soybean.

Increasing levels of boron application showed an increasing trend in seed and haulm yield of soybean. Application of 2.0 kg B per ha obtained significantly higher grain (2,704 kg/ha) and haulm (2,959 kg/ha) yield than its lower doses, but remain at par with 1.5 kg B per ha. The lowest seed and haulm yield recoded were with control. This might be due to the favorable role of boron in nodulation and seed formation process. The results are in consistent with the findings of Saxena and Nainwal (2010) who reported that seed and haulm yield increased significantly with incremental dose of sulphur and boron.

Quality and nutrient uptake

Protein and oil content significantly increased with each incremental application of sulphur level and highest protein and oil content was associated with 40 kg S per ha and lowest was with control. However protein and oil content noticed at 30 kg per ha S application was found to be on par with 40 kg S. It is evident from the results (Table 3) that sulphur had remarkable influence on protein and oil content because sulphur is required for the synthesis of fatty acids and sulphur containing amino acids such as cystine, cysteine and methionine an essential component of protein synthesis (Havlin *et al.,* 1999). The above results are in conformity with reports of Babhulkar *et al.* (2000) who reported that protein and oil content increased with increase in sulphur levels. The data also revealed that protein content was influenced by boron fertilization and significantly highest value was recorded with application of 2.0 kg B per ha, which was on par with 1.5

Table 3. Effect of sulphur and boron fertilization on quality and nutrient uptake by soybean (Pooled data of 2 years)

Treatment	Oil content (%)	Protein content (%)	Sulphur uptake (kg / ha)	Boron uptake (g / ha)
S level (kg/ha)				
0	18.21	30.07	12.40	111.57
10	18.91	31.21	17.09	129.38
20	19.71	31.76	18.55	137.60
30	20.51	32.16	19.32	143.32
40	20.82	32.50	20.00	146.12
SEm (±)	0.23	0.04	0.15	1.28
CD (P=0.05)	**0.66**	**0.12**	**0.43**	**3.64**
B level (kg/ha)				
0	19.17	31.43	14.66	116.49
0.5	19.75	31.48	17.26	130.80
1.0	19.81	31.49	17.97	136.55
1.5	19.82	31.64	18.65	141.16
2.0	19.62	31.66	18.82	142.99
SEm (±)	0.23	0.04	0.15	1.28
CD (P=0.05)	**NS**	**0.12**	**0.43**	**3.64**

kg B per ha. The above results are in conformity with Brady (1996) who reported that boron is involved in the synthesis of protein.

Sulphur uptake increased with increasing levels of sulphur; maximum being associated with the application of 40 kg S per ha. The control treatment recorded the lowest uptake of sulphur. The above results revealed that sulphur doses increased sulphur uptake due to high sulphur content and grain yield. Similar findings are also reported by Ganeshamurthy (1996) who reported that application of sulphur significantly increased the sulphur uptake in soybean. The highest boron uptake was achieved by boron application @ 2.0 kg B per ha, which was closely followed by 1.5 kg B per ha. The lowest boron uptake was observed with 0 kg B per ha.

Economics evaluation

Economic evaluation (Table 2) revealed that the maximum net returns (₹ 20,115/ha) were obtained with 40 kg S per ha, which was significantly superior over control, but at par with 30 kg S per ha. Similarly, application of 2.0 kg B per ha recoded maximum net returns (₹ 19,591/ha), which was significantly superior to 0.5 kg B per ha and control, but was on par with 1 kg and 1.5 kg B per ha. The highest B: C ratio of 1.98 was recorded with the application of 30 kg S per ha. Further increase in sulphur level reduced the B: C ratio. Application of 1.5 kg B per ha registered maximum benefit cost ratio (1.95) which was significantly superior to control. However, the rest of the boron levels were found at par with each other.

On the basis of results of two years experimentations it may be concluded that sulphur and boron application @ 30 kg S per ha and 1.5 kg B per ha, respectively enhanced growth, yield and quality parameters of soybean and proved most economical in acid upland soil of Jharkhand.

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Dynamics of Potassium in Vertisols under Soybean-Wheat Cropping System

B P MEENA[1], S D BILLORE[2] and A RAMESH[3]
Institute of Agricultural Science, Bundelkhand University, Jhansi, Uttar Pradesh
E mail: bk.agronomy@gmail.com

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ABSTRACT

A field experiment was conducted during 2006-08 to study the effect of potassium application on its use efficiency, transformation, balance and productivity of soybean– wheat cropping system. Results revealed that normal sowing date of soybean–wheat system recorded significantly higher soybean seed (20 %) and straw yield (30 %), higher system K uptake (14 %), use efficiencies, K harvest index (3.9 %), higher K fractions (NH_4-OAC-K and $CaCl_2$-K) as compared to late planting system. The application of 33.2 kg K per ha to each crop recorded maximum system production efficiency, agronomic and physiological K use efficiency. Partial factor productivity (PFP) and internal K use efficiency decreased as the levels of K increased and showed a positive balance in soil. All the three soybean genotypes were found to be identical in yield. On comparing the system uptake of K, JS 335 and NRC 7 differed non-significantly and showed their superiority over JS 93 05. Soybean genotype JS 335–wheat system showed significantly higher amount of all the three fractions of K than JS 93 05/ NRC 7–wheat system. Genotypes, namely NRC 7 and JS 93 05 were found to be more efficient in extracting native soil K than JS 335. The soil K balance was negative in case of JS 335–wheat, while it was positive in JS 93 05-wheat and NRC 7-wheat systems.

Key words: Genotypes, potassium dynamics, potassium use efficiency, Vertisols

Inclusion of soybean in nutrient management is essential for sustained productivity of soybean, but lacks adequate attention while formulating fertilizer schedules in Vertisols. The application of K is meagre, to an extent of only 2.6 kg K per ha in Madhya Pradesh. Srinivasa Rao *et al.* (1999) have reported that continuous cropping without K inputs through fertilizers is likely to cause a decline of non-exchangeable K reserves in soil and application of K is of an utmost

[1]M Sc (Ag) Scholar; [2] Sr. Scientist, Directorate of Soybean Research, Indore (Madhya Pradesh)

importance to sustain productivity. It is imperative to study the effect of nutrients in the succeeding crops as normally soybean constitutes a part of cropping systems followed. Soybean-wheat is a pre-dominant cropping system in *Malwa* region of the state of Madhya Pradesh (Yadav and Subba Rao, 2001) under irrigated water regime and therefore it is of paramount importance to study the efficiency of applied potassium under soybean-wheat system. Keeping above facts in view, the present investigation was initiated to study the effect of potassium application on its use efficiency, transformation, balance and yield under soybean–wheat cropping system.

MATERIAL AND METHODS

A field experiment was conducted at research farm of Directorate of Soybean Research, Indore during 2006-07 and 2007-08. The experiment consisted of four levels of K (0, 16.6, 33.2 and 49.8 kg K/ha) and three soybean genotypes (JS 335, NRC 7 and JS 93 05) preceding wheat (var. Sujata) under two sowing dates (1st on the onset of monsoon and 2nd 15 days after 1st sowing) were laid out in split plot design with three replications taking sowing date and K levels in main plots and genotypes in sub-plots treatments. The control treatment was maintained for both the crops, while in case of wheat crop the remaining treatments received only 33.2 kg K per ha. Rests of the crop growing practices were followed as per standard recommendations. A basal dose of 20 kg N per ha and 60 kg P_2O_5 per ha was applied to soybean and 100 kg N per ha and 60 kg P_2O_5 per ha was applied to wheat crop.

The surface (0-30 cm) soil samples collected before experiment-tation and at harvest of soybean crop were subjected to the analysis of the forms of K (water soluble K, neutral 1 M ammonium acetate K, 0.01M $CaCl_2$- K, and 1 M boiling HNO_3 solution K) as per standard procedures. Total K uptake (kg/ha) by the system (soybean and wheat) was calculated by sum of total K uptake in soybean and in wheat. Agronomic K use efficiency (AE), apparent recovery efficiency (RE), physiological effici-ency (PE), partial factor productivity (PFP) and internal K use efficiency (IUE) were determined as per standard formulae. The balance sheet of potassium was also worked out using the K uptake and soil K data.

RESULTS AND DISCUSSION

Effect of sowing time

Results accrued over two years revealed that the date of sowing significantly influenced the soybean yield (Table 1). Normal planting of soybean produced significantly higher seed yield to the tune of 27.45 and 13.41 per cent during 2006 and 2007 with the average of 20.28 per cent over delayed planting. Similarly soybean straw yield also found to reduce when soybean was planted late. While the wheat seed and straw yields remained unaffected due to soybean sowing date. The system productivity was also significantly higher in normal planting. The reduction in soybean yield due to delayed planting may be ascribed to shortening of the vegetative growth period leading to less dry matter accumulation in plant and early commencement of reproductive phase. Similar observations were earlier reported by Billore *et al.* (2000).

Potassium uptake in soybean and wheat as well as in the system was significantly higher under early planting than late planting during both the years (data for individual year is not presented) of study as well as in pooled data analysis (Table 1). Normal (early) planting of soybean had longer life cycle than delayed sown soybean and therefore in case of former plants had sufficient time to assimilate more potassium resulting in higher uptake. Normal planting of soybean showed higher system PFP and potassium harvest index as compared to late planting. While the AE, RE, PE and IUE were higher in case of delayed planting of soybean (Table 2). The higher PFP and potassium harvest index under normal planting might be due to it is a function of yield and applied K levels and total seed K and total K uptake of the system. In case of other efficiencies which

Effect of different levels of potassium

Application of K had a significant influence on productivity of soybean and wheat over control

Table 1. Seed and straw yield, total uptake of potassium and potassium harvest index as influenced by sowing dates, potassium levels and soybean genotypes

Treatment	Soybean yield (kg/ha)		Wheat yield (kg/ha)		Soybean equiva-lent yield (kg/ha)	Soybean total K uptake (kg/ha)	Wheat total K uptake (kg/ha)	System total K uptake (kg/ha	Potassium harvest index
	Seed	Straw	Seed	Straw					
Sowing date									
Normal	2544	2481	4908	7284	7452	32.75	58.95	91.70	35.26
Late	2115	1902	4938	7215	7030	26.28	54.10	80.38	33.95
CD (P=0.05)	**153**	**221**	**NS**	**NS**	**242**	**1.95**	**2.43**	**3.96**	**1.09**
K levels (kg/ha)									
0	2006	2054	4366	7429	6372	23.45	49.40	72.85	33.27
16.6	2230	2189	4778	7283	7008	28.02	54.87	82.89	34.29
33.2	2461	2216	5139	7061	7600	31.62	58.73	90.35	35.41
49.8	2643	2308	5403	7233	8046	35.16	63.10	98.26	35.42
CD (P=0.05)	**73**	**115**	**141**	**117**	**173**	**1.39**	**1.74**	**2.84**	**0.79**
Genotype									
JS 335	2349	2227	5034	7454	7383	27.27	60.64	87.91	31.04
JS 93 05	2350	2326	4860	6921	7210	30.28	52.09	82.37	34.53
NRC 7	2305	2059	4913	7319	7218	30.66	56.47	87.13	35.71
CD (P=0.05)	**NS**	**94**	**115**	**95**	**140**	**1.12**	**1.40**	**2.29**	**0.98**

Table 2. System K use efficiencies and balance sheet as influenced by soybean sowing date and genotypes and potassium levels (pooled)

Treatment	PFP (kg yield/ kg K)	AE (kg yield/ kg K)	RE (%)	PE (kg yield /kg K uptake)	IUE (kg yield/ kg K uptake)	Balance sheet of K					
						Available K		Change in available K	K added	Total K removal	Contri-bution from soil
						2006	2008				
Sowing date											
Normal	100.05	14.03	22.28	60.11	81.26	630.0	654.3	-24.30	99.6	183.4	59.5
Late	94.76	15.52	20.28	76.15	87.45	630.0	609.5	20.50	99.6	160.8	40.7
K levels (kg/ha)											
0	-	-	-	-	86.90	630.0	595.5	-35.0	0.00	145.6	110.6
16.6	116.80	10.59	16.73	67.43	84.55	630.0	601.1	-29.0	99.6	165.8	37.2
33.2	95.00	15.11	21.88	72.51	84.11	630.0	644.0	14.0	132.8	180.7	61.9
49.8	80.46	14.78	25.41	69.97	81.88	630.0	670.1	40.0	166.0	196.5	70.5
Genotype											
JS 335	98.92	14.57	22.78	89.91	83.98	630.0	693.0	-63.0	99.60	175.8	13.2
JS 93 05	96.96	14.76	20.51	75.94	87.53	630.0	607.6	22.40	99.60	164.6	42.7
NRC 7	96.76	13.76	20.25	69.56	82.84	630.0	595.0	35.0	99.60	174.3	39.7

PF P- Partial factor productivity; AE – Agronomic efficiency; RE – Recovery efficiency; PE – Physiological efficiency; IUE- Internal use efficiency

were higher under delayed planting, may be ascribed to the variations in seed yield and K applied and total K uptake.

Potassium fractions after two years of cropping were significantly influenced by the treatments (Table 3). The ammonium acetate K and calcium chloride K were significantly higher with normal planting than late planting of soybean while the nitric acid K remained unaffected due to planting date of soybean. With normal planting of soybean followed by wheat, the K removal was significantly higher than late planting which also exhibited a net negative K balance in soil after two crop rotations (Table 2).

Effect of different levels of potassium

Application of K increased the soybean seed yield (pooled) to the tune of 11.11, 22.68 and 31.75 per cent due to 16.6, 33.2 and 49.8 kg K per ha, while the corresponding increases in wheat were 9.43, 17.70 and 23.75 per cent over control, respectively. However in case of soybean straw yield, all the levels of K increased the straw yield over control and remained at par among them. Significantly highest straw yield of soybean was recorded under control and the difference between 16.6 and 49.8 kg K

Table 3. Potassium transformation as influenced by soybean sowing date and genotypes and potassium levels after two years

Treatment	NH_4OAC-K	$CaCl_2$ K	HNO_3 K
Sowing date			
Normal	654.26	26.17	829.17
Late	609.47	21.99	816.66
SEm (±)	4.42	0.33	9.84
CD (P=0.05)	**26.71**	**2.04**	**NS**
K levels (kg/ha)			
0	595.47	21.67	725.00
16.6	601.07	23.00	758.34
33.2	644.00	24.67	841.67
49.8	670.14	26.99	966.67
SEm (±)	6.23	0.47	13.92
CD (P=0.05)	**19.28**	**1.46**	**42.91**
Genotype			
JS 335	693.00	28.00	862.50
JS 93 05	607.60	22.00	787.50
NRC 7	595.00	22.25	818.75
SEm(±)	5.42	0.41	12.05
CD (P=0.05)	**15.61**	**1.18**	**34.73**

per ha was non-significant. The lowest straw yield was with 33.2 kg K per ha. The results reveal that application of 33.2 and 49.8 kg K per ha to soybean and 33.2 kg K to wheat application will suffice to attain the optimum yield. The system productivity (soybean equivalent yield) revealed an increasing trend with increasing potassium levels. External application of K maintained the availability of K in the root zone of growing soybean plants as envisaged by Kolar and Grewal (1994) and this might have translated into better crop growth rate, higher leaf area, K accumulation influencing seed yield and yield attributes as also reported earlier (Chaturvedi and Chandel, 2005).

Application of graded levels of K significantly enhanced the K uptake in soybean as well as in wheat leading to higher cropping system uptake. Application of K might have increased the nutrient concentration in soil solution, buffering capacity and nutrient diffusion thereby increased nutrient uptake. This in turn might have contributed for the uptake of other nutrients *viz.*, N and P applied extraneously or from the reserve pool or fixed in soil colloids.

System K harvest index and RE increased as the levels of K increased. While the PFP and IUE decreased as the levels of K increased. The highest agronomic and physiological K use efficiency was associated with 33.2 kg K per ha. In contrast to the present findings, Reddy *et al*. (1999) observed that apparent K recovery decreased with increase in fertilizer K rate as was observed with phosphorous fertilizer. Kolar and Grewal (1994) reported that up to 40 kg K per ha had a higher apparent K recovery efficiency applied either basal or split and declined thereafter. The higher apparent K recovery up to 40 kg K_2O per ha may be a consequence of better competition among the nutrient and less priming effect to mobilized to native soil K. Conversely at higher rates of K addition, the crop might have used a relatively lower proportion of fertilizer K. The PFP decreased with increase in K application whether basal or split indicating that with increasing the level and method of K application there was a decrease in the utilization of indigenous K nutrient (Yadav, 2003). Kolar and Grewal (1994) also reported a depression in agronomic K use efficiency with increase in K application above 50 kg K per ha. It can be presumed from the results that there was no significant influence in physiological efficiency with K application at higher rates of K supply though the K concentration in grain and straw was enhanced but increases in grain yield was not proportional and hence, efficiency reduced.

All the three K fractions of K after two cycles of crops exhibited an increasing trend as the levels of K increased. Water-soluble K was maintained at more or less at the same level *i.e.*, did not attain the level of significance even after K application over control except at basal application of 60 and 80 kg K_2O per ha. Water-soluble being a readily available source of soil K may be subjected to change either under cropping or external supply of K in the form of inorganic K fertilizers. This form is in dynamic equilibrium with exchangeable K and whatever change induced by crop removal of K is compensated by the release of exchangeable K into solution (Srinivasa Rao *et al*., 2000). There was depletion in $CaCl_2$-K in the control. The change in readily available K ($CaCl_2$-K) was not comparable to the large K removal by the crops and the changes can be attributed to the distribution between the forms of soil K. Application of K above 40 kg K_2O per ha significantly increased 1M NH_4-OAC-K over initial K content, control (no K treatment) and lower levels of K application. A slight decline in 1M HNO_3-K was noticed in this experiment. However, a decline in 1M HNO_3-K irrespective of extraneous application of soil K is in line with the findings of Ganeshamurthy and Biswas (1985).

The total uptake of K increased as the levels of K increased. However, the application of 16.6 kg K to soybean and 33.2 kg K per ha to wheat showed a negative balance of K in soil. Application of higher levels of K showed a positive balance of soil K. This is due to the dynamic equilibrium between the exchangeable and non-exchangeable forms of K (Srinivasa Rao *et al*., 2000).

Performance of soybean genotypes

Soybean genotypes did not differ significantly with reference to seed yield. However, the yield of wheat was significantly influenced by preceding soybean genotypes. The highest wheat yield was recorded when grown after JS 335 followed by NRC 7 and JS 93 05. The highest straw yield was recorded in JS 93 05. Wheat straw yield was significantly affected due to soybean genotypes. The highest straw yield was noted when wheat grown after JS 335. The differences in seed and straw yield of soybean might be due to their differential genetic makeup (Billore and Joshi, 1997).

The highest total K uptake was recorded with NRC 7. The significantly low uptake was noted in JS 335. While in case of wheat, the reverse trend was observed. The maximum uptake in wheat was recorded when grown after JS 335. On comparing the system uptake of K, JS 335 and NRC 7 differed non-significantly and showed their superiority over JS 93 05.

The highest K harvest index was associated with NRC 7. While, the maximum PFP, RE and PE was with JS 335, however, the remaining two genotypes showed more or less identical values of these efficiencies (Table 2). JS 93 05 showed its superiority in case of AE and IUE.

Soybean genotype JS 335–wheat system showed significantly higher amount of all the three fractions of K than JS 93 05 and NRC 7–wheat system (Table 3). The highest K removal was noted when JS 335–wheat system. Genotypes like NRC 7 and JS 93 05 were found to be more efficient in extracting native soil K than JS 335. Genotype JS 335–wheat system showed a negative soil K balance in soil while remaining two soybean genotypes exhibited positive soil K balance (Table 2).

On the basis of two years experimentation (*kharif* 2006-08), it could be suggested that the application of 33.2 kg K per ha to both the crops in soybean–wheat system was found to be the most productive and maintained the soil fertility.

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Optimization of Nutritional Levels for Newly Released Soybean [*Glycine max* (L.) Merrill] Varieties in Mollisols of Uttarakhand

S C SAXENA[1], RAKESH CHANDRA NAINWAL[2] and ASHOK JOSHI[3]
Department of Agronomy, College of Agriculture,
G. B. Pant University of Agriculture and Technology, Pantnagar
263 145, Uttrakhand
(E-mail: drscsaxena@rediffmail.com)

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ABSTRACT

A field experiment was conducted during kharif *seasons of 2009-10 and 2010-11 at N. E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar to assess the optimum nutritional levels for newly released soybean* (Glycine max *L. Merrill) varieties in Mollisols of Uttarakhand. The experiment was laid out in factorial RBD with 3 replications, having 2 varieties of soybean (PS 1347 and SL 525) and 10 nutrient management treatments. The dry matter, crop growth rate (CGR), yield attributing characteristics, grain yield, protein yield, oil yield and nutrient uptake in soil were significantly higher with the application of 125 per cent RDF with FYM @ 5 t per ha over control. The highest net returns of ₹31,992 by soybean* cv. *PS 1347 was recorded with the application of 100 per cent RDF with FYM @ 5 t per ha. Soybean* cv. *PS 1347 produced significantly higher grain yield over control with the application of 125 per cent RDF with FYM @ 5 t per ha.*

Key words: Mollisols, nutrient management, nutrient uptake, soybean varieties

Soybean [*Glycine max* (L.) Merrill] in India is cultivated over an area of 9.4 million ha with production of 9.6 million tons (AICRP on soybean, 2010) and is known as "Golden Bean" of 20th century. Though soybean is a legume crop, yet it is widely used as an oilseed. It is now occupying first place among all the oilseed crops in India followed by rapeseed-mustard and groundnut, respectively. It grows in varied agro-climatic conditions. Due to its world- wide popularity, the international trade of soybean has spread globally. Soybean possesses a very high nutritional value and is the richest, cheapest and easiest source of the best quality proteins (40 %) and oil (20 %) having a vast multiplicity of uses as food

[1] Professor Agronomy; [2, 3] Research Scholar

and industrial products.

After introduction of soybean as a commercial crop, many varieties were developed in different parts of India but nutrient recommendations for most of them were same. Initially varieties responded well to these recommended levels but gradually the performance of these varieties decreased. This may be due to soil factors, unbalanced use of fertilizers or due to degradation of genetic and physical purity. Among them, wrong combination of varieties and unbalanced dose of fertilizers was the major cause of low production and productivity of soybean in India.

Keeping these points in view, the recent study was conducted to find out the optimum nutrient level for the better response of newly released soybean varieties for north plain zone.

MATERIAL AND METHODS

A field experiment was conducted during *kharif* seasons of 2009-10 and 2010-11 at N. E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar to assess the optimum nutritional levels for newly released soybean varieties under *Tarai* conditions of Uttarakhand. The experiment was laid out in factorial RBD, with 3 replications, having two soybean varieties namely, PS 1347 and soybean SL 525, and ten nutrient management treatments, namely 50 per cent recommended dose of fertilizers (RDF), 50 per cent RDF with FYM @ 5 t per ha, 75 per cent RDF, 75 per cent RDF with FYM @ 5 t per ha, 100 per cent RDF, 100 per cent RDF with FYM @ 5 t per ha, 125 per cent RDF, 125 per cent RDF with FYM @ 5 t per ha, FYM @ 10 t per ha, and absolute control (inoculated only). The sowing was done on 10 July utilizing seed rate of 75 kg seed per ha at 45 cm of row spacing and was harvested on 16 November, during both the years. Recommended dose of fertilizer was @ 20 kg N + 80 kg P_2O_5 + 20 kg K_2O + 5 kg Zn per ha and treatments were applied as basal at the time of sowing. The fertilizers used were urea, single super phosphate and muriate of potash. Zn was supplied through $ZnSO_4$ @ 25 kg per ha. FYM applied had, 0.27 per cent N, 0.20 per cent P and 0.38 per cent K. Other packages of practices were followed as per recommenda-tions for raising the crop.

The soil of the experimental field was silty loam in texture and the initial sample had 195.6 kg per ha available nitrogen, 19.7 kg per ha available phosphorous and 192.4 kg per ha available potassium. The data were computed following the procedure of Panse and Sukhatme (1978). The error variance of the 2-year experiment were subjected to a homogeneity test and found to be homogenous, so the results were pooled.

The oil content in seed was determined by Soxhlet Extraction apparatus using petroleum ether as extractant (A O C S, 1964). The nitrogen was estimated by micro-Kjeldahl method (Jackson, 1973) and per cent protein in grains was calculated by multiplying the nitrogen content of grain with 6.25. The phosphorous content in grain and straw at maturity was determined by tri-acid digestion method. Total phosphorous was analyzed by Vanadomolybdate phosphoric acid yellow colour method in nitric acid system (Jackson, 1973) total potassium content both in soybean shoot and grain was determined with the help of flame photometer (model : Systronics modiflame 127) (Jackson, 1973).

RESULTS AND DISCUSSION

Dry matter accumulation

Varietal effects for dry matter accumulation were non-significant at 30 days after sowing (DAS), but significant at 45 and 60 DAS. Soybean variety PS 1347 produced significantly higher dry matter. Among nutrient management treatments, 125 per cent RDF with FYM @ 5 per t ha had significantly higher dry matter accumulation at 30 and 45 DAS (5.56 g/plant and 14.81 g/plant, respect-tively) over all other treatments, except on par with 100 per cent RDF with FYM @ 5 t per ha (28.16 g/plant) at 60 DAS (29.16 g/plant). The significant increase in dry matter accumulation at different stages is due to high accumulation of photo-synthates due to efficient availability of energy sources *i.e.*, ATP and NADP for which nitrogen, phosphorous and potassium elements were responsible (Table 1).

Leaf area index

Soybean *cv*. PS 1347 had significantly higher leaf area index (LAI) at 30 (3.53) and 45 DAS (10.05) than soybean *cv*. SL 525 (3.37 and 9.28, respectively), but effect was non-significant at 60 DAS.

The nutrient management treatment revealed significant differences. At 30 and 45 DAS, the application of 125 per cent RDF with FYM @ 5 t per ha recorded significantly higher LAI than all other treatments, but at 60 DAS, its value (14.18) was at par with 100 per cent RDF, 100 per cent RDF with FYM @ 5 t per ha, 125 per cent RDF and FYM @ 10 t per ha. The LAI per plant probably increased due to more activities of meristematic tissues of the plant producing more number of trifoliates, correlated with increase in total photosynthetic surface and increased LAI of the plant during the vegetative phase. Thus, contributed towards the higher production of branches and also increased dry matter production (Millholon, 1985) (Table 1).

Crop growth rate

The varieties differed significantly with respect to crop growth rates (CGR) between 30 and 45 and 45 and 60 DAS. Soybean *cv.* PS 1347 had significantly higher CGR over soybean *cv.* SL 525 at both the growth periods. At 30-45 DAS treatment 125 per cent RDF with FYM @ 5 t per ha, gave significantly higher CGR over all the other treatments except 100 per cent RDF with FYM @ 5 t per ha and 125 per cent RDF. But between 45 and 60 DAS, application of 100 per cent RDF with FYM @ 5 t per ha, gave the highest CGR which was significantly higher over 50 per cent RDF and control and remaining treatments were statistically on par. High leaf area and dry matter production in plants resulted in increased CGR. Higher values of CGR were observed during 45-60 DAS as compared to 30-45 DAS (Table 1). This might be because between 45-60 DAS plants received optimum input resources and had well developed

Table 1. Effect of varieties and nutrient management on dry matter production, leaf area index, crop growth rate and relative growth rate of soybean

Treatment	Dry matter (g/plant)			Leaf area index			Crop growth rate (g/day)		Relative growth rate (g/g/day)	
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30-45 DAS	45-60 DAS	30-45 DAS	45-60 DAS
Variety										
PS 1347	4.0	11.8	26.1	3.53	10.05	12.19	0.517	0.883	0.072	0.053
SL 525	3.9	10.4	22.7	3.37	9.28	12.02	0.434	0.818	0.066	0.052
SEm (±)	0.1	0.2	0.8	0.05	0.21	0.25	0.015	0.024	0.002	0.001
CD (P=0.05)	**NS**	**0.7**	**2.3**	**0.12**	**0.60**	**NS**	**0.044**	**0.070**	**0.005**	**0.004**
Nutrient treatments										
50 % RDF	2.8	8.8	19.4	2.48	7.55	9.57	0.401	0.703	0.074	0.053
50 % RDF with FYM @ 5t/ha	3.3	9.8	23.8	2.70	9.05	11.41	0.436	0.930	0.071	0.059
75 % RDF	3.0	9.2	22.9	2.63	8.12	11.20	0.418	0.910	0.074	0.062
75 % RDF with FYM @ 5t/ha	3.7	10.6	25.1	2.76	9.35	12.24	0.456	0.965	0.069	0.057
100 % RDF	4.5	12.1	26.3	3.96	10.65	13.43	0.503	0.950	0.065	0.051
100 % RDF with FYM @ 5t/ha	5.0	13.4	28.2	4.69	11.52	14.07	0.560	0.983	0.065	0.049
125 % RDF	4.8	12.9	27.2	4.05	11.39	13.77	0.538	0.956	0.065	0.049
125 % RDF with FYM @ 5t/ha	5.6	14.8	29.2	5.31	12.70	14.18	0.616	0.953	0.064	0.045
FYM @ 10 t/ha	4.2	11.3	25.7	3.66	9.89	13.01	0.470	0.965	0.065	0.054
Control	2.6	8.0	16.4	2.27	6.40	8.17	0.358	0.561	0.073	0.048
SEm (±)	0.1	0.5	0.8	0.10	0.46	0.46	0.035	0.055	0.004	0.003
CD (P=0.05)	**0.4**	**1.5**	**2.3**	**0.29**	**1.34**	**1.60**	**0.100**	**0.158**	**NS**	**NS**

assimilatory surface. During earlier growth period most of the energy was exploited in production of primary plant parts like leaves, stem, primary branches, *etc*, whereas during later period the energy was exploited in expansion of primary plant parts.

Relative growth rate

The values for relative growth rate (RGR) with respect to varieties differed significantly. PS 1347 recorded significantly higher RGR over SL 525 during 30-45 DAS and 45-60 DAS. The RGR values for nutrient management treatments differed non-significantly for periods between 30 and 45 and 45 and 60 DAS (Table 1). With the passage of time, the value of RGR decreased due to increase in relative dry matter of the plants between different growth periods.

Yield contributing characters

Effect of varieties: Effect of varieties on all the yield contributing character was found non-significant.

Effect of nutrient management treatments: All the nutrient management treatments exhibited higher values for number of branches and pods per plant over control. Application of 125 per cent RDF with FYM @ 5 t per ha resulted in highest number of branches (11) and number of pods per plant (105), which was significantly different from all other treatments except 100 per cent RDF with FYM @ 5 t per ha (10.2 and 102.3, respectively). There was no significant difference for grains per pod with respect to nutrient management treatments. As far as the seed index is concerned, the highest value (9.3 g/100 seeds) was associated with 100 per cent RDF with FYM @ 5 t per ha, which was at par with 125 per cent RDF with FYM @ 5 t per ha (9.1 g/100 seeds), 125 per cent RDF (9.1 g/100 seeds) and FYM @ 10 t per ha (8.9 g/100 seeds). The value associated with control was lowest (8.4 g/100 seeds) (Table 2). This might be due to increase in synthesis and translocation of metabolites for the pod development and grain formation under balanced fertilization. Significantly higher seed index was also maintained because of high translocation of photosynthates from source to sink, essential for protein synthesis and carbon assimilation. These findings were in accordance with those of Kandayal *et al.* (1990) who reported that increase in N and P rates increase of the number of pods per plant, seed per pod, seed index and protein content.

Effect of varieties and nutrient management on yield

***Grain yield*:** Soybean *cv*. PS 1347 had significantly higher grain yield (1,899 kg/ha) than soybean *cv*. SL 525 (1,751 kg/ha). All the nutrient management treatments recorded significantly higher grain yield (1,803-1,996 kg/ha) over

Table 2. Effect of varieties and nutrient management on yield attributing characters and yield of soybean

Treatment	Branches (No/plant)	Pods (No/plant)	Grain (No/pod)	Seed index (g/100 seeds)	Yield (kg/ha)		
					Grain	Straw	Biological
Variety							
PS 1347	7.6	83.6	2.2	8.8	1899	3494	5393
SL 525	7.9	81.1	2.2	8.8	1751	3489	5241
SEm (±)	0.4	1.6	0.0	0.1	32	86	84
CD (P = 0.05)	**NS**	**NS**	**NS**	**NS**	**94**	**NS**	**NS**
Nutrient management							
50 % RDF	5.8	63.9	2.2	8.5	1710	2769	4479
50 % RDF with FYM @ 5t/ha	7.2	72.6	2.2	8.6	1803	3361	5164
75 % RDF	6.0	68.2	2.2	8.4	1759	3266	5026
75 % RDF with FYM @ 5t/ha	7.2	80.9	2.2	8.7	1814	3497	5312
100 % RDF	8.7	90.5	2.2	8.7	1870	3806	5677
100 % RDF with FYM @ 5t/ha	10.2	102.3	2.2	9.3	1983	3988	5972
125 % RDF	8.3	95.2	2.2	9.1	1901	3880	5781
125 % RDF with FYM	11.0	105.0	2.3	9.1	1996	3949	5946
FYM @ 10 t/ha	7.8	86.1	2.2	8.9	1826	3720	5546
Control	5.3	59.1	2.1	8.4	1588	2682	4270
SEm (±)	0.5	3.5	0.0	0.1	73	193	188
CD (P=0.05)	**1.45**	**10.0**	**NS**	**0.39**	**211**	**553**	**538**

control (1,710 kg/ha) except 50 per cent and 75 per cent RDF. Maximum grain yield (1,996 kg/ha) was recorded with application of 125 per cent RDF with FYM @ 5 t per ha, followed by 100 per cent RDF with FYM @ 5 t per ha and 100 per cent RDF without FYM, respectively (Table 2). However, except 50 and 75 per cent RDF all other nutrient management treatments were at par. On supplementation of optimum balanced nutrition, the crop responded well. Similar findings were also obtained by Deshmukh *et al.* (2005).

Interaction effect between variety and nutrient levels for grain were significant. Soybean variety PS 1347 responded better to nutrient management treatment as compared to SL 525. Both the varieties (PS 1347 and SL 525) produced significantly higher grain yield (29 and 20.5 %, respectively over control. In case of PS 1347, all the nutrient managements treatments except 50 and 75 per cent led to significant increase in yield over control, while in 100 per cent RDF with FYM @ 5 t per ha and 125 per cent RDF with FYM @ 5 t per ha significant increase over control was in SL 525 (Table 3).

***Straw and biological yield*:** All the nutrient management treatments except 50 per cent RDF showed significantly higher straw yield (3,266-3,988 kg/ha) over control (2,682 kg/ha). Similar to grain yield, the straw yield recorded was higher on application of 100 per cent RDF with FYM @ 5 t per ha (3,988 kg/ha) and 125 per cent RDF with FYM @ 5 t per ha (3,949 kg/ha). Biological yield as well followed the same trend (Table 2). The effect of variety on straw yield was found to be non-significant (Data not shown). A variety under a particular environment appeared to perform best with a specific package of nutrient dose.

Table 3. Interaction effect of nutrient treatments and varieties on grain yield of soybean

Treatment	PS 1347	SL 525
50 % RDF	1753	1667
50 % RDF with FYM @ 5 t/ha	1893	1714
75 % RDF	1823	1697
75 % RDF with FYM @ 5 t/ha	1906	1723
100 % RDF	1987	1753
100 % RDF with FYM @ 5 t/ha	2036	1931
125 % RDF	2014	1788
125 % RDF with FYM @ 5 t /ha	2092	1901
FYM @ 10 t/ha	1920	1736
Absolute control	1576	1602
SEm (±)	104	
CD (P= 0.05)	**298**	

Effect of varieties and nutrient management treatments on quality parameters

Protein content and yield: The varieties did not differ with respect to protein content in seed. Application of 125 per cent RDF with FYM @ 5 t per ha gave highest oil content (41.87 %) followed by 100 per cent RDF with FYM @ 5 t per ha (40.53 %). However, 125 and 100 per cent RDF along with above two treatments also showed significantly higher protein content as compared to control (33.67 %). The protein yield was significantly higher in most of the nutrient management treatments (647.42 - 836.13 kg/ha) except

Table 4. Effect of varieties and nutrient management on quality parameters and economics of soybean

Treatment	Protein content (%)	Protein yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)	Net returns (₹/ha) PS 1347	SL 525
Variety						
PS 1347	37.40	712.93	19.20	315.22	-	-
SL 525	37.64	660.94	18.94	287.70	-	-
SEm (±)	0.74	16.58	0.41	9.55	-	-
CD (P=0.05)	**NS**	**47.47**	**NS**	**27.36**	**-**	**-**
Nutrient management						
50 % RDF	34.58	589.32	17.11	251.14	29710	27887
50 % RDF with FYM @ 5t/ha	35.98	647.42	18.46	286.70	30145	26390
75 % RDF	35.40	622.83	18.09	274.53	29591	26947
75 % RDF with FYM @ 5t/ha	37.39	680.55	19.02	297.41	29840	25994
100 % RDF	38.58	721.47	19.69	315.74	31471	27267
100 % RDF with FYM @ 5t/ha	40.53	802.67	20.95	359.95	31992	29804
125 % RDF	39.07	737.30	19.96	330.33	31476	26736
125 % RDF with FYM @ 5t/ha	41.87	836.13	20.94	360.68	31617	27606
FYM @ 10 t/ha	38.14	695.54	19.41	305.52	29235	25444
Control	33.67	536.13	17.09	233.20	27071	27618
SEm (±)	1.66	37.08	0.92	21.37	-	-
CD (P=0.05)	**4.75**	**106.16**	**2.63**	**61.18**	**-**	**-**

in case of 50 (589.32 kg/ha) and 75 (622.83 kg/ha) per cent RDF which were at par with control (536.13 kg/ha) (Table 4). Nitrogen being a basic constituent of protein and with increase in rates of nitrogen application, its availability also increased, resulting in higher protein content in seeds. Warade *et al.* (1992) reported that increase in nitrogen and phosphorous rates up to 60 kg per ha resulted in increased protein content in soybean.

Table 5. Effect of varieties and nutrient management on nitrogen, phosphorus and potassium contents and uptake by soybean seeds

Treatment	Nitrogen		Phosphorus		Potassium	
	Content (%)	Uptake (kg/ha)	Content (%)	Uptake (kg/ha)	Content (%)	Uptake (kg/ha)
Variety						
PS 1347	7.98	159.79	1.015	20.83	2.604	58.84
SL 525	7.95	149.79	0.999	19.61	2.556	55.13
SEm (±)	0.12	2.75	0.014	0.42	0.044	1.46
CD (P=0.05)	**NS**	**7.88**	**NS**	**1.20**	**NS**	**NS**
Nutrient management						
50 % RDF	7.04	117.08	0.894	15.44	1.683	31.34
50 % RDF with FYM @ 5t/ha	7.62	142.98	0.939	18.10	2.003	42.90
75 % RDF	7.33	132.28	0.913	17.08	1.812	38.27
75 % RDF with FYM @ 5t/ha	7.89	150.88	0.967	19.16	2.385	51.94
100 % RDF	8.36	170.68	1.046	21.98	3.094	70.02
100 % RDF with FYM @ 5t/ha	8.91	193.91	1.159	25.79	3.443	81.83
125 % RDF	8.48	175.89	1.062	22.81	3.325	76.05
125 % RDF with FYM @ 5t/ha	9.24	201.48	1.233	27.55	3.690	87.79
FYM @ 10 t/ha	8.09	159.54	0.983	20.07	2.813	62.51
Control	6.67	103.18	0.876	14.24	1.552	27.22
SEm (±)	0.27	6.15	0.031	0.94	0.098	3.27
CD (P=0.05)	**0.78**	**17.63**	**0.09**	**2.69**	**0.282**	**9.38**

Oil content and yield: The varieties did not differ with respect to oil content in seed. However, PS 1347 produced significantly higher oil yield (315.22 kg/ha) as compared to SL 525 (287.70 kg/ha). Maximum oil content was observed by application of 100 per cent RDF with FYM @ 5 t per ha and 100 per cent RDF with FYM @ 5 t per ha followed by 125 per cent RDF and these treatments were significantly better than control. Except 50 per cent RDF, 75 per cent RDF and 50 per cent RDF with FYM @ 5 t per ha, remaining nutrient management treatments differed significantly over control in oil yield per ha; highest values being associated with 125 per cent RDF with FYM @ 5 t per ha and 100 per cent RDF with FYM @ 5 t per ha (Table 4). The reason for increase in oil yield may be the balanced use of NPK and FYM which enhanced crop root and shoot growth. This also increased the uptake of micronutrient, necessary for synthesis of fatty acids and ultimately higher oil content in seeds. The results of experiment were in conformity with Majumdar *et al.* (2001).

Nutrient contents and uptake in seed

***Effect of varieties*:** The two varieties did not differ significantly with respect to nitrogen, phosphorus and potassium contents in seed. There was no significant difference with respect to potassium uptake also (Table 5).

***Effect of nutrient management treatments*:** Evaluated nutrient management treatments exerted significant differences with respect to nitrogen, phosphorus and potassium contents as well as uptake. In general, all the nutrient management treatments led to significant increase in contents and uptake of these three major nutrients except levels lower than RDF over control. Maximum values of contents and uptake of these three nutrients were associated with 125 per cent RDF with FYM @ 5 t per ha (content - 9.24 % N, 1.233 % P and 3.69 % K, and uptake - 201.48 kg N/ha, 27.55 kg P/ha and 87.79 kg K/ha) and 100 per cent RDF with FYM @ 5 t per ha (content - 8.91 % N, 1.159 % P and 3.443 % K, and uptake - 193.91 kg N/ha, 25.79 kg P/ha and 81.83 K/ha). The respective values for control were 6.67 % N, 0.876 % P and 1.552 % K, and 103.18 kg N per ha, 14.24 kg P per ha and 27.22 kg K per ha (Table 5).

The uptake of nutrients is a primarily function of total biomass production and nutrient content at cellular level. Increased nutrient uptake might be due to higher availability of plant nutrients from soil reservoir and additional quantity of nutrients supplied by adding fertilizers (Sharma and Dixit, 1987). Prasad and Sanoria (1981) reported that applied phosphorous improving the nutrient uptake may be attributed to its significant role in regulating the photosynthesis, root enlargement and better microbial activities. The high level of P resulted in the maximum uptake of N, P, and K due to close interrelationship between N and P metabolism in plant cell.

Net returns

PS 1347 and SL 525 varieties of soybean recorded absolute higher net returns ` 31,992 per ha and ` 29,804 per ha with the application of 100 per cent RDF with FYM @ 5 t per ha, respectively (Table 4). Similar findings were reported by Deshmukh *et al.* (2005). Ramesh *et al.* (2009) also reported that the integrated nutrient management resulted in highest economic returns. Chaturvedi *et al.* (2009)

as well reported that maximum net returns were obtained with the application of RDF with 10 t FYM per ha.

The performance under certain nutrient combination is highly dependent on the varietal characteristics of the plant species. An appropriate combination of variety and optimum dose of nutrient can give maximum yield as well as returns. Therefore, the findings of experiment brought out that both the varieties of soybean (PS 1347 and SL 525) performed well under similar nutrient combinations. Therefore, it can be concluded that 125 per cent RDF with FYM @ 5 t per ha sustained higher quality and grain yield of soybean but the optimum level to obtain higher yield and returns from both the varieties is 100 per cent RDF with FYM @ 5 t per ha and between these two varieties PS 1347 performed better in Mollisols of Uttarakhand.

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Comparative Efficacy of Herbicides for Weed Management of Soybean (*Glycine max*) in Uttrakhand

RAKESH CHANDRA NAINWAL[1], S C SAXENA[2] and ASHOK JOSHI[3]
Department of Agronomy, College of Agriculture,
G. B. Pant University of Agriculture and Technology,
Pantnagar 263 145, Uttrakhand
E-mail: nainwal.rakesh@gmail.com

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ABSTRACT

A field experiment was conducted during the kharif *2008 and 2009, to assess the efficacy of different herbicides on weed infestation and seed yield of soybean [*Glycine max *(L.) Merrill]. The results revealed that among the different herbicide, the highest seed yield was recorded with alone application of diclosulam 18 g per ha as pre-emergence supplemented with one hand weeding at 20 DAS and application of diclosulam 18 g per ha as pre-emergence followed by haloxyfop 100 g per ha as post-emergence. However, these were at par with weed-free treatment. The highest weed control efficiency and the lowest weed biomass were recorded in weed-free treatment followed by application of diclosulam 18 g per ha as pre- emergence with one hand weeding at 20 DAS. Application of diclosulam solely as pre-emergence also performed better over the standard check either applied pendimethalin as pre-emergence or fluchloralin as pre-plant incorporation, to minimize the weed load in soybean and reflected to enhance the seed yield.*

Key words: Herbicides, soybean, weed control

Soybean [*Glycine max* (L.) Merrill] is an important pulse as well as oilseed crop. Even though the area under soybean in India has shown an appreciable increase over past four decades, the productivity has remained only 1 t per ha as against world average of 2.2 t per ha. Among several factors responsible for lower productivity, the yield erosion on account of weeds is one of the important factors. Soybean is very sensitive to early weed competition. Weed infestation in soybean field may reduce yield up to 77 per cent depending upon the intensity, nature, and the duration of weed competition (Tiwari and Kurchania,

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[1, 3] Research Scholar; [2] Professor (Agronomy)

1990). To avoid competition during the early growth stages, soybean field should be kept free from weeds for the first 30-40 days after sowing. Chhokar *et al*. (1995) reported that weed free maintenance up to 45 days after sowing resulted in 96 per cent increase in grain yield of soybean. The crop smothers the weeds that emerge 30-40 days after sowing. Mechanical as well as chemical methods are adopted for control of weeds in soybean field. During rainy season, incessant rains and consequent wet condition does not permit inter-cultural operations or normal manual/mechanical weeding in the standing crop. Moreover, the scarcity of labour and high wages restricts their utilization in weeding. It is, therefore, necessary to evaluate alternative method for controlling weeds during critical growth period. Therefore, the present investigation was undertaken to find out the efficacy of some of the herbicides for weed management in soybean

MATERIAL AND METHODS

A field experiment was laid out during the *kharif* season of 2008 and 2009 at Crop Research Centre of GBPUA and T, Pantnagar. The soil of the experimental field was silty clay loam in texture, containing 0.54 per cent organic carbon, 210.8 kg per ha available nitrogen, 24.18 kg per ha available phosphorus and 190.8 kg per ha available potassium, with pH of 7.2. The planting was done on July 10, 2008 and July 7, 2009 with a seed rate of 75 kg per ha at 45 cm of row spacing and was harvested in November during both the years.

The experiment laid out in randomized block design consisted of 10 treatments namely, control (weedy check), weed free, fluchloralin 45 EC @ 1000 g per ha as pre-plant incorpo-ration (PPI), and pendimethalin 30 EC @ 1000 g per ha as pre-emergence (PE), diclosulam 84 WP @ 26 g per ha as PE , diclosulam 84 WP @ 18 g per ha as PE followed by one hand weeding at 20 days after sowing (DAS), fluchloralin 45 EC @ 1000 g per as PPI followed by diclosulam 84 WP @ 18 g per ha as PE, haloxyfop 10 EC @ 100 g per ha, fluchloralin 45 EC @ 1000 g per ha as PPI followed by haloxyfop 10 EC @ 100 g per ha as post-emergence (PoE) and diclosulam 84 WP @ 18 g per ha as PE followed by haloxyfop 10 EC @ 100 g per ha as PoE. All the herbicides were sprayed by using a knap sack sprayer fitted with flat fan nozzle with volume of 750 litre water per ha. Recommended dose of fertilizer (20 kg N + 80 kg P_2O_5 + 5 kg Zn/ha) was applied as basal at the time of sowing. Soybean seed (*var*. PS 1347) was treated with thiram 75 per cent WP (2 g) + bavistine (1.0 g) per kg seed before inoculation with *Bradyrhizobium japonicum* culture @ 7 g per kg seed. To protect the crop from stem fly, 2 to 3 sprays of trizophos 40 EC 500 ml per ha was done during both the year of experimentation. Thinning to maintain optimum plant population (0.4 million plants/ha) was completed within 15-20 DAS during both the years.

Weed control efficiency (WCE) was computed by using formula, WCE = (P - Q/P) x 100, where P and Q respectively, refer to oven dry weight of weeds at specific sampling in weedy check and particular treatment for which value is computed. Weed index (WI) was computed by WI = (A - B/A) x 100, where A and B respectively, refer to grain yield in weed-free plot and grain yield in treated plot. Necessary statistical analysis was carried out by method of Cochran and Cox (1959).

RESULTS AND DISCUSSION

The predominant weeds encountered in the experimental plot were *Echinochloa colona* (27 %), *Eleusine indica* (9 %), *Brachiaria ramose* (7 %), *Digitaria sanguinalis* (6 %), *Eragrostis japonica* (4 %) among the monocot weeds while *Celosia argentia* (34 %), *Lindernia ciliate* (4 %), *Eclipta alba* (4 %) and *Trianthema monogyna* (6 %) were among the dicot weeds at both the stages of crop growth (30 and 60 DAS). Singh *et al*. (2004) also reported that soybean fields are infested predominantly with *Cyperus rotundus, Echinochloa colona, Commelina benghalensis* and *Celosia argentea*. Other weeds infesting soybean crop found were *Cucumis trigosus, Eleusine indica, Cleome viscosa, Dactyloctenium aegyptium, Digitaria sanguinalis, Digera arvensis, Parthenium hysterophorus, Trianthema monogyna, Eclipta alba* and *Brachiaria* spp. Their occurrence and intensity varied in different treatments. Intensity of weeds varied due to application of different herbicide and manual weeding plots at different growth stages. The highest weed infestation was recorded in control (weedy check) plot.

Weed density

The total weed density was significantly reduced by the application of evaluated herbicides, either applied as pre- or post-emergence or pre-plant incorporation, at both the stages of crop (30 and 60 DAS) growth. Application of diclosulam proved to be most effective to control the broad spectrum of weed flora, whereas haloxyfop was only effective to control the monocots. Application of diclosulam @ 18 g per ha supplemented with one hand weeding at 20 DAS recorded significantly lowest population of monocots as well as dicot weeds at both 30^{th} and 60^{th} days stage (Table 1). Tiwari *et al.,* (2007) also reported that haloxyfop application in soybean as post-emergence gave effective control over the monocots weeds.

Dry matter, weed control efficiency (WCE) and weed index (WI)

In general, the dry matter accumulation of weeds at 60 DAS increased with increasing the weed density as well as variation of weed species and their growth. The highest weed dry matter was achieved under weedy check (Table 1) and the lowest was recorded in weed-free plot. Among the herbicidal treatments, diclosulam 18 g per ha supplemented with one hand weeding (20 DAS) resulted in maximum reduction (69.3 % over control) in weed dry matter. However, the highest weed dry matter was recorded with sole application of fluchloralin @ 1,000 g per ha, which was followed by sole application of haloxyfop @ 100 g per ha and combined application of both fluchloralin @ 1000 g per ha as PPI and haloxyfop @ 100 g per ha as PoE. This can be accounted for less effectiveness of these herbicides in controlling the dicots

Table 1. Effect of different weed control treatments on density and dry matter of weed at 30 and 60 DAS in soybean (data pooled over of 2 years)

Treatments	Weed density (no/m^2)				Weed dry matter (60 DAS) (g m^{-2})
	30 DAS		60 DAS		
	Monocot	Dicot	Monocot	Dicot	
Control	178 (5.0)*	124 (4.3)	222 (5.3)	85 (4.4))	813 (6.7)
Weed free	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0.0 (0.0)
Fluchloralin 45 EC (PPI) @ 1000 g/ha	73 (3.9)	43 (2.8)	185 (5.0)	65 (4.2)	681 (6.5)
Pendimethalin 30 EC (PPI) @ 1000 g/ha	33 (3.1)	23 (3.1)	128 (4.5)	53 (4.0	497 (6.2)
Diclosulam 84 WP @ 26g/ha	18 (2.3)	7 (1.5)	59 (3.9)	29 (3.2)	363 (5.7)
Diclosulam 84 WP (PE) @ 18 g/ha) + HW (20 DAS)	13 (2.5)	6 (1.4)	26 (3.1)	18 (2.7)	250 (5.5)
Fluchloralin 45 EC (PPI) @ 1000 g/ha + Diclosulam 84 WP (PE) @18 g/ha	26 (3.0)	14 (2.4)	84 (4.0)	34 (3.3)	394 (5.9)
Haloxyfop 10 EC (PoE) @ 100 g/ha	29 (3.2)	20 (2.6)	36 (3.5)	49 (3.8)	581 (6.3)
Fluchloralin 45 EC (PPI)@ 1000 g/ha + Haloxyfop 10 EC @ 100 g/ha	29 (3.2)	19 (2.5)	34 (3.5)	47 (3.9)	576 (6.3)
Diclosulam 84 WP (PE)@ 18 g/ha + Haloxyfop 10 EC (PoE) @ @ 100 g/ha	17 (2.8)	10 (1.7)	34 (3.5)	44 (3.8)	306 (5.7)
SEm (±)	0.3	0.3	0.1	0.1	0.1
C.D. (P = 0. 5%)	**0.8**	**0.9**	**0.3**	**0.3**	**0.3**

**Figures in parenthesis are logarithmic transformed {log (x+1)} data; DAS – days after sowing* weeds (especially *Celosia argentia*) and its vigorous growth.

The highest weed control efficiency was achieved by weed-free plots followed by application of diclosulam @ 18 g per ha supplemented with one hand weeding at 20 days stage (69 %) than the combined application of diclosulam @ 18 g per ha as pre-emergence followed by haloxyfop @ 100 g per ha (62 %) as post-emergence. Among the herbicidal treatments, sole application of fluchloralin @ 1000 g per ha recorded the lowest weed control efficiency (16 %) while the highest weed index (75 %) was recorded in sole application of haloxyfop @ 100 g per ha, however, the lowest weed index (11 %) was observed with application of diclosulam @ 18 g per ha supplemented with one hand weeding (at 20 DAS) due to broad spectrum effect on different weed species (Fig. 1).

Yield

The seed yield was significantly influenced by different weed control treatments. Weed-free treatment significantly enhanced the seed yield (81 %) over the control followed by the application of diclosulam @ 18 g per ha supplemented with one hand weeding (20 DAS) and enhanced the seed yield up to 78.8 per cent over the control. This treatment was found *at par* with combined application of diclosulam @ 18 g per ha and haloxyfop 100 g per ha used as pre- and post-emergence, respectively and alone application of diclosulam at higher dose (26 g/ha) (Table 2).

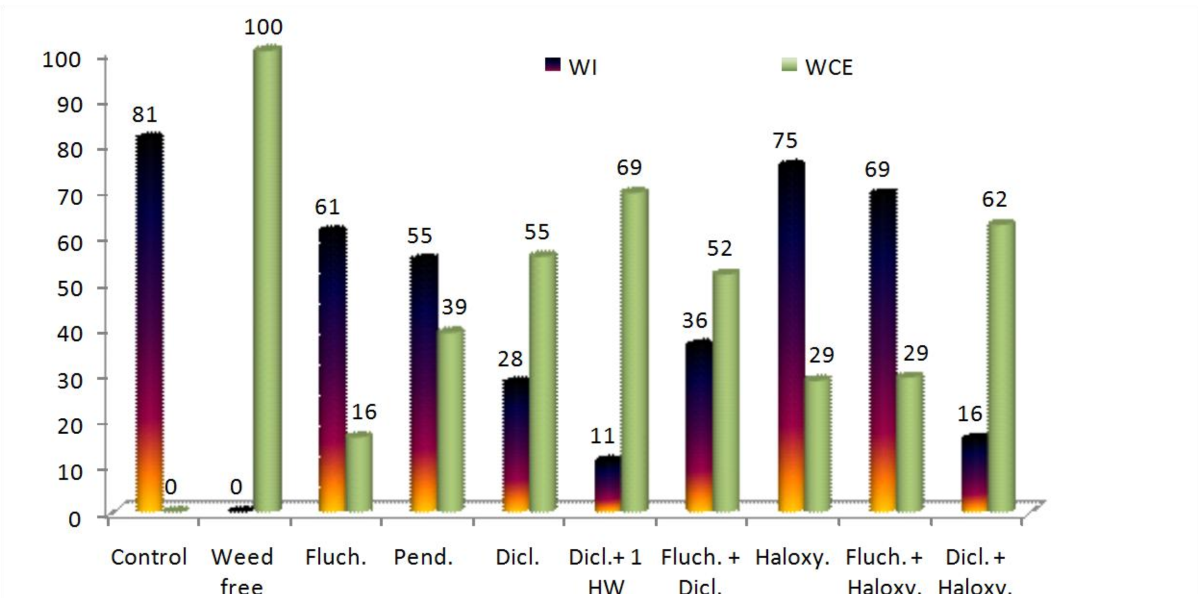

Fig. 1. Effect of weed control treatments on weed index (WI) and weed control

The lowest seed yield (454 kg/ha) was obtained in weedy plot indicating the higher weed infestation and its impact on soybean crop. Tiwari and Kurchania (1990) also reported that weed infestation in soybean field may reduce yield up to 77 per cent depending upon the intensity, nature and the duration of weed competition. The lowest seed yield was recorded with weedy plot which was at par with sole application of haloxyfop @ 100 g per ha and combined application of fluchloralin @ 1000 g per ha followed by haloxyfop @ 100 g per ha applied as pre-plant incorporation and post-emergence, respectively. The lower yield obtained in these treatments might be due to the higher infestation of broad leaved weeds and their high dry matter accumulation in those plots and less effectiveness against broad leaved weeds. On the other hand, the higher seed yield obtained with application of diclosulam showed its higher efficacy to control the broad spectrum of weeds. Therefore, it can be concluded that application of diclosulam 18 g per ha supplemented with one hand weeding (20 DAS) or sole application of diclosulam at its higher rate (26 g / ha is beneficial to effectively control the broad spectrum of weeds in soybean fields.

Table 2. Effect of different weed control treatments on seed yield and straw yield of soybean (data pooled over of 2 years)

Treatments	**Yield (kg/ha)**	
	Seed	**Straw**
Control	454	1497
Weed free	2394	4332
Fluchloralin 45 EC (PPI) @ 1000 g/ha	935	2052
Pendimethalin 30 EC (PPI) @ 1000 g/ha	1085	2414
Diclosulam 84 WP @ 26g/ha	1923	3661
Diclosulam 84 WP (PE) @ 18 g/ha) + HW (20 DAS)	2129	4392
Fluchloralin 45 EC (PPI) @ 1000 g/ha + Diclosulam 84 WP (PE) @18 g/ha	1527	3256
Haloxyfop 10 EC (PoE) @ 100 g/ha	596	1286
Fluchloralin 45 EC (PPI)@ 1000 g/ha + Haloxyfop 10 EC @ 100 g/ha	743	1786
Diclosulam 84 WP (PE)@ 18 g/ha + Haloxyfop 10 EC (PoE) @ @ 100 g/ha	2015	4416
SEm (±)	145	471
C.D. (P = 0. 5%)	**423**	**1353**

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Feasibility of Organic Farming System under Soybean - Wheat Cropping System in *Malwa* Region of Western Madhya Pradesh

R GALLANI[1], S K SHARMA[2], P SIROTHIA[3] and O P JOSHI[4]
Mahatma Gandhi Chitrakut Gramin Vishwavidyalaya, Chitrakut 485 780, Madhya Pradesh
Email: roshanjgallani@yahoo.co.in

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ABSTRACT

Feasibility of organic farming system was studied during 2008-09 and 2009-10 at farmers' fields of Indore district. Treatments comprised of organic farming (≥ 3 years), organic farming (< 3 years), recommended dose of fertilizers, and farmers' practice of nutrient application. Each farmer was taken as one replication. The results showed a positive effect of organic farming on productivity, B: C ratio of soybean, and sedimentation value of wheat flour. Conversely, in wheat crop, the higher productivity and B: C ratio was observed with inorganic farming (RDF). However, overall B: C ratio was significantly high in soybean - wheat cropping system with organic farming (≥ 3 years), because of longer time span. Food qualities of soybean oil and wheat flour remain unaffected due to different farming systems.

Key words: Economic feasibility, food qualities, organic farming, soybean – wheat cropping system

Organic farming in India is not gaining as much momentum as in developed countries. Beside its positive effect on soil health, the commercial organic farming is still at a very nascent stage. In India, about 5,28,171 hectare area is under organic farming (certified and area under organic conversion) with 44,926 number of certified organic farms. This accounts for about 0.3 per cent of total agricultural land (APEDA, 2010).

One of the major reasons for slow adoption of organic farming is the general perception that it cannot produce higher than conventional farming system. Low yield as well as non-availability of premium price for organic produce restricted its popularization among the farmers. As such the farming community is more concerned for crop productivity

[1]*Subject Matter Specialist, KVK, Ratlam, M P;* [2]*Senior Scientist, College of Agriculture, Indore, M P;* [3]*Associate Professor, MGCGVV, Chitrakoot:* [4]*Emeritus Scientist, DSR, Indore, Madhya Pradesh*

and monetary returns than soil health and sustainable crop production. The productivity of the agricultural land and soil health need to be improved to meet the food, fibre, fuel, fodder and other needs of the growing population. Now, the nutrient management practices should be shifted from the "resource degrading" chemical agriculture to a "resource protective" biological or organic agriculture. In fact, organic farming today is not a traditional agriculture. The principles governing organic farming are more scientific than even the principles followed in modern agriculture. (Shroff, 1994; Deshpande, 2009). Of the research done on organic farming; however, only a few have reported. In order to understand the feasibility of the organic farming system so far, there is a need to assess productivity, quality of produce and economics involved in organic and inorganic farms under real farm conditions with different time span. Soybean and wheat crops constituted the most predominating cropping system of Central India with around 2.0 million hectares area in Madhya Pradesh (JNKVV, 2008). Hence, the present study was conducted in the *Malwa* region of Madhya Pradesh, on soybean - wheat cropping system which is practiced to the great extent.

MATERIAL AND METHODS

The experiment was conducted on the farmers' field in Indore district using randomized block design with five replications (each farmer was taken as one replication). The study was carried out during *rabi* and *kharif* seasons of 2008-09 and 2009-10 in five villages namely, Semliyachau, Asrawad Khurd, Badiya Khema, Ralamandel and Morod Haat of Indore district. These villages were adopted by the Department of Farmers' Welfare and Agriculture Development (Govern-ment of Madhya Pradesh), as bio-villages and farmers have been practising organic farming for last 2-7 years. To assess productivity and economic feasibility of the soil under different farming systems, four treatments were classified as organic farming (≥ 3 years), organic farming (< 3 years), inorganic farming with recommended dose of fertilizers (RDF) and farmers' practice of nutrient application.

Organic farming (≥ 3 years) in soybean comprised of application of NADEP compost @ 7.5 t per ha, vermicompost @ 2.5 t per ha, bio-gas slurry @ 2.0 t per ha and biofertilizers (Bradyrhizobium + PSB) as seed inoculants @ 10 g per kg seed each and soil application @ 5 kg per ha. For succeeding wheat, it involved vermicompost @ 2.5 t per ha, bio-gas slurry @ 2.0 t per ha and biofertilizers (azotobacter + PSB) as seed inoculants @ 10 g per kg seed each and soil application @ 5 kg per ha. The contents of N, P_2O_5 and K_2O in NADEP compost were

0.5, 1.5 and 1.8 per cent, respectively. Vermicompost had 2.2, 1.5 and 1.6 per cent, while bio-gas slurry had 2.0, 1.8 and 1 per cent N, P_2O_5 and K_2O, respectively. Organic farming (< 3 years) received similar practice as of organic farming (≥ 3 years) expect the duration. Apart from this, organic farmers did crop residue management by using rotavator. For plant protection they relied on mechanical and biological control like use of pheromone traps, *Beauveria bassiana* and bio-pesticides. RDF comprised application of $N:P_2O_5:K_2O$ @ 20:60:20 kg per ha and @ 120:60:30 kg per ha in soybean and wheat, respectively through chemical fertilizers. Farmers' practice involved application of $N:P_2O_5:K_2O$ @ 40:40:0 kg per ha and @ 150:50: 0 through chemical fertilizers in soybean and wheat, respectively. The soils of the experimental fields are medium black, predominantly clayey in texture with high moisture retention capacity. The cultivar Lok 1 of wheat and JS 335 of soybean were used for the experiment. The data on various parameter recorded in both the years were analysed statistically and presented on pooled basis.

Sensory evaluations of *chapatis* made of wheat flour were carried out using 10-point hedonic scale. The trained taste panel was asked to rate the *chapatis* for their various sensory attributes like colour, taste, flavour, texture, appearance and overall acceptability as described by Larmond (1977). The sedimentation value of the grain was estimated by sodium dodecyl sulphate (SDS) test by following standard analytical procedure (Mishra and Gupta, 1995).

Nitrogen content in seed was determined for estimating protein content using Foss Near-Infrared Spectrophotometer. The protein content was estimated by multiplying nitrogen content value of wheat seed by 6.25 and soybean by 5.71 (Sadasivam and Manickam, 1996). The total oil content of soybean seed was determined by analytical supercritical fluid extraction (SFE) with carbon dioxide as the extraction solvent and expressed as per cent.

RESULTS AND DISCUSSION

Effect of different farming systems on grain yield

Pooled productivity of soybean was significantly higher under organic farming (≥ 3 years) (17.09 and 37.37 %), followed by inorganic farming with RDF (12.92 and 32.49 %) over organic farming (< 3 years) (1,849 kg/ha) and farmers' practice (1,576 kg/ha). In case of wheat, the inorganic farming with RDF gave significantly higher productivity (3,995 kg/ha) as compared to rest of the treatments (3,376-3,698 kg/ha) (Table 1). Enhanced soybean productivity might have resulted due to adequate availability of nutrients throughout the crop growth as soybean, which is capable of mustering

Table 1. Wheat and soybean productivity as influenced by organic and conventional farming systems

Treatment	Grain yield (kg/ha)					
	Soybean			Wheat		
	2008-09	**2009-10**	**Pooled**	**2008-09**	**2009-10**	**Pooled**
Organic farming (≥ 3 years)	2430	1900	2165	3536	3860	3698
Organic farming (< 3years)	2138	1560	1849	3232	3520	3376
Inorganic farming with RDF	2356	1820	2088	3850	4140	3995
Farmers' practice of nutrient application	1752	1400	1576	3254	3580	3417
SEm (±)	4.68	10.65	6.47	13.64	12.94	8.09
C.D. (P = 0. 5%)	**14.41**	**32.83**	**19.93**	**42.04**	**39.87**	**24.94**

its nitrogen requirement through symbiotic N-fixation. Further, the addition of the biofertilizers might have boosted the activity of beneficial microorganisms like *Bradyrhizobium japonicum* and PSM/PSB, which mediated higher availability of nutrients. through processes like N- fixation and P- solubilzation. Lower productivity of wheat under organic farming systems may be argued on the basis of low availability of nutrients, particularly that of nitrogen at various growth stages, which should be more for cereals. Besides, it might be due to slow mineralization of organic manure and non-availability of required nutrients, it resulted in a setback in crop growth at early stage of wheat and thus affected the crop productivity. Similar arguments were presented by Gill (2008) for achieving low productivity of paddy, groundnut, garlic and durum wheat under organic farming.

A significantly higher (8.22 %) wheat productivity was observed under organic farming (≥ 3 years) than farmers' practice of nutrient application (3,417 kg/ha). It indicated that after harvest of soybean crop, there must have been substantial increase in availability of nutrients in the soil under the said treatment. Thus, organic farming (≥ 3 years) treatment showed pronounced residual effect of organic manures than chemical fertilization. Hence, there was significant effect of nutrient management practices through organics for extended period on the succeeding wheat crop (Shwetha, 2007). Most comparisons of organic and conventional systems showed that organically grown wheat produces lower yields than that by conventionally grown. Halberg and Kristensen (1997) reported that grain yields of organic farms were consistently lower than those of conventional farms.

Effect of different farming systems on food/ grain quality

It is evident from the data that the sensory evaluation of wheat *chapattis* made of flour of any of the treatment was not significantly influenced under the study (Table 2). Though, numerically higher grain sensory qualities were recorded under organic farming (≥ 3 years). Results of oil and protein content in soybean and wheat (Table 3) showed non-significant

Table 2. Sensory score of wheat Chapati as influenced by organic and conventional farming systems

Treatment	Colour	Taste	Flavour	Texture	Appearance	Overall acceptabi-lity
Organic farming (≥ 3 years)	7.56	7.76	6.72	6.92	8.04	9.16
Organic farming (< 3years)	7.56	7.72	6.56	6.64	7.78	8.94
Inorganic farming with RDF	7.54	7.74	6.70	6.82	8.00	9.14
Farmers' practice of nutrient application	7.44	7.64	6.6	6.74	7.78	8.82
SEm (±)	0.08	0.11	0.04	0.07	0.08	0.10
C.D. (P = 0. 5%)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 3. Food quality of soybean seed and wheat flour as influenced by organic and conventional farming systems

Treatment	Soybean seed		Wheat flour	
	Oil content (%)	Protein content (%)	Protein content (%)	Sedimentation value (ml)
Organic farming (≥ 3 years)	20.24	39.40	12.36	42.56
Organic farming (< 3 years)	20.06	39.50	12.06	42.30
Inorganic farming with RDF	20.38	39.74	12.40	42.12
Farmers' practice of nutrient application	20.02	39.32	12.22	41.88
SEm (±)	0.12	0.15	0.09	0.15
C.D. (P = 0. 5%)	**NS**	**NS**	**NS**	**0.46**

differences among the treatments. This was quite expected, as grain sensory quality and protein content are the inherent characteristics of a variety and might not affected by nutrient management systems. Bora *et al.* (2006) found that except for higher be mineral content in organically grown chickpea and wheat, values for all other parameters like sensory quality, cooking quality and physicochemical properties were not significantly different. The sedimen-tation value, an index of baking quality of flour, gives an idea about glutenin strength. The highest sedimentation value

Table 4. Economics of soybean and wheat as influenced by organic and conventional farming systems

Treatment	Soybean			Wheat			Wheat - Soybean		
	Cost of cultivation (INR/ ha)	**Net returns (INR/ ha)**	**B:C Ratio**	**Cost of cultivation (INR/ha)**	**Net returns (`INR/ha)**	**B:C Ratio**	**Cost of cultivation (INR/ha)**	**Net returns (INR/ ha)**	**B:C Ratio**
Organic farming (≥ 3 years)	17450	30180	2.73	19130	25250	2.32	36800	55300	2.50
Organic farming (< 3years)	17450	23230	2.52	19130	21182	2.02	36800	44390	2.22
Inorganic farming with RDF	18375	27560	2.50	20055	29920	2.66	38100	55100	2.47
Farmers' practice of nutrient application	17690	16980	1.96	20500	20510	2.01	36840	36850	1.99
SEm (±)	36.70	770.00	0.02	35.52	760.00	0.03	48.00	870.00	0.03
CD at 5%	**111**	**2308**	**0.06**	**115**	**2287**	**0.09**	**142**	**2610**	**0.09**

was obtained with treatment comprising of organic farming (≥ 3 years) followed by treatments having organic farming (< 3 years). Different manure or fertilizers mineralize their nitrogen in a different rhythm, and that might influence the composition of gluten proteins. Jaana and Marjo (1998) reported, an improved soil structure seemed to influence the development of baking quality of spring wheat at Finland. The same reason would also be true for better sedimentation value with the treatment organic farming (≥ 3 years).

Effect of different farming systems on economics

To compare the economics of soybean – wheat cropping sequence as influenced by different farming practices the B: C ratio was calculated by taking into account the cost of cultivation, gross and net returns (Table 4). In case of soybean, the highest B: C ratio was obtained with treatment comprising of organic farming (≥ 3 years) followed by treatment having organic farming (< 3 years) and inorganic farming with RDF. The lowest B: C ratio was obtained in case of farmers' practice, which was found statistically inferior to the rest of the treatments. The higher B: C ratio with organic farming system could be attributed to higher grain yield of soybean and reduction in cost of cultivation. Though inorganic farming system supplemented with fertilizer produced higher yield, noticed comparably lower net returns which might be because of higher cost of production with respect to application costly inorganic fertilizers. This trend was not maintained by both the crops, as wheat crop showed significantly higher B: C ratio in the treatment inorganic farming with RDF, which gave significantly higher B: C ratio as compared to rest of the treatments. This might be due to much higher wheat yield under the treatment inorganic farming with RDF. The B: C ratio in soybean-wheat cropping sequence was higher in case of organic farming (≥ 3 years) than inorganic farming with RDF. But these two were statistically at par with each other. Remaining two treatments were statistically inferior to above treatments. It suggests that organic farming (≥ 3 years) is suitable for soybean-wheat cropping sequence. Even though the grain yields were not on higher side but owing to application of on farm produced organic manure reduced cost of production and ultimately gave better B: C ratio.

A 21 years Swiss study of organic and conventional farming system by Emily Green (2002) also concluded that the organic farming is economically viable and environmentally sustainable over long haul, although crop yields still fall short of conventional method. Ramesh *et al.* (2006) also reported that the cost of cultivation of organic farming is less than inorganic farming but the net income, and B: C ratio was slightly less in organic farming than conventional farming when income was calculated without the premium price. On the basis of these investigations, it is purported that organic farming approach can be implied without any risk to get rather improved level of productivity in long run than crops raised using chemicals provided proper knowledge is gained from the institute/ agencies who are practising organic farming.

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Assessment of Genetic Variability, Correlation and Path Analysis of Quantitative Traits in Soybean [*Glycine max* (L.) Merrill]

R K MAHAWAR[1], L L PAWAR[2], N R KOLI[3], H R CHAUDHARY[4], D S MEENA[5] and MASHIAT ALI[6]
Agriculture Research Station MPUA and T), Kota 324 001, Rajasthan
E-mail: atar_rajesh@yahoo.com

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In India, soybean continues to rank number one oilseed crop followed by rapeseed and mustard, groundnut and sunflower. The cultivation of soybean in India has reached about 10.18 million hectare, with the total production of about 12.28 million tones and average productivity of about 1,207 kg per hectare in *kharif* 2011 (DAC, 2012). The knowledge of certain genetic parameters is essential for proper understanding and their manipulation in any crop improve-ment programme. Existence of genetic variability is a pre-requisite for the genetic improvement of any crop through breeding methods. Similarly, correlation and path analysis studies are of great help in formulating efficient scheme of multiple traits selection, as they provide means for direct and indirect selection of component characters. Yield is a polygenic trait and function of various component traits. Seed yield is the result of the expression and association of several plant growth components. Thus, direct selection would not be a reliable approach on account of its being highly influenced by environmental factors. The knowledge of association between yield and its components and among components themselves is of immense practical value in crop improvement through selection. Path coefficient analysis (Wright, 1921) brings out the direct and indirect effects of component traits on yield. The present investigation was carried out with 42 genotypes of soybean to explore the association of certain characters, their direct contribution to yield and indirect effect through other characters.

The experimental material consisted of forty two genotypes of soybean (collections from different centers of

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[1, 3, 5] *Assistant Professor;* [2,4,6] *Professor*

AICRP on Soybean, India) grown in randomized complete block design (RCBD) with 3 replications during *kharif* 2011 and 2012 at the experimental farm of Agricultural Research Station, Kota, Rajasthan. Each plot consisted of 3 rows of 3 meters length with a spacing of 45 cm x 10 cm. Standard agronomic package of practices was followed to raise a healthy crop. Five equally competitive plants were randomly sampled from central row of each plot and were picked up for recording data of selected parameters namely, plant height (cm), number of pod cluster per plant, number of primary branches per plant, number of pods per plant, number of seeds per pod, dry matter yield per plant (g), harvest index (%), and yield per plant (g). Days to 50 per cent flowering, days to physiological maturity and seed filling period were recorded on the plot basis. 100 seed weight (g) and oil content (%) was recorded from sample taken from bulk of plot yield. Oil content was determined using Nuclear Magnatic Resonance Spectroscopy.

The average pooled data of two years was subjected to standard statistical techniques (Panse and Sukhatme, 1969) for analysis of variance to test the significance level of variation among the genotypes for different characters. Genetic para-meters; correlation coefficients were computed according to the method suggested by Singh and Chaudhry (1979). Path coefficients were worked out by the methods used by Dewey and Lu (1959).

The results regarding of variance and genetic parameters (mean, range, genotypic and phenotypic variance, SEm, heritability and genetic advance as % of mean for thirteen characters) revealed signifi-cant differences among all the genotypes for all the characters under this study (Table 1). This indicated the existence of significant amount of variability among the genotypes for all the characters studied.

Both, genotypic coefficient of variance (GCV) and phenotypic coefficient of variance (PCV) estimates were higher for harvest index (30.71 and 31.44) followed by number of seeds per pod (26.69 and 30.11), number of primary branches per plant (23.34 and 30.67) and number of pod clusters per plant. The lowest magnitude of PCV was recorded for days to physiological maturity, oil content, days to 50 per cent flowering and seed filling period. The difference between GCV and PCV were very small for oil content, yield per plant, 100 seed weight, harvest index and dry matter yield per plant indicating lesser contribution by environmental variation towards expression of these traits. The selection based on the phenotypic performance of these characters would be effective to bring about considerable improvement in these characters. The heritability estimates help the plant

Table 1. Analysis of variance and genetic variability parameters in quantitative traits of soybean genotypes

Character	Mean sum of squares			Phen-otypic Range	SEm (±)	Mean	GCV (%)	PCV (%)	h^2 % (bs)	GAM (% age mean)
	Repli-cation	Geno-types	Error							
Days to 50 % flowering	0.34	11.30**	1.66	37.33-46.00	0.74	42.09	4.26	5.25	66.0	7.13
Days to physiological maturity	10.96	46.34**	3.80	83.0-106.00	1.13	94.52	3.98	4.49	78.9	7.29
Seed filling period	9.50	23.05**	3.43	43.67-60.00	1.07	52.43	4.88	6.02	65.6	8.14
Plant height	6.49	259.16**	23.00	59.00-106.07	2.77	91.23	9.73	11.06	77.4	17.62
Pod clusters/ plant	0.25	3.64**	0.14	3.00-7.33	0.22	4.46	24.22	25.64	89.3	47.14
Primary branches/ plant	1.81	4.07**	0.79	2.33-6.67	0.51	4.48	23.34	30.67	57.9	36.59
Pods/plant	225.21	1262.53**	79.25	46.33-132	5.14	82.93	23.95	26.24	83.3	45.02
Seeds/pod	0.09	0.96**	0.08	1.13-3.57	0.16	2.03	26.69	30.11	78.6	48.75
Dry matter yield/plant	343.75	305.00**	8.30	29.23-68.00	1.66	49.79	19.98	20.80	92.3	39.52
Harvest index	20.41	465.43**	7.31	21.00-66.00	1.56	40.24	30.71	31.44	95.4	61.80
100 seed weight	0.14	6.29**	0.12	9.12-14.12	0.20	10.92	13.13	13.51	94.5	26.29
Oil content	0.02	2.50**	0.04	18.40-21.43	0.12	19.88	4.56	4.67	95.3	9.16
Yield/plant	1.76	33.35**	0.87	9.63-22.50	0.54	16.47	19.99	20.77	92.6	39.62

**Significant at 5% level of significance; ** Significant at 1% level of significance, SEm -Standard error of mean, GCV -Genotypic coefficient of variance, PCV - Phenotypic coefficient of variance, h^2 - Heritability (Broad sense), GAM - Genetic advance as percentage of mean* breeders in the selection based on the phenotypic performance. In the present study, high heritability was observed for all the characters which indicated that the selection would be effective for these characters. But this selection may be misleading because heritability estimate along with genetic advance is more useful than the heritability value alone for improving a particular trait (Johnson *et al.,* 1955). The high heritability combined with high genetic advance as per cent of mean observed for the characters like harvest index, 100-seed weight, seed yield per plant, number of seeds per plant, dry matter yield per plant, number of pod clusters per plant and number of pods per plant indicated that these characters are in the control of additive gene action (Panse, 1957) and would respond very well to continuous selection. These results are in agreement with the findings of Sahay *et al*. (2005) for number of pods per plant, 100-seed weight (g) and number of pod clusters per plant, Karnwal and Singh (2009) for number of pods per plant and 100-seed weight, and Gohil *et al*. (2006) for seed yield per plant. High heritability and low genetic advance was observed for days to 50 per cent flowering, days to maturity, seed filling period, plant height and oil content indicating involvement of non-additive genes, hence heterosis breeding involving population improvement exercise may be useful for improvement of these characters. Similar results were reported for days to 50 per cent flowering, days to maturity and oil content (%) by Ramteke *et al.* (2010).

The genotypic correlation coefficients were higher as compared to phenotypic and environmental correlation coefficient (Table 2). Direction of phenotypic and genotypic correlations was almost same for the character combination. This indicated greater contribution of genotypic factor in the development of the character association. Seed yield per plant had highly positive significant correlation with days to 50 per cent flowering, days to physiological maturity, seed filling period, plant height, pod cluster per plant, primary branches per plant, pods per plant, dry matter yield per plant and harvest index at genotypic and phenotypic level. This shows that selection for these eight traits can results in high yielding variety. Similar results were reported for days to 50 per cent flowering, days to maturity and grain filling period (Machikowa *et al.,* 2005), for dry matter yield per plant (g), number of primary branches per plant, number of pods per plant, and harvest index (Aditya *et al.,* 2011; Karnwal and Singh, 2009: Singh and Singh, 1996), for harvest index (Mehetre *et al*., 1997, Basavraja *et al*., 2005; Bhusan *et al*., 2006), for dry matter yield per plant (Chamundeswari and Aher, 2003), for plant height, primary branches per plant, pods per plant and harvest index (Bhusan *et al.,* 2006) and for pods per plant (Arshad *et al*., 2006).

Table 2. Estimate of genotypic and phenotypic correlation coefficient among quantitative traits in soybean genotypes

Character		Days to 50 % flow-ering	Days to physio-logical maturity	Seed filling period	Plant hei-ght	Pod clus-ter/ plant	No of primary branche s/plant	Pods/ plant	Seeds/ pod	Dry matter yield/ plant	Har-vest index	100 seed wei-ght	Oil cont-ent
Days to 50 % flowering	G	0.80	0.48	0.37	0.20	-0.27	0.05	0.19	0.32	0.31	-0.23	-0.10	0.32
	P	0.69**	0.22*	0.26**	0.16	-0.12	0.06	0.12	0.25**	0.26**	-0.20*	-0.9	0.25**
Days to physiological maturity	G		0.90	0.63	0.13	-0.04	0.18	0.25	0.48	0.40	-0.28	-0.09	0.48
	P		0.86**	0.49**	0.09	-0.03	0.17	0.16	0.41**	0.34**	-0.23**	-0.08	0.42**
Seed filling period	G			0.66	0.05	0.13	0.24	0.24	0.49	0.36	-0.24	-0.06	0.49
	P			0.48**	0.01	0.04	0.18*	0.12	0.37**	0.27**	-0.18*	-0.04	0.38**
Plant height	G				0.19	0.22	0.26	0.15	0.64	0.44	-0.28	0.01	0.64
	P				0.16	0.17	0.18*	0.08	0.50**	0.37**	-0.24**	0.00	0.50**
Pod cluster/ plant	G					0.33	0.39	-0.19	0.20	-0.01	0.06	-0.11	0.20
	P					0.30**	0.33**	-0.16	0.21*	-0.01	0.06	-0.10	0.21*
No of primary branches/plant	G						0.24	0.00	0.38	0.35	-0.17	-0.35	0.38
	P						0.13	-0.00	0.27**	0.28**	-0.13	-0.24**	0.27**
Pods/ plant	G							-0.27	0.28	0.14	-0.20	-0.25	0.28
	P							-0.24**	0.24**	0.11	-0.18*	-0.22	0.24**
Seeds/ pod	G								0.29	0.43	-0.03	0.01	0.29
	P								0.25**	0.36**	-0.02	0.02	0.25**
Dry matter yield/plant	G									0.71	-0.32	-0.13	0.97
	P									0.66**	-0.28**	-0.14	0.99**
Harvest index	G										-0.31	-0.24	0.70
	P										-0.29**	-0.25**	0.66**
100 seed weight	G											0.09	-0.31
	P											0.08	-0.28**
Oil content	G												-0.14
	P												-0.14

**: significant at 5% level of significance; **: significant at 1% level of significance*

Table 3. Path coefficient analysis showing the direct (bold and diagonal) and indirect effects of twelve component quantitative characters on yield at genotypic level

Character	r_g	Days to 50 % flowering	Days to physiological maturity	Seed filling period	Plant height	Pod cluster/ plant	No of primary branches/ plant	Pods/ plant	Seeds/ pod	Dry matter yield/ plant	Harvest index	100 seed weight	Oil content
Days to 50 % flowering	0.32**	0.83	0.67	0.40	0.31	0.16	-0.22	0.04	0.16	0.26	0.26	-0.19	-0.08
Days to physiological maturity	0.48**	-1.32	-1.64	-1.49	-1.03	-0.22	0.07	-0.30	-0.42	-0.80	-0.65	0.45	0.15
Seed filling period	0.49**	0.49	0.93	1.02	0.68	0.06	0.13	0.24	0.24	0.50	0.37	-0.25	-0.06
Plant height	0.64**	0.01	0.02	0.02	0.04	0.01	0.01	0.01	0.01	0.02	0.02	-0.01	0.00
Pod cluster/ plant	0.20*	0.01	0.00	0.00	0.01	0.03	0.01	0.01	-0.01	0.01	0.00	0.00	0.00
No of primary branches/plant	0.38**	0.01	0.00	0.00	-0.01	-0.01	-0.03	-0.01	0.00	-0.01	-0.01	0.01	0.01
Pods/ plant	0.28**	0.00	-0.01	-0.01	-0.01	-0.02	-0.01	-0.04	0.01	-0.01	-0.01	0.01	0.01
Seeds/ pod	0.29**	-0.02	-0.02	-0.02	-0.01	0.02	0.00	0.02	-0.09	-0.03	-0.04	0.00	0.00
Dry matter yield/plant	0.97**	-0.48	-0.73	-0.74	-0.96	-0.31	-0.58	-0.43	-0.45	-1.50	-1.07	0.48	0.21
Harvest index	0.70**	-0.14	-0.17	-0.16	-0.19	0.01	-0.15	-0.06	-0.19	-0.31	-0.43	0.13	0.11
100 seed weight	-0.31**	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	-0.03	0.00
Oil content	-0.14	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	0.00	0.00	-0.01	0.00	0.03

The negative correlation of 100-seed weight and oil content with grain yield is likely to pose problem in combining these important traits in a single genotype for high grain yield. Some suitable recombination might be obtained through bi- parental mating, mutation breeding or diallel selective mating by breaking undesirable linkage (Gafoor *et al*., 1990). This result was similar to previous work reported by Aditya *et al.* (2011) for 100 seed weight and Xinihai *et al.* (1999) and Johnson *et al.* (1955) for oil content.

As regards, inter-relationship between yield and component characters it was observed that harvest index, days to physiological maturity, seed filling period plant height and dry matter yield per plant were mutually correlated with each other. The results are in conformation with the findings of Aditya *et al*. (2011) for dry matter yield and harvest index. 100 seed weight was negatively correlated with all the characters except number of pod clusters per plant and oil content. These results are in corroboration with earlier findings of Ramteke *et al*. (2010) for days to 50 per cent flowering, days to physiological maturity and oil content.

Correlation results does not provide the true contribution of the characters towards the yield; therefore; the path coefficient analysis was used to partition the correlation coefficients with seed yield, in to direct and indirect effects through various yield contributing characters (Table 3). Seed filling period had highest direct effect (1.02) on seed yield per plant followed by days to 50 per flowering (0.82), plant height (0.04) and number of pods per plant (0.03). Seed filling period and days to flowering showed highly positive significant correlation with seed yield and this was due to direct effect of the characters. Similar results were reported in soybean for number of pods per plant by Karnwal and Singh (2009).

Dry matter yield showed highly positive significant correlation with seed yield per plant, but the direct effect of this character was negative which counter balanced positive indirect effect of 100 seed weight. Direct effects of days to flowering, seed filling period, plant height, number of pod clusters, oil content and yield per plant were positive while the remaining characters exhibited negative direct effect.

In the present study, highest value of phenotypic coefficient of variation than the genotypic coefficient of variation were recorded for primary branches per plant (30.67, 23.95) followed by seed per pod (30.11, 26.60), pods per plant (26.24, 24.95) and pod cluster per plant (25.64, 24.22). High heritability coupled with high genetic advance for harvest index, pod cluster per plant, pods per plant and seed per plant, and whereas, high heritability coupled with low genetic advance was found in oil content, days to flowering and seed filling period. In general, genetic correlation coefficients were found higher than the phenotypic correlation coefficient for the entire trait studied. On the basis of these findings plant height, number of primary branches per plant, seeds per pod, pods per plant and number of pod clusters per plant are useful components for improving the seed yield. Therefore, these traits should be considered for yield improvement in any breeding programme.

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Effect of Phosphorus and Boron on Production Potential, Profitability and Efficiency Indices of Soybean

SENTIMENLA[1], A K SINGH[2], MANDHATA SINGH[3] and R C GUPTA[4]
Department of Agricultural Chemistry and Soil Science,
School of Agricultural Sciences and Rural Development
Nagaland University, Medziphema 797106, Nagaland
E-mail: aksingh_1967@yahoo.co.in

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Soybean is an important crop with very high nutritional value containing 40 per cent protein and 20 per cent oil. In Nagaland, the estimated area under soybean cultivation is 26,500 ha with a production of 31,270 tonnes with an average productivity of 1,180 kg per ha (Anonymous, 2008). Soybean is one of the most popular food items of majority of the Naga people and is utilized as fermented product as well as pulse crop. In spite of its popularity, the farmers give a little priority for its cultivation on a large scale due to the lower productivity. Soils of Nagaland are acidic in nature and the availability of phosphorus and boron limits the productivity of crops. Soybean requires large amount of phosphorus in the early stage of the plant life for the development of roots as well as in later stage for seed formation and good yield. Deficiency of boron has been reported in the other North Eastern states because of the coarse texture of soil and leaching (Takkar, 1996). Boron is necessary for the translocation of sugars, starches and phosphorus, and helps in the absorption of nitrogen and formation of nodules. Soybean requires an adequate supply of available boron especially during flowering stage and seed formation. Keeping the above facts of essentiality of both the nutrients, the present investigation was carried out to assess the effect of P and B levels on production potential, profitability and efficiency indices of soybean.

The experiment was carried out during the *kharif* season of 2009 at the Experimental Farm of the School of Agricultural Sciences and Rural Development, Medziphema, Nagaland

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[1]M Sc(Ag) student, [2]Assistant Professor, [3]Junior Scientist (Agronomy), [4]Professor and Head

which is located at an altitude of 310 m above mean sea level and 25^0 45′ 45′′ N latitude and 93^0 53′ 04′′ E longitudes. The area lies under the humid sub-tropical zone with average rainfall of 2000 – 2500 mm and temperatures ranging from 21 to 32 ^{0}C during summer and a minimum of 8 ^{0}C in winter. The soil of the experimental field was having pH 4.9, organic carbon 13.6 g per kg and available nitrogen, phosphorus, potassium and boron 203.0, 16.5, 159.0 and 0.31 kg per ha, respectively. Treatments consisted of four levels of phosphorus (0, 8.6, 17.2 and 25.8 kg/ha) and four levels of boron (0. 0.5, 1.0 and 1.5 kg/ha),which were applied through triple super phosphate and borax, respectively. The experiment was laid out in randomised block design with three replications. Soybean seeds were inoculated with *Bradyrhizobium japonicum* culture @ 7 g per kg seed. Nitrogen and potassium were applied @ 20 and 30 kg per ha through urea and muriate of potash, respectively. Soybean seeds (JS-335) were sown on 15th June 2009 at a spacing of 30 cm between rows and 10 cm between plants and raised with the recommended agronomic practices. Plant height and number of leaves were recorded at 60 days after sowing (DAS) while number and fresh weight of nodules were recorded at 45 DAS. The crop was harvested at full maturity and data regarding yield attributes and yield were recorded. Seed and stover samples were dried, ground in Willey Mill and analysed for the nutrient contents. Nitrogen content was determined by micro Kjeldahl method. P and K contents were determined by Vanadomolybdo-phosphoric yellow colour method and flame photometrically, respectively (Jackson, 1973). Seed and stover samples were ignited in a muffle furnace at 550 ^{0}C for total content of B. Plant extract of B was determined by carmine method (Hatcher and Wilcox, 1950). Agronomic efficiency and physiological efficiency were calculated as described by Baligar *et al.* (2001).

Economic analysis was done on the basis of prevailing market price of input used and the output obtained from each treatment. Statistical analysis was done as per the methodology of Gomez and Gomez (1984).

Effect on yield attributes and yield: Plant growth parameters namely, height, number of leaves and nodules and their dry weight significantly increased with different levels of P and B. Taller plants with higher number of leaves per plant were recorded with each increment of P and B (Table 1). Application of 25.8 kg P per ha and 1.0 B per ha recorded maximum plant height and was found at par with 17.2 kg P and 1.5 kg B per ha. The improvement in plant height might be due to the increased metabolic activities, stimulation of root growth resulting in enhanced uptake of nutrients. These findings are in accordance with Laltlanmawia *et al.* (2005), Khan *et al.* (2005) and Cirak *et al.* (2006).

Table 1. Effect of phosphorus and boron on plant height, number of leaves, number of nodules, nodules dry weight and number of pods of soybean

Treatment	At 60 DAS		At 45 DAS		Pods (No/ plant)	Filled pods (No/ plant)
	Plant height (cm)	Leaves (No/ plant)	Nodules (No/ plant)	Dry nodules (g/plant)		
P levels (kg/ha)						
0	50.18	67.07	22.17	0.30	127.9	114.7
8.6	54.50	76.50	24.08	0.33	163.8	172.7
17.2	59.79	88.75	26.25	0.40	196.2	182.9
25.8	60.95	108.27	28.33	0.50	213.9	189.1
SEm (±)	0.68	1.29	0.60	0.006	3.35	5.09
CD (P = 0.05)	**1.92**	**3.81**	**1.77**	**0.02**	**9.93**	**15.2**
B levels (kg/ha)						
0	52.25	72.94	20.67	0.28	165.3	144.2
0.5	54.37	81.80	23.84	0.35	172.8	156.3
1	59.81	89.36	27.00	0.43	176.1	172.2
1.5	58.98	96.49	29.33	0.48	187.8	186.7
SEm (±)	0.68	1.29	0.60	0.006	3.35	5.09
CD (P = 0.05)	**1.92**	**3.81**	**1.77**	**0.02**	**9.93**	**15.2**

Increasing levels of P and B increased the number and dry weight of nodules per plant due to increased availability of phosphorus and boron. The highest number of and dry weight of nodules per plant was registered with 25.8 kg P and 1.5 kg B per ha followed by 17.2 kg P and 1.0 kg B per ha. Phosphorus application might have favoured vigorous root development, accelerated rhizobium activity and increased root-nodule formations. Laltlanmawia *et al.* (2005) reported that increasing levels of P up to 25.8 kg per ha increased nodulation in soybean. Increase in the number of nodules per plant with the increase of boron application has also been reported by Bharti *et al*. (2003).

Application of 25.8 kg P and 1.5 kg B per ha recorded maximum number of pods and filled pods per plant and was significantly superior to control. Increased number of filled pods per plant might be due to significant increase in plant height, number of leaves, nodulation, growth and efficient nutrient utilization. These results corroborates with the findings of Cirak *et al*. (2006) and Kumar *et al*. (2006).

Table 2. Effect of phosphorus and boron on yield, agronomic and physiological efficiency and economics of soybean

Treatment	Yield (kg/ha)		Agronomic efficiency*		Physiological efficiency**		Net returns (₹/ha)	B:C ratio
	Seed	Stover	P	B	P	B		
P levels (kg/ha)								
0	2105	2559	0.0	71.2	0.00	69.05	28200	1.87
8.6	2331	3026	36.8	218.5	179.04	95.37	31315	2.03
17.2	2427	3225	17.0	314.1	154.63	45.99	31340	2.03
25.8	2752	3433	25.1	648.6	144.81	45.11	36950	2.06
SEm (±)	9.0	7.0					452.60	0.03
CD (P=0.05)	**28.0**	**20.0**					**1357**	**0.08**
B levels (kg/ha)								
0	2283	2807	18.9	0.0	127.55	0.00	28430	1.85
0.5	2326	2958	16.3	615.5	143.29	103.87	31475	1.99
1	2448	3159	20.4	361.0	104.94	78.77	33350	2.06
1.5	2557	3320	23.3	275.8	102.70	72.88	34550	2.08
SEm (±)	9.0	7.0					452.60	0.03
CD (P=0.05)	**28.0**	**20.0**					**1357**	**0.08**

**kg seed/kg P or B; **kg biomass yield /kg uptake of P or B*

Seed and stover yield of soybean (Table 2) increased signifi-cantly with the increasing levels of P and B. Application of 25.8 kg P per ha, recorded maximum seed yield (2,752 kg/ha) and was found statistically superior over rest of the P levels. Crop fertilized with 1.5 kg B per ha produced higher seed yield than other levels. Increased seed yield might be due to improvement in growth and yield attributes. These results are in line with the findings of Cirak *et al*. (2006) and Kumar *et al*. (2006). The stover yield was significantly higher when crop received 25.8 kg P and 1.5 kg B per ha and was found superior to other levels of P and B. The increased stover yield might be due to availability of higher photosynthetic area and better conversion of solar radiation to photosynthates by increased number of leaves (Saxena and Nainwal, 2010).

Effect on agronomic and physiological efficiency: Agronomic and physiological efficiencies were affected by different levels of phosphorus and boron. Highest agronomic efficiency of phosphorus on added P (kg seed increased/kg P applied) was recorded with 8.6 kg P application. In case of added B, agronomic efficiency increased with increasing the levels of B up to 1.5 kg per ha. Boron fertilization had a significant effect on agronomic efficiency of applied boron and 0.5 kg B per ha recorded maximum agronomic efficiency over other B levels. Agronomic efficiency of boron was increased with increasing the level of P up to 25.8 kg per ha. Physiological efficiency of phosphorus on added P (179.04 kg biomass/kg P) and B (143.29 kg biomass/kg P) was highest under 8.6 kg P and 0.5 kg B per ha, respectively and physiological efficiency of boron on added P (95.37 kg biomass/kg B) and B (103.87 kg biomass/kg B) was highest under 8.6 kg P and 0.5 kg B per ha, respectively.

Effect on economics: Economic analysis (Table 2) showed that application of 25.8 kg P per ha fetched significantly higher net returns (₹ 36,950) and B : C ratio (2.06) over rest of the P level. The additional net returns was to the tune of ₹ 8,750 due to application of 25.8 kg P per ha over control. The application of B also recorded significantly higher net returns and benefit cost ratio. Crop fertilized with 1.5 kg B per ha recorded higher net returns (₹ 34,550) and benefit cost ratio (2.08). This might have been achieved due to

Table 3. Effect of phosphorus and boron on nutrients (N, P, K and B) content in seed and stover of soybean

Treatment	Seed				Stover			
	N (%)	P (%)	K (%)	B (mg/kg)	N (%)	P (%)	K (%)	B (mg/kg)
P levels (kg/ha)								
0	5.32	0.40	1.32	14.21	1.39	0.24	0.46	7.38
8.6	5.93	0.44	1.40	15.18	1.54	0.32	0.48	7.46
17.2	6.25	0.48	1.43	15.38	1.60	0.36	0.51	7.98
25.8	6.48	0.55	1.46	16.13	1.64	0.40	0.54	8.16
SEm (±)	0.03	0.006	0.006	0.03	0.006	0.003	0.006	0.021
CD (P = 0.05)	**0.10**	**0.02**	**0.02**	**0.10**	**0.02**	**0.01**	**0.02**	**0.06**
B levels (kg/ha)								
0	5.84	0.44	1.32	14.80	1.49	0.31	0.42	7.46
0.5	5.96	0.46	1.36	15.09	1.54	0.32	0.49	7.66
1	6.05	0.48	1.42	15.46	1.55	0.33	0.50	7.87
1.5	6.12	0.50	1.51	16.75	1.58	0.34	0.58	7.89
SEm (±)	0.03	0.006	0.006	0.03	0.006	0.003	0.006	0.021
CD (P = 0.05)	**0.10**	**0.02**	**0.02**	**0.10**	**0.02**	**0.01**	**0.02**	**0.06**

higher productivity as well as lower cost of cultivation owing to increased economic returns.

Effect on nutrient contents: The application of phosphorus signifi-cantly increased the content of nitrogen in both seed and stover of soybean (Table 3). Maximum of 6.48 per cent N in seed and 1.64 per cent N in stover was observed by the application of 25.8 kg P per ha.

This increase in N content might be due to the vigorous growth of roots and increased uptake of N by the complementary effect applied phosphatic fertilizer. Similar observations have been reported by Singh and Singh (2004). Application of B significantly increased the nitrogen content of soybean. Maximum N content in seed and stover 6.12 and 1.58 per cent, respectively were recorded by the application of 1.5 kg B per ha. Kumar *et al*. (2006) reported that *Bradyrhizobium* along with micronutrients significantly increased N uptake in both seed and stover. Phosphorus content of soybean seed and stover was significantly increased with the application of P. Maximum P content of seed 0.55 per cent and of stover 0.40 per cent was recorded with the application of 25.8 kg P per ha. This finding is in accordance with findings of Jain *et al*. (2007).

The application of both P and B significantly increased the K content of soybean seed and stover. Maximum K content of 0.54 per cent in stover and 1.46 per cent in seed was recorded with 25.8 kg P per ha while 0.58 per cent in stover and 1.51 per cent in seed with 1.5 kg B per ha. Singh and Singh (2004) observed that application of phosphorus increased K content and their uptake by seed and stover. The application of P and B significantly increased the B content in both seed as well as stover. Maximum B content in seed (16.75 mg/kg) and stover (7.89 mg/kg) were also observed at 1.5 kg B per ha.

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Evaluation of Water Production Functions and Irrigation Scheduling for Soybean in South-Eastern Rajasthan

PRATAP SINGH[1], I N MATHUR[2], R S NAROLIA[3] and P K GUPTA[4]
AICRP on Water Management, Agricultural Research Station (MPUA&T), Kota 324 001, Rajasthan
(E-mail: psd427@ rediffmail.com)

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Soybean is an important *kharif* crop of the south-eastern Rajasthan occupying an area of 8.2 lakh hectares. Although edaphic and climatic conditions are favorable, the productivity of soybean in this region is low (971 kg/ha). Among various factors responsible for low productivity, soil moisture availability has been regarded as the most limiting factor. Besides these, untimely and excess irrigations by the farmers are major factors of low productivity of soybean in the Chambal command region. The selection of varieties is one of the basic inputs of crop production under unfavorable climatic conditions. For successful crop production, crop must be supplied with adequate quantity of water at required frequency. The efficiency of irrigation depends upon how much to irrigate, how to irrigate and when to irrigate. In the absence of such irrigation schedules, farmers are following vague irrigation practices which results in either sub-optimal or excess irrigation. In order to optimize the amount of water use, relationship between yield and irrigation water should be known. Relationship between yield and water used for raising the crop is termed as "water production function", which depends upon the crop, crop environment and sensitiveness to depth of irrigation and type of genotypes. Crop-water production function indicates the functional relationship between the crop yield and water supply. Thus, for preparing irrigation plan for a particular command area, water production function model is necessary to design the optimal irrigation schedules in the area. Hence, the study was conducted to evaluate water production functions, irrigation schedules and to find out the most suited soybean variety to the Chambal command region

[1]*Chief Scientist and Agronomist;* [2]*Agricultural Engineer;* [3]*Junior Agronomist;* [4] *Zonal Director Research*

of Rajasthan in the changing scenario of the climate.

The field experiments were conducted during *kharif* 2004 to 2008 at Agricultural The field experiments were conducted during *kharif* 2004 to 2008 at Agricultural Research Station, Kota. Soil was clay-loam (Vertisols) with pH 7.7, organic carbon 0.56 per cent, field capacity 28 per cent, wilting point 14 per cent, bulk density 1.38 g per cc and EC 0.23 dS per m,. The treatments comprised five irrigation treatments namely, irrigations at 40 per cent depletion of available soil moisture (ASM), irrigations at 60 per cent depletion of ASM, two irrigations each at branching and pod development stages, one irrigation at pod development stage and control (rainfed) allocated to main plots and four soybean varieties namely, NRC 7, MACS 450, Pratap soy 1 and JS 335 to the sub-plots. The experiment was conducted in split plot design with four replications. In each of the irrigation, 6 cm water was applied on the basis of area-volume method. The crop was sown with the onset of monsoon in the month of July dated 10, 14, 19, and August 2 of the year 2004, 2005, 2007 and 2008 respectively, except 3 August in 2006 due to delayed onset of monsoon and harvested in the month of October except in 2006 in November. Row to row spacing was 30 cm and the crop received the recommended dose of fertilizers ($N:P_2O_5:K_2O$::40:40:40 kg/ ha). The climate of area is sub-humid with an average annual rainfall of 750 mm but rainfall was low during the experimentation (Fig. 1) The rainfall received was 500 mm (2004), 550 mm (2005), 450 mm (2006), 253 mm (2007), 560 mm (2008) and 550 mm (2009). The maximum relative humidity falls in the range of 85 to 90 per cent during rainy months of July–September. The maximum and minimum temperature ranges between

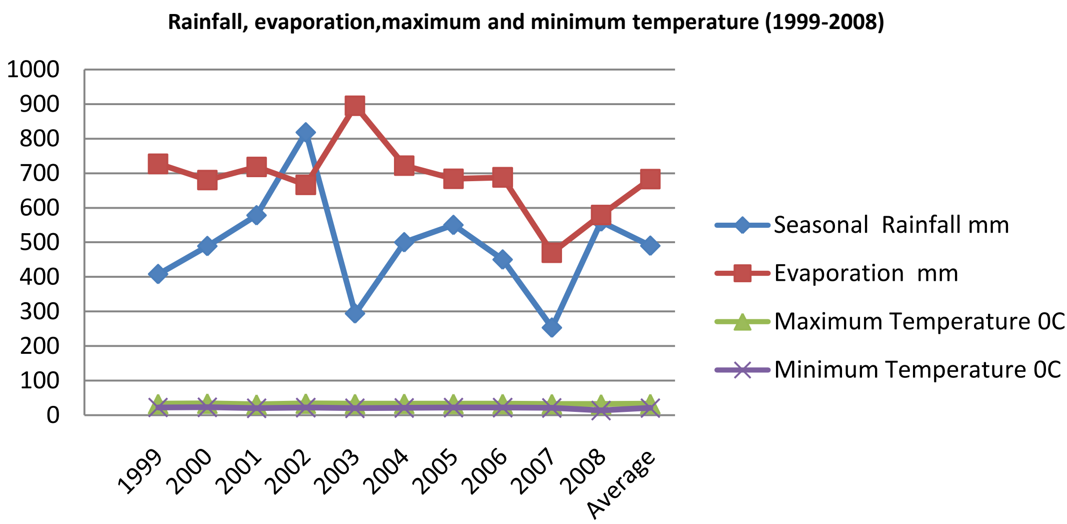

Fig. 1. Rainfall, evaporation, maximum and minimum temperature during last ten years

Table 1. Effect of irrigation scheduling on the yield, water use efficiency and water use efficiency of soybean

Treatments	Seed yield (kg/ha)						WEE (kg/ha-cm)	WUE (kg/ha-mm)
	2004	2005	2006	2007	2008	Pooled	Pooled	Pooled
Irrigation Schedules								
40 % depletion of ASM	2805	2435	1655	1820	788	1901	36.9	4.2
60 % depletion of ASM	2841	2359	1509	1747	759	1843	35.4	4.0
Branching & Pod development	2742	2215	1409	1692	694	1750	37.0	3.9
Pod development	2652	1977	1175	1686	691	1636	37.2	3.6
Control	1864	1903	939	1435	687	1366	34.3	3.0
CD (P = 0.05)	**46.7**	**21.4**	**34.8**	**27.2**	**12.7**	**202**	**1.2**	**0.08**
Varieties								
JS 335	2689	2298	1517	1768	475	1749	34.3	3.9
MACS 450	2300	1979	1049	1518	570	1483	28.5	3.3
NRC 37	2459	2065	1201	1562	1125	1682	32.9	3.7
Pratap Soya 1	2877	2369	1582	1821	726	1875	36.4	4.2
CD (P = 0.05)	**35.9**	**47.9**	**19.0**	**18.1**	**13.5**	**232**	**0.9**	**0.06**

28.7-33.6 and 13.8-22.5 ^{0}C respectively, during the crop period. Linear logarithmic model was used for calculating water production function (Alam and Singh, 2000). Crop water use efficiency (WUE) and water expense efficiency (WEE) were computed using following formula.

WUE (kg/ha-mm) = Crop yield (kg/ha) x 100/Evaporation seasonal (mm)

WEE (kg/ha-cm) = Crop yield (kg/ha) x 100/Total water applied (cm)

Pooled data over five years revealed that irrigation applied at 40 per cent depletion of ASM significantly increased the seed yield of soybean over control and one irrigation at pod development. The irrigation at 40 per cent depletion of ASM increased yield by 39.2, 16.2, 8.6 and 3.2 per cent over control, irrigation at pod development, irrigations at branching and pod development and irrigation at 60 per cent depletion of ASM, respectively The maximum soybean seed yield of 1,901 kg per ha was achieved when irrigation was applied at 40 per cent depletion of ASM. Water use efficiency (WUE) was highest (4.2 kg/ha-mm) in this treatment as compared to 4.0 kg per ha-mm at 60 per cent depletion of ASM and 3.9 kg kg per ha-mm with two irrigations, and 3.0 kg per ha-mm with one irrigation. Irrigation at 40 per cent depletion of ASM, water expense efficiency was also significantly better (36.9 kg/ha-cm) than irrigations at branching and pod development (37.0 kg/ha-cm) and irrigation at pod development (37.2 kg/ha-cm).

Among the soybean varieties Pratap soy 1 performed better with respect to the grain yield (1,875 kg/ha) irrespective of the irrigation schedules and closely followed by JS 335 (1749 kg/ha). The WUE of Pratap soy 1 was the highest (4.2 kg/ha-mm) and water expense was also highest (36.40 kg/ha-cm)

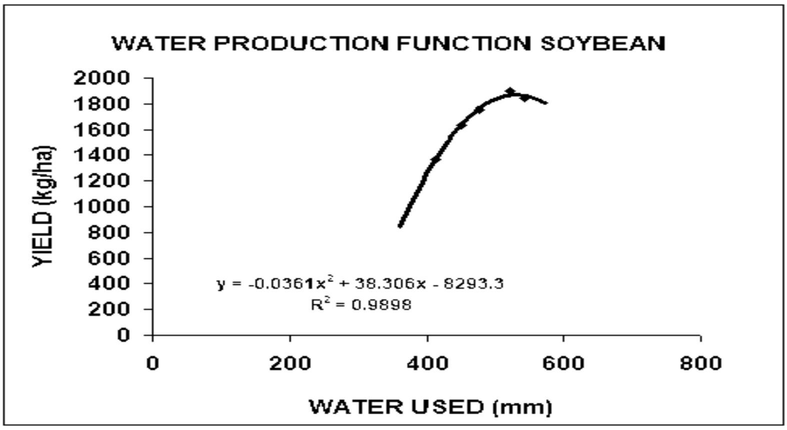

Fig. 2. Water production function of soybean

as compared to other varieties. Pratap soy 1 and JS 335 performed better than other varieties. The water production function evaluated and an equation, Yield (kg/ha) = $-0.0361x^2 + 38.306\,x - 8293.3$ was drawn (Fig. 2) wherein "x" is the water used (mm) was worked out. The correlation coefficient was $R^2 = 0.9898$. Nielsen (2011) at Akron, USA observed that soybean shows the highest seed yield for any given amount of water and linear regression production functions was 148.1* (in-0.7).

A linear relationship between seed yield and ET with a week but positive slope was found in soybean by Karan *et al*. (2005).

The results of the study brings out that the seed yield of soybean can be sustained by applying irrigation at 40 per cent depletion of ASM approach in the command areas. In all the growing seasons, irrigation regimes had been predominant factor influencing performance of the crop. Rainfed conditions throughout the experimentation period caused reductions in grain yield of soybean in comparison to irrigation treatments. Variety Pratap soy 1 yielded higher than others under the same weather conditions may be attributed to the fact that it is drought tolerant and of shorter duration.

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Bio-efficacy and Optimization of Effective Dose of Flubendiamide against Green Semilooper (*Chrysodeixis acuta* Walker) on Soybean

H R CHAUDHARY*[1]*, CHAMAN JADON*[2]*, V R MEENA*[2]*,
***H P MEGHWAL*[3]*, D S MEENA*[3]*, R K MAHAWAR*[3] *and M ALI*[1]**
Agricultural Research Station (MPUA and T), Ummedganj,
Kota 324 001, Rajasthan
E mail: hrkota@gmail.com

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Soybean [*Glycine max* (Linn.) Merrill] ranks first in the world for production of edible oil. India ranks fourth in the world in respect of area and fifth in terms of production. The productivity of soybean in India is only 1006 kg per ha. Rajasthan ranks third in the country and occupies an area of 7.70 lakh ha and the production is 11.20 lakh tones, while first in productivity with 1,461 kg/ha (Anonymous, 2010). Insect pests are one of the most important constraints for low productivity of soybean in the country. The crop is reported to be attacked by 270 species of insects. About two dozen insect pests have been observed on crop in the area. Among them defoliator semilooper (*Chrysodeixis acuta* Walker) is of economic significance, which causes severe damage and consequent reduction in yield (Sharma, 1999). It also feeds on buds, flowers and even on young pods inflicting substantial losses in seed yield (Singh *et al*., 1990). The control of insect pests by various means of pest management tactics is well documented on crop (Chaudhary and Meghwal, 2012). Some newer chemical molecules are being introduced in the market having noval mode of approaches, hence it became imperative to test them. Therefore, the present investigation was carried out to optimize the effective dose of Flubendiamide with other insecticides which could be utilized for the effective management of green semilooper in soybean eco-system

Field experiments were conducted at experimental farm of Agricultural Research Station, Ummedganj, Kota during *kharif* 2009 and 2010 in randomized block design having six treatments with four replication including control. The

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[1] *Professor;* [2] *Technical Assistant;* [3] *Assistant Professor*

soybean variety JS 335 was sown after the onset of monsoon keeping 30 cm row-to-row and 10 cm plant-to-plant distance in plot size of 3.0 m x 5.0 m during 2009 and 4.2 m x 5.0 m during 2010 following standard package of practices for raising the crop. Three doses of Flubendiamide 480 SC (125, 150 and 187.5 ml/ha) along with Quinalphos 25 EC @ 1000 ml per ha and Triazophos 40 EC @ 800 ml per ha were evaluated for their efficacy against green semilooper. During the first year (*kharif,* 2009), all the treatments were applied when the population pressure was maximum coinciding with the most vulnerable stage of the crop. The population of green semilooper (*Chrysodeixis acuta* Walker) was counted after 10 days of treatment application on random samples of per metre row length area by using "vertical beat sampling technique". Three such observations were taken plot-wise against the test insect and mean was worked out. The number of larvae was transformed to square root values for statistical analysis. Seed yield was recorded from each replication after the harvest of the crop and subjected to the statistical analysis. Data for both the years were subjected for pooled analysis. Net returns in term of rupees and IBCR were also worked out by comparison of protective sprays and net gain over the control. Per cent avoidable yield loss was also calculated as yield loss in unprotected crop when compared to respective, protected treatments as follows.

Avoidable yield loss (%) = Yield in protected – Yield in unprotected/ Yield in protected x100

Green semilooper (Chrysodeixis acuta Walker): The data recorded on green semilooper population per metre row length during *kharif* 2009 (Table 1) revealed that 10 days after treatments application, green semilooper population ranged from 0.92 to 2.25 larvae per m row length in different insecticidal treatments as compared to 4.33 larvae per m row length in untreated control. All the insecticidal treatments were found significantly superior over untreated control. The treatment Flubendiamide 480 SC @ 187.5 ml per ha was found to be significantly superior recording only 0.92 larvae per m row length and was on par with Triazophos 40 EC @ 800 ml per ha (1 larvae/m row length). Similar trend was observed during 2010 also.

Pooled data of green semilooper population for *kharif* 2009 and 2010 also revealed that all the treatments (0.59 to 1.46 larvae/m row) were significantly superior as compared to untreated control (3.69 larvae/m row). Among the treatments application of Flubendiamide 480 SC @ 187.5 ml per ha further established its effectiveness against green semilooper with 0.59 larvae per m row length and remained significantly superior over rest of the doses/ treatments except Triazophos 40 EC.

Table 1. Effect of different doses of Flubendiamide on insect-pest and seed yield of soybean

Treatment	Dose (ml/ha)	Green semilooper population/m row length			Seed yield (kg/ha)		
		2009	2010	Pooled	2009	2010	Pooled
Flubendiamide 480 SC	125	2.25 (1.66)	0.67 (1.05)	1.46 (1.37)	1300	2048	1674
Flubendiamide 480 SC	150	1.92 (1.55)	0.63 (1.04)	1.27 (1.30)	1450	2143	1796
Flubendiamide 480 SC	187.5	0.92 (1.19)	0.25 (0.85)	0.59 (1.02)	1567	2357	1962
Quinalphos 25 EC	1000	1.75 (1.50)	0.58 (1.01)	1.17 (1.27)	1467	2202	1835
Triazophos 40 EC	800	1.00 (1.22)	0.42 (0.94)	0.71 (1.09)	1533	2262	1898
Untreated control	Water spray	4.33 (2.20)	3.04 (1.83)	3.69 (2.04)	1200	1452	1326
SEm (±)		0.049	0.057	0.038	34.74	56.11	48.59
C.D. at 5%		**0.148**	**0.165**	**0.110**	**104.7**	**169.1**	**140.2**

Figures in parentheses are square root (x + 0.5) transformed value

Seed yield

During *kharif* 2009, seed yield levels, in general, were low because of unfavourable weather conditions. However, all the insecticidal treatments recorded significantly superior yield over untreated control except Flubendiamide 480 SC @ 125 ml per ha. The seed yield in rest of the insecticidal treatments varied from 1,300 to 1,567 kg per ha as compared to 1,200 kg per ha in untreated control. The treatment of Flubendiamide 480 SC @ 187.5 ml per ha was found most effective with maximum seed yield (1,567 kg/ha) and was on par with Triazophos 40 EC (1,533 kg/ha) and Quinalphos 25 EC (1,467 kg/ha). During *kharif* 2010, similar trend in efficacy was observed but the yield levels in all insecticidal treatments was more than 2,000 kg per ha.

Pooled seed yield data of *kharif* 2009 and 2010 further confirmed that all the insecticidal treatments/doses (1,674 to 1,962 kg/ha) were significantly superior over untreated control (1,326 kg/ha). The treatment of Flubendiamide 480 SC @ 187.5 ml per ha was found to be most effective with maximum seed yield (1,962 kg/ha) and on par with recommend-ded insecticides Triazophos 40 EC (1,898 kg/ha) and Quinalphos 25 EC (1,835 kg/ha).

Table 2. Economics and incremental benefit cost ratio of insecticides in soybean

Treatments	Dose (ml/ ha)	Seed yield (kg/ ha)	Addit-ional yield over control (kg/ha)	Avoi-dable yield loss (%)	Addi-tional returns (₹/ha)	Cost of insect-cide (₹/ha)	Net returns (₹/ha)	IBCR
Flubendi-amide 480 SC	125	1674	348	20.79	8004	1500	6504	5.34
Flubendi-amide 480 SC	150	1796	470	26.17	10810	1800	9010	6.01
Flubendiamide 480 SC	187.5	1962	636	32.42	14628	2250	12378	6.50
Quinalphos 25 EC	1000	1835	509	27.74	11707	260	11447	45.03
Triazophos 40 EC	800	1898	572	30.14	13156	340	12816	38.69
Untreated control	Water spray	1326	-	-	-	-	-	-

Soybean= Rs 2300/q, Flubendiamide = Rs 12000/l, Triazophos = Rs 425/l and Quinalphos = Rs 260/l

Economic evaluation

Data on economic evaluation (Table 2), revealed that the highest additional yield (636 kg/ha) over control, avoidable yield loss (32.42 %) and additional return (₹ 14,628/ha) was obtained in the treatment Flubendiamide 480 SC @ 187.5 ml per ha followed by Triazophos 40 EC @ 800 ml per ha. Whereas, maximum net returns (₹ 12,816/ha) was recorded in the treatment of Triazophos 40 EC @ 800 ml per ha followed by Flubendiamide 480 EC @ 187.5 ml per ha (₹ 12,378/ha). However, because of lower price the incremental benefit cost ratio obtained from the application of traditional/ conventional insecticides was higher as compared to highly priced Flubendiamide.

It is inferred that on the basis of criteria considered (Green semilooper population/m row length, seed yield and economics) for evaluation of insecticides, Flubendiamide 480 SC @ 187.5 ml per ha and Triazophos 40 EC @ 800 ml per ha were found most effective where low population of green semilooper larvae, high seed yield and more net returns were obtained.

The present findings are well accordance with the findings of Chaudhary and Bajpai (2007) reported the effectiveness of Triazophos. Kumar and Ram (2002) also observed comparatively higher yield with two spray of chemical insecticide against insect pests in soybean crop.

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