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Evaluation of Improved Water Management Practices on Soybean Grown in the Chambal Command Area of South-Eastern Rajasthan

R S NAROLIA[1], B S MEENA[2], H P MEENA[3], D S MEENA[4],
ABHAY DASHORA[5] and PRATAP SINGH[6]

AICRP on Irrigation Water Management, Agricultural Research Station
(Agriculture University), Kota 324 001, Rajasthan

E mail: narolia2007@gmail.com

ABSTRACT

Field experiments were conducted during 2009 to 2014 at farmer's field under ORP of AICRP on irrigation water management at Agricultural Research Station, Kota to study the impact of improved water management practices on yield, water productivity, sustainability and economics of soybean. Treatments comprised irrigation scheduling at flowering and pod development stages by border strip (6 x 50 m) method using 80 per cent cut off ratio (improved water management practices), which was compared with farmer's practice (wild flooding). Results revealed that improved water management practices (IWMP) gave higher and sustainable yield of soybean over the years. The mean yield recorded (1,489 kg/ha) under IWMP being 6.17 per cent higher as compared to the yield (1,402 kg/ha) observed in farmer's practice. Pooled sustainability yield index (0.654) and value index (0.474) were found 3.65 and 8.47 per cent higher, respectively. IWMP possessed higher water use efficiency (24.9 kg/ha/cm), water productivity (3.0 Rs/M³) and incremental benefit cost ratio (1.4) over farmer's practices.

Soybean [*Glycine max* (L.) Merrill] is commonly known as golden bean, occupies coveted place with top rank among oilseed crops of world as well as India. It is a most important *kharif,* oilseed crop of south eastern Rajasthan. Low productivity in the Rajasthan state is mainly due to occurrence of intermittent dry spells, erratic rainfall during the growing season, improper water management and other agronomic practices. The present scenario in India is demanding higher production and productivity, which is putting more pressure on land and water resources in the country. Therefore, immediate action is needed to increase the productivity and water use efficiency of soybean (Singh *et al.,* 2013). Keeping this in view, demonstrations were conducted at farmer's field under Operational Research Programme with the aim to

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[1,2,3,4]*Assistant Professor (Agronomy);* [5]*Soybean Breeder;* [6]*Professor (Agronomy)*

improve water productivity at field level and to show the benefits of demonstrated water management practices in terms of enhanced yield and saving of irrigation water.

MATERIAL AND METHODS

A total of 18 on farm trials (nine each at left main and right main canal of Chambal command) were conducted each year at adopted villages namely Manasganv, Soli, Kotsuan Mandawari of Kota and Kotkhera, Khothiya and Lesarda of Bundi districts during *kharif* seasons for consecutive six years (2009 to 2014) in the selected farmers field. For the selection of farmers to conduct the demonstrations, a group meeting was convened each year and receptive and innovative farmers were selected. Selected villages of Chambal command lies between 25° and 26° North latitude and 75°-30' and 76°-6' East longitude in the south eastern part of Rajasthan. It comes under agro-climatic zone V (humid south eastern plain) of Rajasthan. The soils of the adopted villages for demonstrations belong to the order Vertisols and Inceptisols, mainly comprise of Chambal series (62 %) and Kota variant (23 %). The bulk density, pH and cation exchange capacity of these soils varies between 1.34-1.60 Mg per m^3, 7.74-8.40 and 30-40 Cmol per kg, respectively. The soils have a very low water intake rate (approximately 0.25 cm/h) on surface, but are almost impermeable at 1.2 to 1.5 m depth. The potential moisture retention capacity is almost 120 mm of water in 1 m depth. The soils of the selected villages for demonstrations are poor in organic carbon (0.50 ± 0.08) and available nitrogen (275 ± 12 kg/ha) but are low to medium in available P_2O_5 (24.2 ± 1.0 kg/ha) and medium to high in available K_2O (292 ± 12 kg/ha).

Improved water management practices (IWMP) includes one irrigation at pod development stage with 6 cm depth by border strip method (6 m x 50 m) at 80 per cent cut off ratio and compared with the farmer's practice (FP), *i.e.* flooding method of irrigation with no control over the depth of irrigation (usually about 10 cm) and without consideration of critical stages of the soybean. Recommended package of practices *viz.*, high yielding varieties (RKS 24), seed treatment, recommended dose of fertilizer (20:40:40:30 kg/ha, NPKS), weed management, crop geometry (30 cm x 10cm) and seed rate (80 kg/ha) were used in test block as well as control block during each year. Each demonstration was laid out in an area of 0.1 ha. For assessing impact of improved water management practices (IWMP), the adjoining field with similar area cultivated to soybean crop by the farmer himself was considered which served as check plot (FP). For the test plots, measurement of water was done by velocity-area method at field level. The demonstration plots were sown with improved water management practices during first fortnight of July and harvested in the mid of October every year. The rainfall received during growing period of soybean were239.5 mm, 523 mm, 635.7 mm, 693.7 mm, 887.8 mm and 734.6 mm for the years of 2009,

2010, 2011, 2012, 2013 and 2014, respectively. Except rainfall received during growing period, only one irrigation at pod development stage was applied each year for the calculating water use efficiency of the crop. Potential yield of soybean crop in humid south eastern plain zone of Rajasthan was 3,000 kg per ha. Production efficiency was calculated on the basis of average maturity days (98 days) of variety RKS 24. Water productivity was also analyzed using standard method (Singh and Kumar, 2011). For economic evaluation in term of gross and net returns and incremental benefit ratio, the prevailing market rates for input, labour and produce was utilized. Data were recorded from demonstration blocks and farmer's practice blocks. These recorded data were analyzed for different parameters, using following formulae, suggested by Prasad et al. (1993).

(A) Extension Gap = Demonstration yield (Di) – Farmer's practice yield (Fi)
(B) Technology Gap = Potential yield (Pi)- Demonstration yield (Di)
(C) Technology Index = (Pi-Di)/Pi x 100

Statistical analysis of the data for standard deviation and coefficient of variation was done as described by Panse and Sukhatme (1985). Sustainability indices [Sustainability yield index and sustainability value index] were work out using formula (Singh et al., 1990).

SYI   =   Estimated average yield (kg/ha) - Standard deviation/ Maximum yield (kg/ha)

SVI   =   Estimated net return (Rs/ha) - Standard deviation/ Maximum net return (Rs/ha)

Water use efficiency   =   Economic crop yield (kg/ha)/ Evapotranspiration (ha cm)

Water productivity   =   Net return (Rs/ha)/ Water applied (m³)

RESULTS AND DISCUSSION

Grain yield

Cumulative data over six year (Table 1) revealed that seed yield of soybean (1,489 kg/ha) was found to be 6.17 per cent higher with the mean production efficiency (15.19 kg/ha/day) under improved water management practices than the average yield (1,402 kg/ha) and production efficiency (14.30 kg/ha/day) obtained under farmer's practices (Table 2). Year-wise per cent increase in seed yield of demonstrations over farmer's practices ranged from 5.33 to 7.49. The higher seed yield and production efficiency under demonstrations could be attributed to adoption of improved water management practices. Year-wise observed variation in seed yield might be due to variation in the environmental conditions prevailed during that particular year. This fact has been reported by Narolia et al. (2013) stating that improved water management practices along with recommended practices of soybean have shown positive effect on yield.

Table 1. Effect of improved water management practices on seed yield, water use efficiency and gap indices of soybean

Year	Yield (kg/ha)		% increase over FP	Water applied (cm)		WUE(kg/ha-cm)		WP(Rs./M3)		Extension gap (kg/ha)	Technology gap (kg/ha)	Technology index (%)
	IWMP	FP		IWMP	FP	IWMP	FP	IWMP	FP			
2009	1315	1224	7.49	29.9	33.9	43.9	36.0	4.00	3.23	92	1685	56.2
2010	1717	1619	6.00	58.3	62.3	29.4	26.0	3.57	3.15	97	1284	42.8
2011	1790	1699	5.33	69.6	73.6	25.7	23.1	3.45	3.11	91	1210	40.3
2012	1710	1608	6.35	75.4	79.4	22.7	20.3	3.38	3.03	102	1290	43.0
2013	1184	1111	6.57	94.8	98.8	12.5	11.2	1.41	1.27	73	1816	60.5
2014	1217	1152	5.63	79.5	83.5	15.3	13.8	2.18	1.99	65	1783	59.4
Mean	**1489**	**1402**	**6.17**	**67.9**	**71.9**	**24.9**	**21.7**	**3.00**	**2.60**	**86.6**	**1511**	**50.4**

WUE=water use efficiency, WP= water productivity

Table 2 . Economic analysis of improved water management practices on soybean at farmer's field

Year	Cost of inputs (Rs./ha)		Additional cost in IWMP (Rs./ha)	Sale price (Rs./q)	Total return((Rs./ha))		Additional return in IWMP(Rs./ha)	Effective gain (Rs./ha)	IBCR	Production efficiency (kg/ha/day)	
	IWMP	FP			IWMP	FP				IWMP	FP
2009	13000	12300	700	1900	11993	101951	1042	342	1.5	13.41	12.48
2010	13500	12750	750	2000	20839	19637	1202	452	1.6	17.52	16.52
2011	13600	12800	800	2100	23982	22886	1096	296	1.4	18.26	17.34
2012	13850	12950	900	2300	25483	24038	1445	545	1.6	17.45	16.41
2013	14000	13100	900	2300	13366	12587	779	-121	0.9	12.10	11.34
2014	14300	13360	940	2600	17346	16601	1113	303	1.4	12.42	11.75
Mean	**13708**	**12877**	**832**	**2200**	**18835**	**17783**	**1113**	**303**	**1.4**	**15.19**	**14.30**

Water use

Efficiency indices for water use were estimated in terms of water use efficiency and water productivity. Mean data of six years indicated that water use efficiency (24.9 kg/ha/cm) and water productivity (3.0 Rs/M^3 water) being 14.7 and 15.4 per cent higher in soybean grown with improved water management practices as compared to farmers practices, respectively. During the six years study, maximum water use efficiency (43.9 kg/ha/cm) and water productivity (4.0 Rs/M^3 water) was observed in 2009 which was due to lesser quantities of water used in test blocks. Results were reported by the Chery *et al.* (2014).

Gap Analysis

Extension gap, Technology gap and Technological index were evaluated for all the six years. Extension gap is a parameter to know the yield difference between the demonstrated technology and farmer's practice; for study this ranged from 65 to 102 kg per ha with an average of 86.6 kg per ha (Table 1). This indicated a wide gap between the demonstrated improved technology and its adoption by the farmers. Technology gap is a measure of difference between potential yield and yield obtained under improved water management technology demonstration, this is of greater significance than other parameters as it indicates the constraints in implementation and drawbacks in our package of practices, these could be environmental or varietal. This also reflects the poor extension activities, which resulted in lesser adoption of improved water management technology and package of practices by the farmers. Technology gap can be lowered down by strengthening the extension activities and further research to improve the package of practices. It is dependent on technology gap and is a function expressed in per cent. For the six years of study it varied from 40.3 percent to 60.5 per cent, with an average of 50.4 per cent. The very low technology index (40.3 %) during the year 2011 could be due to adoption of improved water management practices, favorable climatic conditions, free from insect pest and disease incidence. High technology index (60.5 %) observed in the year 2013. This was mainly due to early withdrawal of monsoon and unfavorable climatic conditions with incidence of pest and diseases. Such higher technology indices have been also reported by Narolia *et al.* (2013).

Economic analysis

Mean data (Table 2) of six years revealed that 5.91 per cent higher net return was found in improved water management practices (Rs. 18835/ha) as compared to farmers practices. Grain yield, cost of inputs and sale price of produce determine the economic returns and these vary from year to year. The year wise additional returns from improved water management practices over farmer's practice varied from Rs 779 to Rs 1445. The mean additional cost of input of all the demonstrations for six years was Rs. 832 (Table 2). This additional investment along with non-monitory management factors gave an additional mean return of Rs 1,113. The

Table 3. Effect of improved water management practices on sustainability yield and value index of soybean

Particulars		2009		2010		2011		2012		2013		2014		Pooled	
		IWMP	FP	IWMP	FP	IWMP	FP	IWMP	FP	IWMP	FP	IWMP	FP	IWMP	FP
Seed yield (kg/ha) range	H	1400	1350	1774	1721	1874	1806	1847	1819	1248	1195	1348	1268	1582	1527
	T	1215	1000	1624	1471	1704	1576	1567	1539	1118	1025	1148	1004	1396	1269
Mean yield (kg/ha)		1315	1224	1717	1619	1790	1699	1710	1608	1184	1111	1217	1152	1489	1402
S D		67.5	80.8	62.7	70.9	51.9	67.6	78.0	81.5	59.1	51.9	61.6	71.9	263	255
CV (%)		5.1	6.6	3.6	4.4	2.9	4.0	4.6	5.1	5.0	4.7	5.1	6.2	17.7	18.2
SYI		0.891	0.847	0.932	0.900	0.927	0.904	0.884	0.839	0.901	0.886	0.857	0.852	0.654	0.631
Net returns range(Rs/ha)	H	13600	13350	21980	21670	25754	25126	28631	28887	14704	14385	20748	19608	20903	20504
	T	10085	6700	18980	16670	22184	20296	22191	22447	11864	10625	15548	12744	16809	14914
Mean Net returns (Rs./ha)		11993	10951	20830	19637	23987	22886	25488	24038	13366	12587	17346	16601	18835	17783
S D		1282	1536	1254	1419	1091	1420	1793	1875	1346	1173	1601	1870	5276	5155
CV (%)		10.7	14.1	6.0	7.23	4.5	6.2	7.0	7.8	10.1	9.3	9.2	11.3	28.0	29.0
SVI		0.788	0.705	0.891	0.841	0.889	0.854	0.828	0.767	0.817	0.793	0.759	0.751	0.474	0.437

H= Maximum yield at head reach of canal; T= Minimum yield at tail reach of canal; IWMP=Improved water management practices; FP=Farmer's practice; SD= Standard deviation; SYI= sustainability yield index; SYI= sustainability value index

higher sale price of produce, in spite of low production and higher additional cost of input during 2008 gave highest additional returns under improved technology demonstrations over farmer's practice. The incremental benefit cost ratio (IBCR) on overall average basis was 1.4. The highest IBCR during six years was observed in 2010 and 2012 (1.6) this is due to comparatively higher grain yield, less cost of input and a good sale price.

Sustainability

Lower standard deviation and coefficient of variation in yield were observed under the demonstrations on improved water management practices as compared to the farmer's practices for all the six years. This may be due to lesser variation in the yield from farmer to farmer under improved water management practices and higher in farmer's practices demonstrations. However, the sustainability yield index (SYI) and Sustainability value index (SVI) was more under improved water management practices than farmer's practices (Table 3). The mean SYI and SVI over these 6 years under improved technology of water management, ranged from 0.857 to 0.932 and 0.759 to 0.891 with the pooled of 0.654 and 0.474, while the corresponding values under farmers practice were 0.839 to 0.904 and 0.705 to 0.854 with the pooled of 0.631 and 0.437, respectively. This showed that the improved technology is more sustainable as compared to farmer's practice. Similar results have been reported by Billore *et al.* (2009) and Narolia *et al*. (2013).

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Effect of Organic Sources in Combination with Fertilizers on Nodulation, Growth and Yield of Soybean (*Glycine max*) in Soybean-Wheat Cropping System in Vidisha District of Madhya Pradesh

O P S RAGHUWANSHI[1], M S RAGHUWANSHI[2], S R S RAGHUWANSHI[3] and R F AHIRWAR[4]

College of Agriculture, Ganjbasoda, District Vidisha, Madhya Pradesh
E mail: omprakashsinghraghuwanshi@yahoo.com

ABSTRACT

Field experiments were conducted for consecutive two years (2014-15 and 2015-16) during kharif season on clay soil of Vidisha district of Madhya Pradesh to evaluate the effect of different organic sources (FYM, vermicompost and poultry manure) in combinations with variable levels of recommended fertilizers (RDF) on nodulation, growth and yield of soybean in soybean-wheat cropping system. The value of different attributes associated with 75 per cent RDF of NPK coupled with application of poultry manure @ 5 t per ha was maximum. As compared with no fertilizer, the enhancement in seed and stover yield by best treatment was 49 per cent. Thus, the combined use of different organic sources played a significant role in increasing seed and stover yields of soybean.

Key words: Growth, fertilizers, nodulation, organic sources, soybean-wheat system

Soybean [*Glycine max* (L.) Merrill] is an important oil and protein yielding *kharif* season crop. It covers the largest area of 12.20 m ha among the oilseeds in India (2013-14). Soybean-wheat is a predominant and more remunerative system as compared to other cropping system in Vidisha District of Madhya Pradesh. In Madhya Pradesh soybean occupied 6.38 m ha and 5.79 m ha under wheat in 2013-14 (http://eands.dacnet.nic.in). In spite of significant contribution of both the crops in total production, the productivity of both crops is much below (soybean 842 kg/ha and wheat 2,405 kg/ha in Madhya Pradesh) than the potentials realized under real farm situations. Sub-optimal and skewed nutrition management in practice in soybean (Joshi, 2004) is considered to be one of the limiting factors in productivity from soybean-wheat cropping system. Since, nutrient management plays a key role in augmenting the productivity of crops, a study to visualize the effects of integration of chemical fertilizers with FYM, vermicompost and poultry manure on soybean in soybean-wheat cropping system was carried out and results pertaining to soybean are discussed.

[1]*Field Extension Officer;* [2]*Project Assistant;* [3]*Associate Professor (Soils);* [4]*Assistant Professor*

MATERIAL AND METHODS

Field experiment were conducted during *kharif* and *rabi* seasons of 2014-15 and 2015-16 at a fixed site of farmers field Village Kakravada, Tehsil Ganj Basoda district Vidisha (M. P.). The soil of experimental site was clay in texture with pH 7.8, organic carbon 4.8 g per kg and EC 0.29 dSm^{-1}. The available N, P_2O_5 and K_2O contents were 218, 11.3 and 426 kg per ha, respectively. The experiment was laid out in a randomized block design (RBD) with four replications and thirteen treatments encompassing graded doses of recommended doses of fertilizers (RDF) and their combinations with different manures along with control (Table 1).The total rainfall received (June to October) during the first (2014) and second (2015) year of experimentation was 1239.4 and 678.4 mm, respectively. All the agronomic operations were carried out as per recommendations. The crop soybean JS 93-05 was sown on 13th July 2014 and 07th July 2015 and harvested on 16th October 2014 and 10th October, 2015 during the experimentations. The recommended dose of nutrients for soybean (20:60:20 kg N:P_2O_5:K_2O/ha) was applied as basal through urea, single super phosphate and muriate of potash. The recommended dose of nutrient for wheat (120:60:40 kg N: P_2O_5:K_2O/ha), was also applied using the same nutrient carries. Full dose of phosphorus and potassium along with one third dose of nitrogen were applied as basal and the remaining dose of nitrogen was applied in two equal splits at the time of first and second irrigation to wheat. FYM, vermicompost and poultry manure were incorporated 15 days prior to sowing of soybean. The data on dry matter accumulation, nodulation and yields were recorded in different treatments and analyzed statistically (Panse and Sukhatme, 1978) and pooled data for two years are utilized for presenting results. The economics of different treatments was also worked out and analyzed statistically. The prevailing cost of inputs and produce were used to perform economic evaluation of the treatments.

RESULT AND DISCUSSION

Dry matter accumulation recorded at 30, 45, 75 days after sowing (DAS) and at harvest revealed that it increased gradually with advancement of crop age; the maximum rate of increase was between 45 and 75 DAS in almost all the treatments (Table 1). The dry matter accumulation was significantly higher in nutrient management treatments over control. The combination treatments of organic resources and fertilizers invariably showed higher values of dry matter accumulation over sole fertilizer treatments. Maximum dry matter accumulation (25.5 g/plant) was noticed in 75 per cent optimal NPK + poultry manure @ 5 t per ha, which was superior over other combination treatments and statistically higher over control as well as sole fertilizer treatments at all the growth stages. These results gain support from the findings of Paliwal *et al.* (2011), who reported similar growth responses due to combined application of vermicompost with fertilizers.

Table 1. Effect of organic sources in combination with graded fertilizer levels on dry matter production, nodulation, seed and stover yields, harvest index and economic viability of soybean (Data pooled for two years)

Treatments	Dry matter accumulation (g/plant)				Nodulation at 45 DAS		Yield (kg/ha)		Harvest Index	Net returns (Rs/ha)	B:C ratio
	30 DAS	45 DAS	75 DAS	At harvest	Number/ plant	Dry weight (g/plant)	Seed	Stover			
Control	3.8	6.4	10.0	15.4	14.80	0.164	577	646	47.17	18827	1.23
50 % RDF	4.4	7.6	11.8	20.6	22.80	0.236	649	727	47.16	21227	1.39
75 % RDF	4.7	8.1	12.3	22.8	25.90	0.248	680	762	47.15	22281	1.46
100 % RDF	4.9	8.7	13.4	23.0	26.30	0.259	710	795	47.18	23178	1.52
75 % RDF + FYM @ 5 t/ha	5.1	8.9	13.6	23.2	27.85	0.266	743	862	46.29	24287	1.59
75 % RDF + FYM @ 10 t/ha	5.4	9.5	13.9	23.7	28.45	0.276	785	911	46.29	25756	1.69
100% RDF + FYM @ 5 t/ha	5.2	9.3	13.7	23.4	28.22	0.272	752	873	46.28	24582	1.61
75 % RDF + vermicompost @ 2.5 t/ha	5.5	9.6	14.0	23.9	28.31	0.285	805	949	45.90	26330	1.73
75 % RDF + vermicompost @5 t/ha	5.8	10.0	14.4	24.9	29.40	0.299	868	1025	45.85	28500	1.87
100% RDF + vermicompost @ 2.5 t/ha	5.6	9.8	14.2	24.5	28.92	0.292	855	1009	45.87	28070	1.84
75 % RDF + poultry mManure @ 2.5 t/ha	5.9	10.1	14.6	25.0	29.99	0.304	947	1136	45.46	31110	2.04
75 % RDF + poultry manure @5 t/ha	6.2	10.5	14.9	25.5	35.05	0.326	1134	1269	47.19	37138	2.44
100% RDF + poultry manure @ 2.5 t/ha	6.0	10.3	14.7	25.1	32.68	0.311	1066	1214	46.76	34940	2.29
CD (P = 0.05)	0.7	1.4	1.5	1.7	3.80	0.06	253	271	NS	2490	NS

Different nutrient management recorded significantly higher number of nodules as well as their dry weight over control as recorded at 45 DAS (Table 1). Numerically these two parameters showed an increasing trend with increase in sole fertilization level, but the values were significantly higher than control. In general, fertilizer combinations with poultry manure recorded higher number and dry weight of nodules followed by vermicompost and FYM. Maximum values of both parameters were recorded in 75 per cent RDF + poultry manure @ 5 t per ha followed by 100 per cent RDF + poultry manure, and these two treatments were significantly superior over remaining treatments in case of nodule dry weight. The effect of treatments was more conspicuous in case of dry weight of nodules. The improvement in these parameters might be the result of improved soil environment due to fertilizer application alone and in combination with organic sources (Das and Dkhar, 2011) and Thakur *et al.* (2011).

The seed and stover yields increased with sole fertilization and combination of fertilizers with organic sources over control. However, in case of both the parameters, significant increase over other treatments was only noticed when vermicompost/poultry manure @ 5 t per ha with 75 per cent RDF or vermicompost /poultry @ 2.5 t with 100 per cent RDF or vermicompost @ 2.5 t per ha with 75 per cent RDF was incorporated. Maximum seed yield (1,134 kg/ha) was recorded when poultry manure @ 5 t per ha was coupled with 75 per cent RDF, which was at par with application of poultry manure @ 2.5 t per ha with either 75 or 100 per cent of RDF. The combinations of poultry manure with 75 or 100 per cent of RDF were superior over combinations with vermicompost or FYM. This also brought out that 25 per cent of RDF can be shunned with coupling with poultry manure @ 5 t per ha. Application organic sources in combination with fertilizer are known to increase the microbial activity, nutrient availability and improves soil physico-chemical environment in the soil for plant growth, the enhanced productivity was noticed in the combination treatments. The results reported (Mandal *et al.*; 2000; Sable, 2005) in the past provides support to these results. The harvest index values did not differ significantly with nutrient management treatments. Chakraborty and Hazari (2016) also found a significantly higher yield by 100 per cent RDF + FYM @ 5 t per ha. Sharma *et al.* (2014) also found a significantly higher yield by 75 per cent NPKS + FYM + PSB + *Rhizobium* + Zn + Mo. Waghmare *et al.* (2014) also found pod yield per plant, seed yield per plant, 100 seed weight, seed yield, protein and oil yield in soybean seed by 75 per cent NPK with 5 t FYM and *rhizoboum* + PSB.

The economic evaluation of the nutrient management treatments revealed that most of the treatments fetched significantly higher monetary returns over control except 50 per cent RDF application. Although, the combination treatments invariably had higher net returns as compared to

control, the combined treatments of sole fertilization, fertilizers with FYM, fertilizers with vermicompost and fertilizers with poultry manure led to higher monetary returns by 18, 32, 47 and 83 per cent. This brought out that to fetch higher returns; the fertilizers may be coupled with poultry manures as tested in the experiment. Among fertilizer and poultry manure combinations, incorporation of poultry manure @ 5 t per ha with 75 per cent of RDF led to highest returns of Rs 37,138 per ha followed by poultry manure @ 2.5 t per ha with 100 per cent RDF. The B:C ratios for the different treatments showed non-significant differences, the said two

best treatments had higher values of 2.44 and 2.29, respectively.

The study suggested that combined application of fertilizers with organic sources leads to better performance of soybean than non application and application of nutrients through fertilizers only. Higher yields and monetary returns can be achieved by combining poultry manure, vermicompost and FYM in that order. The treatment combination poultry manure @ 5 t per ha with 75 per cent RDF followed by 2.5 t per ha poultry manure with 100 per cent RDF proved to be best for higher yield and monetary returns.

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Effect of Different Organics in Combinations with Natural Sources on Yield and Quality Soybean (*Glycine max*) Grown in Soybean-Wheat Cropping System in Vindhyan Plateau of Madhya Pradesh

S R S RAGHUWANSHI[1], O P S RAGHUWANSHI[2], M S RAGHUWANSHI[3], DHIRENDRA KHARE[4] and I M KHAN[5]

College of Agriculture (JNKVV), Ganjbasoda, Vidisha -464 221, Madhya Pradesh
E mail: shivramsinghraghuvanshi@yahoo.com

ABSTRACT

Agricultural management systems that sustain crop productivity, quality of produce and improves soil quality is of a paramount importance as compared to conventional systems relying heavily on inorganic fertilizers, pesticides and devoid of organic sources which are domain to sustainable agricultural development. In this context, a field experiments were conducted at research farm, College of Agriculture, Ganj Basoda, Madhya Pradesh for three consecutive kharif *and* rabi *seasons (2013-14, 2014-15 and 2015-16) on clay soil of Vindhyan Plateau of Madhya Pradesh to evaluate the effect of different organic sources (cow dung, vermicompost and poultry manure) in combinations with variable levels of natural sources (rock phosphate, feldspar and gypsum) on growth, yield, protein content, oil content and economics of soybean in soybean-wheat cropping system. The values of different yield attributes, protein content, oil content and economics were found to be significantly higher with the application of 75 per cent recommended dose of fertilizers (RDF) through poultry manure + 25 per cent through natural sources + biofertilizers (Rhizobium + phosphorus solubilizing bacteria - PSB). The seed and stover yield enhancement in this treatment was 20.07 and 20.36 per cent respectively, as compared to RDF through natural resources. These treatment combinations enhanced the nitrogen, phosphorus, potassium, sulphur and oil and protein contents, but were also economically viable over control. Thus, the combined use of different organic sources played a significant role not only in increasing yield and yield attributes, but also the quality of soybean and economically sustainable.*

Soybean [*Glycine max* (L.) Merrill] is an important oil and protein yielding *kharif* season crop in the state of Madhya Pradesh. It covers an area of 12.20 m ha and is one of the important oil and protein yielding *kharif* season crops in

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[1]*Associate Professor (Soils);* [2]*Field Extension Officer;* [3]*Project Assistant;* [4]*Director of Research Services and Director Instruction;* [5] *Dean*

India (2013-14). Soybean-wheat is a predominant and more remunerative system as compared to other cropping system in Vidisha District of Madhya Pradesh. In Madhya Pradesh soybean occupied 6.38 m ha and wheat 5.79 m ha in 2013-14 (http://eands.dacnet.nic.in). In spite of significant contribution of both the crops in total production, their productivity is much below (soybean 842 kg/ha and wheat 2,405 kg/ha in Madhya Pradesh) as against the potentials realized under real farm situations.

The inherent characteristic of these soils such as high clay content, low in organic carbon content, poor infiltration, drainage, excessive run off and soil loss, depletion/ loss of nutrients and shifts in microbiome acts as a deterrent to sustainable management and to achieve improved crop productivity. Moreover, sub-optimal and skewed nutritional management in practice in soybean (Joshi, 2004) is considered to be one of the limiting factors in productivity from soybean-wheat cropping system. This leads us to identification of appropriate agricultural management systems that can not only improve soil quality but also crop productivity and quality of produce to achieve sustained agricultural development (Hernandez *et al.*, 2015; Tamilselvi *et al.*, 2015). There are many agricultural interventions such as organic amendment, improved integrated systems, minimizing tillage and microbial inoculants (Máder *et al.*, 2002; Masto *et al.*, 2013; Li *et al.*, 2015), for above purpose. Agricultural management practices through incorporation of organic sources and microbial sources and adopting best management practices like crop rotation, pest control and soil management can be a viable option to ensure improved nutrient cycling, agro-biodiversity and overcoming soil degradation which is a common phenomenon in this region (Máder *et al.*, 2002; Forster *et al.*, 2013). Since, nutrient management plays a key role in augmenting the productivity of crops, a study to visualize the effects of integration of natural resources with FYM, vermicompost and poultry manure on soybean in soybean-wheat cropping system was carried out and results pertaining to soybean are discussed in the paper.

MATERIAL AND METHODS

Field experiments were carried out during *kharif* and *rabi* seasons of 2013-14, 2014-15 and 2015-16 on a fixed site at research farm, College of Agriculture, Ganj Basoda district Vidisha of Vindhyan Plateau of Madhya Pradesh. The soil of experimental site was clay in texture with pH 7.60, organic carbon 0.48 per cent and EC 0.38 dSm^{-1}. The available N, P_2O_5, K_2O and S contents were 190, 12.4, 290 and 9.2 kg per ha, respectively. The experiment was laid out in a randomized block design and comprised of four replications and seven treatments encompassing graded levels of recommended doses of nutrients through natural resources and their combinations with different organic sources (cow dung, vermi-compost and poultry manure) along with control (RDF During the three years of experimentation, the crop suffered due to

excess or deficit rainfall with dry spells. The average rainfall (June to October) of the district is 1229.9 mm and rainfall received during *kharif 2013*-14 was 2038.6 mm with 62 rainy days. During July, 2013, continuous rains received with high intensity and in the month of September (1st -20th) water stress was experienced. During *kharif* 2014-15, the rainfall received was 770.6 mm with 34 rainy days with uneven distribution creating dry spells (between 20 and 28 August and September 18 and 20) during the cropping season. In *kharif* 2015-16 also, total rainfall was 899.2 mm with 41 rainy days since June to October, 2015 with uneven distribution leading to water stress. All the agronomic operations were carried out as per recommendations. The crop soybean JS 95-60 was sown on 8th July 2013, 2nd July 2014 and 4th July 2015 and harvested on 11th October 2013, 10th October 2014 and 9th October, 2015. The recommended dose of nutrients for soybean (20:60:20:20 kg N: P_2O_5:K_2O:S/ha) was applied as basal through urea, rock phosphate, feldspar and gypsum. The nitrogen was compensated using urea. The recommended dose of nutrient for wheat (120:80:40 kg N: P_2O_5:K_2O/ha), was also applied using the same set of nutrient carriers. Full dose of phosphorus and potassium along with one third dose of nitrogen were applied as basal and the remaining dose of nitrogen was applied in two equal splits at the time of first and second irrigation to wheat. Cow dung, vermicompost and poultry manure with different combinations of natural sources (rock phosphate, feldspar and gypsum)

were incorporated 15 days prior to sowing of soybean. The data on plant growth, seed and stover yields, seed index and harvest index were recorded in different treatments at harvest. Protein content in soybean seed was derived from nitrogen estimated by Kjeldhal Method (1983) and oil content was analyzed by AOAC (1984).The pooled data for three years was statistically analyzed (Panse and Sukhatme, 1978) and utilized for presenting results. The economics of different treatments was also worked out and analyzed statistically. The prevailing cost of inputs and produce were used to perform economic evaluation of the treatments.

RESULT AND DISCUSSION

Growth attributes

All the combination treatments recorded significantly higher values for plant height and dry matter accumulation over RDF alone (Table 1). The treatments did not differ significantly in the case of seed index and harvest index. The higher values for plant height and dry matter accumulation were recorded with treatment combination of 75 per cent RDF through poultry manure + 25 per cent through natural sources + biofertilizers (*Rhizobium* + PSB) (44.37 cm and 21.47 g/plant, respectively) followed by 50 per cent RDF through poultry manure + 25 per cent through natural sources + biofertilizers (*Rhizobium* + PSB) (42.57 cm and 20.64 g/plant, respectively) and differed significantly over other combination treatments and RDF alone. Even number of pods per plant in these

Table 1. Effect of different organic sources in combination with natural sources rock phosphate, feldspar and gypsum on growth, seed and stover yields, seed index and harvest index of soybean (Data pooled for three years)

Treatments	Plant height (cm)	Dry matter accumu-lation (g/plant)	Pods (No /plant)	Seed index (g/100 seeds)	Harvest Index (%)	Seed yield (kg/ha)	Stover yield (kg/ha)
RDF through natural resources	36.67	14.87	31.87	10.11	39.97	677	1017
50% RDF through vermicompost +50% through natural sources + biofertilizers (*Rhizobium* + PSB)	38.57	17.65	37.67	10.87	39.93	767	1154
75% RDF through vermicompost + 25% through natural sources + biofertilizers (*Rhizobium* + PSB)	39.87	18.69	41.77	10.83	39.93	779	1173
50% RDF through cow dung + 50 % through natural sources + biofertilizers (*Rhizobium* + PSB)	37.27	15.69	32.27	10.31	39.77	707	1070
75% RDF through cow dung +25% through natural sources + biofertilizers (*Rhizobium* + PSB)	38.37	16.65	36.67	10.61	39.95	739	1111
50% RDF through poultry manure + 50 % through natural sources + biofertilizers (*Rhizobium* + PSB)	42.57	20.64	46.87	10.91	39.92	797	1200
75% RDF through poultry manure + 25% through natural sources +biofertilizers(*Rhizobium* +PSB)	44.37	21.47	47.27	11.07	39.88	847	1277
SEm (±)	1.04	0.53	1.71	0.09	0.04	21	27.71
CD (P = 0.05)	3.12	1.62	5.16	NS	NS	63	83.17

(Sources: N-Urea, P-rock phosphate, K-feldspar and S-gypsum).

Table 2. Effect of different organic sources in combination with natural sources rock phosphate, feldspar and gypsum on nutrient content, oil content and economics of soybean (Data pooled for three years)

Treatments	Nutrient content (%)				Protein (%)	Oil (%)	Net returns (Rs/ha)	B:C ratio
	N	P	K	S				
RDF through natural resources	5.88	0.34	2.03	0.10	33.55	19.61	12019	1.45
50% RDF through vermicompost +50% through natural sources + biofertilizers (*Rhizobium* + PSB)	6.37	0.48	2.21	0.15	36.36	20.11	14096	1.79
75% RDF through vermicompost + 25% through natural sources + biofertilizers (*Rhizobium* + PSB)	6.47	0.50	2.29	0.17	36.92	20.28	14177	1.83
50% RDF through cow dung + 50 % through natural sources + biofertilizers (*Rhizobium* + PSB)	6.23	0.40	2.16	0.13	35.58	20.66	12952	1.57
75% RDF through cow dung +25% through natural sources + biofertilizers (*Rhizobium* + PSB)	6.29	0.42	2.18	0.14	35.93	20.92	13575	1.68
50% RDF through poultry manure + 50 % through natural sources + biofertilizers (*Rhizobium* + PSB)	6.63	0.52	2.32	0.21	37.87	21.18	14422	1.90
75% RDF through poultry manure + 25% through natural sources +biofertilizers(*Rhizobium* +PSB)	6.72	0.53	2.38	0.25	38.31	21.81	15549	2.10
SEm (±)	0.077	0.017	0.04	0.007	0.21	0.16	73.67	0.057
CD (P = 0.05)	0.23	0.05	0.12	0.02	0.64	0.48	221	0.17

(Sources: N-Urea, P-rock phosphate, K-feldspar and S-gypsum).

two treatments showed higher values (47.27 and 46.87). The combination treatments of organic resource (especially with poultry manure) and natural sources invariably showed their superiority in these yield attributing characters of soybean. These results gain support from the findings of Paliwal *et al.* (2011), who reported similar growth responses due to combined application of vermicompost with fertilizers.

Seed and stover yield

The unfavourable weather conditions as mentioned in text above did not permit the crop variety to realize its field potential and yield levels achieved were low. However, the treatments expressed the contribution of yield attributes in realization of seed and strover yield of soybean. The higher seed and stover yield of soybean was recorded in combination treatments 75 per cent RDF through poultry manure + 25 per cent through natural sources + biofertilizers (*Rhizobium* + PSB) (847 and 1277 kg/ha, respectively) followed by 50 per cent RDF through poultry manure + 25 per cent through natural sources + biofertilizers (*Rhizobium* + PSB) (797 and 1200 kg/ha, respectively) and differed significantly over RDF alone. The seed yield increment in the combination treatments was between 4.43 and 25 per cent over control (677 kg/ha) indicating the superiority of these treatment in improving growth, soil physico-chemical environment and biological environment in the soil. Stover yield also showed a similar trend. The combinations of organic with inorganic sources have been reported to enhance the yield and soil

physico-chemical and biological properties and creation of favourable soil environment for crop growth (Table 1) (Anonymous, 1998). Chakraborty and Hazari (2016) and also observed significantly higher yield and Mandal *et al.*, (2000) on growth, yield and economic efficiency in soybean by combined application of RDF with FYM.

Nutrient content

The nutrient composition of soybean seed was significantly influenced by different treatments also showed that the contents of N, P, K, and S were significantly increased in all the combination treatments over control. The two treatments, namely 75 per cent RDF through poultry manure + 25 per cent through natural sources + biofertilizers (*Rhizobium* + PSB) (6.72, 0.53, 2.38 and 0.25 %, respectively) followed by 50 per cent RDF through poultry manure + 25 per cent through natural sources + biofertilizers (*Rhizobium* + PSB) (6.63, 0.52, 2.32, 0.21 %, respectively) significantly increased the nutrient acquisition and in general showed significantly higher values than rest of the treatments and control. This signifies the role of organic manures in mobilizing and available nutrients in soil and help in acquisition by the plants. Sharma *et al.* (2014) also reported a significantly higher yield and nutrient uptake by 75 % NPKS + FYM + PSB + *Rhizobium* + Zn + Mo.

Oil and protein contents

The oil and protein contents also increased as compared to control in all the combination treatments and values were higher in best two treatments stated

above. The oil content in combination treatments ranged between 20.11 and 21.81 per cent and protein content between 36.36 and 38.31 per cent in combination treatments, whereas were low in RDF alone (19.61 and 33.55 %). Such increase in these quality parameters by combined application of organics with inorganic nutrient sources was earlier reported by Waghmare *et al.* (2014), who observed that yield attribute, seed yield and oil and protein contents were enhanced by application of 75 per cent NPK with 5 t FYM per ha along with biofertilizers (*Rhizobium* + PSB).

Economic analysis

The economic analysis of the treatments revealed that all the combination treatments invariably generated significantly higher net returns (between Rs 12952 and 15549/ha) as compared to RDF Rs 12019/ha). The B:C ratio for combination treatments (1.57-2.10) followed a similar trend and was higher than RDF (1.45).

The study suggested that combined application of fertilizers with organic sources lead to better performance of soybean than application of inorganic sources alone. Higher yields and monetary returns can be achieved by combining poultry manure, vermicompost and cow dung in that order. The treatments integrated application of 75per cent RDF through organic source + 25 per cent RDF through natural sources + biofertilizer (*Rhizobium* + PSB) followed by 50 per cent RDF through poultry manure + 25 per cent through natural sources + biofertilizers (*Rhizobium* + PSB) proved best for optimizing the yield, improving oil and protein contents and monetary returns from soybean.

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Bio-efficacy Evaluation of Premix Formulation of Sulfentrazone + Clomazone against Major Weeds in Soybean

S D BILLORE[1]

ICAR-Indian Institute of Soybean Research, Indore 452 001, Madhya Pradesh
E mail: billsd@rediffmail.com

ABSTRACT

An experiment was conducted during kharif *2014 and 2015 to evaluate the bio-efficacy of pre-mix formulation of sulfentrazone + clomazone as pre-emergence herbicide for season long weed control and higher productivity of soybean under Vertisols of Malwa region. The experiment was laid out in randomized design with three replications. Two years pooled data revealed that application of pre-emergence or post-emergence herbicides significantly minimized the weeds during the critical period of crop-weed competition. The yield reduction was observed due to weeds was 52.74 per cent. Hand weeding twice at 20 and 40 days after sowing had substantial higher weed control efficiency, which was eventually reflected higher soybean yield. Among herbicidal treatments, maximum weed control efficiency (83.08 %) and highest seed yield (2,030 kg/ha) was with imazethapyr @ 100 g a i/ha applied as post-emergence and remained at par with pre-mix formulation of sulfentrazone + clomazone @ 870/725 g a i per ha and all these treatments were significantly superior than clomazone and pendimethalin alone and pre-mix pendimethalin + imazethapyr. The pre-emrgence and post-emergence herbicides are found equally effective to manage weeds season long in soybean. The pre-mix formulation of sulfentrazone + clomazone @ 725 g a i per ha was found to be effective against major weeds of soybean*

Key words: Soybean, weed, weed control efficiency

Soybean is a leading oilseed crop of the world and India. Soybean productivity is oscillating between 1.0 to 1.3 t per ha in past few years as compared to other soybean growing countries (2.5 t/ha). One of the major reasons for lower productivity is abiotic and biotic factors encountered during rainy season. Among the biotic factors, weed is the most crucial menace for reducing seed yield to the tune of 20-77 per cent depending on the type of soil, season and intensity of weed infestation (Billore *et al.*, 1999; Kuruchania *et al.*, 2001). Soybean suffers from heavy weed competition especially in the early stages of growth. The use of pre-emergence (PE) herbicides played a great role in controlling the weeds in

[1]*Principal Scientist (Agronomy)*

earlier years of introduction of this crop in India. While now-a-days newer molecules of effective post-emergence (PoE) herbicides have changed the whole scenario of herbicide use pattern. The availability of newer molecules of PoE offered multiple options to farmers for efficient weed management up to 20-25 days after sowing. There is still a need to provide more optional effective pre-plant incorporation (PPI), PE or PoE herbicides for better management of weeds to achieve sustainable production of soybean. Therefore, the present investigation was initiated to study the bio-efficacy of new molecule of herbicides for season long weed management and higher productivity of soybean.

MATERIAL AND METHODS

An experiment was conducted during *kharif* 2014 and 2015 at research farm of ICAR-Indian Institute of Soybean Research, Indore, situated at latitude and longitude of 22° 44' N and 75° 50' E with mean sea level of 550 m, to evaluate the bio-efficacy of sulfentrazone + clomazone (pre-mix) as PE herbicide for weed control in soybean. The soil belonged to fine, montmorrillonitic, isothermic family of Typic Haplusterts. It analyzed: pH 7.8, EC 0.14 dS per m, organic carbon 0.3 per cent, available phosphorus 10.1 kg per ha and potassium 280 kg per ha. The experiment consisted of eleven treatments involving three levels of sulfentrazone + clomazone as PE (580, 725 and 870 g a i/ha); sulfentrazone @ 360 g a i per ha as PE, and check herbicides, namely clomazone (@ 375 and

1000 g a i /ha) as PE, pendimethalin + imazethapyr (@ 960 g a i/ha) as PE and imazethapyr (@ 100 g a i/ha) as PoE along with hand weeding twice at 20 and 40 days after sowing (DAS) and a weedy check (Table 1). All the eleven treatments were replicated thrice in randomized block design. Soybean cultivar "JS 20 29" was sown on July 17th, 2014 and June 26th, 2015 and harvested on October 20th and 9th, 2014 and 2015, respectively. All the PE herbicides were applied just after sowing of soybean while PoE herbicides were applied after 15-20 days of sowing (DAS) using 500 litres of water per ha. Soybean was raised as per the recommended package of practices. Weed count and their dry biomass were recorded at 30 and 45 days after sowing Weed control efficiency of each treatment was determined by using the standard formula at 30 and 45 DAS. Yield and yield attributes were recorded at the time of harvesting. The data were pooled over the years as per standard statistical procedures.

RESULTS AND DISCUSSION

During the investigation, soybean was infested mainly with *Parthenium hysterophorus, Digera arvensis, Acalypha indica, Commelina* spp., *Alternenthera* spp., *Corchorus* spp. and *Euphorbia geniculata* of broad leaved weeds and *Dinebra arabica, Echinocloa* spp., *Brachiaria* spp., *Digitaria sanguinalis* and *Cynodon dactylon (L.)* Pers of grassy weeds and *Cyperus rotundus (L.)* (sedges).

All the weed control treatment substantially reduced the weed count and their dry matter at both the stages 30 and

Table 1. Effect of herbicides application on weed count, dry matter and weed control efficiency in soybean (Pooled means of two years)

Treatment	30 DAS			45 DAS		
	Count (m²)	Dry matter (g/m²)	WCE (%)	Count (m²)	Dry matter (g/m²)	WCE (%)
Untreated control	7.51 (55.58)*	5.23 (34.95)	-	7.57 (56.91)	7.27 (53.27)	-
Sulfentrazone + Clomazone @ 580 (300+280) g a i/ha as PE	4.89 (22.93)	2.55 (8.72)	75.85	5.11 (25.12)	4.60 (21.14)	61.84
Sulfentrazone + Clomazone @ 725 (375+350) g a i/ha as PE	3.78 (13.39)	1.85 (4.45)	87.95	3.77 (13.28)	3.27 (10.10)	81.65
Sulfentrazone + Clomazone @ 870 (450+420) g a i/ha as PE	3.41 (10.70)	1.76 (3.43)	90.55	3.28 (9.98)	3.08 (8.91)	83.95
Clomazone 50 EC @ 375 g a i/ha as PE	5.91 (33.88)	3.36 (14.41)	99.2	5.84 (33.40)	5.27 (27.64)	48.73
Sulfentrazone 48% SC @ 350 g a i/ha as PE	5.11 (25.17)	2.95 (10.83)	69.36	5.09 (25.12)	4.78 (22.55)	58.13
Clomazone 50 EC @ 1000 g a i/ha as PE	5.37 (27.87)	3.21 (12.79)	63.64	5.19 (26.21)	4.82 (22.83)	57.41
Sulfentrazone 48% SC @ 360 g a i/ha as PE	5.03 (24.37)	2.92 (10.41)	70.45	5.04 (24.50	4.71 (21.92)	59.43
Pendimethalin 30% EC + Imazethapyr 10% SL Premix @ 960 g a i/ha as PE	5.92 (34.15)	3.47 (14.96)	57.39	5.93 (34.61)	5.32 (28.16)	47.67
Imazethapyr 10% SL @ 100 g a i/ha as PoE	3.51 (11.38)	1.78 (3.44)	90.47	3.58 (11.90)	3.16 (9.40)	83.08
Hand weeding Twice at 20 and 40 DAS	1.76 (2.67)	1.61 (0.80)	96.96	1.00 (0.00)	1.00 (0.00)	100.00
SEm (±)	1.05	1.575	-	0.52	0.58	-
C D (P = 0.05)	**3.00**	**4.48**	**-**	**1.48**	**1.65**	**-**

Square root transformed value (x+1) of weed count used for statistical analysis; Data in parenthesis are original values of weed counts

45 DAS of observations as compared to weedy check (Table 1). The highest weed control efficiency was observed with hand weeding twice at both the stages of observations (30 and 45 DAS). The weed control efficiency of herbicides declined as the crop age advanced. The weed control efficiency of the sulfentrazone + clomazone at all the stages of observations were higher than check pre-mix herbicide formulation pendimethalin + imazethapyr and closely followed by Imazethapyr (Table 2). The higher weed control efficiency may be due to effective control of weeds which indicated lower weed count and their dry matter (Table 1).

The variation in weed count and their dry matter and weed control efficiency might be due the differences in effectiveness of herbicides against different weeds in the field. The effectiveness of PE and PoE was found to be equal for managing weeds in soybean (Billore *et al*., 1999). Many researchers have reported lower weed densities in soybean with the use of herbicides like sulfentrazone (Vidrine *et al*., 1996; Niekamp *et al.,* 2001; Krausz *et al.,* 2003) and pendimethalin (Nayak *et al.,* 2000; Raskar and Bhoi, 2002, Chauhan *et al*., 2002) and clomazone (Werling and Bhuler, 1988).

Results further revealed that soybean plant height and branches per plant remained unaffected due to various treatments (Table 2). However, numerically lower plant height and branches per plant was observed in sulfentrazone @ 360 g a i per ha as PE and imazthapyr @ 100 g a i per ha as PoE,

respectively. The maximum pods per plant were observed with two hand weeding and showed non-significant differences with imazethapyr @ 100g a i per ha, sulfentrazone + clomazone @ 870 and 725 g a i per ha compared to rest of the herbicides. The maximum seed index was also recorded with two hand weeding and remained at par with all the herbicidal treatments over untreated control. Maximum yield reduction was observed to the extent of 52.74 per cent, if weeds were not managed and least in two hand weeding. All the treatments showed higher seed yield over control as well as clomazone @ 375 g a i per ha. The yield enhancement due to weed control treatments was to the tune of 13.79 to 111.60 per cent over control. Significantly and maximum seed yield (2,224 kg/ha) was recorded with two hand weeding and remained at par with imazethapyr @ 100 g a i per ha as PoE (2,030 kg/ha) and sulfentrazone + clomazone @ 870 g ai per ha (1,978 kg/ha) as PE and least in untreated control (1,051 kg/ha). Among the herbicides, however, the lower level of sulfentrazone + clomazone @ 725 g a i per ha was equally effective as its higher level and imazethapyr @ 100 g a i per ha. All the three levels of sulfentrazone + clomazone produced significantly higher seed yield than check herbicides, namely pre-mix pendimethalin + imazethapyr @ 960 g a i per ha, clomazone @ 375 g a i per ha and sulfentrazone @ 350 g a iI per ha alone as PE. The more or less similar pattern was also recorded in straw yield. The harvest index remained unchanged due to different treatments.

The yield enhancement in weed

Table 2. Effect of herbicides application on soybean growth, yield attributes and yield (Pooled means of two years)

Treatment	Plant height (cm)	Branches (No/ plant)	Pods (No/ plant)	Seed index	Seed yield (kg/ha)	Straw yield (kg/ha)	HI (%)
Untreated control	55.83	3.50	24.17	10.79	1051	2520	33.02
Sulfentrazone + Clomazone @ 580 (300+280) g ai/ha as PE	54.66	4.03	35.67	12.39	1699	3527	33.80
Sulfentrazone + Clomazone @ 725 (375+350) g ai/ha as PE	56.09	4.03	41.00	12.66	1844	3736	35.11
Sulfentrazone + Clomazone @ 870 (450+420) g ai/ha as PE	56.37	4.08	43.84	12.98	1978	3911	35.05
Clomazone 50 EC @ 375 g ai/ha as PE	58.50	3.97	29.70	12.11	1196	2808	33.56
Sulfentrazone 48% SC @ 350 g ai/ha as PE	58.57	3.84	38.80	11.57	1597	3494	33.10
Clomazone 50 EC @ 1000 g ai/ha as PE	56.80	3.84	39.47	12.35	1558	3444	33.75
Sulfentrazone 48% SC @ 360 g ai/ha as PE	53.43	3.70	36.40	12.12	1694	3625	33.35
Pendimethalin 30% EC + Imazethapyr 10% SL Premix @ 960 g ai/ha as PE	54.10	3.84	31.37	12.05	1500	3176	33.74
Imazethapyr 10% SL @ 100 g ai/ha as PoE	54.93	3.30	43.74	13.30	2030	3983	35.28
Hand weeding Twice at 20 & 40 DAS	54.76	3.77	45.64	13.59	2224	4369	34.78
SEm(±)	2.46	0.27	2.20	0.76	92.00	212.42	3.42
C D (P = 0.05)	**NS**	**NS**	**6.28**	**2.17**	**262.94**	**607.11**	**NS**

control treatment might be due to the effective control of weeds which offers less competition between crop and weeds during the critical period of crop-weed competition. The similar results were also reported by Singh *et al.* (2004), Singh and Jolly (2004) and Mishra and Singh, (2009).

On the basis of two years pooled data results, it could be concluded the application of sulfentrazone + clomazone (pre-mix) @ 870 or 725 g a i per ha as PE was found to be as effective as imazethapyr @ 100 g a i per ha as PoE and better than alone application of pendimethalin and clomazone as PE.

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In-Vitro Evaluation of Different Agro-chemicals against *Macrophomina phaseolina*

B M INGOLE[1*], L F AKBARI[2*] and D N KSHIRSAGAR[3]
*** College of Agriculture, Junagarh Agricultural University, Junagarh, Gujarat
and
** College of Agriculture, (MarathwadaAgriculture Univerity, Parbhani),
Jalana, Maharashtra**
E mail: pathologist10dk@gmail.com

ABSTRACT

Different agro-chemicals were evaluated against (Macrophomina phaseolina). In non-systemic fungicides, zineb 75 WP gave total inhibition of growth and sclerotial formation at minimum concentration of 500 ppm followed by copper hydroxide 77 WP (53.63 %). In systemic fungicides, carbendazim 50 WP proved best with mean inhibition of 97.81 per cent and completely inhibited the growth of pathogen at higher concentration of 500 ppm followed by thiophanate methyl 70 WP (84.57 %) and tebuconazole 25.9 EC (80.50 %). These fungicides do not allow sclerotial formation at all concentrations tested. The combinations of fungicides pyraclostrobin 13.3 WP + epoxyconazole 5 WP and metalaxyl 8 WP + mancozeb 64 WP gave cent per cent inhibition of mycelial growth and sclerotial formation at all the concentrations tested. Among the different herbicides, quizalophop-p-ethyle 5 EC gave total inhibition of mycelial growth and sclerotial formation at all the concentrations followed by the propaquizafop 10EC (96.05 %), oxyfluorfen 23.5 EC (88.70 %) and oxadiargyl 6 EC (82.23 %). Among the chemical fertilizers, diammonium phosphate was quite effective in inhibiting growth and sclerotial formation at all the concentrations followed by ammonium sulphate (72.20 %).

Soybean plant is susceptible to a number of pathogens which reduces the quality and quantity of seed yield. Yield losses between 30 and 50 per cent due to *Macrophomina phaseolina* in soybean crop were reported by Yang and Navi (2005). The pathogen is soil and seed borne, and causes severe losses in yield mainly due to moisture stress (Arya *et al.*, 2004). Since last few years, root rot disease is being reported in severe proportions from many places of Saurashtra region of Gujarat, potentially limiting soybean cultivation in the region. *As Rhizoctonia bataticola* (pycnidial stage - *Macrophomin phaseolina*) is more economically

[1]MSc student; [2]Assistant Research Scientist;[3]Assistant Professor

important pathogen on soybean, the present investigation was undertaken to evaluate different agro-chemicals against this pathogen.

MATERIAL AND METHODS

Collection, isolation and purification of the pathogen

The samples of naturally infected soybean plants were collected from Oil Seed Research Station (Gujarat Agricultural University), Junagadh as well as from the farmers' fields for the isolation of causal fungus. The culture thus obtained was purified by single hyphae isolation technique. The purified culture was maintained at 10°C and transferred periodically to potato dextrose agar (PDA) slants.

Effects of different agro-chemicals against *Macrophomina phaseolina in vitro*

Different concentrations of fungicides, herbicides and fertilizers were tested for the growth inhibition and sclerotial formation of *M. phaseolina* using poisoned food technique (Sinclair and Dhingra, 1985).

The required quantity of each chemical was incorporated aseptically in 100 ml of PDA in 250 ml flasks to make various concentrations of fungicides, herbicides, and fertilizers. The medium was shaken well to give uniform dispersal of the chemical and then 20 ml of medium was poured aseptically to each plate with four replications. After solidification, the plates were inoculated with mycelial discs of 4 mm diameter of five days old culture. The mycelium disc which was placed in the center of the

plates, in an inverted position to make a direct contact with the poisoned medium, was incubated at 28 ± 1^0C for seven days.

The linear growth (mm) of the fungal colonies was measured from two different angels and the average values were calculated. Sclerotial formations were counted in fungal culture suspensions under the microscope at low power (10 x). The fungal culture suspension was prepared by vigorously shaking the 4 mm mycelial disc of the fungus in 10 ml sterilized distilled water.

The per cent inhibition of growth of the fungus in each treatment was calculated by using the following formula (Vincent, 1947).

I = C-T /C x 100; where, I = Per cent inhibition; C = Colony diameter in control (mm); T = Colony diameter in respective treatment (mm)

RESULTS AND DISCUSSIONS

Effect of different non-systemic fungicides on the growth and sclerotial formation of *M. phaseolina*

The relative efficacy of seven different non-systemic fungicides tested at 500, 1000, 1500 and 2000 ppm concentrations revealed that the maximum toxicity index (400) was observed in zineb (Table 1). The growth inhibition and sclerotial formation was decreased with the increase in concentrations for all the chemicals tested. Zineb gave cent per cent inhibition of mycelial growth and sclerotial formation at minimum concentration of 500 ppm. Thiram and mancozeb at 1000 ppm concentration were found effective

Table 1. Fungal growth inhibition and sclerotial formation of *M. phaseolina* by non-systemic fungicides after seven days of incubation at 28 ± 1 °C

Fungicide	Concentration (ppm)/ per cent inhibition*				Mean	Toxicity Index[#]
	500	1000	1500	2000		
Zineb	A 100.0	100.00	100.00	100.00	100.00	400
	B -	--	--	--		
Copper hydroxide	A 17.78	51.15	62.25	83.35	53.63	214.52
	B ++	+	+	--		
Thiram	A 48.68	53.61	63.36	66.68	58.08	232.32
	B +	--	--	--		
Copper oxychloride	A 22.25	36.68	38.89	42.24	35.01	140.04
	B ++	++	+	--		
Chlorothalonil	A 4.46	23.36	27.78	67.78	30.85	123.4
	B ++	++	++	+		
Mancozeb	A 2.25	50.00	57.78	88.89	49.74	198.96
	B ++++	--	--	--		
Wettablesulphur	A 2.36	2.90	3.35	44.46	13.26	53.04
	B +++	+++	+++	++		
Control	0.00	0.00	0.00	0.00	0.00	0.00
	Fungicide (F)		Concentration (C)			F×C
CD (P = 0.01)	0.761		1.006			2.011

Mean of four replications; #Toxicity index; A = Growth inhibition;B = Sclerotial formation: ++++ = abundant; +++ = good; ++ = moderate; + = scanty; --= absent

and completely suppressed the sclerotial formation, whereas the wettable sulphur failed to restrict the sclerotial formation. Mancozeb and copper hydroxide at 2000 ppm concentration found quite effective and gave 88.89 and 83.35 per cent growth inhibition, respectively. The effectiveness of mancozeb and zineb against *R. bataticola* in soybean was earlier reported by Syed and Ghaffar (1995). Singh (1997) and Devi and Singh (1997) also found mancozeb @ 0.2 per cent to be most effective growth inhibitor of *M. phaseolina*. Contrary to the finding of Mathukia (1982), Chattopadhyay and Sastry (2002) and Malathi and Sabitha (2003), thiram was moderately effective against *M. phaseolina* in the present investigation. Less effectiveness of chlorothalonil was as well contrary to the finding of Prashanthi *et al.* (2000) and Mathur (2006), who found it to be most effective against *M. phaseolina*.

Effect of different systemic fungicides on the growth and sclerotial formation of *M. phaseolina*

All the seven systemic fungicides were capable of inhibiting the growth of *M. phaseolina* at various concentrations as

compared to control. Except carboxin and showed more than 50 per cent growth inhibition at lower concentration of 50 ppm. Carbendezim at 500 ppm gave complete inhibition of pathogen with mean inhibition of 97.81 per cent. Thiophanate methyl and tebuconazole were also effective with mean inhibition of 84.57 and 80.50 per cent, respectively. Difenconoazole, carboxin, hexaconazole and tridemorph were moderately effective with mean inhibition of 75.76, 62.55, 61.55 and 61.24 per cent, respectively. Maximum toxicity index of 391.24, 338.29 and 322.32 was observed in case of carbendazim, thioaphanate hexaconazole, the remaining fungicides methyl and tebuconazole, respectively, whereas minimum (245.16) was with tridemorph. The effect of different concentrations of systemic fungicides on sclerotial formation was found related with the inhibition of growth. No sclerotial formation was observed in all concentrations of carbendazim, thiohanate methyl and hexaconazole. Good sclerotial formation was observed in tebuconazole and difenoconazole. Tridemorph and carboxin supported moderate to scanty sclerotial formation (Table 2).

Table 2. Fungal growth inhibition and sclerotial formation of *M. phaseolina* by systemic fungicides after seven days of incubation at 28 ± 1 °C

Fungicide	Concentration (ppm)/ per cent inhibition*				Mean*	Toxicity Index#
	50	100	250	500		
Tridemorph 25 EC	A 55.55	61.72	61.12	66.67	61.24	245.16
	B ++	++	--	--		
Difenoconazole25 EC	A 72.23	74.45	77.78	77.78	75.56	302.24
	B ++	++	++	++		
Carboxin 75 wp	A 38.88	50.22	77.78	83.34	62.55	250.20
	B ++	++	+	--		
Thioaphanate methyl 70WP	A 83.34	84.45	84.95	85.55	84.57	338.29
	B --	--	--	--		
Carbendazim 50 WP	A 94.30	97.71	99.22	100.00	97.81	391.24
	B --	--	--	--		
Hexaconazole 5 EC	A 33.78	66.30	70.98	75.56	61.55.	246.62
	B --	--	--	--		
Tebuconazole 25.9 EC	A 77.39	79.22	80.08	85.31	80.50	322.32
	B ++	++	++	+		
Control	0.00	0.00	0.00	0.00	0.00	0.00
	Fungicide (F)		Concentration (C)			F×C
CD (P = 0.01)	0.184		0.2434			0.4868

Mean of four replications; # toxicity index; A = Growth inhibition;   B = Sclerotial formation:++++ = abundant; +++ = good; ++ = moderate; + = scanty; --=absent

Testing of relative efficacy of seven different systemic fungicides at 50, 100, 250 and 500 ppm concentrations revealed that all of them were capable of inhibiting the growth of fungus at various concentrations as compared to control. Carbendezim at 500 ppm gave total inhibition of pathogen. Several workers (Bhatia *et al.*, 1997; Chattopadhyay and Sastry, 2002; Malathi and Sabrtha, 2003; Choudhary *et al.*, 2004; Jha and Sharma, 2006) recorded carbendazim to be the most effective fungicide for inhibition of *M phaseolina*. Thiophanate methyl, hexaconazole and tebuconazole were also found effective with mean inhibition of 84.57, 81.15 and 80.50 per cent, respectively. No sclerotial formation was observed in all concentrations of carbendazim, thiphanate methyl and tebuconazole (Table 2). The effectiveness of carbendazim and thiophanate methyl against *M. phaseolina* has been recorded earlier (Mathukia, 1982; Devi and Singh, 1997; Singh 1997; Lambhate *et al.*, 2002). In addition to this, Mathur (2006) also achieved good control of *M. phaseolina* with thiophanate-methyl, carbendazim, tebuconazole 2 DS, tebuconazole 250 WE and hexaconazole 5 per cent EC.

Effect of different combination of fungicides on the growth and sclerotial formation of *M. phaseolina*

All the seven combinations of fungicides evaluated at different concentrations were effective in growth inhibition of *M. phaseolina.* The pyraclostrobin 13 WP + epoxyconazole 5 WP and metalaxyl 8 WP + mancozeb 64 WP gave complete inhibition of mycelium along with non-formation of sclerotia at all their concentration evaluated. The cymoxanil 8 WP + mancozeb 64 WP, carbendazim 12 WP + mancozeb 63 WP, metiram 55 WP + pyraclostrobin 5 WG and zineb 60 WP + hexaconazole 4 WP could completely inhibit the mycelium and sclerotial formation at higher concentrations (1000 and 2000 ppm). Iprodione 25 WP + carbendazim 25 WP gave minimum mycelium inhibition associate with good sclerotial formation. Maximum toxicity index of 400 was recorded in pyraclostrobin 13.3 WP + epoxyconazole 5 WP and metalaxyl 8 WP + mancozeb 64 WP (Table 3).

All the combinations of fungicides gave more than 50 per cent mean growth inhibition of the fungus. The pyraclostrobin 13.3 WP + epoxyconazole 5 WP and metalaxyl 8 WP + mancozeb 64 WP led to total mycelium growth inhibition and no sclerotial formation at all their concentration tested with maximum toxicity index of 400. The cymoxanil 8 WP + mancozeb 64 WP, carbendazim 12 WP + mancozeb 63 WP, metiram 55 WP + pyraclostrobin 5 WG and zineb 60 WP + hexaconazole 4 WP were found effective and gave complete mycelium inhibition at higher concentrations (1000 and 2000 ppm) as well as suppressed the sclerotial formation. The effectiveness of combination of fungicides carbendazim + thiram against *R. bataticola* (chickpea isolate) and benomyl + morocide against *M. phaseolina* (betel vine isolate) under laboratory condition has earlier been reported (Prajapati *et al.*, 2002:

Table 3. Fungal growth inhibition and sclerotial formation of *M. phaseolina* by combination of fungicide after seven days of incubation at 28 ± 1 °C

Fungicide	Concentration (ppm)/ per cent inhibition*				Mean*	Toxicity Index#
	250	500	1000	2000		
Iprodione 25WP +	A 26.6	40.24	47.15	87.25	50.30	201.2
Carbendazim 25WP	B +++	+++	++	++		
Carbendazim 12WP +	A 72.4	77.13	100.0	100.0	87.47	349.88
Mancozeb 63WP	B +	+	--	--		
Cymoxanil 8WP +	A 66.64	83.35	100.0	100.0	87.50	350.00
Mancozeb 64WP	B +	+	--	--		
Metiram 55WP +	A 78.56	83.96	100.0	100.0	90.63	362.52
Pyraclostrobin 5WG	B +	+	--	--		
Zineb 60WP +	A 87.56	88.85	100.0	100.0	94.10	376.4
Hexaconazole 4 WP	B +	+	--	--		
Pyraclostrobin 13.3 WP +	A 100	100.0	100.0	100.0	100.0	400.00
Epoxyconazol 5 WP	B --	--	--	--		
Metalaxyl 8 WP +	A100.0	100.0	100.0	100.0	100.0	400.00
Mancozeb 64 WP	B --	--	--	--		
Control	0.00	0.00	0.00	0.00	0.00	0.00
	Fungicide (F)		Concentration (C)			F×C
CD (P = 0.01)	0.523		0.692			1.384

Mean of four replications; # toxicity index; A = Growth inhibition;B = Sclerotial formation: ++++ = abundant; +++ = good; ++ = moderate; + = scanty; --= absent

Anwar *et al.,* 2006)

Effect of different herbicides on the growth and sclerotial formation of *M. phaseolina*

Efficacy of nine different herbicides revealed that all of them were significantly superior in inhibiting the growth of the test fungus at different concentrations as compared to the control (Table 4). Among them, quizalophop-p-ethyle 5 EC inhibited total mycelial growth at all concentration tested followed by propaquizafop 10 EC, which gave complete mycelial growth inhibition above 1500 and 2000 ppm, respectively.

Oxadiargyl 6 per cent EC and oxyfluorfen 23.5 per cent EC were also found effective and gave complete inhibition of mycelial growth at higher concentration (2000 ppm). Paraquate dichloride, metasulfuron-methyl, fenoxaprop-p-ethyle were moderately effective with mean growth inhibition of 65.30, 58.78, 54.10 per cent. Whereas, the performance of pendimethalin 30 EC, glyphosate 41 EC was poorer as compared to other herbicides.

The formation of sclerotia was completely inhibited in quizalophop-p-ethyle 5 EC, propaquizafop 10 EC, oxadiargy 6EC and oxyfluorfen 23.5 EC

Table 4. Fungal growth inhibitionand sclerotial formation of *M. phaseolina*by herbicides after seven days of incubation at 28 ± 1 °C

Herbicide	Concentration (ppm)/ per cent inhibition*				Mean*	Toxicity Index#
	500	1000	1500	2000		
Propaquizafop 10EC	A 86.51	97.71	100.00	100.00	96.05	384.20
	B +	--	--	--		
Quizalophop-p-ethyle 5 EC	A 100.0	100.00	100.00	100.00	100.00	400.00
	B --	--	--	--		
Pendimethalin 30 EC	A 16.68	22.25	38.85	55.58	33.34	121.36
	B ++	++	++	++		
Metasulfuron-methyl 20 WG	A 48.88	57.78	62.24	66.25	58.78	235.12
	B +	+	+	+		
Glyphosat 41 EC	A 8.77	18.88	27.77	42.26	24.42	97.68
	B +++	+++	++	+		
Oxadiargyl 6 EC	A 61.13	73.35	94.46	100.00	82.23	328.92
	B +	--	--	--		
Oxyfluorfen 23.5 EC	A 75.57	85.57	93.68	100.00	88.70	354.80
	B +	--	--	--		
Fenoxaprop-p-ethyle 10 EC	A 4.24	61.14	67.69	83.35	54.10	216.40
	B ++	++	++	++		
Paraquate dichloride 24 SL	A 37.78	77.77	75.77	88.84	65.30	65.30
	B ++	+	+	+		
Control	0.00	0.00	0.00	0.00	0.00	0.00
	Herbicide (H)	Concentration (C)				H×C
CD (P = 0.01)	2.952	4.429				8.858

Mean of four replications; # toxicity index; A = Growth inhibition;B = Sclerotial formation: ++++ = abundant; +++ = good; ++ = moderate; + = scanty; --= absent

at 1000 ppm concentration whereas, good to moderate sclerotial formation was observed in rest of herbicides tested. Maximum toxicity index (400) was recorded in quizalophop-p-ethyle. All herbicides were significantly superior in inhibiting the growth of the test fungus as compared to the control. Among different herbicides, quizalophop-p-ethyle 5 EC gave total inhibition of mycelia growth at all concentrations tested followed by propaquizafop 10 EC, which gave total growth inhibition at 1500 and 2000 ppm. De *et al.* (2007) reported good control of *M. phesolina* in (jute isolate) *in vitro* using quizalofop-ethyl. Oxadiargyl 6 EC and oxyfluorfen 23.5 EC were also found effective and gave complete inhibition of mycelia growth at highest concentration (2000 ppm). As per Jha and Sharma (2006), oxyfluorfen inhibited the mycelia growth of *R. bataticola* effectively and affected sclerotial   morphology.

Pendimethalin 30 EC and glyphosate 41 EC performed poor as compared to other herbicides. This observation is contrary to the finding of Chavan (2006), who recorded 73.37 per cent growth inhibition of *M. phaseolina* (cotton isolate) with pendimethalin.

Effects of various fertilizers on the growth and sclerotial formation of the *M. phaseolina*

Relative efficacy of all the seven different fertilizers was found to reduce the growth of fungus as compared to control. Among them, diammonium phosphate was most effective and gave complete growth inhibition and no sclerotia were formed at all the concentrations. Ammonium sulphate, urea and SSP at 3000 ppm to 4000 ppm gave more than 70.0 per cent growth inhibition and supported sclerotial

Table 5. Fungal growth inhibition and sclerotial formation of *M. phaseolina* by fertilizers after seven days of incubation at 28 ± 1 °C

Fertilizer	Concentration (ppm)/ per cent inhibition*				Mean*	Toxicity Index#
	1000	2000	3000	4000		
Diammonium phosphate	A100.0B --	100.0 --	100.0 --	100.0 --	100.0	400.0
Ammonium sulphate	A 67.6 B +	69.9 +	74.6 +	76.6 --	72.2	288.7
Urea	A 61.3 B +	65.3 +	72.9 +	74.9 --	68.6	274.4
Single Super Phosphate	A 54.3 B ++	64.3 ++	71.7 +	72.1 +	65.6	262.4
Murate of potash	A 21.1 B +++	32.2 +++	53.1 ++	64.6 +	42.8	171.0
Narmadaphos CAN (20:20:0)	A 24.9 B +++	34.3 +++	42.6 +++	52.5 ++	38.6	154.3
IFFCON:P:K (12:32:16)	A 21.9 B +++	35.9 +++	42.9 +++	47.5 +++	37.1	148.4
Control	0.00	0.00	0.00	0.00	0.00	0.00
	Fungicide (F)		Concentration (C)			F×C
CD (P = 0.01)	**1.05**		**2.10**			**2.205**

Mean of four replications; # toxicity index; A = Growth inhibition; B = Sclerotial formation:++++ = abundant; +++ = good; ++ = moderate; + = scanty; --= absent

formation moderately. Murate of potash, Narmada CAN (20:20:0) and IFFCO N:P:K (12:32:16) were moderately effective and gave 42.80, 38.60 and 37.10 per cent growth inhibition and supported

good to moderate sclerotial formation. The toxicity index of 400 was recorded with diammonium phosphate (Table 5).

Relative efficacy of different fertilizers showed that all of them were

effective to reduce the growth of fungus as compared to control. Diammonium phosphate was most effective and gave total growth inhibition of test pathogen and restricted sclerotial formation. Ammonium sulphate, urea and SSP at 3000 ppm to 4000 ppm gave more than 70.0 per cent growth inhibition and supported sclerotial formation moderately. According to Khalid-Iftikhar *et al.* (2001), higher amount of N, P and K were more effective in reducing the dry root rot disease *(M. phaseolina)* incidence and sclerotial population. Desai and Kulkarni (2002) recorded total inhibition of growth and sporulation of *M. phaseolina with* urea at 1000 ppm concentration.

The study suggested that for the management of root rot caused by *Macrophomina phaseolina* in soybean, among the agro-chemicals evaluated, zineb 75 WP (non-systemic), carbendazim 50 WP (systemic) and combination of fungicides pyraclostrobin 13.3 WP + epoxyconazole 5 WP or metalaxyl 8 % WP + mancozeb 64 WP are most effective. Use of herbicide quizalophop-p-ethyle 5 EC and fertilizer diammonium phosphate were also quite effective for the purpose.

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Bridging Yield Gap in Soybean Production through Technology Demonstration: Potential Source for Increasing Farmers Income in Central India

S B NAHATKAR[1], MONI THOMAS[2] and PARVEZ RAJAN[3]

Directorate of Research Services, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur 482 004, Madhya Pradesh
E mail: sbnahatkar@rediffmail.com, parvezrajan@gmail.com

ABSTRACT

Soybean is an important commercial crop of kharif *season in Madhya Pradesh, part of Maharashtra and Rajasthan. In these areas major portion of farmers' income is dependent on this crop, which is having 95 per cent marketable surplus. Therefore, huge potential for increasing farmers' income through bridging yield gap with the help of demonstrations of production and crop management technologies exists. Demonstrations on soybean production technologies were conducted under Technical Cooperation Project of Japan International Cooperation Agency (JICA). For present investigation primary data were collected from six beneficiaries and six non-beneficiaries soybean growers from each six demonstration sites; the ultimate sample size comprises of 72 soybean growers (36 beneficiaries and 36 non-beneficiaries). The results showed that the adoption level of beneficiary soybean growers is higher as compared to non-beneficiary soybean growers. The gap in adoption practices reflected in average yield gap of about 400 kg (37 %). On the basis of yield gap, the additional total income of Rs 13,825 with an additional expenditure of Rs 4,000 having surplus additional income of Rs 9,825 per ha with C:B ratio of 3.45 was worked out. At state level, the additional production potential of 2,374.20 thousand tons worth of Rs 8,310 million is estimated. This revealed that the additional expenditure for adoption of improved soybean production technology is economically viable. For achieving the target of doubling the farmers' income by 2022, more emphasis needs to be given on pre-planting training and number of effective demonstrations backed up by assured availability of recommended inputs for adoption along with required farm mechanization in soybean growing areas of central India.*

In India, this crop is cultivated in an area of 11.66 million hectares. In the state of Madhya Pradesh, the area under this crop is about 5.91 million hectares. Madhya Pradesh has its major share in area (50.65 %) and production (57.13%) in India for the year 2015 (GoI, 2016) and hence known as "Soya State". In the

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[1]*Associate Director of Research Services;* [2]*Principal Scientist;* [3]*Assistant Professor*

state the average productivity of soybean is very low (1.0-1.2 t/ha) as compared to its genetic potential (2.5 t/ha). The major factor for higher yield gap is lack of knowledge about management of biotic and abiotic stresses. The adoption of recommended technology of soybean production by the soybean growers is also not to the desired level. Soybean growers are not much aware of low-cost and no cost production technologies like seed grading of farm saved seed, use of *Trichoderma, biofertilizers*, and choice of suitable variety, row to row distance and seed rate according to different growing habits of soybean varieties (Rao *et al*., 2017).

Promising varieties of soybean were developed in different parts of India with different maturity periods and high yield potentials (Vyas and Kushwaha, 2015), which contributed in expansion of area of soybean in the country with growth rate of more than 22 per cent. Soybean crop has significantly changed the socio-economic status of the resource poor farmers of the state (Badal and Kumar, 2000; Sharma *et al*., 2016). Gradual climatic changes have enhanced the biotic and abiotic stresses during last five years that resulted in drastic reduction of production. Technology to combat biotic and abiotic stresses in soybean production is available, but problem is with its horizontal spread and development of decision support system by farmers themselves for timely management of such problems. Adoption of recommended production technologies among farmers is not very encouraging (Nahatkar *et al*., 2007, 2008; Sharma *et al*.,

1996, 2000, 2004, 2006). Access and reach of the technology to the farmer's fields may be the reason (Dubey *et al*., 2014), as the extent of knowledge is directly related to extent of adoption. Singh and Singh (2013) reported that majority of the farmers were having maximum knowledge about fertilizer application and improved varieties of soybean. Relationship and association between extent of knowledge and extent of adoption of technology is usually high (Rajan *et al*., 2016). The FLD produces a significant positive result and provided the researcher get an opportunity to demonstrate the productivity potential and profitability of the latest technology under real farming situation, which they have been advocating for long time (Singh *et al.,* 2014). Thus, there exist huge potential for increasing production of soybean and income of the farmers through bridging yield gap with the help of demonstrations of production and crop management technologies because soybean is an important commercial crop of *kharif* season in Madhya Pradesh, part of Maharashtra and Rajasthan. In Madhya Pradesh, it accounts for more than 50 per cent of the cropped area during *kharif* season and therefore major portion of farmers' income is dependent on this crop which is having 95 per cent marketable surplus.

MATERIAL AND METHODS

JNKVV, Jabalpur initiated Technical Cooperation Project with Japan International Cooperation Agency (JICA) for maximization of soybean production in Madhya Pradesh. It provided an

opportunity to assess adoption level of soybean growers about soybean production technologies on the basis of demonstrations conducted in six districts (Jabalpur, Rewa, Chhindwara, Tikamgarh, Sagar and Hoshangabad) of Madhya Pradesh. For collection of primary data, six beneficiaries and six non-beneficiaries soybean growers from each demonstration sites were selected purposively. Thus, the sample size from each district was 12 and the sampling frame comprises of 72 soybean growers (36 beneficiaries and 36 non-beneficiaries). The data were collected from sample farmers through personal interviews with the help of pre-tested interview schedule, which pertains to the year 2016-17. However, the data for yields was three years mean (2013-14 to 2015-16). The data were analyzed using simple statistical tools.

RESULTS AND DISCUSSION

Adoption of technologies

The level of adoption of technology determines the level of productivity and thus income from soybean production. The data on adoption of various technological components of soybean production (Table 1) revealed that out of total beneficiaries, 61.11 per cent had low adoption of field preparation, 38.89 per cent had medium and none was found in high category. While in case of non-beneficiaries, all of them had low adoption of field preparation practices. Thus, it revealed that the majority of beneficiaries and non-beneficiaries had low adoption of field preparation

practices specially preparation for proper drainage of rainwater because in most of the parts of central India the rainfall was in the range of 800 to 1000 mm and thus soybean crop suffers due to heavy and continuous rains.

In case of seed and sowing management in soybean, the data revealed that out of total beneficiaries, 50.00 per cent had medium, 47.22 per cent had high and 2.78 per cent had low adoption of seed and sowing management. While majority of non-beneficiaries (88.89 %) had low adoption, followed by medium (11.11 %) and none was found in high category. Thus, it can be concluded that the majority of beneficiaries had medium and non-beneficiaries had low adoption of seed and sowing management practices of soybean especially proper row to row distance, selection of variety, optimum seed rate, seed treatment and ridge and furrow method of planting.

The data regarding fertilizer application indicated that out of the total beneficiaries, 63.89 per cent had high, 27.78 per cent had medium and 8.33 per cent had low adoption. While majority of non-beneficiaries (77.78 %) had low, 22.22 per cent had medium adoption and none was found in high category. This indicated that the majority of beneficiaries had high and non-beneficiaries had low adoption of fertilizer application practices especially for use of potash and sulphur in soybean crop.

The data regarding irrigation management during stress condition showed that out of the total beneficiaries,

69.44 per cent had high, 25.00 per cent had medium and 5.56 per cent had low adoption, while the highest percentage, (50.00 %) of non-beneficiaries had medium, 38.89 per cent had low and 11.11 per cent had high adoption. Thus, it is evident from the above data that the majority of beneficiaries had high adoption regarding irrigation management under moisture stress condition in soybean crop because moisture stress specially during R2 and R4 stage affects the productivity of soybean adversely (Rao *et al.,* 2017).

Table 1. Distribution of respondents according to adoption of recommended technology of soybean production

Technology component	Categories	Beneficiaries N=36		Non-Beneficiaries N=36		Total N=72	
		Frequency	%	Frequency	%	Frequency	%
Field preparation	Low	22	61.11	36	100.00	58	80.56
	Med	14	38.89	-	-	14	19.44
	High	-	-	-	-	-	-
Seed and sowing management	Low	1	2.78	32	88.89	33	45.83
	Med	18	50.00	4	11.11	22	30.56
	High	17	47.22	-	-	17	23.61
Fertilizer application	Low	3	8.33	28	77.78	31	43.06
	Med	10	27.78	8	22.22	18	25.00
	High	23	63.89	-	-	23	31.94
Irrigation management	Low	2	5.56	14	38.89	16	22.22
	Med	9	25.00	18	50.00	27	37.50
	High	25	69.44	4	11.11	29	40.28
Weed management	Low	13	36.11	33	91.67	46	63.89
	Med	16	44.44	3	8.33	19	26.39
	High	7	19.44	-	-	7	9.72
Plant protection management	Low	11	30.56	33	91.67	44	61.11
	Med	24	66.67	3	8.33	27	37.50
	High	1	2.78	-	-	1	1.39

*Low below 33.33 %;medium between 33.33 to 66.66 %; high above 66.66 %

In case of weed management, the data revealed that out of total beneficiaries, 44.44 per cent had medium, 36.11 per cent had low and 19.44 per cent had high adoption. On the other hand, majority (91.67 %) of non-beneficiaries had low, 8.33 per cent had medium and none was found in high adoption category. Thus, it may be inferred from the data that the highest percentage (44.44 %) of beneficiaries had medium adoption and 91.67 per cent non-beneficiaries had low adoption of weed management practices in soybean cultivation and this is one of the important factor for high incidence of

insect-pest along with retarded growth of the crop (Rao *et al.,* 2017).

Regarding plant protection, the data revealed that majority of beneficiaries (66.67 %) had medium, 30.56 per cent had low and 2.78 per cent had high adoption. Majority of non-beneficiaries (91.67 %) had low adoption, 8.33 per cent had medium and none was found in high category. Thus, it revealed that the majority of beneficiaries had medium adoption and non-beneficiaries had low adoption of plant protection management practices. This gap in adoption practices on beneficiary and non-beneficiary farms reflects in average yield gap of about 400 kg or (37 %). This clearly indicated that increased adoption of soybean production practices by the demonstrated farmers helps in enhancing the average yield.

Statistical Parameters of Adoption

The statistical parameters of adoption of soybean production technologies such as mini-max score, mean score, standard deviation and t-test of difference between mean score of beneficiaries and non-beneficiaries is worked out (Table 2) The data revealed that the mean score for adoption of field preparation practices on beneficiaries and non-beneficiaries were 22.08 and 19.78 per cent with standard deviation of 2.13 and 1.46, respectively. The t-test was found to be significant, thus, indicating that there is significant difference in field preparation practices of beneficiaries and non-beneficiaries soybean growers.

In case of adoption of seed and sowing management practices, the mean score for beneficiaries and

Table 2. Distribution of respondents according to their mean score, standard deviation, and t-test of adoption level with respect to different technological components

Technology Component	Statistical parameters				
	Category of Respondent	Min-max score	Mean score	S.D	t- test
Field Preparation	B	Max 42	22.08	2.13	7.19 **
	NB	Min 14	19.78	1.46	
Seed and sowing management	B	Max 78	60.44	8.54	12.67**
	NB	Min 26	37.83	5.75	
Fertilizer application	B	Max 12	9.72	2.20	10.02**
	NB	Min 4	5.25	1.36	
Irrigation management	B	Max 6	5.33	1.10	7.28**
	NB	Min 2	3.67	1.39	
Weed management	B	Max 18	12.06	3.05	6.20**
	NB	Min 6	8.17	1.54	
Plant Protection management	B	Max 36	23.06	3.89	9.68**
	NB	Min 12	15.86	3.59	

**Significant at 0.01 probability level; /B=Beneficiaries, NB= Non-Beneficiaries

non-beneficiaries were 60.44 and 37.83 with standard deviation of 8.54 and 5.75, respectively. The t-test was found to be significant, indicating that there is difference in adoption of seed and sowing management practices.

For fertilizer application, the mean score for beneficiaries and non-beneficiaries respondents were 9.72 and 5.25 with standard deviation of 2.30 and 1.36, respectively. The t-test was found to be significant, indicating that there is difference in adoption practices of fertilizer application.

In relation to adoption of irrigation management under stress condition, mean score for beneficiaries and non-beneficiaries respondents were 5.33 and 3.67 with standard deviation of 1.10 and 1.39 respectively. The t-test was found to be significant, indicating that there is difference in adoption of irrigation management practices during moisture stress condition.

In case of adoption of weed management practices, the mean score for beneficiaries and non-beneficiaries respondents were 12.06 and 8.17 with standard deviation of 3.05 and 1.54, respectively along with significant t-values for differences revealing that beneficiaries are adopting weed management practices for control of weeds.

In relation to adoption of plant protection management, the mean score for beneficiaries and non-beneficiaries were 23.06 and 15.86 with standard deviation of 3.89 and 3.59 respectively. The t-value for difference between two groups for mean score was found to be significant depicting that the beneficiaries are managing insect-pests in a better way as compared to non-beneficiaries.

The adoption level of beneficiary soybean growers is higher as compared to non-beneficiary soybean growers highlighting the facts that the demonstration of technologies makes a difference in adoption. The mean score when tested on the basis of different statistical parameters also shown significant difference in adoption of soybean technologies of beneficiary soybean growers as compared to non-beneficiary soybean growers.

Yield gap and production potential

The data on yield gap between farmers practice and recommended package of practices showed that the average yield of farmers' practices was 1,069 kg per ha and this is more or less identical with the state average yield of soybean. The average yield under recommended package of practices was 1,464 kg per ha showing yield gap of 395 kg (36.95 %) (Table 3).

On the basis of yield gap, the incremental income and incremental C-B ratio is worked out. The data shows that farmers can generate an additional total income of Rs 13,825 per ha with an additional expenditure of Rs 4,000 per ha having surplus income of Rs 9,825 per ha with C-B ratio of 3.45. This clearly indicated that adoption of soybean production technology is an economically viable for enhancing farmers' income in the central India.

On the basis of data of yield gap,

Table 3. Yield gap, additional income and C-B ratio on farmers' field

Particulars	Estimates
Yield under farmer's practices (kg/ha)	1069
Yield under recommended package of practices (kg/ha)	1464
Yield gap (kg/ha)*	395 (36.95)
Incremental income (395 kg x Rs 35/kg)	13825
Incremental cost (Rs/ha)*	4000
Incremental net income (Rs/ha)*	9825
Incremental C-B ratio	3.45

Average of over six locations for 36 farm families for three years; Figure in parentheses shows percentage gap

Table 4. Production Potential and possibilities of generating additional income through bridging yield gap in soybean

Particulars	Estimates
Yield gap (kg/ha)*	395
Area under soybean in Madhya Pradesh (000' ha)	6045.70**
Production of soybean in Madhya Pradesh (000' tons)	6476.80**
Average Yield in Madhya Pradesh (kg/ha)	1071#
Production potential in Madhya Pradesh (000' tons)	8851.00@
Additional production (000 tons)	2374.20
Value of additional production (@ Rs 35000/tons)	831 million
Cost for additional production (@ Rs 4000/ha)	241.83 million
Additional cost benefit ratio	3.43

*Average of over six locations for 36 farm families for three years; ** Average of TE 2015-16; # Estimates as figure of row six/figure of row 5; @ Estimated as figure of row 2 X figure of row five divided by 10.*

the production potential and possibilities of generating additional income for the state of Madhya Pradesh was also worked out (Table 4).

The estimated production potential stood at 8,851 thousand tons with an additional production potential of 2,374.20 thousand tons for the state as a whole. In terms of value, it is worth of Rs 831 million and estimated additional cost required for adoption of improved technologies @ Rs 4,000 per ha will be Rs 241.83 million with additional cost benefit ratio of 3.43. This revealed that the additional expenditure for adoption of improved soybean production practices is economically viable in terms of cost-benefit ratio. Besides this additional production will bring additional foreign exchange and will generate additional employment to handle additional volume.

Soybean producers of the state are mainly constrained by availability of quality seed of desired varieties, quality biofertilizers, insecticides and fertilizers along with sowing devices for effective sowing using ridge and furrow method (Nahatkar *et al*, 2008 and Sharma *et al.*, 2004). If these constraints are overcome, soybean growers will be benefited with incremental yield and income because it

is hidden potential for increasing farmers' income. For achieving the target of doubling the farmers' income by 2022 more emphasis needs to be given on pre-planting training and number of effective demonstrations across the soybean growing areas of Central India. The training and demonstration programmes should be fully backed up by assured availability of recommended inputs for adoption along with required farm mechanization. More number of field days should be organized at demonstration site for horizontal spread of technology at faster rate.

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Genetic Variation and Correlation Studies of Soybean

A K MISHRA[1]

RVSKVV-Krishi Vigyan Kendra, Shajapur (465001), Madhya Pradesh
E mail: anil1961.mishra@gmail.com

Soybean is an important source of high quality protein and oil. It is, however, characterized with low yielding varieties with lodging and pod shattering traits, which constitute major production constraints. Soybean has the highest protein content of all other food crops and contributes more than 25 per cent of total edible oil produced in the country. Assessing genetic diversity of presently cultivated genotypes of soybean is very important to select better genotypes for hybridization programme. The scope of plant genetic improvement through the manipulation of available genetic diversity in plant breeding is obvious from the results obtained in different crops.

Seed yield is a complex trait governed by several plant growth components. Correlation coefficients, although, are very useful in quantifying the size and direction of trait association, can be misleading if the high correlation between two traits is a consequence of the indirect effect of other traits (Dewey and Lu, 1959). The object of this study was to determine genetic variability from the available material and association between yield and yield components.

Sixty four genotypes of soybean were evaluated for morphological traits under field condition at KVK, Shajapur. The experiment planted on June 15, 2015 and July 16, 2016 in a augmented field design; each plot consisted of two rows and 5 m long with row to row distance 30 cm. Data were recorded on seven quantitative traits, days to maturity, plant height, number of branches per plant, number of pods per plant, seed index, oil content and seed yield per plant. For observation ten plants randomly selected from each plot. The oil content was estimated employing method suggested by Tomi *et al*. (1995). The meteorological data for the two cropping season is shown in table 1.

Combined analysis of variance for the data (Table 2) showed that highly significant differences existed among evaluated genotypes for the traits measured, thus indicating that there in variability in genotypes studied. Knowledge of the relationship among the plant characters is useful while selecting traits for improvement.

The correlation coefficient among quantitative characters was computed for the year 2015 and 2016 (Table 3).

[1]Senior Scientist

Table 1. Meteorological data of Shajapur during growing period of soybean

Month	2015					Month	2016				
	Temperature (°C)		Humidity (%)		Rainfall (mm)		Temperature (°C)		Humidity (%)		Rainfall (mm)
	Max.	Min.	Max.	Min.			Max.	Min.	Max.	Min.	
June 15	44.6	21.5	98	71	98	June 16	46.6	23.1	90	51	125
July 15	40.7	22.0	98	97	98	July 16	37.4	23.2	98	67	459
Aug. 15	33.6	22.0	98	97	98	Aug. 16	33.0	21.6	98	61	424
Sept. 15	37.0	19.4	90	45	90	Sept. 16	35.2	21.2	90	39	82
Octo. 15	37.2	19.4	72	27	72	Octo. 16	35.5	14.1	88	25	-
Total					1315						1090

Table 2. Mean sum of squares of sixty-four genotypes of soybean for seven quantitative traits

Source	Degree of freedom.	Days of maturity	Plant height (cm)	Branches (No/plant)	Pods (No/plant)	Seed index	Oil content (%)	Seed yield (g/plant)
Genotypes	63	80.6[xx]	498.36[xx]	2.71[xx]	867.40[xx]	10.23[xx]	6.17[xx]	101.37[xx]
Years	1	18.6	172.61	12.37[xx]	157.60	12.27[xx]	4.17[xx]	134.38[xx]

Table 3. Correlation coefficients of sixty-four soybean genotypes among quantitative traits evaluated during 2015 and 2016

Traits	Days of maturity	Plant height (cm)	Branches (No/plant)	Pods (No/plant)	Seed index	Oil content (%)	Days of maturity	Plant height (cm)	Branches (No/plant)	Pods (No/plant)	Seed index	Oil content (%)
				2015						2016		
Plant height (cm)	0.98	`					0.41**					
Branches (No/plant)	0.45**	0.08					0.69**	0.17*				
Pods (No/plant)	0.14	0.14	0.36**				0.48**	0.14	0.59**			
Seed index	-0.018	-0.13	-0.22**	0.12			-0.11**	-0.20*	-0.28**	0.11		
Oil content (%)	0.11	-0.28**	-0.24**	0.01	0.54**		-0.41**		-0.17*	0.03	0.61**	
Seed yield (g/plant)	0.18**	0.11	0.19*	0.89**	0.48**	0.19ˣ	0.44**	0.11	0.46**	0.77**	0.49**	0.24**

*Significant at the 0.05% probability; **Significant at the 0.01% probability*

Results showed that seed yield per plant had significant and positive correlation with all traits except plant height, which had positive but non-significant relationship.

The high positive correlations (r = 0.89** and 0.77**) observed were between seed yield and number of pods per plant, followed by 100 seed weight, number of branches per plant, days to maturity and oil content during both the years. The significant and positive correlation between oil content and seed index (r= 0.54** and 0.61**), while significant negative association between oil content and plant height (r= -0.28**) and number of branches per plant (- 0.24** and - 0.17**) were observed during both the years (Table 3 and 4). Days to maturity revealed significantly positive association with number of branches per plant (0.45** and 0.69**) during both the years.

Number of branches per plant as well revealed significantly positive correlations with pods per plant (0.36** and 0.59**) for both the years. Jyoti and Tyagi (2005) revealed significant and positive correlation of seed yield per plant with 100 seed weight. Lu *et al*. (2005) also reported positive association of seed yield to maturity, number of pods per plant and 100 seed weight. Faisal *et al.* (2007) suggested that the information as above is useful in breeding programmes.

The present study showed that the genotypes under consideration showed significant genetic variation in different traits The results revealed that days to maturity, number of pods per plant and number of branches per plant correlated significantly with seed yield and could effectively be utilized in breeding programmes to develop improved soybean varieties.

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Effect of Application of Fungicides and Bioagents on Nodulation, Growth and Yield of Soybean (*Glycine max* L. Merrill)

RINI LABANYA[1]*, NARENDRA KUMAR*[2] and MAHENDRA SINGH**[3]
*Department of Soil Science, G. B. Pant University of Agriculture and Technology, Pantnagar 263 145, Uttarakhand
**Department of Soil Science and Agricultural Chemistry, Bihar Agriculture University, Sabour, Bhagalpur 813 210, Bihar
E mail: rinilabanya@gmail.com

Nodulation and nitrogen fixation by symbiotic bacteria in association with legume crops play a crucial role in supplying and maintaining nitrogen cycle in agricultural systems. Like other legume crops, soybean also does not need additional nitrogen fertilization in the presence of effective homologus strains of *Bradyrhizobia* in soil. The symbiotic relationship between soybean and *Bradyrhizobium* is a well-organized system and it goes through many steps, which begins at the root surface of soybean and resulting in the formation of nitrogen fixing nodule (Vincent, 1980). The host legume plant acts as a source of carbohydrate substrate (source of energy), and in exchange the bacteria reduce atmospheric nitrogen to plant in available form which is transported to plant tissues for succeeding steps of protein synthesis. Efficiency of the symbiotic nitrogen fixation is mainly dependent on the mutual compatibility of both the partners, and is also affected by a number of environmental factors (Vincent, 1980)**.** Seed treatment through fungicides has become a broadly accepted practice as it acts as a cost effective agent against seed and soil-borne pathogens. But the toxicity of most of the fungicides to *Bradyrhizobia* has often been unnoticed. Seed dressing through fungicides, which are used to hasten the plant emergence are often affect the *Rhizobium* detrimentally, when they are applied as inoculants to legume seed. Some study reports little damage, which may reveal the considerable variation present within and in between different groups of *Rhizobium* according to their sensitivity to fungicides (Curley and Burton, 1975). Fungicide can affect nodulation, nitrogen fixation and growth of various legumes negatively. Fungicides tend to inhibit the population of soil fauna. But in general, the fact is that most of the chemicals which are used in crop field can be degraded by soil microorganisms. This particular pheno-

[1]*PhD Scholar;* [2]*Professor;* [3]*Assisstant Professor*

menon is termed as biodegradation. In general, most efficient fungicides have the most detrimental effect to *Rhizobium* (Aggarwal *et al.,* 1986)**.**

Similarly, soybean seeds are often treated with fungicides and bioagents to provide protection from soil-borne diseases. Efficient fungicides can also suppress the proliferation of *Rhizobium* in the rhizosphere soil (FAO, 1984). On the contrary, successful inoculation of *Rhizobium* to legume plants depends on many factors (Dowling and Broughton, 1986). So, the present investigation was carried to study the influence of applied commercial fungicides and bioagents on nodulation and yield of soybean.

A field experiment was conducted during *kharif* season of 2016 at Pantnagar to study the effect of selected fungicides and bioagents on nodulation, growth and yield of soybean variety PS 1347. The soil of the experimental site was silty clay loam in texture having pH 7.4, organic carbon 0.87 per cent, available nitrogen 192 kg per ha, available phosphorus 24.6 kg per ha and available potassium 160.16 kg per ha. The experiment was conducted in randomized block design with three replications in 5 m x 3.6 m plots. Soybean seed was sown @ 80 kg per ha with a spacing of 45 cm between rows, at 5 cm depth.

The crop was uniformly fertilized with a basal dose of nitrogen (urea), phosphorus (SSP) and potassium (MOP) at 20 (N), 60 (P_2O_5), 40 (K_2O) kg per ha, respectively at the time of sowing. Plant population was maintained to 40 plants per square meter area. Soybean seed was treated with different fungicides. Seed inoculation of *Bradyrhizobium japonicum* culture was done in all the treatments uniformly. There were fourteen treatments, namely control, Carbendazim @ 1.5 g per kg seed, Mancozeb @ 2.5 g per kg seed, Thiram @ 2.5 g per kg seed, Captan @ 2.0 g per kg seed, *Pseudomonas fluorescens* @ 5 g per kg seed, *Trichoderma viride* @ 5 g per kg seed, Carbendazim + Mancozeb @ 3 g per kg seed, Carbendazim + Thiram @ 3 g per kg seed, Carbendazim + Captan @ 3 g per kg seed, Mancozeb + Thiram @ 4 g per kg seed, Mancozeb + Captan @ 4 g per kg seed, Thiram + Captan @ 4 g per kg seed and *Pseudomonas fluorescens* + *Trichoderma viride* @ 5 g per kg seed.

Observations for different growth parameters were taken at 50 per cent flowering stage and at harvest of crop. Three random plants from each plot were carefully uprooted from the side rows without damaging nodules. Nodules from the washed roots of these plants were detached and counted manually. After counting, the nodules were oven dried in hot air oven at 70 $^{\circ}$C for 48 hours till constant weight, which was recorded.

After threshing and proper cleaning, the grain yield of individual plot was recorded with single pan balance and converted into kg per ha. Straw yield was recorded by subtracting the grain yield from the total biological yield and reported in kg per ha.
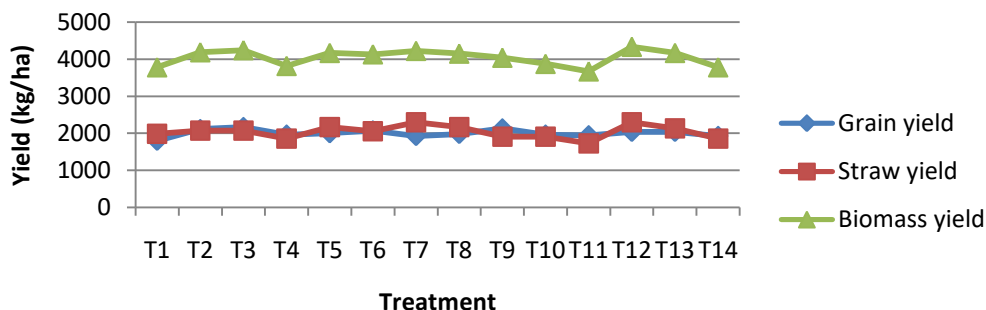
Effect on nodule number: Application of fungicides and bioagents had significant effect on the number of nodules in soybean *var.* PS 1347 at 50 per cent flowering stage. Although, all the
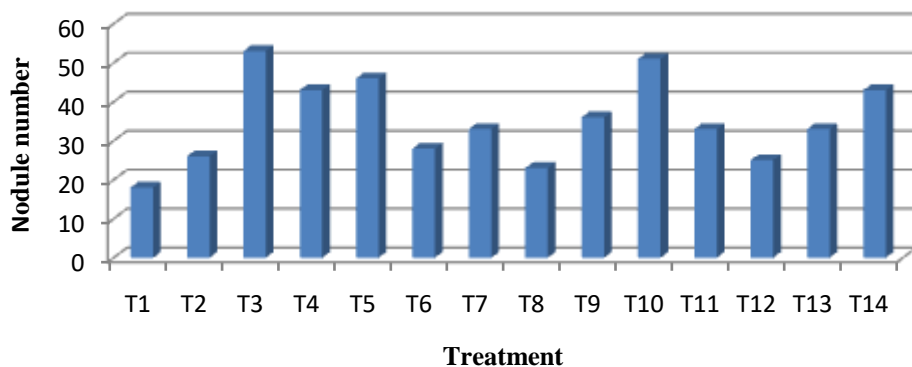
Fig. 1 Effect of fungicides and bioagents on nodule number
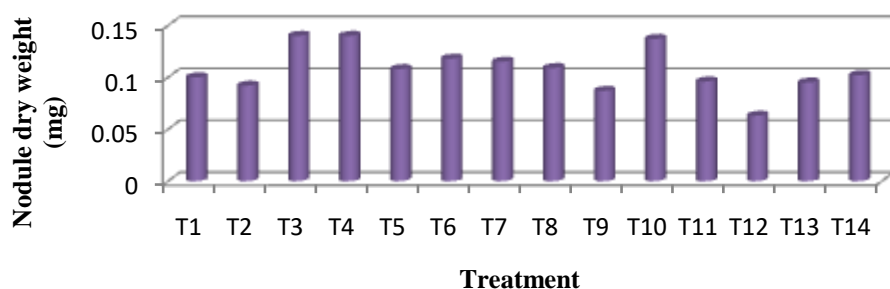
Fig. 2 Effect of fungicides and bioagents on nodule dry weight (mg)

Fig. 3 Effect of fungicides and bioagents grain, straw and biomass yield (kg/ha)

T1 – Control, T2 - Carbendazim @ 1.5 g/kg seed, T3 - Mancozeb @ 2.5 g/kg seed, T4 - Thiram @ 2.5 g/kg seed, T5 - Captan @ 2.0 g/kg seed, T6 - Pseudomonas fluorescens @ 5 g/kg seed, T7 - Trichoderma viride @ 5 g/kg seed, T8 - Carbendazim + Mancozeb @ 3 g/kg seed, T9 - Carbendazim + Thiram @ 3 g/kg seed, T10 - Carbendazim + Captan @ 3 g/kg seed, T11 - Mancozeb + Thiram @ 4 g/kg seed, T12 - Mancozeb + Captan @ 4 g/kg seed, T13 - Thiram + Captan @ 4 g/kg seed and T14 - Pseudomonas fluorescens + Trichoderma viride @ 5 g/kg seed.

treatments led to numerically higher number of nodules, Mancozeb (53/plant), Thiram (43 /plant), Captan (46 /plant), *Pseudomonas fluorescens* (38 /plant), Carbendazim + Thiram (36 /plant), Carbendazim + Captan (51 /plant) and combined application of *Pseudomonas fluorescens + Trichoderma viride* (43 /plant) were significantly superior over control treatment (18 /plant) (Fig.1). Application of Carbendazim + Mancozeb gave minimum number (23/plant) of nodules.

The increase in the number of nodules in soybean with the use of fungicides might be due to suppression of soil borne pathogenic fungi which resulted in the reduction of competition among microorganisms in the rhizosphere soil for nutrients, space *etc.* and it might have favoured the growth of nodulating bacteria in rhizosphere which synthesized more number of nodules. Such effects of fungicides on nodulating bacteria have been reported by Bikrol *et al.* (2005) in soybean. These findings are in agreement with those of Ehteshamul Haque and Ghaffar (1995), Siddiqui *et al.* (1998) and Gupta *et al.* (1985), who reported that application of Thiram along with inoculation proved to enhance the nodulation ability of legume crops.

Nodule dry weight: Application of fungicides and bioagents on the nodule dry weight in soybean variety PS 1347 at 50 per cent flowering stage, did not show significant effect on the nodule dry weight (Table 1, Fig 2). However, most of the treatments with fungicides showed favorable effect on the nodule dry weight. The highest nodule dry weight of

0.140 mg per plant was supported by Mancozeb and Thiram each. However, the use of Carbendazim, Carbendazim + Thiram, Mancozeb + Thiram, Thiram + Captan, and Mancozeb + Captan registered less nodule dry weight than control treatment.

The reduction in nodule dry weight with the use of Carbendazim, Carbendazim + Thiram, Mancozeb + Thiram, Thiram + Captan and Mancozeb + Captan may be due to their phytotoxic effect depending on the chemical composition of the fungicide. Zilli *et al.* (2009) found that soybean seed treatment with combined application of Carbendazim and Thiram resulted in almost 50 per cent reduction in nodule dry weight of soybean. Hansen (1994) concluded that fungicides may inhibit nodulation by affecting cellulolytic and pectolytic enzyme production by the *Rhizobium*. These enzymes secreted by *Rhizobium* are essential for root hair penetration.

The favorable effect may be due to the fact that some fungicides may serve as source of carbon, nitrogen and sulphur, *etc.* to the soil microbes. Increase in nodulation in soybean plants can be attributed to decrease in the fungal population in soil due to application of fungicides and therefore minimized the negative effect of fungi on bacterial nodules in soybean (Abdel Kader *et al.*, 1986).

Biomass yield: The use of fungicides through seed treatment in soybean did not have significant effect on the biomass yield (Fig. 3). However, the biomass yield of soybean in all the fungicide treatments

was higher than control treatment except Mancozeb + Thiram. The treatment having combined use of *Pseudomonas fluorescens* + *Trichoderma viride* produced similar biomass yield as that of control. The favorable effect on the biomass yield can be attributed to more availability of nutrients to plant due to reduced microbial competition for nutrients. These findings are closely correlated with the study of Soares *et al.* (2004), who also observed that fungicide treated plant show higher yield than non treated plant up to 27.3 per cent.

Grain yield: Application of fungicides and bioagents revealed that the use of fungicides did not show significant effect on the grain yield of soybean (Fig. 3). However, noticeable increases in grain yield ranging from 7.2 to 20.7 per cent over control by applications of treatments was observed. The highest grain yield of 2,167 kg per ha was obtained with the use of Mancozeb, whereas the lowest yield of 1,796 kg per ha was registered in control. Zaidi and Singh (2001) also observed that inoculation with *B. japonicum* strain SB-12 and *Pseudomonas fluorescens* gave significantly increased yield in comparison to control treatment.

Straw yield: The application of fungicides through seed treatment did not show significant effect on the straw yield (Table 1, Fig 3). Most of the treatments indicated higher straw yield than control. However, the treatments having Mancozeb + Thiram gave lower straw yield of 1,722 kg per ha, which was 13 per cent less than control treatment. The highest straw yield of 2,296 kg per ha was obtained from the plot treated with *Trichoderma viride* and Mancozeb + Captan.

Increase in the plant biomass, grain yield, straw yield and biomass yield of soybean can be attributed to the favourable effect of some fungicides by suppressing soil borne pathogens and reduction in microbial competition for nutrients, space and moisture. The reduction in these parameters by the use of some fungicides and bioagents may be due to the antagonistic effect on soil microflora and phytotoxic effects on soybean crop. These findings are corroborated with the study of Zaidi and Singh (2001).

The study showed that application of Mancozeb resulted in highest number of nodules (53/plant) and highest nodule dry weight (0.140g/plant). A statistically non-significant impact of fungicides and bioagents on yield parameters was recorded. In general, the study suggested that seed treatment/inoculation of fungicide and bioagents have salutary effect on nodulation, grain, straw and biological yield of soybean.

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Effect of Sowing Dates on Growth, Yield Attributes and Productivity of Soybean [*Glycine max* (L.) Merrill] Genotypes under Rainfed Conditions

SADHANA RAGHUWANSHI[1], M D VYAS[2] and P S MARAVI[3]
RAK Collage of Agriculture, (RVSKVV), Sehore 466 001, Madhya Pradesh, India
E mail: Sadhna.raghu91@gmail.com

Timely sowing is an important management aspect to optimize yield of soybean. Delayed sowing reduces the days to flowering as well as days to maturity and thereby decreasing the length of regulative and reproductive periods of development, which ultimately leads to lower yield. The growth and yield responses of soybean to sowing dates depend on the environment, genotype and production practices. The objective of this study was to find out optimum sowing date for soybean and identify suitable genotype of soybean under rainfed conditions.

A field experiment was conducted at Collage of Agriculture, Sehore (Madhya Pradesh) under All India Co-ordinate Research Project on Soybean during *kharif* 2015. Soil of the experimental site was medium black, having nearly neutral pH (7.7) electrical conductivity (497dS/cm), medium in available nitrogen (266 kg/ha) and phosphorus (11.40 kg/ha), and high in potassium (497 kg/ha). The experiment was laid out in split plot design with three replications. Treatments included two sowing dates with intervals of 20 days as main factors (25th June and 15th July) and five genotypes as sub-factor (JS 20-89, RVS 2002-4, JS 20-79, JS 20-53 and JS 97-52). Each plot contained 8 rows, each 6 m long and 45 cm apart. Crop management practices were followed as per recommendations. The data on plant height, number of branches, plant dry weight, number of root nodules, nodules dry weight, crop growth rate (CGR), relative growth rate (RGR), pods per plant, seeds per pods, seed yield, seed index, grain production efficiency, seed yield, straw yield and harvest index were recorded and analyzed statistically (Panse and Sukhatame, 1985).

As compared to 15th July sowing, sowing on 25th June recorded higher values of growth parameter, namely plant height, number of branches, plant dry weight, nodules, and nodules dry weight, CGR and RGR. However, significant differences were noted in plant height, CGR and RGR (Table 1). Dogra *et al*. (2014) also observed that the sowing in last week of June is appropriate time for soybean.

[1]Research Scholar, [2]Principal Scientist, [3]Field Extension Officer

Table 1. Effect of sowing date and genotypes on growth attributing characters

Treatment	Plant height (cm)	Branches (No/plant)	Plant dry weight (g)	Nodules (No/plant)	Nodule dry weight (mg/plant)	(CGR) (g/m^2/day)	(RGR) (g/g/day)
Sowing dates							
25th June	70.06	5.32	22.62	34.44	426.26	33.53	0.081
15th July	51.22	4.18	15.05	27.62	541.37	16.41	0.055
S Em (±)	2.44	0.29	6.17	4.39	21.66	2.39	0.003
CD (P=0.05)	**14.84**	**NS**	**NS**	**NS**	**NS**	**14.54**	**0.02**
Genotypes							
JS 20-89	60.81	4.80	19.36	39.78	216.83	25.98	0.067
RVS 2002-4	58.03	5.07	18.33	29.08	140.98	24.01	0.073
JS 20-79	68.11	4.60	18.51	29.51	119.71	24.30	0.069
JS 20-53	57.48	4.49	15.96	25.20	153.16	23.08	0.068
JS 97-52	58.75	4.77	21.52	31.58	175.66	27.50	0.066
S Em (±)	2.79	0.37	1.11	4.21	22.81	3.48	0.008
CD (P=0.05)	**NS**	**NS**	**3.63**	**NS**	**NS**	**NS**	**NS**

Table 2. Effect of sowing date and genotypes on yield attributing characters

Genotypes	Pods/plant(no)			Seeds (No/pod))			Seed yield (g//plant)			Seed index (g/100 seeds)		
	25th June	15th July	Mean	25th June	15th July	Mean	25th June	15th July	Mean	25th June	15th July	Mean
JS20-89	70.88	26.77	48.82	3.17	2.77	2.96	13.61	1.55	7.57	8.00	5.00	6.50
RVS 2002-4	59.68	24.55	42.10	3.40	2.77	3.08	14.78	2.00	8.38	9.17	4.00	6.58
JS 20-79	77.88	20.52	49.20	3.23	2.43	2.83	11.55	1.11	6.33	6.50	4.50	5.50
JS 20-53	63.33	19.77	41.55	3.03	2.60	2.81	7.27	0.77	4.02	9.17	5.00	7.08
JS 97-52	90.77	28.97	59.87	3.13	2.80	2.96	6.78	0.66	3.71	6.33	4.83	5.58
Mean	**72.50**	**24.18**		**3.19**	**2.67**		**10.79**	**1.21**		**7.83**	**4.66**	
	G	D	GXD	G	D	GXD	G	D	GXD	G	D	GXD
SEm (±)	3.07	3.27	4.34	0.06	0.09	0.09	0.60	0.40	0.86	0.27	0.35	0.38
CD (P = 0.05)	9.22	19.89	NS	NS	NS	NS	1.82	2.44	2.58	0.80	2.14	1.14

G=Genotype, D=Date of sowing

The soybean genotypes did not differ in above parameters significantly except in case of plant dry weight. The yield attributing parameters seeds per pod, seed yield per plant, pods per plant, seed index, grain production efficiency, grain and straw yield were higher in 25th June sowing as compared to 15th June sowing (Table 2 and 3). However, seeds per plant and harvest index did not show significant differences. Hari Ram *et al.* (2010) reported similar results. The unfavorable weather condition during crop season was adversely affected the yield attributes and yield of soybean.

Genotype RVS 2002-4 recorded

Table 3. Effect of sowing date and genotypes on yields, harvest index and grain production efficiency

Genotypes	Seed yield (kg/ha)			Straw yield (kg/ha)			Harvest index (%)			Grain Production Efficiency (kg/ha/day)		
	25th June	15th July	Mean	25th June	15th July	Mean	25th June	15th July	Mean	25th June	15th July	Mean
JS20-89	1282	486	887	2991	1273	2129	30.04	27.72	28.87	13.22	5.29	9.03
RVS 2002-4	1389	537	963	2764	1143	1949	33.42	32.04	32.72	12.84	5.29	9.82
JS 20-79	768	273	518	3398	1094	2245	18.41	19.97	19.19	6.51	2.58	5.04
JS 20-53	1078	379	726	2838	847	1842	27.52	31.08	31.08	9.54	4.01	7.45
JS 97-52	643	301	472	3555	898	2222	32.04	25.23	25.23	6.06	2.89	4.57
Mean	**1033**	**393**		**3106**	**1050**		**24.94**	**27.20**		**10.39**	**3.97**	
	G	D	GXD	G	D	GXD	G	D	GXD	G	D	GXD
SEm (±)	23	14	32	55	32	79	0.60	0.62	0.85	0.24	0.30	0.35
CD at 5%	**65**	**83**	**92**	**162**	**194**	**231**	**1.79**	**NS**	**2.50**	**0.71**	**1.82**	**1.04**

G=Genotype, D=Date of sowing

higher number of branches, CGR, RGR, seeds per pod, seed yield per plant, grain production efficiency and harvest index, which led to highest seed yield of this variety. Plant dry weight and pods per plant were higher in check genotype JS 97-52. Genotypes JS 20-89 and JS 20-79 recorded higher plant height and seed index, respectively. Genotype JS 2002-04 and JS 20-79 sown on 25th June recorded higher seed yield (963 kg/ha) and straw yield (2,245 kg/ha). The variation in growth and yield attributes with different genotypes was also noticed by Singh (2011), Dogra *et al*. (2014) and Kumar and Badiyala (2005).

The results suggested that sowing of soybean genotype RVS 2002-4 on 25th June is the most suitable combination to obtain higher yield.

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Performance of Soybean Genotypes under Varying Plant Densities

PREETIBALA MEENA[1], P S MARAVI[2] and M D VYAS[3]
RVSKVV-RAK College of Agriculture, Sehore, 466 001, Madhya Pradesh
E mail: vyasmd@rediffmail.com

Soybean [(*Glycine max* (L.) Merrill*)*] is known as the "Golden bean" of the 21st century. Though soybean is a legume crop, it is considered as an oilseed rather than a pulse. Soybean besides having a nutritive value is capable of fixing atmospheric nitrogen through symbiosis with *Bradyrhizobium japonicum* at the rate of 65-115 kg per ha per year (Alexander, 1977). It enriches soil to about 25-30 kg nitrogen after harvest. It builds up the soil fertility by fixing large amount of nitrogen and also through incorporation of foliage at maturity.

One of the most important reasons for low productivity is adoption of high seed rate which results in very high plant population in the farmer's field. Optimum number of plants per unit area is necessary to efficiently utilize the available production resources, such as water, nutrients, light, and CO_2. Maximum exploitation of these resources can be achieved when the plant population exerts maximum pressure on these resources culminating in higher productivity of crops. Varieties play a vital role in the production of grain yield.

Selection of proper varieties for a set of agro-climatic conditions is very important to achieve maximum potential, due to their different growth and development behavior.

The experiment was laid out under split plot design under AICRP on Soybean during *kharif* 2012. The experiment consisted of 12 treatment combinations encompassing of three plant densities (0.30, 0.45 and 0.60 m/ha) as main plot and four genotypes (JS 20-29, NRC 86, JS 20-34 and JS 93-05) as sub-plot with three replications. The soil of the experimental field was medium black (Vertisols), medium in available nitrogen, phosphorus and potassium with pH 7.3. For raising the crop, the recommended package of practices was adopted. The crop was sown on 9th July 2012 at a row to row distance of 45 cm. Observations on growth parameters (plant height, branches/plant, dry weight/plant and root length) and yield attributes (pods/plant, seeds/pod and seed index) were recorded on five randomly selected plants from each treatment. The seed and straw (biological yield - seed yield)

[1]*Research Scholar;* [2]*Field Extension Officer;* [3]*Principal Scientist*

yields were recorded at harvest and expressed in kg per ha. Harvest index was worked out and CGR and RGR for 50-70 days were calculated using following formulae.

CGR $\quad = \quad W_2-W_1/P(t_2-t_1)$
(g/m²/day)

RGR $\quad = \quad \log_e W_2-\log_e W_1/(t_2-t_1)$
(g/g/day)

Where, W_2 and W_1 are dry matter of preceding and succeeding stages and t_1 and t_2 represent the time period at which W_1 and W_2 were recorded. P is the ground area.

Grain production efficiency (kg/ha/day) $\quad = \quad$ Total production/total duration of crop

Plant density of 0.30 million per ha gave highest number of branches and dry weight per plant. Plant density had significant impact on crop growth rate (CGR) between 50-70 days interval. Plant density of 0.60 million per ha recorded significantly highest CGR. The RGR, plant height and root length did not differ significantly due to plant density. Plant density of 0.30 million per ha had significant effect on yield attributes, namely number of pods per plant (36.23), but number of seeds per pod, seed index, harvest index and straw yield did not differ significantly due to plant density. Plant density of 0.60 million per ha gave significantly highest seed yield (1,967 kg/ha) and grain production efficiency (21.24 kg/ha/day) than 0.30 and was at par with 0.45 million per ha (Table 1). In this line, Deshmukh *et al.* (2006), Shamsi and Kobraee (2009) and Singh (2011) reported similar result.

The performance of genotypes revealed that these differed significantly

Table 1. Growth parameters of soybean genotypes influenced by plant densities

Treatments	Plant height (cm)	Branches (No/plant)	Dry weight (g/plant)	Root length (cm/plant)	CGR 50-70 days interval (g/m2/day)	RGR 50-70 days interval (g/g/day
Genotypes						
JS 20-29	59.67	3.77	13.89	18.04	16.64	0.036
NRC 86	53.53	3.38	13.53	18.74	13.92	0.038
JS 20-34	33.51	5.62	9.43	17.82	8.96	0.028
JS 93-05	53.11	3.87	11.97	19.27	10.94	0.037
SEm (±)	1.03	0.17	0.53	0.53	1.87	0.004
CD (P= 0.05)	**3.07**	**0.52**	**1.57**	**NS**	**5.57**	**NS**
Plant Density level(million/ha)						
0.30	50.02	4.41	14.90	19.01	7.19	0.030
0.45	50.62	4.26	11.13	18.47	14.64	0.038
0.60	53.02	3.81	10.59	17.92	16.02	0.037
SEm (±)	0.80	0.05	0.92	0.27	0.89	0.002
CD (P= 0.05)	**NS**	**0.19**	**3.61**	**NS**	**3.51**	**NS**

Table 2. Yield and yield attributing parameters of soybean genotypes influenced by plant densities

Treatments	Pods (No/plant)	Seeds (No/pod)	Seed index (g/100 seeds)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Grain production efficiency (kg/ha/day)
Genotypes							
JS 20-29	35.41	2.11	10.44	1886	2865	39.89	20.07
NRC 86	36.06	2.31	9.28	1807	2421	42.84	18.82
JS 20-34	30.92	2.87	12.28	2044	1353	60.28	23.23
JS 93-05	28.82	2.82	9.89	1877	2523	42.93	19.96
SEm (±)	0.81	0.06	0.09	38	100	1.41	0.44
CD at 5%	**2.42**	**0.14**	**0.26**	**114**	**297**	**4.19**	**1.30**
Plant Density level(million/ha)							
0.3	36.23	2.58	10.58	1842	2164	46.93	19.63
0.45	32.17	2.48	10.16	1901	2325	46.39	20.49
0.6	30.00	2.53	10.67	1967	2382	46.13	21.24
SEm (±)	0.64	0.06	0.12	17	86	1.06	0.23
CD (P= 0.05)	**2.50**	**NS**	**NS**	**38**	**NS**	**NS**	**0.92**

Table 3. Interaction between genotypes and plant densities in seed yield kg/ha

Plant density (m/ha)	Varieties				
	JS 20-29	NRC 86	JS 20-34	JS 93-05	Mean
0.3	1863	1877	1872	1758	**1842**
0.45	1872	1818	2049	1863	**1901**
0.6	1924	1726	2211	2009	**1967**
Mean	**1886**	**1807**	**2044**	**1877**	
	Genotypes(G)	*Plant density (P)*	*GXP*		
SEm (±)	38	17	66		
CD (P= 0.05)	**114**	**68**	**197**		

in growth parameters, namely plant height, branches per plant and dry weight per plant, and dry weight per plant, while root length per plant remained uninfluenced. Genotype response on physiological parameters like crop growth rate (CGR) varied significantly in different genotypes. The CGR recorded for JS 20-29 was significantly higher than JS 93-05, JS 20-34 and at par with NRC 86. Relative growth rate (RGR) did not differ significantly due to genotypes. The response of genotypes on yield attributing traits namely pods per plant, seeds per pod, seed index and harvest index were found to be significant. Seed and straw yield were significantly influenced by genotypes. The highest seed yield (2,044 kg/ha) was obtained with genotype JS 20-34, whereas highest straw yield (2,865 kg/ha) was obtained with genotype JS 20-29. Harvest

index and grain production efficiency were influenced significantly due to genotypes. Genotype JS 20-34 produced highest harvest index (60.28 %) and grain production efficiency (23.23 kg/ha/day) than other genotypes (Table 2). Variation in grain in different soybean genotypes was also reported by Sharma and Sharma (1993), Abbas *et al*. (1994) and Tremblay *et al*. (2002).

The interaction between genotype and plant density was significant for seed yield. The highest seed yield was obtained with combination of genotype JS 20-34 and plant density 0.6 million per ha (Table 3).

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Sharma M P Dr; Principal Scientist (Microbiology), ICAR-Indian Institute of Soybean Research, Indore 452 001, Madhya Pradesh,

Sharma A N Dr; Principal Scientist (Entomology), ICAR-Indian Institute of Soybean Research, ICAR- Indore 452 001, Madhya Pradesh,

Sharma R A Dr; Ex- Dean, College of Agriculture, Indore and Director, Department of Agriculture, Mandsaur University, Mandsaur 458 001, Madhya Pradesh[M.P.]

Sharma Purushottam Dr; Senior Scientist (Agricultural Economics), ICAR-Indian Institute of Soybean Research, Indore 452 001, Madhya Pradesh.

Rajput A M Dr; Ex-Dean, College of Agriculture (RVSKVV), Indore 452 001, Madhya Pradesh

Singh Guriqbal Dr; Senior Agronomist (Pulses), Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana 141 004, Punjab

Sridhar Y Dr; Senior Scientist (Entomology), ICAR-Directorate of Rice Research, Hyderabad, Telengana

Tayade Arjun Dr; Senior Scientist (Agronomy), Sugarcane Breeding Institute, Coimbatore 641 007, Tamil Nadu

Vyas M D Dr; Professor (Agronomy), RAK College of Agriculture, Sehore, Madhya Pradesh

Wanjari R H Dr; Senior Scientist (Agronomy), ICAR-Indian Institute of Soil Scince, Bhopal 462 023, Madhya Pradesh

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References: References should be cited by authors and year: Ansari (2000) or Ansari and Sharma (2000) in the text. References should be arranged in alphabetical order and listed at the end of the paper as follows:

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OBITUARY

We the members of the Society of Soybean Research and Development are deeply grieved on the sad demise of Prof. Yeshwant Laxman Nene on Monday, the January 15, 2018 at the age of 81. Prof. Nene, had been the guiding force of science. With his demise the country has lost a great intellectual and well-wisher of science. It is an irreparable loss to the scientific community and his family.

Prof. Nene was born in Gwalior, India on 24 November 1936. Educated at Janakganj Middle School, Gwalior, 1944-49; V.C. High School, Gwalior, 1949-51; College of Agriculture, Gwalior, 1951-55; College of Agriculture, Kanpur, 1955-57; University of Illinois, Champaign-Urbana, Illinois, USA, 1957-60; B.Sc (Ag.), 1955; M.Sc (Ag.), 1957; Ph.D. 1960.

He was the Professor & Head of Plant Pathology, GB Pant University of Agriculture and Technology (GBPUA&T), Pantnagar, 1960-74; Principal Plant Pathologist (Pulses), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, 1974-80; Leader (Pulses) ICRISAT, 1980-86; Director (Legumes), ICRISAT, 1986-89; Deputy Director General, ICRISAT, 1989-96. He also provided valuable guidance to soybean research as a Chairman of Research Advisory Committee of ICAR-Indian Institute of Soybean Research, Indore during 1998-2001.

He was the Chairman, Asian Agri-History Foundation, Secunderabad. Published in English 8 Ancient Agricultural Classics and publishing a quarterly journal, Asian Agri-History since 1997.

He had been awarded with International Rice Year, 1966; Prize (FAO), 1967; D.Sc. (h.c.), GBPUA&T, 1991; O. P. Bhasin Award, 1991; Gold Medal, Indian Society of Pulses Research and Development, 2001. Lifetime achievement awards by several organizations including Indian Phytopathological Society.

He was the fellow of American Phytopathological Society; Indian Phytopathological Society; Indian Virological Society; Indian Society of Mycology and Plant Pathology; Indian Society of Plant Pathologists; National Academy of Agricultural Sciences. He was also the President of Indian Phytopathological Society in 1986.

Research Areas: Plant Pathology; History of Agriculture. Publications: over 480.

He had a peaceful end of a long, fruitful and highly satisfying life.

On behalf of the Society, we express our deep condolence to bereaved family. Let us all, pray to God that his soul may rest in peace. May God give his family to bear the loss.