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Research Paper

Effect of integrated nutrient management on seed yield, quality and nutrient uptake of soybean (*Glycine max*) under mid hill conditions of Himachal Pradesh

RACHNA RANA[1] AND D. BADIYALA[2]

Chaudhary Sarvan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh 176 062

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) season of 2010 and 2011 at Palampur, Himachal Pradesh to study the effect of organic manures and fertility levels on seed yield, quality and nutrient uptake of soybean [*Glycine max* (L.) Merr.) seed. The experiment, consisted of 12 treatment combinations of 4 organic manures, viz. control, farmyard manure (FYM) @ 5 t/ha, vermicompost @ 2.5 t/ha and FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha, and 3 fertility levels, viz. control, 50% recommended dose of fertilizer (RDF) and 100% RDF. The use of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha resulted in significantly the highest seed (1.82 t/ha) and straw yield (3.25 t/ ha) as compared to application of vermicompost @ 2.5 t/ha and FYM @ 5 t/ha alone. The 100% RDF resulted in significantly the highest seed (1.59 t/ha) and straw yield (3.14 t/ha) as compared to 50% RDF and the control. Significantly the highest number of pods/plant and grains/pod were recorded with the application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha compared to sole application of vermicompost @ 2.5 t/ha, FYM @ 5 t/ha and the control. Application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha recorded significantly highest oil content (18.9%), oil yield (343.9 kg/ha), available nutrients and NPK uptake. Use of 100% RDF also recorded significantly highest oil content (19.7%), oil yield (310.2 kg/ha) and NPK uptake followed by 50% RDF and control.

Key words **:** Economics, Farmyard manure, Fertility levels, Nutrient uptake, Seed yield, Soybean, Vermicompost

Soybean has emerged as one of the major oilseed crops in India, producing 12.28 million tonnes from 10.18 m ha area with the productivity of 1207 kg/ha (DAC, GoI, 2012), whereas in Himachal Pradesh its productivity is very low. It is considered as a cash crop and is more important because of its yield potential and nutritionally ideal complement to the cereal-based Indian diet as its seed. It is a rich source of protein (40%) and oil (20%). Soybean helps in maintaining soil fertility and symbiotically, fixes 61–337 kg N/ha (Salvagiotti *et al.,* 2008). The farmers in Himachal Pradesh grow soybean in marginally poor soils without using fertilizers. Cultivation of soybean in Himachal Pradesh on large scale can be extremely useful, attractive and an economic venture. The low productivity (<1.0 t/ha) of the crop is primarily due to uncontrolled climatic factors like erratic rainfall, low organic matter in the soil due to imbalanced and less use of major nutrients under continuous cropping systems.

Imbalance use of fertilizers has been one of the key factors in declining the crop productivity and depleting the soil fertility. Optimum nutrition is required for getting the maximum seed yield and quality. Organic manures are good complimentary sources of nutrients and improve the efficiency of the applied mineral nutrients on one hand and improve physical and biological properties of soil on the other hand (Chaudhary *et al*., 2004). Therefore, any nutrient-management practice that can improve organic matter status of soil is important. A judicious and combined use of organic and inorganic sources of plant nutrients is essential to maintain soil health and to augment the efficiency of nutrients. Additionally, such integration of organic and inorganic nutrients plays an important role in economizing the use of fertilizers under increasing cost, which is restricting their use to an optimum level. Hence present experiment was carried out to find out the effect of organic manures and fertility levels on seed yield, quality and NPK uptake in soybean.

MATERIALS AND METHODS

The field experiment was carried out during the rainy

[1]Ph.D. Scholar (Agronomy) Department of Agronomy, Forage & Grassland Management, [2]Head, Department of Agronomy, Forage & Grassland management, CSKHPKV, Palampur - 176 062 (HP)

season (June to October) of 2010 and 2011 at the experimental farm of, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur at (32°6 N and 76°3 E with an elevation of 1290.8 m above mean sea level). The experiment was conducted on silty clay loam soil having pH 5.5, organic C (0.78%), available N (333 kg/ha), available P (23 kg/ha) and available K (250 kg/ha). The treatments consisted of 4 levels of organic manures, viz. control, FYM @ 5 t/ha, vermicompost @ 2.5 t/ha and FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha and 3 fertility levels of recommended dose of fertilizers (RDF) (20–25.8–33.2 kg N-P-K/ha), viz. control, 50% RDF and 100% RDF. The experiment was laid out in a factorial randomized block design with 3 replications. The nutrient sources, viz. FYM (0.57% N, 0.32 % P, 0.40% K), vermicompost (1.6 % N, 0.8% P, 1.1% K) as well as required quantity of N, P and K in the form of urea, single super phosphate and muriate of potash, respectively, were applied as per the treatments at the time of sowing. Soybean variety 'Himso 1588' was sown @ 75 kg/ha seed rate at an inter-row spacing of 45 cm on 15 June 2010 and 20 June 2011 respectively, at the same location. Since there was enough rainfall during the crop season, irrigation was not required. The weedicide Alachlor @ 3 litres/ha was sprayed as pre-emergence herbicide to keep the weeds under control. In addition to chemical weed control, 1 manual weeding was carried out 30 days after sowing (DAS). Five random plants/plot were selected in the net plot area and tagged for recording growth and yield attributes. Leaf-area index was calculated by the linear equation suggested by Wiersma and Bailey (1975) as reproduced below:

$$\text{Leaf-area} = 0.411 + 2.008\ \text{LW (terminal leaflet)}$$

$$\text{LAI} = \frac{\text{Leaf area/plant}}{\text{Land area/plant}}$$

The crop was manually harvested, threshed and seed yield was recorded. The soil samples were collected from each plot after harvesting of soybean at 0–15 cm depth and analysed using standard procedures. The total N content of plants was analysed by Micro-kjeldahl method, P by Olsen's method and K by flame photometer method. Total N values thus obtained were multiplied with a factor of 6.25 to obtain the protein content. The estimation of oil content was determined by Soxhlet extraction method following standard procedures as per Association of Official Analytical Chemists (AOAC, 1970). The total oil yield per hectare was also worked out by multiplying seed yield (kg/ha) with the oil % in seed and divided by 100. The net returns and net returns per rupee invested were computed using the prevailing market rates and prices for inputs and seed of soybean. Since data followed the homogeneity test, pooling was done over the seasons and mean data are given.

RESULTS AND DISCUSSION

Growth parameters

Application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha resulted significantly taller plants. However, the plant height in the plots treated with vermicompost @ 2.5 t/ha and FYM @ 5 t/ha was similar. Significantly lower plant height was recorded in the control plots where no organic manure was used (Table 1). The effect of FYM and vermicompost in combination was more pronounced with the advancement of crop growth, indicating better effect on plant height of soybean. This may be owing to continuous availability of nutrients to soybean plants because of their slow release of nutrients from FYM during the crop season. Moreover, vermicompost added a good amount of NPK in the soil, besides supplying other essential macro-and micronutrients. Recommended dose of fertilizer (RDF) resulted in significantly taller plants than 50% RDF and control plots.

Higher leaf-area index (LAI) and dry matter accumulation was recorded with FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha followed by vermicompost @ 2.5 t/ha and FYM @ 5 t/ha alone. The control plots recorded significantly lower leaf-area index (Table 1). The LAI is a resultant of leafy growth of the plant. In the present study, better nutrition of the plants owing to FYM and vermicompost application might have resulted in improvement in leaf size, which might have led to significant improvement in LAI with different levels of FYM and vermicompost. The RDF resulted in significantly higher LAI than 50% RDF and the control plots. In association with soil microorganisms, organic manures are known to help in synthesis of certain phytohormones and vitamins which promote the growth and development of crops. The slow release of nutrients associated with vermicompost might have resulted in higher concentration of nutrients in plant cells resulting in higher dry-matter accumulation. The highest dry-matter accumulation was recorded with 100% RDF at harvesting stage followed by 50% RDF. The leaves of the plant are normally its main organs of photosynthesis. So higher leaf area-index coupled with vigorous vegetative growth at higher fertility levels might be responsible for higher dry-matter production.

Yield attributes

Significantly higher number of pods/plant and grains/pod were recorded with combined application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha followed by application of vermicompost @ 2.5 t/ha and FYM @ 5 t/ha (Table 1). Since the plants were healthy under the treatment hav-

ing combination of FYM and vermicompost, they produced more dry matter which was then reflected in their yield attributes. The minimum number of pods/ plant and grains/pod were recorded in the control plots. Organic manures did not influence the 1,000-seed weight significantly, being a varietal character, is less sensitive to management levels. Application of fertility levels increased the pods/plant and grains/pod significantly, which further increased successively and significantly with the increasing level of fertilizer NPK up to 100% RDF. Suryawanshi *et al.,* (2006) also reported higher number of pods/plant with 100% NPK application. Test weight increased with increasing levels of fertilizer from 0 to 100% RDF and application of manures over the control, but the differences were non-significant.

Yield

Application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha resulted in significantly highest seed and straw yield followed by vermicompost @ 2.5 t/ha and FYM @ 5 t/ha alone. In case of straw yield, the later two treatments were found statistically alike. The increase in the seed yield was 42.6% during 2010 and 41.9% during 2011 (Table 1). Same trend was found when data were pooled. This might be attributed to rapid mineralization of N and steady supply of N from FYM and vermicompost, which might have met the N requirement of crop at critical stages. Further FYM acts as nutrient reservoir and upon decomposition produces organic acids, thereby absorbed ions are released slowly during entire growth period leading to improvement in different yield components thereby resulting in higher seed yield (Maheshbabu *et al.,* 2008). The 100% RDF resulted in significantly higher seed yield followed by 50% RDF. Increase in grain yield with 100% RDF and 50% RDF was 23.7% and 16.4% during 2010 and 25.3% and 17.9% during 2011 respectively, over the control. Similar trend was found when data were pooled (Table 1). Sawarkar *et al.* (2010) also reported similar results. On an average, yield increase was more when fertilizer level increased from 0 to 50% RDF compared to next increase from 50 to 100% RDF.

Economics

Significantly higher net returns (₹64.2 × 10^3/ha and net returns per rupee invested (₹2.09) were also obtained from the crop received FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha followed of vermicompost @ 2.5 t/ha and FYM @ 5 t/ha alone. The lowest net returns and net returns per rupee invested were recorded in the control plots. High cost of FYM and vermicompost, resulted in increased cost of cultivation without too much increase in net returns. Hence, this overall effect of FYM and vermicompost re-

Table 1. Effect of organic manures and fertility levels on yield attributes, seed yield and economic returns of soybean (Pooled data of 2 years)

Treatment	Plant height at harvest (cm)	LAI at 60 DAS	Plant dry matter at harvesting (g/m²)	Pods/ plant	Grains/ pod	1,000-seed weight (g)	Seed yield(t/ha)			Straw yield (t/ha)	Cost of cultivation (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Net returns/ rupee invested
							2010-	2011	Pooled				
Organic manures													
Control	62.8	4.5	425.6	43.0	2.13	130.4	1.04	1.06	1.05	2.22	26.9	28.4	1.05
FYM @ 5 t/ha	69.6	5.1	462.4	50.5	2.33	131.1	1.24	1.29	1.27	2.76	28.9	37.8	1.29
Vermicompost @ 2.5 t/ha	70.7	5.3	477.9	55.6	2.40	132.0	1.49	1.51	1.50	3.08	31.9	47.4	1.47
FYM @ 2.5 t/ha + Vermicompost @ 1.25 t/ha)	76.0	5.7	509.0	63.1	2.56	133.2	1.81	1.82	1.82	3.25	30.5	64.2	2.09
SEm±	1.6	0.1	10.0	1.1	0.05	1.0	0.02	0.03	0.03	0.06		1.2	0.04
CD (P=0.05)	4.8	0.4	29.8	3.3	0.15	NS	0.07	0.09	0.09	0.19		3.5	0.12
Fertility levels													
Control	62.6	4.5	418.7	43.1	2.17	130.5	1.19	1.19	1.19	2.45	28.1	35.3	1.24
50 % RDF	71.1	5.2	470.9	54.2	2.33	131.6	1.43	1.46	1.45	2.89	29.6	46.1	1.54
100% RDF	75.7	5.8	516.8	61.9	2.58	132.9	1.56	1.61	1.59	3.14	31.1	51.8	1.65
SEm±	1.4	0.1	8.7	0.9	0.04	1.9	0.02	0.03	0.03	0.06		1.0	0.03
CD (P=0.05)	4.1	0.3	25.8	2.8	0.13	NS	0.06	0.08	0.07	0.17		3.1	0.10

FYM, farmyard manure; RDF, recommended dose of fertilizer; LAI-leaf area index; DAS, days after sowing
Cost of seed, ₹47/kg, FYM, ₹400/t, vermicompost, ₹2000/t, urea, ₹5.5/kg, single superphosphate ₹6.3/kg, muriate of potash, ₹5.1/kg, straw, ₹300/q

flected in net returns per rupee invested. The 100% RDF recorded significantly higher net returns and net returns per rupee invested among the nutrient levels. The results confirm the findings of Joshi and Billore (2004).

Soil fertility

Application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha resulted in significantly higher soil organic C (0.97%), soil available N (359.6 kg/ha), available P (23.0 kg/ha) and available K (262.3 kg/ha) followed by vermicompost @ 2.5 t/ha and FYM @ 5 t/ha alone. Application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha and vermicompost @ 2.5 t/ha was found statistically similar in respect of P and K availability. The control plots recorded significantly low content of available N, P and K. The 100% RDF resulted in increased organic C, availability of N, P and K followed by 50% RDF and control. The increase in soil organic C from its initial value in manured plots compared to the control may be due to the fact that in manured plots microbial population might have increased, and as a result soil aggregation and decomposition have resulted in increased organic content in soil. The higher fixation of N by soybean with the incorporation of organic manures may be due to release of higher amounts of nitrogenous compounds by root nodules at early stages of growth and their subsequent decomposition at later stages. Farmyard manure increases the absorptive power of the soil for cations and anions particularly phosphates and nitrates. These absorbed ions are released slowly for the benefit of crop during the entire growth period and availability of these nutrients by plants is increased. The increase in available P might be due to the organic acids, which were released during microbial decomposition of organic matter which helped in the solubility of native phosphates as a result of which the availability of P content increased. The higher availability of K in soil may be due to beneficial effect of organic manures on the reduction of K fixation, direct effect of addition of K through manures, higher cation-exchange capacity and exchangeable K. Similar beneficial effects of organics on increased availability of K compared to soils fertilized with chemical fertilizers were reported by Bullack *et al.,* (2002).

Nutrient uptake

Significantly higher uptake of N, P and K was recorded with the application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha followed by vermicompost @ 2.5 t/ha and FYM @ 5 t/ha alone treatments (Table 2). The increasing fertility levels up to 100% RDF resulted in higher N, P and K uptake than 50% RDF and the control plots. The uptake of nitrogen and phosphorus was more in vermicompost-treated plots than in FYM-treated plots, owing to better availability of phosphorus in crop root zone resulting from its solubilization caused by the organic acids, produced from decaying organic matter and also the increased uptake by the soybean roots due to their association with mycorrhizal filaments increasing the ascribing area of roots. The increase in N uptake might be attributed to enhanced activity of nitrogenase and nitrate reductase enzyme in the soil. Chaturvedi *et al.* (2010) also recorded the highest uptake of N, P and K with RDF + FYM in soybean.

Table 2. Nutrient availability (kg/ha), Nutrient uptake (kg/ha), protein content (%), oil content (%) and oil yield (kg/ha) of soybean as influenced by integrated nutrient management (Pooled data of 2 years)

Treatment	Organic carbon (%)	Available nutrients (kg/ha)			Nutrient uptake (kg/ha)			Protein content (%)	Oil content (%)	Oil yield (kg/ha)
		N	P	K	N	P	K			
Organic manures										
Control	0.88	326.9	20.1	239.0	156.6	15.9	41.6	38.3	17.2	180.5
FYM @ 5 t/ha	0.93	342.1	21.7	251.3	183.9	16.8	43.7	38.5	17.9	224.8
vermicompost @ 2.5 t/ha	0.94	349.2	21.8	256.6	208.6	17.1	44.9	39.0	18.3	275.1
FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha)	0.97	359.6	23.0	262.3	234.6	17.8	47.3	39.4	18.9	343.9
SEm±	0.01	2.8	0.6	3.1	3.9	0.2	0.5	0.6	0.2	5.5
CD (P=0.05)	0.03	8.2	1.7	8.9	11.4	0.6	1.5	NS	0.6	16.1
Fertility levels										
Control	0.88	325.6	20.4	239.6	143.8	15.9	40.1	37.9	16.5	199.9
50 % RDF	0.93	343.8	21.3	254.4	202.8	17.0	45.4	38.9	18.0	258.2
100% RDF	0.98	363.8	23.2	262.9	241.3	17.8	47.6	39.5	19.7	310.2
SEm±	0.01	2.4	0.5	2.7	3.3	0.2	0.4	0.5	0.2	4.8
CD (P=0.05)	0.03	7.1	1.5	7.8	9.8	0.5	1.3	NS	0.5	13.9

FYM, Farmyard manure, RDF, recommended dose of fertilizer

Table 3. Interaction effect of organic manures and fertility levels on seed yield (t/ha) of soybean

Organic manures (t/ha)	Fertility levels (kg/ha)		
	Control (F_0)	50% RDF (F_1)	100% RDF (F_2)
Control (M_0)	0.89	1.03	1.19
FYM @ 5 t/ha (M_1)	1.04	1.28	1.41
Vermicompost @ 2.5 t/ha (M_2)	1.28	1.53	1.67
FYM @ 2.5 t/ha + vermicompost @ 1.25t/ha (M_3)	1.56	1.88	1.98
SEm±	0.06		
CD (P=0.05)	0.18		

FYM, Farmyard manure; RDF, recommended dose of fertilizer

Quality

The protein content in soybean was not influenced significantly by different levels of organic manures and fertilizers. As N is a basic constituent of protein and with the increase in rate of N application from organic manures and inorganic fertilizers, the N availability increased which resulted in enhanced protein content in seeds. Oil content and oil yield were significantly influenced by organic manures (Table 2). Application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha recorded significantly higher oil content (%) which was statistically similar with vermicompost @ 2.5 t/ha. Increase in oil content might be attributed to balanced nutrition and supply of these nutrients seems to be involved in an increased conversion of primary fatty acid metabolites to end products of fatty acid resulting in higher oil content (Hemantaranjan *et al.*, 2000). Lowest oil content and oil yield were recorded in control. Patil *et al.* (2008) also reported the maximum oil content under FYM application. Since oil yield is mainly the function of seed yield and their respective oil content in the seed, oil yield increased with increase in fertility levels up to recommended dose of fertilizers.

Interaction

The interaction between organic manures and inorganic fertilizers was also found to be significant with respect to seed yield of soybean (Table 3), where in treatment combination (M_3F_2) (1.98 t/ha) being at par with (M_3F_1) (1.88 t/ha) resulted in significantly higher seed yield than rest of the treatment combinations. Per cent increase in seed yield under treatment combination M_3F_2 and (M_3F_1) was 54.9% and 52.4%, respectively, over treatment combination (M_0F_0). The higher seed yield under treatment combination M_3F_2 and M_3F_1 might be owing to interactive effect of organic manures and fertilizer NPK. Organic manures helps to reduce leaching losses, denitrification, volatilization losses especially N and helps in availability of nutrients in adequate amount to increase growth, yield attributes and finally the seed yield.

Based on 2 years study, it may be concluded that application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha along with 100% RDF to soybean will be helpful in increasing seed yield, quality, available NPK, nutrient uptake and higher net returns in soybean.

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