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Effect of integrated nutrient and agronomic management on growth, productivity, nutrient uptake and soil residual fertility status of soybean

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ABSTRACT

A field experiment on soybean was conducted at the regional research farm of the Punjab Agricultural University, Naraingarh (Distt. Fateh Garh Sahib) for three years under irrigated conditions for productivity enhancement through integrated nutrient and other agronomic interventions. There were twelve treatments comprising different levels of N, P, K, FYM and agronomic management practices. The results revealed that soybean significantly responded to the application of N, P, K and FYM. Maximum yield was recorded in the treatment where FYM was applied with NPK and resulted in an increase of 10.8 per cent over NPK alone. Application of additional 30 kg N ha^{-1} at pre-flowering or at pod initiation did not significantly enhance the yield over the basal dose of NP applied at sowing. Application of 4 tonnes wheat straw mulch + 30 kg N +60 kg P_2O_5 and 30 kg N + 60 kg P_2O_5 ha^{-1} showed similar effect on seed yield of soybean. No statistical difference in soybean yield was observed in the conventional flat and bed sowing treatments. Pre-emergence application of pendimethaline @ 1.5 l ha^{-1} along with one hand weeding at 40 days after sowing (DAS) and two hand weeding at 20 and 40 DAS were equally effective for weed control and in influencing the soybean yield. The application of N, P, K and FYM, in different treatments, treatment with *Bradyrhizobium japonicum* and sowing on beds all significantly improved the N, P and K uptake by soybean over control. Application of FYM to soybean resulted in maximum nutrient uptake by soybean. After three years a significant improvement in soil organic carbon, available N, P and K was observed in all treatments over control.

Key words: Available nutrients, Farm yard manure, Integrated, Nutrients, Organic carbon, Productivity, Soybean, Uptake.

INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] is an important pulse and oilseed crop and is a rich source of high quality protein and essential amino acids. Owing to large amount of dietary fiber and low amount of saturated fat it is also considered as "Golden bean". Its oil is used as cooking medium and for manufacturing several industrial products, such as vanaspati ghee, soaps, paints, insecticides, disinfectants etc. Its seeds are used for preparation of soy tofu, soya milk, soya sprouts, soya nuts, etc. Soybean oil cake is used for preparation of biscuits, protein rich bread and other confectionary, bakery, high protein livestock feed etc. (Chauhan and Singh, 2004). Further, its cultivation also improves soil health as it fixes nitrogen from the atmosphere, thus improves the productivity of succeeding crops.

Soybean being an energy rich legume is very nutrient exhaustive also and requires higher amounts of N, P and K fertilizers as compared to other legumes. But the productivity as well as profitability of soybean cultivation is declining mainly due to imbalanced fertilization. Continuous exploitation of soil resources for cultivation of crops without addition of fertilizers and their inadequate supply create nutrient imbalance in soil, which inhibits the potential productivity of crops (Arbad *et al.*, 2014). Sole application of NPK fertilizers leads to emergence of micro nutrient deficiencies while integrated use of FYM and NPK sustains crop productivity. Further, integrated use of organic as well as inorganic sources of nutrients can have promising effect in arresting the decline in productivity on long term basis by improvement in the physical, chemical and biological properties of the soil (Tiwari, 2002).

Organic manures in addition to inorganic nutrients create congenial soil conditions for nodule development and nitrogen fixation thus improving vegetative growth, metabolic activity and root growth (Singh *et al.*, 2010) which leads to achieve enhanced yields (Shivkumar and Ahlawat, 2008; Mere *et al.*, 2013). Soybean is more responsive to nitrogen fertilization in high yielding environments and an approach to apply nitrogen can be its split application wherein a part can be supplied during the growing season (Mirshekari, 2013). Application of nitrogen at pre-flowering stage improved growth (Bly *et al.*, 1998) and yield of soybean (Mirshekari, 2013). Adequate phosphorus nutrition increases many aspects of plant development *viz.*, flowering, fruiting,

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root growth etc. and play an important role in nitrogen fixation (Lingaraju *et al*., 2016). Balance nutrition is, therefore, of utmost importance to harvest maximum yields from soybean.

In addition to nutrient management, other agronomic manipulations viz., planting methods, weed control, mulching etc. can further help to get improved yields. Therefore, the present investigation was undertaken to evaluate the effect of chemical fertilizers, organic manures and other agronomic interventions on productivity of soybean and soil health under a semi-arid sub tropical environment in north India on a typic haplustept.

MATERIALS AND METHODS

A field experiment was conducted at the research farm of the regional research station, Punjab Agricultural University, Naraingarh during consecutive three *kharif* seasons on a sandy clay loam soil. The soil of the experimental field was low in available N (125.4 kg/ha), high in available P (37.1 kg/ha), and available K (266.0 kg/ ha) having alkaline pH (8.13). Soybean variety SL 525 was sown during second fortnight of June and harvested during second fortnight of October. The experiment was laid in randomized complete block design (RCBD) with twelve treatments each on fixed site *viz*-T_1: Control ($N_0P_0K_0$), T_2: 30 kg N ha^{-1} at sowing, T_3: 30 kg N ha^{-1} + 60 kg P_2O_5 at sowing + 30 kg N ha^{-1} at pre-flowering, T4: 30 kg N + 60 kg P_2O_5 ha^{-1} at sowing, T_5: 30 kg N + 60 kg P_2O_5 + 30 kg K_2O ha^{-1} at sowing,, T_6: 30 kg N + 60 kg P_2O_5 + 10 tonnes FYM ha^{-1} at sowing, T_7: 30 kg N + 60 kg P_2O_5 + 30 kg K_2O + 10 tonnes FYM ha^{-1} at sowing, T_8: 30 kg N + 60 kg P_2O_5 ha^{-1} at sowing without seed treatment with *Bradyrhizobium Japonicum*, T_9: 30 kg N + 60 kg P_2O_5 ha^{-1} at sowing + 4 tonnes wheat straw mulch ha^{-1} immediately after sowing, T_{10}: 30 kg N + 60 kg P_2O_5 ha^{-1} at sowing +Pre-emergence application of Pendimethalin @ 0.45 kg/ ha + one hand weeding 40 days after sowing, T_{11}: 30 kg N + 60 kg P_2O_5 ha^{-1} at sowing +30 kg N ha^{-1} at pod initiation stage, T_{12}: 30 kg N + 60 kg P_2O_5 + 10 t FYM ha^{-1} at sowing on beds spaced 67.5 cm (2 soybean rows apart on 37.5 cm wide bed and 30 cm wide furrow between two beds).

As per the treatments FYM was incorporated at the time of field preparations. The required quantities of nutrient elements N, P and K were applied through urea, SSP/DAP and MOP except for the treatment T_8 respectively. Full dose of N, P and K were applied before the sowing of soybean. The seeds were treated with *Bradyrhizobium japonicum* culture before sowing. Two hand weedings were performed in all treatments except in treatment T_{10}. Soybean was sown at a row spacing of 45 cm and the crop was irrigated as and when required. All the recommended cultural operations other than the treatments were practiced to raise the crop. After three years of experimentation, surface soil samples (0-15 cm) were analyzed for organic carbon (Walkley and Black, 1934), available N (Subbiah and Asija, 1956), available P (Olsen *et al*., 1954) and available K (Merwin and Peech,1950). At the time of harvest, grain and straw samples of soybean were collected from different treatments and were oven-dried at 70°C. The dried samples were ground in a stainless steel Willey mill. For the determination of N in soybean grain and straw, a known weight of grain and straw were digested in concentrated H_2SO_4 at 350°C and the digest was analysed for N by Kjeldahl distillation method. For the determination of P and K the grain and straw samples were digested at 150°C in diacid mixture of $HClO_4$ and HNO_3 in the ratio of 3:1. The uptake of NPK by grain and straw was calculated by multiplying the NPK content with the respective oven dried grain and straw yield of soybean. The total NPK uptake was calculated by summing the grain and straw uptake. The data were statistically analysed in RCBD to determine the significance among different treatments. The correlation and path analysis (Dewey and Lu, 1959) were carried out using SAS (6.2) statistical software.

RESULTS AND DISCUSSION

Growth characters and yield: The number and dry weight of nodules $plant^{-1}$ increased significantly with the inoculation of seed with *Bradyrhizobium japonicum* over the control without seed inoculation with *Rhizobium* (Table 1). Application of 30 kg N, 60 kg P_2O_5 and 30 kg K_2O ha^{-1} along with 10 tonnes of FYM in T_7 recorded the maximum number and dry weight of nodules $plant^{-1}$ followed by T_6. Mere *et al*., (2013) also found that the addition of organic manure along with inorganic fertilizers provided congenial conditions for nodulation and thus resulting more N fixation and higher yield. Plant height was not significantly influenced by the application of different agronomic inputs. Application of 4 tonnes of wheat straw mulch along with 30 kg N and 60 kg P_2O_5 ha^{-1} in T_9 resulted in maximum plant height. Mean pods $plant^{-1}$ was significantly influenced under different treatments. Significantly higher number of pods $plant^{-1}$ were recorded in all the treatments as compared to control (T_1) and where only 30 kg N ha^{-1} (T_2) was applied. Highest number of pods $plant^{-1}$ were observed in T_7 though the 100 seed weight remained statistically similar under all the treatments (Table 1).

A perusal of data in (Table 1) revealed that seed yield ranged from 21.9 to 31.6 q ha^{-1}. Minimum seed yield was recorded in the control (T_1) and maximum under T_7 treatment. Application of 10 tonnes of FYM along with 30 kg N, 60 kg P_2O_5 and 30 kg K_2O ha^{-1} recorded the highest seed yield. These results are corroborated by the findings of Sikka *et al*. (2013) and Arbad *et al*. (2014). The increase in yield over the control (T_1) was significant under all the treatments except T_2 where the increase was non-significant. Highest mean yield observed under T_7 (31.6 q/ha) was 44.3 per cent higher than control treatment. Application of 30 kg N/ha in T_2 resulted in 9.5 per cent increase in yield over control (T_1). Application of 30 kg N ha^{-1} in T_2 and 30 kg N and 60 kg P_2O_5 ha^{-1} in T_4 resulted in 9.6 and 26.9 per cent higher mean yield than the control respectively. Combined

Table 1: Effects of different treatments on yield attributes and yield of soybean (Mean of three years)

Treatments		Plant height (cm)	Nodules/ plant	Dry weight of nodules/ plant (mg)	Pods/plant	100 seed weight (g)	Seed yield (q/ha)	Stover yield (q/ha)
T_1	Control (N_0P_0 K_0)	99.3	34.3	290	107.8	11.7	21.9	45.3
T_2	N_{30}	104.3	46.7	370	111.0	11.7	24.0	46.0
T_3	$N_{30}P_{60}$ + N_{30} at pre F	102.3	44.3	430	132.7	11.0	27.9	44.3
T_4	$N_{30}P_{60}$	100.9	43.7	426	132.4	11.4	27.8	46.2
T_5	$N_{30}P_{60}K_{30}$	103.9	40.7	465	138.5	11.5	28.5	42.4
T_6	$N_{30}P_{60}$ +10t FYM	104.6	50.0	517	159.8	11.1	30.3	46.3
T_7	$N_{30}P_{60}K_{30}$ +10t FYM	105.6	55.7	530	172.6	11.0	31.6	45.7
T_8	$N_{30}P_{60}$ without *Rhizobium*	102.7	52.0	367	129.2	11.7	26.8	43.1
T_9	$N_{30}P_{60}$ + 4t straw mulch	106.3	40.3	260	138.2	11.0	30.0	47.7
T_{10}	$N_{30}P_{60}$ +Pendi @ 0.45 kg/ ha+1 HW	103.6	47.0	437	137.8	11.4	29.4	46.2
T_{11}	$N_{30}P_{60}$ + N_{30} at pod initiation	101.9	41.7	394	141.8	11..3	28.8	45.2
T_{12}	$N_{30}P_{60}$+ 10t FYM on beds	103.9	47.7	424	155.0	11.4	29.3	47.4
	CD (P=0.05)	NS	NS	132	17.4	NS	2.19	NS

Table 2: Correlation coefficients of yield and yield attributes of soybean.

	Plant height (cm)	Nodules/ plant	Dry weight of nodules/ plant (mg)	Pods/ plant	100 seed plant weight (g)	Seed yield (q/ha)
Nodules/plant	0.84**					
Dry weight of nodules/plant (mg)	0.70*	0.81**				
Pods/plant	0.84**	0.79**	0.74*			
100 seed weight (g)	0.38	0.48	0.69*	0.47		
Seed yield (q/ha)	0.81**	0.80**	0.72*	0.94**	0.47	
Stover yield (q/ha)	0.67	0.72*	0.67*	0.65*	0.39	0.71*

** significant at 1% and * significant at 5%

application of N and P in T4 treatment recorded over all increase in yield by 15.8 per cent over the use of N alone in T_2 indicating the importance of P nutrition for soybean. Mean seed yield was highest under T_7 followed by T_6, T_9, T_{10}, T_{12}, T_{11}, T_5, T_3 and T_4 treatments which were statistically at par among themselves but were significantly superior than the control. Combined use of NPK in T_5 tended to enhance the seed yield over NP alone (T_4). The integrated use of FYM with NP in T_6 and with NPK in T_7 enhanced seed yield by 9.0 and 10.0 per cent over T_4 and T_5 treatments, respectively. Mean seed yield of soybean increased by 30.1, 38.4 and 44.3 per cent with the application of NPK, FYM + NP and FYM + NPK over the control, respectively. Hegde *et al.* (1993) also reported that application of FYM @ 10 t/ha for 10 years continuously, improved soil health and maintained yield. Application of additional 30 kg N ha^{-1} in T_3 at pre-flowering stage or at pod initiation in T_{11} did not increase the yield over T_4 where no additional N was applied. There was no significant improvement in yield with the use of wheat straw mulch @ 4 tonnes in T_9 as the differences in yield between T_4 and T_9 treatment at the same level of NP applied were not significant.

Seed treatment with *Bradyrhizobium japonicum* did not cause significant increase in T_4 over T_8 treatment (without inoculation with *Rhizobium*) at the same level of agronomic inputs. Pre-emergence application of pendimethalin at 1.5 l ha^{-1} and one hand weeding at 40 DAS and 2 hoeings at 20 and 40 DAS were equally effective in influencing the yield. Conventional flat sowing in T_6 and bed planting in T_{12} with same inputs of NP + FYM recorded statistically similar yield. Results have indicated that N, NP and integrated use of FYM with NP and NPK are the critical inputs for improving the yield of soybean. Application of wheat straw mulch @ 4 tonnes ha^{-1}, *Rhizobium* inoculation and bed planting with similar inputs and additional application of 30 kg N ha^{-1} at pre-flowering stage or at pod initiation did not improve the yield significantly. Different agronomic inputs did not influence the straw yield significantly (Table 1). However, on an average application of wheat straw mulch in T_9 produced the highest straw yield followed by bed planting in T_{12} and FYM with NP under T_6.

Correlation: Correlation analysis revealed that seed yield was highly positively and significantly correlated with plant height, nodules per plant and pods per plant (Table 2). The results of path analysis revealed that number of pods per plant had a direct effect on seed yield whereas plant height, nodules per plant, dry weight of nodules and stover yield had indirect effect via pods per plant towards seed yield (Table 3). About 94% yield variation was explained by above stated characters. The study suggested that number of pods

Table 3: Direct and indirect effects of yield attributes based on correlation on seed yield of soybean.

	Plant height (cm)	Nodules/ plant	Dry weight of nodules/ plant (mg)	Pods/ plant	100 seed weight (g)	Stover yield (q/ha)	Correlation with seed yield
Plant height (cm)	**0.081**	0.071	0.040	0.66	0.0021	0.045	0.84
Nodules/plant	0.075	**0.081**	0.050	0.57	0.0023	0.046	0.85
Dry weight of nodules/plant (mg)	0.051	0.062	P**0.067**	0.45	0.0045	0.049	0.73
Pods/plant	0.071	0.067	0.045	**0.79**	0.0029	0.045	0.92
100 seed weight g)	0.026	0.029	0.037	0.29	**0.0072**	0.028	0.45
Stover yield(q/ ha)	0.047	0.052	0.049	0.041	0.0021	**0.063**	0.75

Explained variation = 95%Diagonal values represent direct effects and off diagonal values represent indirect effects

Table 4: Effect of different treatments on total N, P and K uptake (Mean of three years)

Treatments		Uptake (kg/ha)			
		N	P	K	NPK
T_1	Control ($N_0P_0K_0$)	168.2	29.7	81.0	278.9
T_2	N_{30}	186.7	30.3	99.2	316.2
T_3	$N_{30}P_{60}$ + N_{30} at pre F	219.0	35.4	98.4	352.8
T_4	$N_{30}P_{60}$	207.0	36.7	107.8	351.5
T_5	$N_{30}P_{60}K_{30}$	218.6	33.5	94.7	346.8
T_6	$N_{30}P_{60}$ +10t FYM	231.8	35.5	113.7	381.0
T_7	$N_{30}P_{60}K_{30}$ +10t FYM	241.3	37.3	111.8	390.4
T_8	$N_{30}P_{60}$ without *Rhizobium*	213.2	32.1	93.1	338.4
T_9	$N_{30}P_{60}$ + 4t straw mulch	229.8	35..7	107.8	373.3
T_{10}	$N_{30}P_{60}$ + Pendi @ 1.5 l ha^{-1} +1 HW	215.6	37.3	89.3	343.2
T_{11}	$N_{30}P_{60}$ + N_{30} at pod initiation	224.2	32.9	95.3	352.4
T_{12}	$N_{30}P_{60}$+ 10t FYM on beds	226.3	35.7	115.7	377.7
	CD (P=0.05)	22.5	4.4	NS	48.9

Table 5: Effect of different treatments on organic carbon and available N, P & K of soil (after three years)

Treatments		OC (%)	Available (kg/ha)		
			N	P	K
T_1	Control ($N_0P_0K_0$)	0.55	97.8	30.1	176.8
T_2	N_{30}	0.62	115.7	29.4	168.1
T_3	$N_{30}P_{60}$ + N_{30} at pre F	0.62	134.2	39.2	187.5
T_4	$N_{30}P_{60}$	0.63	122.4	38.4	191.4
T_5	$N_{30}P_{60}K_{30}$	0.59	128.8	38.4	196.2
T_6	$N_{30}P_{60}$ +10t FYM	0.70	147.8	41.2	188.1
T_7	$N_{30}P_{60}K_{30}$ +10t FYM	0.68	151.4	39.8	216.8
T_8	$N_{30}P_{60}$ without *Rhizobium*	0.58	107.8	34.3	196.2
T_9	$N_{30}P6_0$ + 4t straw mulch	0.62	111.3	34.8	194.2
T_{10}	$N_{30}P_{60}$ + Pendi @ 1.5 l ha^{-1} + 1 HW	0.58	121.2	34.8	188.1
T_{11}	$N_{30}P_{60}$ + N_{30} at pod initiation	0.63	122.4	35.7	178.8
T_{12}	$N_{30}P_{60}$+ 10t FYM on beds	0.67	139.9	40.2	180.3
	CD (P=0.05)	0.02	8.2	1.95	6.3

per plant is the character of prime importance because the component trait has shown significant association with seed yield of soybean.

NPK uptake: The total N uptake increased sequentially over control with the addition of N alone (186.7); nitrogen and phosphorus (207.0 kg ha^{-1}); nitrogen, phosphorus and potassium (218.6 kg ha^{-1}); nitrogen, phosphorus, potassium and FYM (241.3 kg ha^{-1}) and nitrogen, phosphorus and sowing on beds (226.3 kg ha^{-1}). Minimum grain N uptake (168.2 kg ha^{-1}) was recorded in control and the maximum (241.8 kg ha^{-1}) recorded in T_{12} (Table 4). All the fertilizer treatments recorded significantly higher grain N uptake as compared to control (T_1) where no fertilizer was added. Application of additional N at pre-flowering or at pod-initiation significantly increased N uptake as compared to the treatments where no additional N was applied. Application of P along with N recorded significantly higher total P uptake (T_4) as compared to the treatments where only N was applied (T_2). In all the treatments the total P uptake was significantly higher over control. Maximum total K

uptake was also recorded in T_{12} and minimum was recorded in T_1. The differences however were non-significant among T_1, T_5 and T_9 treatments. Maximum mean total NPK uptake was recorded in T_7 treatments and minimum was recorded in control T_1 which was significantly less than the mean total N uptake recorded in all other treatments except T_2 treatment where the increase was statistically non-significant.

Residual available nutrients in soil: Maximum organic carbon (0.70%) was found in T_6 where 30 kg N, 60 kg P_2O_5, and 10 tonnes FYM ha^{-1} was applied and this was significantly higher than all other treatments except T_7 where it was statistically at par (Table 5). Minimum organic carbon (0.55%) was observed under control treatments. The changes in the organic carbon content under T_2, T_3, T_4, T_9 and T_{11} were statistically at par among themselves. Maximum content of available N was recorded under T_7 where 30 kg N, 60 kg P_2O_5, 30 kg K_2O and 10 tonnes FYM ha^{-1} was applied followed by T_6 treatment which were statistically similar with each other but the treatment T_7 recorded significantly higher available N than all other treatments. Application of additional nitrogen at pre-flowering also resulted in significantly higher available N content (T_3) as compared to the treatment where no additional N was applied (T_4). However, minimum available N was recorded under the control treatment. The available P content of the soil varied from 29.4 (T_2) to 41.2 (T_6) kg ha^{-1}. Inclusion of P in different treatments resulted in significantly higher available P content of the soil than the treatment where no fertilizer (T_1) or only N was applied (T_2). The available P content of the soil was statistically at par among T_3, T_6, T_7, T_{12} and among T8, T_9, T_{10}, T_{11} treatments. The available K content of the soil varied from 168.1 to 216.8 kg ha^{-1}. The maximum content of available K was recorded in T_7 where 30 kg N, 60 kg P_2O_5, 30 kg K_2O and 10 tonnes FYM ha^{-1} was applied and minimum was observed under the treatment where only N was applied. In similar studies Sikka *et al.* (2016) also found significant improvement in OC, available N, P and K with the inclusion of N, P, K, FYM and Bio-fertilizer in fertilization schedule as compared to the control. Arbad *et al*. (2014) also reported the buildup of soil nutrients (NPK) with application of 10 t/ha of FYM along with recommended NPK (30 kg N, 60 kg P_2O_5, 30 kg K_2O/ha) to soybean in soybean-safflower cropping system.

CONCLUSION

It maybe concluded that combined application of 10 t FYM along with 30 kg N, 60 kg P_2O_5 and 30 kg K_2O/ha resulted in realizing higher productivity of soybean. Application of additional nitrogen either at preflowering or at pod initiation, sowing on beds and straw mulching did not prove beneficial in increasing the soybean yield. The combined application of FYM along with NPK also helps in maintaining higher levels of available N, P and K besides increasing the organic carbon status of soil.

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