

Productivity, profitability and quality of soybean (*Glycine max*) and residual soil fertility as influenced by integrated nutrient management

SUMIT CHATURVEDI*, A.S. CHANDEL, V.C. DHYANI AND A.P. SINGH

Department of Agronomy, College of Agriculture, G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand 263 145

Received: October, 2009

ABSTRACT

A field experiment was conducted at Pantnagar to assess the effect of various fertilizer and manurial treatments on soybean [*Glycine max* (L.) Merrill] productivity, quality and residual soil fertility during *kharif* seasons of 2003 and 2004. Fourteen treatments that include use of FYM, B and Fe over 50 and 100% recommended dose of fertilizers (RDF) viz., 20.0-26.4-33.3 kg N-P-K/ha. Integrated use of RDF with FYM or soil application of Fe/B being at par increased the seed yield of soybean significantly over RDF alone (3.13 tonne/ha). Highest net returns were recorded with the application of RDF + 10 tonne FYM/ha. Application of FYM/Fe/B with both 50% RDF and RDF markedly improved the unsaturated fatty acids content (linolenic, linoleic and oleic) and reduced saturated fatty acids (palmatic and stearic) content. Use of FYM and micronutrients helped in maintaining soil fertility and rhizospheric microbial population.

Key words : Economics, Fatty acids, Nutrient availability, Residual effects, Soybeans.

Soybean (*Glycine max* (L.) Merrill) with its 40-42% protein and 20-22% oil has already emerged as one of the major oilseed crop in India. In spite of its high yield potential (4.5 tonne/ha), soybean productivity is much less in India (0.95 tonne/ha) than the world average of 2.3 tonne/ha (FAI, 2006). Among the factors responsible for low productivity, inadequate fertilizer use and emergence of multiple-nutrient deficiencies due to poor recycling of organic sources and unbalanced use of fertilizers particularly micro-nutrients are important. Soybean generally grown with inadequate quantity of organic and inorganic sources of plant nutrients has not only deteriorated soil health but also resulted in poor productivity of the crop. Nutrient imbalance is one of the important constraints of soybean productivity in the North Indian Plains (Tiwari, 2001). Due to continuous growing of legumes, regular application of P and N fertilizers, the native micro-nutrient content in soils often becomes inadequate (Singh *et al.*, 2008) for crop. Integration of inorganic fertilizers, organic manures and biological sources and their efficient management has shown promise in not only sustaining the productivity and soil health but also in meeting part of crops nutrient requirement. However, meager information is available on the combined use of *Rhizobium*, farmyard manure and micro-nutrients with recommended fertilizers

in many crops including soybean. Therefore, the present experiment was carried out.

MATERIALS AND METHODS

The field experiment was carried out during *kharif* 2003 and 2004 at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar situated at 29°N latitude, 79.3°E longitude and at an altitude of 243.2 meters. The rainfall received during crop season was 1,111 mm and 1,097 mm in 2003 and 2004, respectively. However, the rainfall was well distributed in 2004. The soil of the experimental field was silty clay loam having pH 7.3 was medium in organic carbon (0.79%), available P (20.1 kg/ha), available K (165.8 kg/ha) and low in available N (199.0 kg/ha) content. The 0.005 M DTPA-extractable Fe was low (4.97 ppm) and available boron was very low (0.43 ppm). The experiment was laid out in randomized block design with three replications. Fourteen treatments were compared comprising of different combinations of two fertility levels i.e. 50% and 100% recommended dose of fertilizers (RDF) i.e. 20-26.4-33.3 kg N-P-K/ha with FYM @ 10 tonne/ha and micro-nutrients viz. boron (2 kg/ha and 0.5 % borax spray) and iron (5 kg/ha and 0.5 % ferrous sulphate spray) besides control. All the treatments including control were treated with *Bradyrhizobium japonicum* culture @ 500 g/75 kg seeds.

The required amount of FYM containing 0.32% N,

*Corresponding author: E mail : bobby_kvkv@rediffmail.com

Table 1. Growth, yield attributes, yield (t/ha) and economics (Rs/ha) of soybean as influenced by integrated nutrient management (Pooled data of 2 years)

Treatment	Plant height (cm)	Dry matter (g/plant)	Pods/ plant	Grains/ plant	Test weight (g)	Grain yield		Biological yield	Harvest index	Cost of cultivation	Net return	B : C ratio
						2003	2004					
						Control	49.5					
2.0 kg boron	50.0	30.5	53.3	103.2	91.1	1.98	1.87	4.96	0.39	8,167	9,719	1.19
5.0 kg iron	50.3	31.3	55.0	108.2	91.2	2.09	2.15	5.05	0.42	9,209	10,498	1.14
10 t FYM	64.5	36.6	66.7	149.7	97.0	2.54	2.69	5.57	0.47	8,211	16,094	1.96
50% RDF	62.5	37.4	68.6	156.0	98.0	2.41	2.50	5.76	0.43	8,575	14,235	1.66
50% RDF + 2.0 kg boron	65.7	40.2	72.5	166.2	101.2	2.73	2.72	6.16	0.44	9,048	16,287	1.80
50% RDF + 5.0 kg iron	66.3	40.6	75.6	179.3	103.2	2.81	2.78	6.33	0.45	10,075	15,919	1.58
50% RDF + 10 t FYM	70.6	47.6	84.3	205.1	104.6	3.15	3.36	6.81	0.48	9,088	21,175	2.33
RDF	70.4	47.8	83.8	207.0	105.6	3.07	3.19	6.74	0.47	9,443	19,642	2.08
RDF + 2.0 kg boron	71.0	48.7	88.8	226.9	106.9	3.48	3.61	7.27	0.49	9,924	23,321	2.35
RDF + 5.0 kg iron	72.3	50.1	90.2	238.6	106.8	3.53	3.63	7.42	0.49	10,740	22,553	2.10
RDF + 10 t FYM	75.0	52.2	94.4	256.4	107.2	3.86	3.98	7.94	0.50	9,958	26,488	2.66
RDF + 0.5% FeSO ₄ spray	72.9	50.1	87.9	229.3	108.8	3.42	3.49	7.21	0.48	10,366	21,769	2.10
RDF + 0.5% Borax spray	72.6	59.1	86.0	219.1	106.7	3.46	3.58	7.17	0.49	10,161	22,558	2.22
SEM±	2.7	1.7	3.9	14.9	4.3	0.13	0.16	0.36	0.03			
CD (P = 0.05)	7.6	4.9	11.3	43.4	13.0	0.40	0.46	1.11	0.07			

Price of soybean grain: Rs 9,300/tonne; RDF: Recommended dose of fertilizer (20-26.4-33.3 kg N-P-K/ha)

0.20% P, 0.40% K, 2.1 ppm B and 2,000 ppm Fe as per the treatments were incorporated into the soil 15 days before sowing. Soybean 'PK 1042' was grown during July to November at a row spacing of 60 cm. N, P and K fertilizers were applied just before the sowing according to the treatments using urea, single super phosphate and muriate of potash. Boron and iron were applied as borax (Na₂B₄O₇·10H₂O) and ferrous sulphate (FeSO₄·7H₂O) commercial grade at sowing and thoroughly mixed in 0-15 cm soil, whereas spray of borax and ferrous sulphate was done at 45 days after sowing in respective treatments. Optimum plant population of 0.4 million/ha was maintained by thinning 1 week after germination. The observations on growth parameters such as plant height and dry matter yield were recorded at 60 days stage. The concentration of N, P, K, B and Fe in soil (0-30 cm), seed and straw of the plant were analyzed following standard procedures. Total uptake (seed+straw) was calculated by multiplying the concentration with their respective dry matter accumulation. The protein and oil content were analyzed following standard procedures given by Association of Official Analytical Chemists (AOAC). Fatty acids were determined in Hewlett Packard (model 5980 series II) gas chromatograph (GC) equipment. Microbial population (*Pseudomonas*, *Rhizobium*, *Azotobacter*, VAM, Actinomycetes and fungal count) were determined using serial dilution technique. Since data followed the homogeneity test, pooling was done over the seasons and mean data are given.

RESULTS AND DISCUSSION

Growth and yield attributes

Growth parameters i.e. plant height and dry matter production and yield attributes differed significantly due to different treatments (Table 1). Maximum plant height and dry matter production were recorded in recommended dose of fertilizer (RDF) + FYM which was statistically at par with all the other treatments comprising RDF. Better dry matter production was also observed in treatments receiving boron and iron spray along with RDF when compared with other treatments. Response of soybean to optimum nutrition revealed that dry matter production increased with RDF over control and 50% RDF whether applied along with FYM, iron and boron or alone. This might be due to high accumulation of net photosynthates due to optimum dose of N P K and availability of energy sources for prolonged time from integrated sources of nutrients. On the other hand, lowest plant height and dry matter production were recorded in control plots. Similar findings were reported by Tomar *et al.* (1991).

RDF resulted in significantly higher number of pods/

Table 2. Nutrient uptake (kg or g*/ha), protein, oil content (%), oil yield (kg/ha) and fatty acid composition (%) of soybean as influenced by INM (Pooled data of 2 years)

Treatment	Nutrient uptake					Protein content (%)	Oil		Unsaturated Fatty Acid			Saturated Fatty Acid	
	N	P	K	B*	Fe*		Content	Yield	Linolenic	Linoleic	Oleic	Acid	
												Palmitic	Stearic
Control	118.0	16.1	36.8	346.0	58.5	37.36	18.22	263.2	6.15	56.36	19.68	13.32	2.73
2.0 kg boron (B)	141.5	18.5	46.2	369.4	64.4	38.50	18.40	295.9	6.26	56.34	19.94	13.00	2.68
5.0 kg iron (Fe)	150.6	20.2	49.9	384.9	65.0	38.96	18.30	337.9	6.27	56.36	19.93	13.00	2.48
10 t FYM	183.7	24.6	58.1	527.1	91.9	39.95	18.48	427.5	6.29	56.44	20.07	12.86	2.41
50% RDF	179.4	23.7	56.8	500.6	87.4	39.08	18.47	396.6	6.34	56.24	20.06	13.06	2.71
50% RDF + B	192.3	26.9	66.1	539.5	102.2	39.66	18.90	442.1	6.39	57.45	21.17	11.86	1.98
50% RDF + Fe	197.5	27.3	68.6	573.7	102.7	39.75	18.91	452.1	6.54	56.51	20.67	12.08	2.00
50% RDF + 10 t FYM	221.9	30.2	73.0	608.1	114.3	40.15	19.70	569.3	6.87	57.16	21.17	11.62	2.06
RDF	220.8	29.8	73.1	642.7	113.7	41.36	20.06	549.8	6.23	56.86	20.71	13.05	2.70
RDF + B	248.1	33.5	83.2	699.4	126.6	41.99	20.17	625.7	6.79	56.97	21.39	11.55	2.28
RDF + Fe	250.4	34.3	86.7	742.3	126.6	41.57	20.10	627.5	6.80	56.80	21.46	12.05	2.39
RDF + 10 t FYM	270.1	39.1	96.0	778.9	137.3	42.17	20.43	699.3	7.12	56.83	21.85	11.76	2.05
RDF + 0.5% FeSO ₄ spray	242.8	34.3	86.5	754.0	122.7	42.00	20.15	604.3	6.85	56.93	21.33	12.02	2.07
RDF + 0.5% Borax spray	246.9	34.0	85.0	688.9	126.0	41.87	20.20	621.4	6.87	56.99	21.33	11.63	2.08
SE _{mean} ±	13.7	1.6	3.6	22.5	4.8	0.72	0.64	23.9	0.18	0.49	0.17	0.18	0.13
CD (P = 0.05)	39.7	4.3	9.2	65.5	14.0	2.08	NS	69.6	0.51	NS	0.52	0.50	0.38

plant, seeds/pod, and test weight as compared to control. These attributes also increased significantly due to integration of FYM/iron/boron with recommended dose of fertilizer. However, maximum values of yield attributes were recorded in combined application of RDF + FYM, indicating that complimenting fertilizers with FYM improved the general soil environment, physico-chemical and biological conditions. This resulted in improved soybean growth and yield contributing characters. Similar findings were also reported by Singh *et al.* (2007).

Yield

Increasing application of chemical fertilizers from control to 50% RDF and further to RDF and combined application of FYM/Fe/B with RDF also increased grain and biological yield of soybean (Table 1). Recommended dose of fertilizer + FYM gave the maximum yield which was 25.3% higher over RDF. Further, application of FYM with 50% RDF gave higher yield than RDF alone. The results on grain yield thus confirmed the trend observed earlier in the yield contributing characters and upheld the need of supplementing the RDF with FYM, emphasized the utter need for organic manuring along with chemical fertilizers. Similar trends were observed in biological yield. Harvest index was found to be significantly higher in RDF when compared with control. However, non-significant increase was observed in harvest index due to the integration of FYM/iron/boron with RDF.

Quality

Nutrient management had significant influence on protein content, oil content, oil yield and oil quality (Table 2). Significantly higher protein and oil content were observed in RDF + FYM treatment which were statistically similar with RDF + boron or iron (soil application or foliar spray). As N is a basic constituent of protein and with increase in rates of N application from 50 to 100% RDF, the N availability increased which resulted in increased protein content in seeds. Increase of protein content with boron at respective fertility levels has also been reported by Liu and Yang (2003). Increase in oil content might be attributed to balanced nutrition and increased availability of boron, iron, and other nutrients. The supply of these nutrients seems to be involved in an increased conversion of primary fatty acid metabolites to end products of fatty acid by increased activity of acetyl Co-A resulting in higher oil content, (Hemantaranjan *et al.*, 2000). Lowest protein and oil content and oil yield were recorded in control. Since, the oil yield is mainly the function of seed yield and their respective oil content in the seed, oil yield increased with the increase in the fertility levels and successive addition of supplementary ingredients viz.,

FYM, boron and iron.

A desirable and significantly negative effect of integrated plant nutrient management (IPNM) was recorded on saturated fatty acid content i.e. palmitic and stearic, which decreased with increase in fertilization either inorganic or organic or both when compared with control whereas, significantly positive effect was observed for unsaturated fatty acid content i.e. oleic, linoleic and linolenic, which increased progressively with increase in nutrient application. All the fertilizer treatments were significantly superior to control in increasing the unsaturated fatty acid content and reducing the undesirable saturated fatty acid content. Application of FYM (10 t/ha), B (2.0 kg/ha) and Fe (5.0 kg/ha) at both 50% RDF and RDF proved to be useful in improving the quality of soybean oil, increasing the content of unsaturated fatty acid and reducing that of undesirable saturated fatty acid significantly. Higher percentage of unsaturated fatty acid with IPNM may be attributed to the balanced nutrition of the crop. Increase of unsaturated fatty acid and reduction in saturated fatty acid with application of organics and micronutrients at respective fertility levels has also been reported by Rani *et al.* (2006).

Nutrient uptake and soil fertility

Increasing the fertility level up to RDF and integration with FYM or iron boron resulted in higher nutrient uptake (Table 2) and soil available nutrients (Table 3). Highest N, P, K, Fe and B uptake was observed with RDF + FYM. This might be due to increased supply of nutrient sources to the crop, as well as due to the indirect effect resulting

from reduced loss of nutrients from organic sources. It was probably due to the fact that application of FYM increased apparent availability of native and added B from soil to crops and higher biomass production. Similar findings were also reported by Sharma *et al.* (1999). Integrated nutrient management had significantly increased the available N, P, Fe and B content in soil, however, K did not increase significantly as compared to initial values, whereas, in control plots all the nutrients declined significantly. The highest available N, P and K were recorded with the application of RDF + FYM indicating the benefits occurring from the integrated use of fertilizers and manures. These findings are in the line of Bharadwaj and Omanvar (1992). Whereas, highest available iron and boron content in soil were recorded when respective micronutrient was applied with recommended dose of fertilizer. Higher amount of residual N, P and K analyzed might be attributed to the increased activity of micro-organisms and nodulation leading to greater mineralization of applied and inherent nutrients. The reason for higher iron content in soil with FYM was that FYM improved availability of both native and added Fe through transformation of solid phase to soluble metal complex (Pathak *et al.*, 2005) and boron availability was increased as application of FYM increased the content of hot-water soluble boron in the soil after crop harvest (Sharma *et al.*, 1999).

Microbial population *viz.*, bacterial (*Pseudomonas*, *Rhizobium* and *Azotobacter*), VAM fungi and actinomycetes (Table 3) were enhanced significantly with integration of FYM/iron/boron with RDF after harvest of soybean than the initial values. The highest bacterial and

Table 3. Soil available nutrients and total microbial population as influenced by INM (Pooled data of 2 years)

Treatment	Available nutrient status					Total microbial population count (log CFU/g of soil)				
	N (kg/ha)	P (kg/ha)	K (kg/ha)	B (mg/kg)	Fe (mg/kg)	<i>Pseudomonas</i>	Rhizobial	<i>Azotobacter</i>	Fungus	Actinomycetes
Control	196.4	19.5	164.1	0.415	4.77	6.09	4.08	4.48	1.93	4.30
2.0 kg boron (B)	196.7	21.5	170.5	0.456	4.81	6.34	4.34	4.46	1.85	4.35
5.0 kg iron (Fe)	197.0	21.5	170.2	0.424	4.84	6.38	4.32	4.51	1.86	4.31
10 t FYM	199.2	21.2	171.6	0.450	4.88	6.59	4.41	4.64	1.70	4.75
50% RDF	200.3	21.9	170.9	0.461	5.65	6.48	4.38	4.58	1.56	4.63
50% RDF + B	202.1	21.0	172.4	0.504	5.26	6.53	4.37	4.70	1.87	4.58
50% RDF + Fe	203.4	22.0	170.8	0.465	5.66	6.56	4.37	4.72	1.89	4.55
50% RDF +10 t FYM	207.2	23.7	175.6	0.495	5.33	6.65	4.54	4.81	1.69	4.75
RDF	206.2	22.2	173.4	0.484	5.74	6.60	4.59	4.66	1.65	4.71
RDF + B	207.0	22.1	174.1	0.544	5.79	6.57	4.51	4.62	1.58	4.68
RDF + Fe	207.4	22.7	175.1	0.527	5.90	6.65	4.53	4.64	1.63	4.65
RDF + 10 t FYM	213.8	25.0	176.1	0.536	5.86	6.70	4.62	4.84	1.46	4.80
RDF + 0.5% FeSO ₄ spray	207.1	21.3	173.3	0.517	5.86	6.62	4.55	4.68	1.66	4.67
RDF + 0.5% Borax spray	206.7	22.4	173.6	0.536	5.76	6.62	4.53	4.66	1.57	4.67
SEm±	6.3	0.7	3.9	0.029	0.30	0.03	0.03	0.02	0.04	0.03
CD (P = 0.05)	17.2	2.0	NS	0.083	0.80	0.08	0.09	0.06	0.11	0.09
Soil initial values	199.0	20.1	165.8	0.431	4.97	5.80	3.04	3.00	1.70	3.48

actinomycetes count were registered with RDF +FYM. This increase might be due to increased organic matter content in the soil and higher availability of nutrients to the crop (Patil and Varade, 1998). Addition of FYM increased the activity of micro-organisms when compared with fertilizers alone. However, fungal population was lower in fertilized plots either with inorganic or organic or both in combination. It might be due to the fact that higher bacterial population might have competed with fungi for substrate in neutral pH soil. Control plots had the highest population of fungi, Application of FYM and micronutrients in combination with RDF were found to be most promising in enhancing actinomycetes and bacterial population in soil.

Economics

Net returns and benefit: cost ratio increased with supplementation of recommended dose of fertilizer with FYM/boron/iron at both the fertility levels. Highest net returns and benefit: cost ratio was obtained with RDF + FYM. It was because additional cost of organic manures was compensated by the additional yield of soybean. FYM integrated with 50% RDF also resulted in higher net returns and B: C ratio than RDF alone. This was due to higher returns obtained and relatively low cost of FYM and 50% substitution of RDF (Table 1).

Thus, it can be concluded that integrated use of 10 t FYM along with recommended dose of fertilizer (20-26.4-33.3 kg N-P-K/ha) is essential for exploiting the production potential of soybean as well as for maintaining soil fertility. The study also indicated the response of soybean to boron and iron fertilization in *Terai* region of Uttarakhand.

REFERENCES

- Bharadwaj, V. and Omanwar, P.K. 1992. Impact of long term fertility treatment on bulk density, water content and microbial population of soil. *Journal of Indian Society of Soil Science* **49**(3): 553–555.
- FAI. 2006. *Fertilizer Statistics, 2005-06*. The Fertilizer Association of India, New Delhi.
- Hemantaranjan, A., Trivedi, A.K. and Mini Ram. 2000. Effect of foliar application of boron and soil applied iron and sulfur on growth and yield of soybean *Glycine max* (L.) Merr. *Indian Journal of Plant Physiology* **5**(2): 142–144.
- Lindsay, W.L. and Norvell, W.A. 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal* **42**: 421–428.
- Liu, P. and Yang, Y.A. 2003. Effect of molybdenum and boron on quality of soybean. *Scientia Agricultura Sinica* **36**(2): 184–189.
- Pathak, S.K., Singh, S.B., Jha, R.N. and Sharma, R.P. 2005. Effect of nutrient management on nutrient uptake and changes in soil fertility in maize (*Zea mays*) - wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **50**(4): 269–273.
- Patil, R.B. and Varade, P.A. 1998. Microbial population in rhizosphere as influenced by high input rates of fertilizer application to sorghum on a vertisol. *Journal of Indian Society of Soil Science* **46**(2): 223–227.
- Rani, A., Kumar, V. and Chauhan, G. S. 2006. Fatty acid composition in germinating soybean. *Journal of Oilseed Research* **23**(1): 139–141.
- Sharma, K.R., Srivastava, P.C., Ghosh, D. and Gangwar, M.S. 1999. Effect of boron and farmyard manure application on growth, yields, and boron nutrition of sunflower. *Journal of Plant Nutrition* **22**(4 and 5): 633–640.
- Singh, M.V., Dube, B.K. and Maji, A.K. 2008. Iron fertility status in soils of Uttar Pradesh. Micronutrient Fertility Mapping of Indian Soils. *Technical Bulletin, AICRP on Micronutrients, Indian Institute of Soil Science, Bhopal* **7**: 1–60.
- Singh, S.R., Najar, G.R. and Singh, Ummed. 2007. Productivity and nutrient uptake of soybean (*Glycine max*) as influenced by bioinoculants and farmyard manure under rainfed conditions. *Indian Journal of Agronomy* **52**(4): 325–329.
- Tiwari, S.P. 2001. Shattering the production constraints in soybean based cropping systems. *Jawaharlal Nehru Krishi Vishwa Vidyalyaya Research Journal* **35**(1&2): 1–10.
- Tomar, R.K.S., Raghu, J.S., Yadav, L.N. and Ghurayya. 1991. Effect of P, *Rhizobium* inoculation and zinc on the yield of soybean (*Glycine max* (L.) Merrill). *International Journal of Tropical Agriculture* **9**(3): 211–214.