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Influence of Different Sources of Plant Nutrients on Soil Fertility, Nutrient Uptake and Productivity of Soybean under Vertisols

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ABSTRACT

A field experiment was conducted at College of Agriculture (RVSKVV), Indore during *kharif* 2013 to study the effect of different sources of plant nutrients on productivity, profitability nutrient uptake and soil fertility of soybean in relation to eight nutrient management treatments (T_1: RDF- recommended dose of fertilizer (N:P:K:S @ 30:60:30:30 kg/ha), T_2: RDF + *Rhizobium* + PSB (20 g/kg seed), T_3: RDF + 50 kg $ZnSO_4$/ha + *Rhizobium* + PSB, T_4: RDF + 1 g $(NH_4)_2MoO_4$/kg seed + *Rhizobium* + PSB, T_5: RDF + 5 kg Borax/ha + *Rhizobium* + PSB, T_6: RDF + 10 kg $FeSO_4$/ha + *Rhizobium* + PSB, T_7: RDF + 25 kg $MnSO_4$/ha + *Rhizobium* + PSB and T_8: RDF + FYM 5 t/ha + *Rhizobium* + PSB.). Highest seed yield (844 kg/ha) was obtained under T_4, which was at par with T_8. The maximum gross returns (`36,376/ha), net returns (`20,132/ha), B:C ratio (2.24), production efficiency (7.47 kg/ha/day) and economic efficiency (`178.16/ha) was also recorded under T_4 treatment. Significantly higher nutrient uptake (52.50 and 22.79 kg N, 3.28 and 6.0 kg P, 17.84 and 24.79 kg K, 85.83 and 382.55 g Fe, 67.50 and 313.02 g Mn and 0.27 and 3.96 g Mo/ha by seed and stover, respectively) were obtained under T_4. However, the highest uptake of Zn (41.39 and 40.55 g/ha by seed and stover, respectively) was recorded in T_3 followed by T_8. While the significantly higher uptake of B by seed and stover (24.17 and 40.80 g/ha) was recorded with the application of RDF + 5 kg Borax/ha + *Rhizobium* + PSB. Application of RDF + FYM 5 t/ha + *Rhizobium* + PSB (T_8) significantly enhanced the available organic carbon (0.40%), N (174.0 kg/ha) and P_2O_5 (18.67 kg/ha) which was at par with T_4. Higher Fe content in soil (4.81 mg/kg soil) was noted with T_6, while maximum Mn (2.0 mg/kg soil) was found under T_7. Maximum Zn content (0.56 mg/kg soil) was found with the application of T_3, whereas, the maximum Mo content (0.048 mg/kg soil) was recorded in T_4.

Key words: Economics, FYM, Micronutrients, Nutrient uptake, RDF, Seed yield, Soil fertility.

INTRODUCTION

Soybean [*Glycine max* (L.) Merill] is also known as a 'Miracle crop'. It is the world's foremost provider of protein and oil. It also contains valuable oil, which is perhaps exceptional in pulse crops. Madhya Pradesh has its major share in area and production of soybean in India (>60%) and hence designated as Soya-state. In India soybean is grown in 11.60 Mha with total production of 8.57 million tonnes. In Madhya Pradesh it is grown in 5.40 m ha with annual production of 5.51 mt (Morya *et al*., 2018 and Tomar *et al*., 2018). One component of seed quality is chemical composition, such as concentration of mineral elements, including micronutrients such as Zn, Fe, Mo, B, Mn and Zn have several important role in plant nutrition *viz*., enzyme activation, protection of bio-membranes, hormones metabolism and other functions. Boron plays an important role in development and growth of new cells in plant meristem. Mn is also an essential component of the major enzyme nitrate-reductase in plant. Iron plays an important role in nitrogen fixation and photosynthesis. Molybdenum plays an important role in nitrogen fixation. Bioinoculants have promising effect on nutrient availability and nitrogen fixation. Rosas *et al.* (2002) reported that combined inoculation of soybean by symbiotic bacteria of soybean and phosphate solubilizing bacteria improved dry weight of soybean. The use of FYM helps in maintaining soil productivity by improving the soil structure. It also keep control on soil pH, thus help in maintaining the availability of plant nutrients. Like other leguminous crops, requirement of nitrogen is substantially fulfilled from symbiotic nitrogen fixation through *Rhizobium i.e*. 125-150 kg N/ha is utilized and leaves about 30-40 kg N/ha for the succeeding crop (Saxena and Chandel, 1992). Crop fertilization can be achieved by using integration of chemical, organic and biofertilizers fertilizers. Most of the chemical fertilizers are composed of a combination of nitrogen, phosphorus and potassium. Organic fertilizers include compost, green manure, grass clippings or decaying leaves and biofertilizers. Hence, a balanced nutrients supply is must to harness the productivity of the crops. Intensively cultivated

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soils are being depleted with available nutrients especially secondary and micronutrients. Therefore, assessment of fertility status of soils, nutrient uptake and yield that are being with soybean crop needed to be carried out.

MATERIALS AND METHODS

The experiment was carried out during rainy season (*kharif*) of 2013 at Research Farm, College of Agriculture, Indore. Soil of the experimental field was light to medium black soils, having pH 7.8, organic carbon 0.34% and 162, 14 and 464 kg/ha, available N, P and K, respectively. The experiment was laid out in randomized block design (RBD) with eight treatments and three replications. The treatments consisted of T_1: RDF- Recommended dose of fertilizer (N:P:K:S @ 30:60:30: 30 kg/ha), T_2: RDF + *Rhizobium* + PSB (20 g/kg seed), T_3: RDF + 50 kg $ZnSO_4$/ha + *Rhizobium* + PSB, T_4: RDF + 1 g $(NH_4)_2MoO_4$ /kg seed + *Rhizobium* + PSB, T_5: RDF + 5 kg Borax/ha + *Rhizobium* + PSB, T_6: RDF + 10 kg $FeSO_4$/ha + *Rhizobium* + PSB, T_7: RDF + 25 kg $MnSO_4$/ha + *Rhizobium* + PSB and T_8: RDF + FYM 5 t/ha + *Rhizobium* + PSB. The farm yard manure was applied well before sowing as per treatments. Quantity of FYM to be added to each treatment was calculated on the basis of N content of FYM to substitute 25 and 50% of N through FYM treatment wise. *Rhizobium* and PSB @ 20 g/kg seed was treated as per the treatment combinations. Entire quantity of nitrogen, phosphorus and potassium (as per treatments) were applied at the time of sowing. The crop was sown on 20th June in 2013 at 30 cm row spacing with seed rate of 80 kg/ha. During the crop seasons two manual weedings (25 and 45 days after sowing) were done to manage weeds in the experimental crop. All other cultivation practices were followed as per the recommended package of practice.

For the determination of soil nutrients content composite samples were collected randomly with the help of soil augar before sowing and after harvesting of crop from each plot and to estimate the uptake of NPK and micronutrients (Fe, Zn, Mn, B and Mo) by crop, plant samples were collected treatments wise for their analysis. Soil samples were collected from 0 to 15 cm layer, dried and ground to pass through 2 mm sieve. Soil samples were then analyzed for pH, organic carbon (Walkley and Black, 1934), available N (Subbiah and Asija, 1956), available P (Olsen *et al.,* 1954) and available K (Jackson, 1973), Fe, Zn Mn, (Lindsay and Norvell, 1978), Mo (Singh *et al.*, 2005) and B (Dible *et al*., 1954). At the time of harvest, seed and stover samples of soybean were collected from different treatments and oven-dried at a temperature of 70°C. The dried samples were ground in a stainless steel Willey mill. For the determination of N in soybean seed and stover, a known weight of seed and stover were digested and followed the standard procedures for analysis. The uptake of macro (N, P and K) and micro nutrients (Fe, Zn, Mn, Mo and B) by seed and stover was calculated by multiplying the nutrient content with the respective seed and stover yield. The data were analyzed in RBD to determine the significance among different treatments.

The maximum temperature during crop season ranged between 24.6-32.0°C and minimum temperatures were between 19.7-24.4°C during 2013 (Fig 1). The total rainfall received from sowing to harvest was 1287 mm in 46 rainy days. At the flowering stage to pod development prolong dry spell was occurs and received uneven distribution of rainfall. Therefore, the yield of soybean was lower than the average of state.

RESULTS AND DISCUSSION

Yields and economics

The productivity and economics of soybean were influenced significantly by various nutrient management treatments (Table 1). The highest seed yield (844 kg/ha) was obtained with the application of RDF + 1 g ammonium molybdate/kg seed + *Rhizobium* + PSB, it was closely followed by RDF + 5 t FYM/ha + *Rhizobium* + PSB (832 kg/ha) and significantly superior to rest of the treatments. Stover yield did not significantly affected by various nutrient management treatments, however, the highest value was recorded under RDF + 5 t FYM/ha + *Rhizobium* + PSB (1649 kg/ha) followed

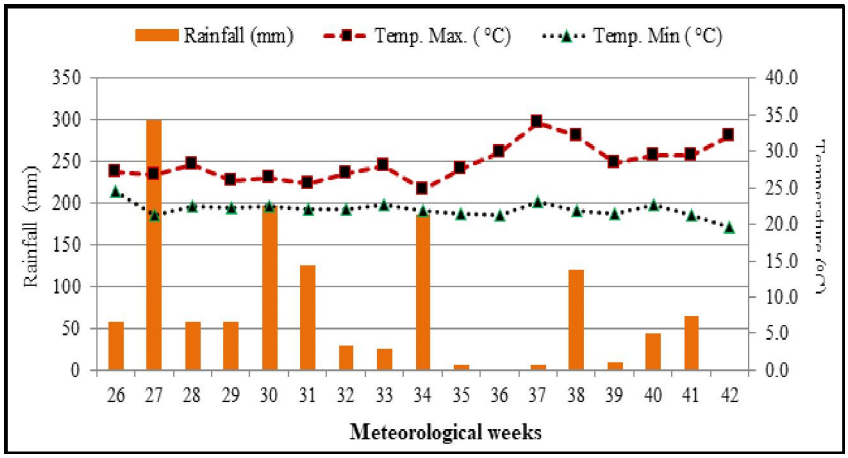


Fig 1: Mean weekly meteorological data during crop season (*kharif,* 2013).

by RDF + 1 g Ammonium molybdate/kg seed + *Rhizobium* + PSB (1629 kg/ha). There were 20.92 and 19.20% increase in seed yield with the application of RDF + 1 g $(NH_4)_2MoO_4$ /kg seed + *Rhizobium* + PSB and RDF + FYM 5 t/ha + *Rhizobium* + PSB over application of RDF. This improved performance may be attributed to improved soil fertility and microbial activity in the rhizosphere due to application of RDF, FYM, micronutrient and biofertilizers. Kumar *et al.*, (2006) also found that increased seed yield of soybean due to combined use of organic and inorganic sources of plant nutrients and their complementary effects on soil bio-chemical reactions and soil fertility. These results are in agreement with those of Kumawat *et al*. (2009a) in mungbean, Sikka *et al.* (2013) and Tomar *et al*. (2018) in soybean.

The economic returns were significantly affected by various nutrients inputs (Table 1). Among the various treatment, maximum gross returns (`36,376), net returns (`20,132/ha), B:C (2.24) ratio, production efficiency (7.47 kg/ha/day) and economic efficiency (`178.16 /ha/day) were recorded with the supplementation of RDF + 1 g ammonium molybdate/kg seed + *Rhizobium* + PSB. This was mainly due to higher seed yield, stover yield and net returns and relatively low cost of biofertilizers and micronutrients. The additional cost of organic manures was compensated by the additional yield of soybean.Similar trends have been observed by Singh *et al*. (2013) and Bhagwat *et al*. (2018).

Nutrients uptake by crop

The nutrients uptake by seed and stover (macro nutrients *i.e*. N, P and K and micronutrients *i.e*. Fe, Mn Zn, B, Mo) were significantly influenced due to different treatments (Table 2). All the treatments recorded higher values of nutrients uptake by seed and stover in comparison to control (RDF). Significantly highest N and K uptake by seed and stover were recorded in the treatment T_4 (RDF + 1 g ammonium molybdate/kg seed + *Rhizobium* + PSB), which was statistically at par with RDF + 5 t FYM/ha + *Rhizobium* + PSB over the rest of the treatments. Similarly, highest P uptake by seed and stover were recorded under RDF + 1 g ammonium molybdate/kg seed + *Rhizobium* + PSB which was significantly superior among the nutrient management treatments. Further data presented in Table 2 showed that maximum Fe uptake by seed as well as stover was observed with the application of RDF + ammonium molybdate/kg seed + *Rhizobium* + PSB which was statistically comparable with RDF + 10 kg $FeSO_4$/ha + *Rhizobium* + PSB and RDF + 5 t FYM/ha + *Rhizobium* + PSB when compared to RDF and other remaining treatments. Application of RDF + 1 g ammonium molybdate/kg seed + *Rhizobium* + PSB significantly improved the Mn uptake by seed and stover and at par with RDF + 25 kg $MnSO_4$/ha + *Rhizobium* + PSB (T_7) and RDF + 5 t FYM/ha + *Rhizobium* + PSB (T_8). Among the various treatments, highest uptake of Zn by seed and stover was noted under RDF + ammonium molybdate/kg seed + *Rhizobium* + PSB followed by RDF + 5 t FYM/ha +

Table 1: Yield and economics of soybean as influenced by various sources of plant nutrient under vertisols.

Treatments	Seed yield (kg/ha)	Stover yield (kg/ha)	Cost of cultivation (`ha^{-1})	Gross return (`ha^{-1})	Net return (`ha^{-1})	B:C ratio	Production efficiency (kg/ha/day)	Economic efficiency (`/ha/day)
T_1: Recommended dose of fertilizer (RDF)	698	1386	15197	30247	15050	1.99	6.18	133.19
T_2: RDF + *Rhizobium* + PSB	755	1518	15332	32808	17476	2.14	6.68	154.65
T_3: RDF + 50 kg $ZnSO_4$/ha + *Rhizobium* + PSB	785	1545	17249	33954	16705	1.97	6.94	147.83
T_4: RDF + 1g Ammonium molybdate/kg seed+ *Rhizobium* + PSB	844	1629	16244	36376	20132	2.24	7.47	178.16
T_5: RDF + 5 kg Borax/ha+ *Rhizobium* + PSB	774	1542	16232	33580	17348	2.07	6.85	153.52
T_6: RDF + 10 kg $FeSO_4$/ha + *Rhizobium* + PSB	776	1538	17222	33620	16398	1.95	6.87	145.12
T_7: RDF + 25 kg $MnSO_4$/ha + *Rhizobium* + PSB	778	1549	29332	33726	4394	1.15	6.88	138.88
T_8: RDF + 5 t FYM/ha + *Rhizobium* + PSB	832	1649	19392	36030	16698	1.86	7.36	147.77
SEm ±	22	71	-	-	-	-	0.20	-
C.D. (P=0.05)	68	NS	-	-	-	-	0.60	-

Table 2: Nutrient uptake by seed and stover of soybean as influenced by various sources of plant nutrient under Vertisols.

Treatments	Nutrient uptake by seed								Nutrient uptake by stover							
	N (kg/ha)	P (kg/ha)	K (kg/ha)	Fe (g/ha)	Mn (g/ha)	Zn (g/ha)	B (g/ha)	Mo (g/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Fe (g/ha)	Mn (g/ha)	Zn (g/ha)	B (g/ha)	Mo (g/ha)
T_1: Recommended dose of fertilizer (RDF)	41.34	1.87	12.72	67.02	50.27	28.80	16.96	0.13	15.00	2.87	17.49	292.48	253.66	22.63	29.30	2.36
T_2: RDF + *Rhizobium*+PSB	45.32	2.34	14.40	73.57	55.47	33.09	18.53	0.16	17.56	3.77	19.75	327.56	281.84	28.01	33.00	2.66
T_3: RDF + 50 kg $ZnSO_4$ /ha + *Rhizobium* + PSB	48.17	2.03	15.37	77.69	59.42	41.39	19.43	0.19	19.65	4.81	21.29	339.87	291.22	40.55	33.98	2.79
T_4: RDF + 1g Ammonium molybdate/kg seed+ *Rhizobium* + PSB	52.50	3.28	17.84	85.83	67.50	37.53	21.14	0.27	22.79	6.00	24.79	382.55	313.02	32.13	36.63	3.96
T_5: RDF + 5 kg Borax/ha + *Rhizobium* + PSB	47.54	2.63	15.00	74.90	58.44	33.79	24.17	0.16	18.34	4.77	20.81	333.77	289.18	29.94	40.80	2.72
T_6: RDF + 10 kg $FeSO_4$/ha + *Rhizobium* + PSB	47.43	2.64	15.21	85.36	57.92	31.95	19.18	0.17	19.21	4.33	21.06	372.14	287.13	28.84	33.86	2.74
T_7: RDF + 25 kg $MnSO_4$/ha + *Rhizobium* + PSB	47.45	2.26	15.02	76.83	67.20	32.70	19.10	0.16	18.91	4.34	20.61	339.54	304.87	27.87	33.66	2.71
T_8: RDF + 5 t FYM/ha + *Rhizobium* + PSB	50.58	2.65	16.63	82.44	63.76	37.72	20.74	0.21	20.92	4.27	23.21	371.06	311.75	33.17	37.12	3.15
SEm ±	1.37	0.09	0.43	1.71	2.25	1.57	0.98	0.02	0.82	0.40	1.12	13.60	13.51	2.43	2.65	0.14
C.D. (P=0.05)	4.17	0.28	1.32	5.21	6.85	4.79	2.99	0.05	2.49	1.20	3.39	40.79	40.50	7.39	7.93	0.42

Rhizobium + PSB when compared to rest of treatments. Similarly, the maximum B uptake by seed and stover was recorded in RDF + 5 kg Borax/ha+ *Rhizobium* + PSB which was significantly higher over RDF and rest of the treatments. Due to application of RDF + ammonium molybdate/kg seed + *Rhizobium* + PSB significantly enhanced the Mo uptake by seed and stover over the rest of treatments. Combined application of micronutrient, biofertilizers and organic manures in conjunction with 100% RDF, inorganic form resulted in highest nutrient uptake which was significantly different from rest of the treatments. The higher nutrients uptake was attributed to continuous and steady supply of available nutrients throughout crop growing period because of application of both organic, inorganic micronutrient in available forms. Other possible reasons are higher mineralization of nutrients from applied organic and inorganic source. FYM application reduced the loss of nutrients through leaching and made available significant amount of plant nutrients, which created a balancing effect on supply of nitrogen, phosphorus and potassium. Similar results were reported earlier by Kumawat *et al*. (2009b), Kumar and Kumawat (2014) and Yaduwanshi *et al.* (2018).

Fertility status after harvest of crop

Organic carbon, soil macronutrients (N, P and K) and micronutrients (Fe, Mn, Zn, B and Mo) were influenced significantly with the nutrient management practices. Organic carbon (OC) significantly improved with the applied different treatments as compared to control (RDF). The organic carbon in RDF + FYM 5 t/ha + *Rhizobium* + PSB was significantly higher than all other treatments except RDF + 1 g $(NH_4)_2MoO_4$ /kg seed + *Rhizobium* + PSB, RDF + 10 kg $FeSO_4$/ha + *Rhizobium* + PSB and RDF + 50 kg $ZnSO_4$/ha + *Rhizobium* + PSB. This was probably due to the high C:N ratio of FYM resulting organic carbon build up in soil. Biofertilizer improved soil fertility by increasing organic carbon content and effective bacterial population in soil (Dhage *et al.,* 2008). The available N content ranged from 143.00 kg/ha in RDF (T_1) to 174.0 kg/ha in RDF + FYM 5 t/ha + *Rhizobium* + PSB. The application of RDF + 5 t FYM/ha + *Rhizobium* + PSB significantly enhanced the available N content in soil and it was found at par with RDF + 1 g $(NH_4)_2MoO_4$ /kg seed + *Rhizobium* + PSB than all other treatments. Similarly, the highest P content in soil was also found with RDF + FYM 5 t/ha + *Rhizobium* + PSB treatment and it was comparable with RDF + 1 g $(NH_4)_2MoO_4$ /kg seed + *Rhizobium* + PSB and RDF + 5 kg Borax/ha + *Rhizobium* + PSB treatments. Improvement in available nitrogen, phosphorus and potassium status of soil might be due to increased activity of microorganisms leading to greater mineralization of native and added nutrients. Addition of FYM might also be brought about improvement in soil chemical properties. Similar findings were reported by Sikka *et al*., (2013).

Application of RDF + 10 kg $FeSO_4$/ha + *Rhizobium* + PSB significantly improved the Fe content as compared to rest of the treatments. While significantly maximum Mn

Table 3: Soil fertility status after harvest of soybean as influenced by various sources of plant nutrient under Vertisols.

Treatments	pH	EC (dS/m)	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	B (mg/kg)	Mo (mg/kg)
T_1: Recommended dose of fertilizer (RDF)	7.77	0.44	0.32	143.00	14.83	478.00	4.56	1.90	0.43	1.45	0.042
T_2: RDF + *Rhizobium* + PSB	7.79	0.43	0.35	155.67	16.23	481.00	4.50	1.87	0.41	1.38	0.037
T_3: RDF + 50 kg $ZnSO_4$/ha + *Rhizobium* + PSB	7.80	0.43	0.36	155.67	13.50	482.33	4.39	1.79	0.56	1.31	0.031
T_4: RDF + 1g Ammonium molybdate /kg seed+ *Rhizobium* + PSB	7.90	0.44	0.39	162.00	17.67	485.33	4.28	1.70	0.38	1.29	0.048
T_5: RDF + 5 kg Borax/ha + *Rhizobium* + PSB	7.78	0.43	0.35	155.67	16.67	482.67	4.43	1.85	0.34	1.60	0.034
T_6: RDF + 10 kg $FeSO_4$/ha + *Rhizobium* + PSB	7.78	0.44	0.36	155.67	16.50	484.00	4.81	1.81	0.36	1.33	0.034
T_7: RDF + 25 kg $MnSO_4$/ha + *Rhizobium* + PSB	7.78	0.43	0.35	149.33	16.33	484.67	4.40	2.00	0.35	1.34	0.033
T_8: RDF + 5 t FYM/ha + *Rhizobium* + PSB	7.77	0.45	0.40	174.00	18.67	488.00	4.33	1.74	0.47	1.31	0.031
SEm ±	0.03	0.01	0.01	4.97	0.68	3.39	0.03	0.02	0.02	0.02	0.002
C.D. (P=0.05)	NS	NS	0.04	15.10	2.06	NS	0.08	0.06	0.06	0.07	0.006

content was observed under RDF + 25 kg $MnSO_4$/ha + *Rhizobium* + PSB as compared to other treatments. The Zn content in soil increased with the application of RDF + 50 kg $ZnSO_4$/ha + *Rhizobium* + PSB as compared to other treatments. B content in soil was significantly enhanced due to application of RDF + 5 kg Borax/ha+ *Rhizobium* + PSB which was proven superiority as compared with other treatments. The maximum Mo content was recorded in RDF + 1g Ammonium molybdate/kg seed+ *Rhizobium* + PSB and it was found superior to other treatments. The reason for higher Fe, Mn, Zn, B and Mo content in post harvest soil may be due to improved activity of microorganisms leading to greater mineralization of applied and inherent micronutrients through transformation of solid to soluble metal complex. Similar findings have been reported by Chaturvedi *et al.* (2010).

CONCLUSION

It could be concluded that integrated use of RDF (30 kg N + 60 kg P_2O_5 + 30 kg K_2O/ha) + seed treatments with 1g ammonium molybdate/kg seed and biofertilizers (*Rhizobium* + PSB) is beneficial and advisable for higher productivity, profitability and soil fertility of soybean under Malwa Plateau region of Madhya Pradesh.

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