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EFFICACY OF CO-INOCULATION OF BIOFERTILIZERS ON YIELD, NUTRIENT UPTAKE OF SOYBEAN (*Glycine max* (L) Merrill) AND SOIL FERTILITY IN BLACK SOIL.

ANUPRIYA SHARMA, Dr. R.C.JAIN*, ANKITA DHOTE, DR. B.K. SHARMA, AJAY BIRLA AND NIMISHA RAJ JAIN
Department of Soil Science
RAK College of Agriculture, Sehore-466001(M.P.)

ABSTRACT

A field experiment was conducted during *kharif* season of 2018 and 2019 at the Research Farm, RAK College of Agriculture, Sehore (M.P.), India to study the efficacy of co-inoculation of biofertilizers on yield, nutrients uptake of soybean and soil fertility. The combined application of 50% RDF + *Glomus geosporum* (AMF) + PGPR (*Paenibacillus polymyxa*) + *Rhizobium japonicum* (T_7) significantly influenced the N, P, K and S contents and their uptake in seed and straw over absolute control (T_1), followed by 50% RDF + *Glomus geosporum* (AMF) + PGPR (*Paenibacillus polymyxa*) (T_6) which remained at par with (T_7). Balance of N, P, K and S after harvest of the crop was found better under the treatment of the combined application of 50% RDF + *Glomus geosporum* (AMF) + PGPR (*Paenibacillus polymyxa*) + *Rhizobium japonicum* (T_7) over the other treatments. Thus, the treatment T_7 produced maximum total biomass (grain + straw upto 30.55 q/ha), total uptake of nutrients upto 111.1 kg N/ha, 12.82 kg P/ha, 52.57 kg K/ha and 8.45 kg S/ha by soybean along with improved available NPK

i.e. 244.66, 12.51 and 418.32 and 9.88 ppm, respectively in the post-harvest soil. The second best treatment was T_6 having 50% RDF + *Glomus geosporum* (AMF)+ PGPR (*Paenibacillus polymyxa*) and then T_5 having 50% RDF + *Rhizobium japonicum* (T_5),

Key words: Co-inoculation, inoculation, soybean

*Corresponding author Principal Scientist (Soil Science) E-mail:rcj2011@gmail.com

INTRODUCTION

The deficiency of multi-nutrients in soil is posing a great threat towards sustainable productivity of soybean. The heavy withdrawal of nutrients by high-yielding varieties, intensive cropping systems, imbalanced and insufficient use of manures and fertilizers, use of S and Zn-free fertilizers aggravated the multi-nutrient deficiencies in the soil. The general tendency is that the total crop removal is never replenished.. That is why soil health and sustainable productivity of soybean is becoming the burning problem. It is well known fact that soybean, a dual purpose crop, is heavy feeder of nutrients and highly responsive to the applied nutrients including phosphorus, sulphur and zinc. Due to fertility variations in different soil types, the response of a certain soybean genotype to combined biofertilizers application is highly inconsistent, location and over site specific.

Soybean is an important oilseed-cum-pulse crop. It contains 40% protein and 20% oil. Soybean is capable of fixing atmospheric-N at the rate of 65-115 kg N/ha/year with a symbiosis of *Rhizobium japonicum* microorganism.

The impact of co-inoculation with various strains of *Bradyrhizobium japonicum* and arbuscular mycorrhizal fungi (AMF) species on soybean development, root colonization, and supplement take-up of N, P, Zn, Fe, and Cu. Co-inoculation with different AMF species and rhizobia altogether expanded the soybean biomass production (Hemmat Jou, 2017).

Microbes play a vital role in maintaining soil and plant health and thus help sustain crop production and food security. Plant growth-promoting rhizobacteria (PGPR) are the group of bacteria that colonize in the rhizosphere, at root surfaces, in association with roots and can improve plant growth directly or indirectly. Several PGPR inoculants are being commercialized to promote plant growth by various mechanisms like improved nutrient acquisition, suppression of plant disease, phytohormone production (Anonymous, 2017). The significant residual effect of Arbuscular Mycorrhizal fungi and PGPR in vertisol in increasing the physico-chemical properties, nutrients availability in soil, growth, nodulating traits, nutrients uptake and yield of soybean have also been reported by Jain and Dhote,2019). In view of the above facts, the present research was taken up.

MATERIALS AND METHODS

The field experiment was conducted during *kharif* season of 2018 and 2019 at the Research Farm, RAK College of Agriculture, Sehore (M.P.), India. The soil of the experimental field was medium black (Vertisol) having clay loam texture, low in available nitrogen (208 N kg/ha), medium in available phosphorus (13 P kg/ha), high in available potassium (420 kg K/ha) and Normal in available sulphur (8.80 S kg/ha) with pH of 7.5. The experiment consisted of 7 treatments laid out in randomized block design keeping 3 replications. The treatment included absolute control (T_1),100% RDF (T_2), 50% RDF + *Glomus geosporum* (AMF culture) (T_3), 50% RDF + PGPR (*Paenibacillus polymyxa*) (T_4), 50% RDF + *Rhizobium japonicum* (T_5), 50% RDF + *Glomus geosporum* (AMF)+ PGPR (*Paenibacillus polymyxa*) (T_6), 50% RDF+ *Glomus geosporum* (AMF) + PGPR (*Paenibacillus polymyxa*)+ *Rhizobium japonicum* (T_7). The soybean var. RVS-24 was sown on 4th and 2nd July in 2018 and 2019, respectively. The 50 percent recommended doses of fertilizers were applied as per package of practices for soybean @ 20:60:20:20 kg/ha N, P_2O_5, K_2O and S, respectively. The crop was harvested on 3rd October, 2018 and 15th October, 2019. The available N, P_2O_5, K_2O and S were determined by standard procedures.

Table 1 Chemical analysis of plant samples

S. No.	Particular	Method adopted
1	Nitrogen Content (%)	Micro Kjeldahl method as described by Jackson, 1973.
2	Phosphorus Content (%)	Vanadomolybdo Yellow Colour Method (Koeing and Johnsons,1942)
3	Potassium content (%)	Di-acid digestion method by Flame photometer (AOAC,1984)
4	Sulphur content (%)	Turbidimetric Method (AOAC, 1984)

RESULTS AND DISCUSSION

Nitrogen content (%) in seed, straw and total uptake (kg/ha)

Significant and higher values of N content and uptake in seed and straw were noted under the treatment T_7 (50% RDF + *Glomus geosporum* + PGPR + *Rhizobium japonicum*). The different combined treatments showed a significant difference in respect to N-content in seed and straw. This increase was ascribed due to the beneficial and judicious combination of different treatments. Further the concomitant beneficial effect of 50% RDF + *Glomus geosporum* + PGPR + *Rhizobium japonicum* might be due to the improved physical conditions of the soil and the role of these inputs to supply enhanced mineralization, mobilization of nutrients together with the number of beneficial soil microbes giving such response. Application of treatment (T_7) recorded the highest (121.39 kg/ha) total N-uptake (seed + straw), which was observed significantly superior over rest treatments. The increase in uptake of nitrogen ascribed due to result of enhanced physiological processes within the plant system which resulted in the increased absorption of nitrogen by soybean plant and thereby translocation of nitrogen. Supplementation of *Paenibacillus polymyxa*, *Glomus geosporum* and *Rhizobium japonicum* improves the fair availability of nutrients in the soil hence crop growth and thereby, uptake of nitrogen. The results are also well corroborated the findings of Jain (2015), Jain and Virendra (2017), Jain and Singh (2018) and Jain and Dhote(2019).

Phosphorus content (%) in seed, straw and total uptake (kg/ha)

The application of (50% RDF + *Glomus geosporum* + PGPR + *Rhizobium japonicum*) (T_7) recorded the highest P-content in seed (0.71%), straw (0.17%) and total uptake (seed+straw), which was noted significantly superior over rest treatments. This could be due to higher and fair availability of plant nutrients in the soil due to different treatments which resulted in increased absorption of nutrient content in the plant tissues and thus enhanced biomass production due to different combined treatment. These results are in close conformity of the results observed by Jain (2015), Jain and Virendra (2017) and Jain and Singh (2018).

Potassium content (%) in seed, straw and total uptake (kg/ha)

The K-content of straw and seed was significantly affected by the different treatments. The highest uptake was found under treatment T7 (50% RDF + *Glomus geosporum* + PGPR + *Rhizobium japonicum*) which was at par with treatment T_6. The trend of such results could be attributed due to the initial higher availability of potassium in the experimental soil, indicating the higher absorption of potassium by the plants. The total K-uptake was also improved significantly with the treatment T_7 compared to other treatments. The reason being due to the combined application of AM fungi and PGPR which ultimately enhanced K absorption by plants. However, these results are in close conformity of the results observed by Jaybhay *et al*. (2017), Jain (2015), Jain and Virendra (2017), and Jain and Singh (2018).

Sulphur content (%) in seed, straw and total uptake (kg/ha)

The highest S-content in straw and seed was recorded under the application of treatment T_7 (50% RDF + *Glomus geosporum* + PGPR + *Rhizobium japonicum*) compared to other treatments. The trend of such results could be attributed due to the fair availability of sulphur in the experimental soil augmented due to enhanced mineralization, mobilization of nutrients by added different inputs. The total S-uptake was also improved significantly with treatment T_7. The reason being due to the combined application of AM Fungi and PGPR noted to hence increased nutrients uptake. However, these results are in close conformity of

the results observed by Vesey (2003), Jain (2015), Jain and Virendra (2017) and Jain and Singh (2018).

.**Fertility status of post-harvest soil**

The combined application of 50% RDF + *Glomus geosporum* + PGPR + *Rhizobium japonicum* (T7) as well as 50% RDF + *Glomus geosporum* (AMF) + PGPR (*Paenibacillus polymyxa*) (T_6) and then 50% RDF + *Rhizobium japonicum* improved the available N (244.66 kg), P (12.51 kg), K (418.32 kg) and available S (9.88 ppm) contents in the post-harvest soil. The significant residual effect of AM fungi and PFPR in soils in increasing physico-chemical properties and nutrients availability of soil have also been reported by Jain and Dhote (2019).

It is concluded the combined application of 50% RDF + *Glomus geosporum* (AMF) + PGPR (*Paenibacillus polymyxa*) + *Rhizobium japonicum* (T_7) significantly enhanced the N, P, K and S contents and their uptake in seed and straw over absolute control (T_1), followed by 50% RDF + *Glomus geosporum* (AMF) + PGPR (*Paenibacillus polymyxa*) (T_6). Balance of N, P, K and S after harvest of the crop was found better under the same (T_7) treatment.

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Table 1 Total biomass/ha and nutrients uptake of soybean as influenced by combined inoculation of biofertilizers (Pooled for 2 years)

Treatments	Grain yield/ (q/ha)	Straw yield (q/ha)	Total biomas (q/ha)	Total N-uptake (kg/ha)	Total P-uptake (kg/ha)	Total K-uptake (kg/ha)	Total S-uptake (kg/ha)	Available-N (kg/ha)	Available-P (kg/ha)	Available-K (kg/ha)	Available-S (kg/ha)
T_1	10.07	12.56	22.63	76.33	7.43	31.93	4.46	188.30	8.09	376.88	8.63
T_2	11.5	14.21	25.72	90.27	8.89	36.98	5.61	201.95	9.18	388.78	8.87
T_3	11.76	14.96	26.73	94.62	9.44	39.11	6.00	219.83	9.75	401.03	9.02
T_4	12.18	15.17	27.35	99.46	10.16	40.80	5.48	229.55	10.57	406.92	8.20
T_5	12.94	15.70	28.64	105.98	11.19	44.10	7.08	238.57	11.67	414.20	8.57
T_6	13.44	16.21	29.65	111.10	11.98	47.78	7.75	241.10	12.09	416.06	9.83
T_7	13.91	16.64	30.55	116.30	12.82	52.57	8.45	288.44	12.51	418.32	9.88
C.D.(P=0.05)	**1.11**	**1.30**	**2.41**	**10.46**	**1.09**	**4.46**	**0.80**	**13.08**	**1.05**	**21.89**	**0.64**