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EFFICACY OF CO-INOCULATION OF BIOFERTILIZERS ON YIELD, ECONOMICS AND MICROBIAL ACTIVITIES UNDER SOYBEAN (*Glycine max* (L) Merrill) CROPPING IN VERTISOL

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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, economics and microbial activities under soybean cropping. The combined application of 50% RDF + *Glomus geosporum* (AMF) + PGRS (*Paenibacillus polymyxa*) + *Rhizobium japonicum* (T_7) proved most beneficial for growth symbiotic traits, yield-attributes and productivity of soybean in vertisol. This was equally followed by 50% RDF + *Glomus geosporum* (AME) + PGPR (*Paenibacillus polymyxa*) (T_6) and then 50% RDF + *Rhizobium japonicum* (T_5). The grain yield in T_7, T_6 and T_5 treatments was 13.91, 13.44 and 12.94 q/ha, respectively. The combined application of 50% RDF + *Glomus geosporum* (AMF) + PGPR (*Paenibacillus polymyxa*) + *Rhizobium japonicum* (T7) recorded the highest net returns (Rs 29988/ha), and 2.33 B:C ratio, followed by the treatment (50% RDF + *Glomus geosporum* (AMF) + PGPR

(*Paenibacillus polymyxa*) T_6 (Rs 28289/ha) and 2.24 B:C ratio. The highest dehydrogenase activity was found under the same treatment (T_7) 50% RDF + *Glomus geosporum* + PGPR + *Rhizobium japonicum* (19.33 TPF µg 24 hr^{-1} g^{-1}). This was equally followed by T_6 treatment (50%RDF+*Glomus geosporum*+PGPR). The DH activity being 18.29 TPF µg 24 hr^{-1} g^{-1}. The lowest (13.05 TPF µg 24 hr^{-1} g^{-1}) was obtained under absolute control (T_1). The same treatment T_7 also recorded

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the maximum number of fungi population 6.45 (CFU X 10^4 gm^{-1} soil) in the soil. The minimum number of fungi population 4.65 (CFU X 10^4 gm^{-1} soil) was noted under the absolute treatment (T_1).

Key words: Co-inoculation, biofertilizers, soybean

INTRODUCTION

Soybean is an important "edible grain legumes" divided into two types: oilseeds and pulses. Soybean oil and protein content account for about 60 percent of dry soybean by weight (contain protein 40% and oil 20%) known to have great nutritional value. Soybean, besides having a nutritional value is capable of fixing atmospheric nitrogen 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 etc. 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. Dehydrogenase activity (µg TPF/g soil/hr) was determined as described by Klein *et al.* (1971) whereas total number of bacteria & fungi population (cfu/g soil) were recorded as per method described by Chhonkar *et al*. (2006).

RESULTS AND DISCUSSION

Productivity parameters

Grain yield is a complex process which depends on the different yield attributing characters such as number of pods/plant, number of seeds/pod, seed index. The treatment T_7 (50% RDF + *Glomus geosporum* + PGPR + *Rhizobium japonicum*) exerted the maximum seed yield (13.41 q/ha) which was found at par with the treatment T_6 (13.44) and then T_5 (12.94 q/ha). The straw yield was 16.64, 16.21 and 15.70 q/ha, respectively.

Physiological phenomenon and plant growth pattern form an essential basis in crop management, sustained productivity, maintenance of proper soil moisture and reduction of crop-weed competition.

The increment in the supply of essential elements through AM fungi and PGPR sources could be the concomitant mineralization, their availability, mobilization and influx into the plant tissues increased and thus improved growth, yield components and finally the grain yield of soybean. These results corroborate with the findings of Jain (2015), Jain and Virendra (2017), Jain and Singh (2018) and Jain and Dhote (2019).

Economics

Net return is the actual profit gained under a particular combined treatment by subtracting the cost of cultivation from the gross return under the same treatment. The maximum net return obtained with the application of 50% RDF+*Glomus geosporum* + PGPR + *Rhizobium japonicum* (T_7) (Rs.29988/ha) with 2.33 B:C ratio. It was followed by the application of 50% RDF+Glomus geosporum + PGPR (T6) Rs.28289/ha with 2.24 B:C ratio and then T_5 (50%RDF + *Glomus geosporum* + PGPR) Rs.27036/ha with 2.22 B:C ratio.

Microbiological studies

Bacterial and Fungal counts

The highest population of Bacteria (8.15 CFU X 10^6 gm^{-1} soil) and Fungi (6.45 CFU X 10^4 gm^{-1} soil) were observed under treatment T_7 (50% RDF + *Glomus geosporum+PGPR+Rhizobium japonicum*). This increase may be attributed because of enhanced rhizospheric activities due to applied combined treatments. Though the similar findings have also been reported by Singh and Paikara (2014).

Dehydrogenase activity

The significant and highest value of DH activity (19.33 TPF µg 24 hr^{-1} g^{-1}) was found under treatment T_7 (50% RDF+*Glomus geosporum* + PGPR + *Rhizobium japonicum*) followed by Treatment T_6 (18.29 TPF µg 24 hr^{-1} g^{-1}). The different treatments significantly influenced the AM fungi root colonization.. The same treatment T_7 recorded the maximum population (18%) in the soil. The minimum population was recorded under absolute control (T_1). The acceleration in Dehydrogenase activity and AMF root colonization could be attributed due to enhanced microbial activities in the rhizosphere due to applied combined treatments of *glomus geosporum*, PGPR, *Rhizobium japonicum* with 50% RDF. The findings are in close agreement with the results reported by Jain and Singh (2018) and Jain and Dhote (2019).

The results concluded that the combined application of 50 % RDF + AM fungi + PGRS + *Rhizobium* recorded maximum yield, monetary returns and microbial population with increasing in dehydrogenase activity in soil under the soybean cropping.

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Table 1 Yield, economics and microbial activities under soybean cropping under co-inoculation and biofertilizers (Pooled for 2 years)

Treatments	Grain yield/ (q/ha)	Straw yield (q/ha)	Net income (Rs/ha)	B:C ratio	Bacteria(CFU x 10^6 gm^{-1} soil) population	Fungi (CFU x 10^4 gm^{-1} soil) Population	Dehydrogenase activity (TPF µg 24 hr^{-1} g^{-1})	AM fungi root colonization (%)
T_1	10.07	12.56	18770	1.97	6.35	4.65	13.05	12.00
T_2	11.5	14.21	21271	1.96	6.92	4.98	14.10	13.56
T_3	11.76	14.96	22323	2.00	6.99	5.37	14.29	14.85
T_4	12.18	15.17	23412	2.06	7.40	5.69	15.61	16.01
T_5	12.94	15.70	27036	2.22	7.83	6.03	17.15	16.79
T_6	13.44	16.21	28289	2.24	8.09	6.32	18.29	17.18
T_7	13.91	16.64	29988	2.33	8.15	6.45	19.33	18.00
C.D.(P=0.05)	**1.11**	**1.30**	**2.41**	**---**	**---**	**----**	**1.53**	**1.19**