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Interaction effect of microbial inoculation and fertilizer on nutrient availability, yield and quality of Soybean (Glycine max L. Merill) in Soybean-Chickpea sequence

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Abstract
Field experiment were conducted in kharif season 2020 and 2021 on Vertisol (Typic Haplustert) at Experimental Farm, Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Agricultural University, Parbhani to determine the effect of microbial consortia inoculation and chemical fertilizers on nutrient availability, N, P and K in soil, yield and quality of soybean crop. The experiment was laid in Factorial Randomized Block Design with four treatments of microbial consortia inoculants (uninoculated control (S0), Bradyrhizobium + Bacillus megaterium (S1), Bradyrhizobium + Pseudomonas striata (S3) and Bradyrhizobium + Thiobacillus thiooxidans (S4) of microbial consortia inoculation and four levels of chemical fertilizers (control i.e. without fertilizer (T1), 50% RDF (T2), 75 % RDF (T3) and 100 % RDF of chemical fertilizer kg ha^{-1}. The results were clearly indicated that the application of microbial inoculants as well as chemical fertilizers in their graded doses increased the seed, straw yield of soybean and soil availability nutrient N, P and K in soil significantly after harvest of crop. The enhancement in these parameterswere recorded with combined effect of microbial inoculants treatment (S3) Bradyrhizobium + Pseudomonas striata and chemical fertilizers 100 % RDF and that of microbial inoculants with application of chemical fertilizer indicating their significant p.

Keywords: Microbial inoculants, nutrient availability, yield, quality, soybean

Introduction

Microbial inoculation i.e. biofertilizer usually applied in the form of consortium can play role to enhance plant growth. This promotes the recovery of functional beneficial microbial groups that are positively linked to soil fertility and replenishes the natural microbiome, which has been noticed by crop and stimulate plant growth promoting mechanism in both optimal condition under different types of biotic and abiotic stress (Woo and Pepe, 2018) [13]. Further more consistent positive result may be obtained by inoculating plants with microbial consortia containing two or more beneficial microorganisms (Sharma *et al*., 2020; Zang *et al*., 2018). Bioinoculants based or microbial consortia may include bacteria of different species, while others may include both beneficial bacteria and fungi.

Soybean (Glycine max (L.) Merill.) is an annual leguminous species cultivated mainly for its seed. Soybean seed consists of 35 % carbohydrates, 5 % ash, 40 % protein and 20 % oil and its major source of protein and oil for commercial products. About 40 % of the worlds edible oil comes from soybean (Hildebrand *et al*., 1986). Soybean ranks first among the major oilseed crops of the world and has now found a prominent place in India (Mahana *et al*., 2005) [6]. In India production of soybean is dominated by Maharashtra and M.P. and it contributes 89 per cent of total production. Area of soybean in India is 11.38 million ha production is 11.94 million tonnes with average productivity 1050 kg ha^{-1} (Anonymous, 2019) [2], whereas world area, productionand productivity is 121.53 million ha, 334.89 million tones and 2760 kg ha^{-1}, respectively (Terzic *et al*., 2018) [12]. Symbiotic Rhizobium species associated with soybean root nodules benefit plant growth via mediating biological N fixation (Jaiswal *et al*., 2021) [5].

Material and Methods

Field experiment was conducted on Experimental Farm during kharif season of 2020 and 2021 at Vasantrao Naik Marathwada Agricultural University, Parbhani on Vertisol (Typic Haplustert). The initial physio-chemical properties of experimental soil are given in Table 1. The soil was clayey in texture, slightly alkaline in reaction, calcareous in nature and low in salt content. The organic carbon status of soil was medium, however available N, P and K content were low, medium and very high range respectively.

The treatments comprised of four levels of microbial consortia inoculation applied through seed treatment 100 ml per 10 kg seed of Soybean (S1) uninoculated control, (S2) Bradyrhizobhium + bacillus megaterium, (S3) Bradyrhizobium + Pseudomonas striata and (S4) Bradyrhizobium + Thiobacillus thiooxidant and four levels of chemical fertilizers (T1) Control (without fertilizer), (T2) 50% RDF. (T3) 75 % RDF and (T4) 100 % RDF. Thus 12 treatment combinations with three replications in Factorial Randomized Block Design. Chemical fertilizers was applied at the time of sowing through urea, SSP and MOP respectively

The seed and straw yield was recorded from each plot after harvested of crop and the seeds and straw was recorded plot wise and calculated on hectare basis as per standard procedure. Soil available N was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956) [11], available phosphorus determined by 0.5 M sodium bicarbonate (Ph 8.5) as an extractant and measured calorimetrically by using wave length 882 nm (Olsen *et al*., 1954) [7]. and available potassium was determined neutral normal ammonium acetate as an extractant and was measured on flame photometer (Piper, 1966) [8]. Further

quality parameters were oil content of soybean seed was extracted by using Soxhlet Apparatus (Ranganna, 1994) [9].

Results and Discussion

Seed and straw yield

The data on seed yield of soybean are presented in Table 1 & 2. The interaction effect between microbial consortia inoculants x chemical fertilizer were statistically significant and was found highest seed yield of soybean noted in treatment (T3 x S3) Bradyrhizobium + pseudomonas striata with treatment (T3) 75 % RDF (3262.62 and 3270 kg ha-1 and 3266.41 kg ha-1 in pooled) and was found lowest yield in (T1 x S1) uninoculated control (S1) along with (T1) without fertilizer i.e. control treatment during both of experimentation years and pooled data. Similarly straw yield of soybean observed that the effect of microbial consortia along with chemical fertilizers increased maximum straw yield of soybean were recorded in treatment (T4) 100 % RDF with (S3) Bradyrhizobiujm + Pseudomonas striata and value was (3796.06, 4137.33 and 3966.70 kg ha^{-1}) and minimum straw yield of soybean was recorded in treatment (T1) control i.e. without fertilizers along with (S1) uninoculated control treatment of both experimentation years and pooled mean respectively. Increased seed and straw yield of soybean with application of microbial inoculants and chemical fertilizers could might be due to improvement in growth, yield and yield parameters *viz*, N-fixation, number of nodules weight, shoot weight, number of pods, number of seeds per pod, etc. This indicates that nitrogen played important role in increased vegetative growth parameters (Bodkhe and Syed Ismail, 2014) [3]. Dual or more inoculants srhizobium species+ PSB might be due to greater availability of nitrogen and phosphorus in soil which resulted in better nodulation, growth and development, ultimately leading to increased grain yield (Rudraksha *et al*., 2005).

Table 1: Interaction effect of microbial consortia inoculation and chemical fertilizers on soil available phosphorus (kg ha^{-1}) after harvest of soybean (pooled)

Treatment	T_1- Control (without fertilizer)	T_2- 50% RDF	T_3- 75% RDF	T_4- 100% RDF	Mean
S_1- Uninoculated control	15.95	16.09	16.56	16.62	16.30
S_2-Bradyrhizobium+ Bacillus megaterium inoculation (Consortia-I)	17.63	18.43	18.45	19.30	18.45
S_3-Bradyrhizobium + Pseudomona striata inoculation (Consortia-II)	19.24	`20.21	20.62	20.49	20.14
S_4-Bradyrhizobium + Thiobacillusthiooxidant inoculation (Consortia-III)	17.5;9	18.05	18.63	19.04	18.33
Mean	17.61	18.20	18.56	18.86	
	S.E. ± 0.16				
	C.D. at 5% 0.47				

Table 2: Interaction effect of microbial consortia inoculation and chemical fertilizers on oil content (%) of soybean (pooled)

Treatment	T_1- Control (without fertilizer)	T_2- 50% RDF	T_3- 75% RDF	T_4- 100% RDF	Mean
S_1- Uninoculated control	17.47	17.27	17.73	17.83	17.57
S_2- Rhizobium+ Bacillus megaterium inoculation (Consortia-I)	19.47	19.62	19.80	19.82	19.68
S_3- Rhizobium + Pseudomona striata inoculation (Consortia-II)	19.86	19.93	20.09	20.26	20.03
S_4- Rhizobium + Thiobacillusthiooxidant inoculation (Consortia-III)	182.4	18.58	19.38	19.64	18.96
Mean	18.76	18.85	19.25	19.39	
	S.E. ± 0.10				
	C.D. at 5% 0.30				

Nutrient availability

The soil available nutrients N, P and K increased significantly due to application of microbial consortia inoculation and chemical fertilizers (Table 8 and 9). Interaction effect of available N, P and K increased significantly in treatment (T4 x S3) 100 % RDF along with Bradyrhizobium + Pseudomonas striata was observed highest soil available N (236.41 kg), available phosphorus was found highest in treatment Bradyrhizobium + pseudomonasstriataalong with 75 % RDF (23.47 kg) and interaction effect microbial inoculants and chemical fertilizers was found statistically non significant in influencing soil available potassium during 2020 and pooled but it was having significant effect on available potassium.

Results observed in Table in treatment T3 x S3 75 % RDF along with Bradyrhizobium + Pseudomonas striata (706.70 kg ha^{-1}) and minimum available N, P and K was found in treatment combination of (T4 x S3) without fertilizer and uninoculated treatment, respectively. Increase soil available N. Due to the application of different strains with 100 % RDF, increased soil microbial population, particularly n fixing bacteria. These bacteria build up or transform organically bound nitrogen to inorganic form. Similarly reported by Amule *et al*. (2018) [1, 14], Bodkhe *et al*. (2014) [3], they reported that the soil nutrients (NPKS) increased significantly with each successive increase of fertilizer upto 75 % and 100 % RDF in seed inoculation with N-fixers and PSB. Similarly, Sreenivasgan and Babalola (2021), Khandagale *et al*. (2020). Application of Pseudomonas striata and Bacillus megaterium as seed treatment these microbes are able to soluble P from insoluble form. The directly solubilize and improve the root system and plant growth. Kamble *et al*. 2018) reported integrated use of different organic sources and RDF to groundnut increased available N, P after harvest of crop. Similar finding were alsoreported by Ebrahim Pour *et al*. (2011) [17].

Table 3: Interaction effect of microbial consortia inoculation and chemical fertilizers on available nitrogen (kg ha^{-1}) in soil of soybean (pooled)$_3$

Treatment	T_1- Control (without fertilizer)	T_2- 50% RDF	T_3- 75% RDF	T_4- 100% RDF	Mean
S_1- Uninoculated control	152.72	159.11	161.39	166.03	159.15

S_2-Bradyrhizobium+ Bacillus megaterium inoculation (Consortia-I)	170.77	174.30	179.25	185.l01	177.34
S_3-Bradyrhizobium + Pseudomona striata inoculation (Consortia-II)	216.93	226.71	233.38	236.41	228.35
S_4-Bradyrhizobium + Thiobacillusthiooxidant inoculation (Consortia-III)	168.29	172.04	173.58	177.82	172.93
Mean	177.41	183.17	186.33	190.87	
	S.E. ± 3.88				
	C.D. at 5% 11.22				

Quality characteristics

Results also showed that oil content increased significantly with application of microbial inoculants Bradyrhizobium + Pseudomonasstriata with application of 100 % RDF. Treatment combination of (T4 x S3) increase in the oil content of seed of soybean and the maximum values is (20.26 per cent) treatment and was found at par with treatment (T3 x S3) 75 % RDF along with Bradyrhizobium + Pseudomonas striata treatment (S3). The per cent oil increase might be due to higher nitrogen absorption, due to this increased maximum acetyl Co-A formation and which was directly impact on oil formation and P content in inoculants is played important role carbohydrates metabolism and work in converted of carbohydrates into oil. Pseudomonas species play important role in formation of phosphorus indirectly helps in conversion of carbohydrates in to oil. These results confirm the finding of Singh and Sinsinwar (2006) [18]. reported that these biofertilizers increased the oil content positively in mustard.

Table 4: Interaction effect of microbial consortia inoculation and chemical fertilizers on seed yield (kgha^{-1}) of soybean (pooled)

Treatment	T_1- Control (without fertilizer)	T_2- 50% RDF	T_3- 75% RDF	T_4- 100% RDF	Mean
S_1- Uninoculated control	2353.38	2458.45	2590.76	2669.50	2518.02
S_2-Bradyrhizobium+ Bacillus megaterium inoculation (Consortia-I)	2983.11	3032.24	3044.96	3107.79	3029.53
S_3-Bradyrhizobium + Pseudomona striata inoculation (Consortia-II)	3148.66	3199.67	3266.41	3323.81	3234.64
S_4-Bradyrhizobium + Thiobacillusthiooxidant inoculation (Consortia-III)	2926.19	2944.59	2971.48	3041.88	2971.08
Mean	2852.83	2996.24	2968.41	3035.75	
	S.E. ± 21.55				
	C.D. at 5% 62.71				

Table 5: Interaction effect of microbial consortia inoculation and chemical fertilizers on straw yield (kg ha^{-1}) of soybean (pooled)

Treatment	T_1- Control (without fertilizer)	T_2- 50% RDF	T_3- 75% RDF	T_4- 100% RDF	Mean
S_1- Uninoculated control	3013.79	3156.19	3332.09	3345.98	3212.02
S_2-Bradyrhizobium+ Bacillus megaterium inoculation (Consortia-I)	3676.11	3702.56	3732.36	3768.32	3219.83
S_3-Bradyrhizobium + Pseudomona striata inoculation (Consortia-II)	3854.52	3872.32	3921.70	3966.70	3903.81
S_4-Bradyrhizobium + Thiobacillusthiooxidant inoculatio (Consortia-III)	3477.49	3556.70	3631.38	3673.94	3584.88
Mean	3505.46	3571.94	3654.38	3688.75	
	S.E. ± 14.86				
	C.D. at 5% 42.91				

Conclusion

The yield contributing characters' soil fertility with respect of N, P, K and oil content of seed of soybean were improved with treatment Bradyrhizobium + Pseudomonas striata and application of 100 % RDF to the soybean crop.

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