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Nutrient Uptake of Soybean (*Glycine max* L.) Plant as Affected by Liquid Biofertilizers (*Bradyrhizobium* and PSB)

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ABSTRACT

A field experiment was carried out on “Nutrient content and uptake of soybean as influenced by liquid biofertilizers (*Bradyrhizobium* and PSB)”. It was conducted in *Kharif* season during the year 2013-14 at the research farm of Oil Seed Research Station, Latur, Maharashtra, in factorial randomized block design with three replications and variety MAUS-81 as a test crop along with 16 treatment combination containing four levels of liquid *Bradyrhizobium* (0ml, 5ml, 10ml, and 15ml) and four levels of liquid PSB (0ml, 5ml, 10ml, and 15ml). Nutrients uptake *viz.* N, P, K and S were significantly increased due to seed inoculation with 10ml of *Bradyrhizobium* (A_2). However in later stages N uptake in soybean was increased significantly due to seed inoculation with 10ml of PSB (B_2).

Introduction

Soybean (*Glycine max*) a leguminous crop originated in China. It is basically a pulse crop and gained the importance as an oil seed crop as it contains 20% cholesterol free oil. It posses a very high nutritional value, and contains 40 per cent high quality protein due to this reason, soybean is known as `poor man’s meat’. India stands next only to China in the Asia pacific region, with respect to production (12.9 m.t). Maharashtra is the second largest producer in India, with 4.86 m.t of production (*Anonymous*, 2013). Soybean played a key role in the yellow revolution. It is newly introduced and commercially exploited crop in India. Soybean has been playing an important role in national economy by earning an average of Rs. 32,000 million per annum through export of soy meal and contributing about 18% to the edible oil production (*Anonymous*, 2012).

The prices of fertilizers are increasing day by day and therefore, it is necessary to reduce the cost of fertilizers by using *Bradyrhizobium* and PSB inoculation to increase yield of legume crops. Biofertilizers cannot replace chemical fertilizers, but certainly are capable of reducing their input. Seed inoculation with effective *Bradyrhizobium* inoculant is recommended to ensure adequate nodulation and N_2 fixation for maximum growth and yield of pulse crop. Biofertilizer do not supply nutrients directly to crop plants but have capacity to fix atmospheric nitrogen and convert insoluble phosphate into soluble form. Hence, soil microorganisms play significant role in mobilizing P for the use of plant and large fraction of soil microbial population can dissolve insoluble phosphate in soil. Zarrin *et al.,* (2007) studied the interactive effect of *Rhizobium* strains and P on soybean yield, Nitrogen fixation and soil fertility and observed the mixed *Rhizobium* inoculation with as well as without phosphorus significantly increased N P K uptake in shoot of soybean as compared to control.

Materials and Methods

The field experiment was conducted in *Kharif* season during the year 2013-14 at the research farm of Oil Seed Research Station, Latur, Maharashtra, geographically situated between 18^0 05' to $18^{0.}$75' N latitude and between 76^0 25' to $77^0$36' E longitude on the Deccan plateau with height mean sea level (MSL) about 633.85 meters and average rainfall is 750-800mm. The experimental soil was deep black in color with good drainage, moderate calcareous in nature and moderate alkaline in reaction with pH (1:2.5) 8.30, EC (1:2.5) 0.36 dSm^{-1} $CaCO_3$ (5.03%) and organic C (5.4 g kg^{-1}) The available soil N, P, K and S were 131.20, 19.68, 597.9, 15.35 $kgha^{-1}$ respectively. Soybean was grown in factorial randomized block design with three replications and variety MAUS-81 as a test crop along with 16 treatment combination containing four levels of liquid *Bradyrhizobium* (0ml, 5ml, 10ml, and 15ml) and four levels of liquid PSB (0ml, 5ml, 10ml, and 15ml). Soybean seed after inoculation with required quantity of liquid biofertilizers *viz. Bradyrhizobium* and PSB was sown at spacing 45 × 5cm @ 75 kg ha^{-1} in 4th July, 2013. A uniform dose of fertilizers (30:60:30:30 kg ha^{-1} of N, P_2O_5, K_2O, S) were supplied through urea, SSP, MOP and bensulph before sowing. Hand weeding was carried out at 26 DAS first spray of Chloropyriphos 25 ml/10lit water, bavistin 20 gm/10lit water at time of incidence of insect pests (30DAS) and second of proclaim (benzoet) 15gm/10lit of water at in 30 days interval of first spray. The crop was harvested on 15 Oct. 2013.

Results and Discussion

Uptake of nutrients

In order to study the impact of different levels of liquid *Bradyrhizobium* and PSB on nutrient uptake in soybean, plant samples were analyzed for N, P, K and S and result presented here.

Nitrogen uptake

In order to study the impact of different levels of liquid *Bradyrhizobium* and PSB on nutrient uptake in soybean, plant samples were analyzed for N, P, K and S and result presented here.

The N uptake in soybean plant was significantly influenced by liquid *Bradyrhizobium* at all the growth stages. Significantly higher N uptake was observed with A_2- 10ml of *Bradyrhizobium japonicum* kg^{-1} seed treatment at branching (43.92 kg ha^{-1}), flowering (59.30 kg ha^{-1}), pod formation (77.05 kg ha^{-1}), maturity (96.42 kg ha^{-1}) and at harvest (80.54 kg ha^{-1}) over A_0 and A_1 treatments. Treatments A_0 (control) and A_1 (5ml *Bradyrhizobium japonicum* kg^{-1} seed) as well as A_2 (10ml *Bradyrhizobium japonicum* kg^{-1} seed) and A_3 (15ml *Bradyrhizobium japonicum* kg^{-1} seed) were at par with each other at all the growth stages of soybean.

Significantly lower N uptake was recorded with treatment A_0 (control). Sheerin *et al.,* (1998) showed that application of N fixing biofertilizers enhances the organic acids which may partly be responsible for quick release of nutrients, resulting in more uptakes of nutrients. These results substantiated the findings of Kumrawat *et al.,* (1997). Further Chandra (2006) observed application of 20 g *Rhizobium* kg^{-1} indicated statistically similar N accumulation in grain (42.5 kg ha^{-1}) and more N uptake by straw (18.4 kg ha^{-1}) than the uninoculated control. The higher (*i.e.*, 40 g kg^{-1} seed) inoculums rate recorded significantly higher N uptake by grain (45.4 kg ha^{-1}) and straw (19.8 kg ha^{-1}) than the uninoculated (control). The N uptake in soybean plant was significantly influenced by liquid PSB levels at all the growth stages of soybean except branching and flowering stage (Table 1). Significantly higher N uptake was observed with B_2 (10ml of PSB kg^{-1} seed) treatment at pod formation (75.01 kg ha^{-1}), maturity (95.56 kg ha^{-1}) and harvest stage (79.75 kg ha^{-1}) over B_0 and B_1 treatments but treatments B_0 (control) and B_1 (5ml PSB kg^{-1} seed) as well as B_2 (10ml PSB kg^{-1} seed) and B_3 (15ml PSB kg^{-1} seed) were were at par with each other at all the pod formation, maturity and harvest growth stages of soybean. Significantly lower N uptake was recorded with treatment B_0 (control). Single inoculation of *Azotobacter* failed to improve the uptake of N and P, but inoculation of soybean with *Rhizobium*, PSB and FYM markedly improved their uptake (Krishna Reddy *et al.*, 2007).

The interaction effect between liquid *Bradyrhizobium* and PSB (A×B) on N uptake in soybean was not significant. The treatment A_2B_2 was not significant but it gave maximum N uptake at all the growth stages of soybean crop. However dual as well as multi inoculation of biofertilizers with or without FYM statistically increased the uptake of N and P. This might be attributed to enhanced activity of nitrogenase and nitrate-reductase enzyme in the soil (Oad *et al.*, 2002).

Uptake of phosphorus

The P uptake in soybean was significantly influenced by liquid *Bradyrhizobium* levels at all the growth stages of soybean except branching and flowering stage (Table 2). At branching and flowering stage results with respect to P uptake were non-significant. Significantly higher P uptake observed with A_2 (10ml of *Bradyrhizobium* kg^{-1} seed) treatment at pod formation (14.21 kg ha^{-1}), maturity (16.65 kg ha^{-1}) and at harvest (13.83 kg ha^{-1}) over A_0 and A_1 treatments but treatments A_0 (control) and A_1 (5ml PSB kg^{-1} seed) as well as A_2 (10ml PSB kg^{-1} seed) and A_3 (15ml PSB kg^{-1} seed) were at par with each other at all the pod formation, maturity and harvest growth stages of soybean. Significantly lower P uptake was recorded with treatment A_0 (control).

The P uptake in soybean plant was significantly influenced by liquid PSB levels at all the growth stages. Significantly higher p uptake observed with B_2- 10ml of PSB kg^{-1} seed treatment at branching (7.95 kg ha^{-1}), flowering (11.21 kg ha^{-1}), pod formation (13.80 kg ha^{-1}), maturity (17.71 kg ha^{-1}) and at harvest (14.77 kg ha^{-1}) over B_0 and B_1 treatments at all the growth stages but treatments B_0 (control) and B_1 (5ml PSB kg^{-1} seed) as well as B_2 (10ml PSB kg^{-1} seed) and B_3 (15ml PSB kg^{-1} seed) were at par with each other at all the growth stages of soybean. Significantly lower P uptake was recorded with treatment B_0 (control).

The higher concentration of phosphorus at branching might be due to the ability of PSB to transform insoluble phosphate in soil in to soluble forms by screating organic acids resulting in effective solubilization and utilization of phosphate.

Table.1 Effect of liquid bio-fertilizers on N uptake at various critical growth stages of soybean

Treatments	N uptake (kg ha^{-1})				
	branching	flowering	pod formation	maturity	harvest
***Rhizobium* levels (A)**					
A_0 (0ml)	38.14	51.47	65.38	86.41	71.31
A_1 (5ml)	39.42	53.43	68.42	88.72	73.44
A_2 (10ml)	43.92	59.30	77.05	96.42	80.54
A_3 (15ml)	41.93	56.13	72.25	92.07	77.93
S.Em±	1.05	1.58	2.21	1.48	1.38
CD at 5%	3.05	4.58	6.38	4.29	4.01
PSB levels (B)					
B_0 (0ml)	38.49	52.32	66.53	86.84	71.70
B_1 (5ml)	39.62	53.85	68.92	89.40	74.07
B_2 (10ml)	43.19	57.84	75.01	95.56	79.75
B_3 (15ml)	42.12	56.35	72.64	91.85	77.72
S.Em±	1.05	1.58	2.21	1.48	1.38
CD at 5%	NS	NS	6.38	4.29	4.01
Interaction (A×B)					
S.Em±	2.11	3.17	4.42	2.97	2.77
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**

Table.2 Effect of liquid bio-fertilizers on P uptake at various critical growth stages of soybean

Treatments	P uptake (kg ha^{-1})				
	Branching	**Flowering**	**Pod formation**	**Maturity**	**Harvest**
***Rhizobium* levels (A)**					
A_0 (0ml)	6.99	9.97	11.97	12.80	10.37
A_1 (5ml)	7.25	10.37	12.57	13.98	11.41
A_2 (10ml)	8.10	11.51	14.21	16.65	13.83
A_3 (15ml)	7.71	10.88	13.28	15.80	13.05
S.Em±	0.20	0.31	0.42	0.81	0.72
CD at 5%	NS	NS	1.22	2.34	2.09
PSB levels (B)					
B_0 (0ml)	7.05	10.12	12.18	12.72	10.30
B_1 (5ml)	7.29	10.45	12.68	13.64	11.12
B_2 (10ml)	7.95	11.21	13.80	17.71	14.77
B_3 (15ml)	7.96	10.94	13.39	15.17	12.49
S.Em±	0.20	0.31	0.42	0.81	0.72
CD at 5%	0.58	0.88	1.22	2.34	2.09
Interaction (A×B)					
S.Em±	0.40	0.62	0.84	1.62	1.44
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**

Table.3 Influence of liquid bio-fertilizers on K uptake at various critical growth stages of soybean

Treatments	K uptake (kg ha^{-1})				
	Branching	**Flowering**	**Pod formation**	**Maturity**	**Harvest**
***Rhizobium* levels (A)**					
A_0 (0ml)	33.34	43.33	45.39	54.79	43.67
A_1 (5ml)	34.58	45.22	48.10	58.12	46.63
A_2 (10ml)	38.80	50.68	55.46	67.34	54.90
A_3 (15ml)	36.94	47.79	51.54	63.62	51.56
S.Em±	1.02	1.53	2.02	2.51	2.24
CD at 5%	2.94	4.42	7.26	4.29	6.46
PSB levels (B)					
B_0 (0ml)	33.72	44.18	46.56	56.17	44.90
B_1 (5ml)	34.79	45.63	48.61	59.56	47.92
B_2 (10ml)	38.06	49.26	53.57	64.96	52.77
B_3 (15ml)	37.10	47.95	51.76	63.18	51.17
S.Em±	1.02	1.53	2.02	2.51	2.24
CD at 5%	2.94	NS	NS	NS	NS
Interaction (A×B)					
S.Em±	2.04	3.06	4.04	5.03	4.47
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**

Table.4 Effect of liquid bio-fertilizers on S uptake at various critical growth stages of soybean

Treatments	S uptake (kg ha^{-1})				
	Branching	Flowering	Pod formation	Maturity	Harvest
***Rhizobium* levels (A)**					
A_0 (0ml)	6.43	9.12	10.57	12.60	10.51
A_1 (5ml)	6.68	9.50	11.14	13.30	11.14
A_2 (10ml)	7.49	10.60	12.68	15.22	12.90
A_3 (15ml)	7.13	10.00	11.82	14.42	12.16
S.Em±	0.20	0.30	0.41	0.50	0.45
CD at 5%	0.57	0.87	1.18	1.46	1.31
PSB levels (B)					
B_0 (0ml)	6.49	9.26	10.77	12.83	10.72
B_1 (5ml)	6.72	9.59	11.25	13.60	11.41
B_2 (10ml)	7.35	10.31	12.29	14.73	12.46
B_3 (15ml)	7.17	10.06	11.92	14.37	12.12
S.Em±	0.20	0.30	0.41	0.50	0.45
CD at 5%	0.57	NS	NS	NS	NS
Interaction (A×B)					
S.Em±	0.40	0.60	0.82	1.01	0.90
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**

Inoculation of PSB alone increased the concentration of phosphorus in plant. Dubey (1997) found that phosphate solubilizing microorganisms play a major role in the solubilization and uptake of native and applied soil phosphorus.

The interaction effect between liquid *Bradyrhizobium* and PSB (A×B) on P uptake in soybean plant was non-significant. The combined treatment A_2B_2 (10ml of *Bradyrhizobium* + 10ml PSB kg^{-1} seed) gave maximum P uptake at all the growth stages of soybean crop.

However dual as well as multi inoculation of biofertilizers with or without FYM statistically increased the uptake of N and P. This might be attributed to enhanced activity of nitrogenase and nitrate-reductase enzyme in the soil (Purbey and Sen 2007), leading to greater biological nitrogen fixation by *Rhizobium* and increased availability of P in the soil due to greater solubilization of phosphate compound by phosphate solubilizing bacteria.

Uptake of potassium

The K uptake in soybean plant was significantly influenced by liquid *Bradyrhizobium* levels at all the growth stages of soybean (Table 3).

Significantly higher K uptake was recorded with A_2 (10ml of *Bradyrhizobium* kg^{-1} seed) treatment at branching (38.80 kg ha^{-1}), flowering (50.68 kg ha^{-1}), pod formation (55.46 kg ha^{-1}), maturity (67.34 kg ha^{-1}) and at harvest (54.90 kg ha^{-1}) over A_0 and A_1 treatments. The treatments A_0 (control) and A_1 (5ml *Bradyrhizobium* kg^{-1} seed) as well as A_2 (10ml *Bradyrhizobium* kg^{-1} seed) and A_3 (15ml *Bradyrhizobium* kg^{-1} seed) were at par with each other at all the growth stages of soybean. Significantly lower K uptake was recorded with treatment A_0 (control). Similar results were found in K uptake by Kapure and Naik (2004) and Thenua *et al.*, (2006).

The data indicated that the difference in K uptake due to different liquid PSB levels were not reach to the level of significance except branching stage. Maximum and minimum K uptake (Table 3) was recorded with B_2 (10ml PSB kg^{-1} seed) and B_0 (control) at all the growth stages of soybean.

Significantly higher K uptake observed with B_2 (10ml of PSB kg^{-1} seed) treatment at branching (38.06 kg ha^{-1}) over B_0 and B_1 treatments but treatments B_0 (control) and B_1 (5ml PSB kg^{-1} seed) as well as B_2 (10ml PSB kg^{-1} seed) and B_3 (15ml PSB kg^{-1} seed) found on par with each other. Significantly lower P uptake was recorded with treatment B_0 (control).

Deshmukh *et al.,* (2005) studied the effect of integrated use of inorganic, organic and biofertilizers on production, nutrient availability and economic feasibility of soybean grown on soil of kaymore plateau and satpura hills and reported that the application of 75% NPK + FYM + PSB significantly increased the uptake of N, P and K by 109.9, 20.9 and 106.4 per cent over farmer's practice.

The interaction effect between liquid *Bradyrhizobium* and PSB (A×B) on K uptake in soybean plant was failed to reach the levels of significance. The combined treatment A_2B_2 (10ml of *Bradyrhizobium* + 10ml PSB kg^{-1} seed) was not significant but it gave maximum K uptake at all the growth stages of soybean crop.

Disintegration of K minerals due to release of organic acids by bioinoculants used for seed inoculation purpose. It was also noticed that dual inoculation of *Rhizobium* + PSB showed its superiority over single inoculation of PSB and *Rhizobium*. These results are in line with the finding of Sharma and Namdeo (1999) found seed inoculation with *Rhizobium* and PSB in presence of FYM gave higher N, P and K contents in plant and seed.

Uptake of sulphur

Data indicating uptake of sulphur recorded at branching, flowering, pod formation, maturity and at harvest was presented in Table 4. It was evident from the results that the sulphur uptake was significantly influenced by individual seed treatment with *Bradyrhizobium* and PSB levels.

Significantly higher S uptake recorded with A_2 (10ml of *Bradyrhizobium* kg^{-1} seed) treatment at branching (7.49 kg ha^{-1}), flowering (10.60 kg ha^{-1}), pod formation (12.68 kg ha^{-1}), maturity (15.22 kg ha^{-1}) and at harvest (12.90 kg ha^{-1}) over A_0 and A_1 treatments.

The treatments A_0 (control) and A_1 (5ml *Bradyrhizobium* kg^{-1} seed) as well as A_2 (10ml *Bradyrhizobium* kg^{-1} seed) and A_3 (15ml *Bradyrhizobium* kg^{-1} seed) were at par with each other at all the growth stages of soybean. Significantly lower S uptake was recorded with treatment A_0 (control). Increased uptake of S by *Rhizobium* in soybean crop might be due to higher concentration of S in plant and increased dry matter yield of soybean crop. The higher content of S in seed and straw together with increased seed and straw yield might be the result of greater uptake of sulphur. These results are in agreement with those of Tomar (2011).

The data indicated that the difference in S uptake due to different liquid PSB levels was significantly affected at branching stage only. The treatment B_2 (10ml of PSB kg^{-1} seed) recorded significantly higher S uptake at branching (7.49 kg ha^{-1}) over B_0 and B_1 treatments but treatments B_0 (control) and B_1 (5ml PSB kg^{-1} seed) as well as B_2 (10ml PSB kg^{-1} seed) and B_3 (15ml PSB kg^{-1} seed) were at par with each other. Significantly lower S uptake was recorded with treatment B_0 (control). The result indicated that the difference in S uptake due to different liquid PSB levels were not reach to the level of significance except branching stage. The higher S uptake was recorded under the treatment B_2 (10ml of PSB kg^{-1} seed) and lower S uptake was observed with B_0 (control) treatment at all the growth stages of soybean except branching stage.

Pratibha and Ramesh (2011) studied the performance of liquid and carrier-based inoculats of *Mesorhizobium ciceri* and PGPR (*Pseudomonas diminuta*) in Chickpea (*Cicer arietinum* L.) on nodulation yield and soil properties and reported that the liquid inoculant of PGPR recorded significantly more S uptake by grain and straw by 6.7 and 19.4 % respectively than its carrier-based inoculants. Similar finding were recorded by Khandelwal *et al.,* (2012).

The interaction effect between liquid *Bradyrhizobium* and PSB (A×B) on S concentration and uptake in soybean was failed to reach the levels of significance. The treatment A_2B_2 (10ml of *Bradyrhizobium* + 10ml PSB kg^{-1} seed) was not significant but it gave maximum S content and uptake at all the growth stages of soybean crop.

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