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RESEARCH ARTICLE :

Effect of liquid biofertilizers (*Bradyrhizobium* and PSB) on growth characters of soybean (*Glycine max* L.)

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SUMMARY : A field experiment was carried out on "Effect of liquid biofertilizers (*Bradyrhizobium* and PSB) on growth characters of soybean". 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).The results of field experiment indicated that the growth parameters *viz.,* plant height, number of functional leaves, root length and dry matter yield were significantly increased due to dual inoculation with 10ml of *Bradyrhizobium japonicum* kg^{-1} seed + 10 ml of PSB kg^{-1} seed (A_2B_2) treatment over rest of the treatments but they were at par with (A_3B_3). Number of branches of soybean was significantly increased with individual seed inoculation of 10ml *Bradyrhizobium japonicum* kg^{-1} seed (A_2) as well as 10 ml of PSB kg^{-1} seed (B_2) over rest of the treatments but they were at par with A_3 (15ml *Bradyrhizobium japonicum* kg^{-1} seed) and B_3 (15 ml of PSB kg^{-1} seed), respectively.

KEY WORDS :
Liquid bio-fertilizers, *Bradyrhizobium,* PSB, Growth characters, Soybean

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BACKGROUND AND OBJECTIVES

Soybean (*Glycine max* L.) 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).

In view 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.

The benefits by the use of *Rhizobium* inoculants show that a quite good deal of money can be saved by marginal farmers by using quality tested inoculants on the farm. (Zarrin *et al*., 2007). PSM encourages early root development, produce organic acids like malic, succinic, fumaric, citric, tartaric and alpha ketoglutaric acid which hastens the maturity and there by increases the ratio of grain to straw as well as the total yield (Pavan and Satyanarayana, 2012).

The application of *Bradyrhizobia* (*Bradyrhizobium japonicum*) and phosphate solubilizing bacteria (*Pseudomonas* spp.) liquid inoculants on soybean seed before sowing plus 20kg N/ha enhanced that nodule number, fresh weight, dry weight of nodules, yield components and grain yield in comparison to conventional farmers fertilizer level. Soybean builds up the soil fertility by fixing large amounts of atmospheric nitrogen through the root nodules and also through leaf fall on the ground at maturity (Tran *et al*., 2007).

RESOURCES 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 colour 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 kg ha^{-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 g/10 lit water at time of incidence of insect pests (30DAS) and second of proclaim (benzoet) 15g/10 lit of water at in 30 days interval of first spray. The crop was harvested on 15 Oct. 2013.

OBSERVATIONS AND ANALYSIS

The results obtained from the present study as well as discussions have been summarized under following heads:

Growth parameters of soybean :

Plant height:

The data regarding plant height recorded at branching, flowering, pod formation and maturity were presented in Table 1. It was evident from the results that the plant height was significantly affected due to individual seed treatment with *Bradyrhizobium* and PSB levels. The taller plants were observed with treatment A_2 (10ml of *Bradyrhizobium japonicum* kg^{-1} seed) at all the critical growth stages of soybean. The treatment A_2 recorded significantly higher plant height at branching (20.76 cm), flowering (39.45 cm), pod formation (46.12 cm) and maturity (49.29 cm) over the A_0 (control) and A_1 (5ml *Bradyrhizobium japonicum* kg^{-1} seed). The treatments A_0 (control), A_1 (5ml *Bradyrhizobium japonicum* kg^{-1} seed) and A_3 (15ml *Bradyrhizobium japonicum* kg^{-1} seed) remained at par with each other. At all the growth stages lower plant height was observed with treatment A_0 (control). Thenua *et al*. (2006) reported that the *Rhizobium* inoculation gave significantly increased plant height (43.08 cm) over uninoculation (control) (40.05 cm) and only chemical fertilizer application in soybean. This increase in plant height might be due to more atmospheric N fixed by *Rhizobium* inoculation which helped in acceleration of various metabolic processes in plants resulting greater apical growth.

Similarly, Hasarin and Viyada (2008) found that the plant height of the soybean was significantly increased under liquid culture doses of *Rhizobium japonicum* inoculums.

PSB levels had remarkable positive effect on plant height. The plant height of soybean was found to increase gradually with increase in rate of liquid PSB level. Among the PSB levels, significantly taller plants were recorded with treatment B_2 (10 ml of PSB kg^{-1} seed) at all the growth stages of soybean (Table 4). The treatment B_2 observed significantly higher plant height at branching (20.99 cm), flowering (39.10 cm), pod formation (46.03cm) and maturity (48.85 cm) than the B_0 (control) and B_1 (5 ml of PSB kg^{-1} seed). The treatment B_0 (control) and B_1 (5 ml of PSB kg^{-1} seed) as well as B_2 (10 ml of PSB kg^{-1} seed) and B_3 (15 ml of PSB kg^{-1} seed) remained at par with each other. At all the growth stages lower plant height was observed with treatment B_0 (control). This increase in plant height might be due to production of growth-promoting hormones by PSB which improved solubilization of P, activity of phosphatase enzyme by PSB and photosynthetic rates, leading to greater apical growth. Umale *et al*. (2002) observed that maximum plant height was recorded with the phosphate solubilizing bacteria and higher levels of phosphorus. Similar finding were recorded by Molla *et al*. (2001) and Singh *et al*. (2009).

The interaction effect of liquid *Bradyrhizobium* and PSB (Table 2) was also found to be significant only at branching stage. Significantly highest plant height of soybean was observed with the treatment combination A_2B_2 (24.88 cm) this treatment combination was found significantly superior over rest of the treatments. This combined treatment A_2B_2 (*Bradyrhizobium* 10ml + PSB 10ml) was not Significant but it gave highest plant height at flowering (43.82 cm), at pod formation (50.49 cm) and at maturity (53.82 cm) growth stages of soybean. This might be due to production of growth-promoting hormones by *Bradyrhizobium* and PSB, leading to greater apical growth. Similarly Menaria *et al*. (2003) found that seed dual inoculation with Rz + PSB had significantly increased 33% plant height at 30 and 60 DAS over control. Similar results finding recoded by Govindan and Thirumurugan (2003).

Number of branches plant^{-1}:

The data pertaining to number of branches plant^{-1}

Table 1: Effect of liquid bio-fertilizers on plant height (cm) of soybean

Treatments	Mean plant height (cm)			
	Branching	Flowering	Pod formation	Maturity
***Rhizobium* levels (A)**				
A_0 (0ml)	18.68	35.80	41.25	44.25
A_1 (5ml)	18.92	36.78	42.31	45.31
A_2 (10ml)	20.76	39.45	46.12	49.29
A_3 (15ml)	19.86	37.81	43.54	46.54
S.E.±	0.46	0.81	1.14	1.17
C.D. (P=0.05)	1.33	2.33	3.28	3.37
PSB levels (B)				
B_0 (0ml)	18.40	35.90	41.12	44.21
B_1 (5ml)	18.93	36.41	42.19	45.27
B_2 (10ml)	20.99	39.10	46.03	48.85
B_3 (15ml)	20.60	38.43	43.88	47.06
S.E.±	0.46	0.81	1.14	1017
C.D. (P=0.05)	1.33	2.33	3.28	3.37
Interaction (A×B)				
S.E.±	0.91	1.62	2.27	2.33
C.D. (P=0.05)	2.65	NS	NS	NS

NS= Non-significant

recorded at all the critical growth stages were presented in Table 3. It was evident from the results that the number of branches plant^{-1} of soybean was influenced due to individual seed treatment with *Bradyrhizobium* and PSB levels. The highest number of branches plant^{-1} was observed with treatment A_2 (10ml of *Bradyrhizobium japonicum* kg^{-1} seed) at all the growth stages of soybean. The treatment A_2 recorded significantly highest number of branches at branching (5.03), flowering (8.72), pod formation (13.74) and maturity (15.97) over the A_0-control and A_1 (5ml *Bradyrhizobium japonicum* kg^{-1} seed). The 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 significantly lower number of branches plant^{-1} was observed in treatment A_0 (control). This increase in number of branches might be due to higher atmospheric nitrogen fixation, physiological efficiency and photosynthetic rates.

Sharma and Namdeo (1999) found that the seed inoculation with *Rhizobium* @ 25g kg^{-1} seed significantly increased number of branches plant^{-1} at branching, flowering, pod formation and maturity stages of soybean crop. These results are in conformity with the finding of Kumrawat *et al*. (1997).

PSB levels had remarkable positive effect on number of branches plant^{-1}. The number of branches of soybean was found to increase gradually with increase in rate of liquid PSB seed treatment upto 10ml PSB level then decreased with 15ml PSB level (Table 3). Among the PSB levels, significantly highest number of branches

Table 2: Interaction effect of liquid bio-fertilizers on plant height (cm) of soybean at branching stage

A×B	A_0 (0ml)	A_1 (5ml)	A_2 (10ml)	A_3 (15ml)
B_0 (0ml)	17.36	18.26	18.85	19.15
B_1 (5ml)	18.95	18.51	18.91	19.36
B_2 (10ml)	19.28	19.66	24.88	19.45
B_3 (15ml)	19.13	19.26	20.39	21.50
S.E.±		0.92		
C.D. (P=0.05)		2.65		

Table 3: Influence of liquid biofertilizers on number of branches plant^{-1} of soybean

Treatments	No. of branches plant^{-1}			
	Branching	Flowering	Pod formation	Maturity
***Rhizobium* levels (A)**				
A_0 (0ml)	3.74	7.12	10.71	13.25
A_1 (5ml)	3.80	7.43	11.51	14.04
A_2 (10ml)	5.03	8.72	13.74	15.97
A_3 (15ml)	4.81	8.15	12.88	15.13
S.E.±	0.14	0.21	0.30	0.34
C.D. (P=0.05)	0.40	0.59	0.88	0.97
PSB levels (B)				
B_0 (0ml)	3.76	7.18	10.84	13.15
B_1 (5ml)	4.09	7.63	11.50	14.01
B_2 (10ml)	4.88	8.53	13.58	16.03
B_3 (15ml)	4.66	8.10	12.92	15.19
S.E.±	0.14	0.21	0.30	0.34
C.D. (P=0.05)	0.40	0.59	0.88	0.97
Interaction (A×B)				
S.E.±	0.28	0.41	0.61	0.67
C.D. (P=0.05)	NS	NS	NS	NS

NS= Non-significant

plant^{-1} were recorded with treatment B_2 (10 ml of PSB kg^{-1} seed) at all the growth stages of soybean. The treatment B_2 observed significantly higher number of branches plant^{-1} at branching (4.88), flowering (8.53), pod formation (13.58) and maturity (16.03) over the B_0 (control) and B_1 (5 ml of PSB kg^{-1} seed). The treatment B_0 (control) and B_1 (5 ml of PSB kg^{-1} seed) as well as B_2 (10 ml of PSB kg^{-1} seed) and B_3 (15 ml of PSB kg^{-1} seed) were at par with each other. At all the growth stages significantly lower number of branches plant^{-1} was observed in treatment B_0 (control). This increase in number of branches might be due to improved solubilization of P through secretion of organic acid and also the activity of phosphatase enzyme by PSB (Pal, 1997). While among PSB inoculation recorded significantly higher number of branches which might be due to greater P solubilization and availability of P (Dubey, 1997).

The interaction effect of liquid *Bradyrhizobium* and PSB (A×B) on number of branches plant^{-1} was failed to reach the levels of significance at all the four growth stages of soybean crop but the combined treatment A_2B_2 (*Bradyrhizobium* 10ml + PSB 10ml kg^{-1} seed) was not significant but it gave higher number of branches plant^{-1}. This increase in number of branches might be due to higher atmospheric nitrogen fixation by *Rhizobium* and improved solubilization of P, activity of phosphatase enzyme by PSB and photosynthetic rates. Combined inoculation of *Rhizobium* and PSB increased number of branches plant^{-1} which might be due to greater P solubilization and atmospheric N fixation (Singh *et al*., 2007). Similar finding were recorded by Govindan and Thirumurugan (2003).

Number of functional leaves plant^{-1}:

The data pertaining to number of functional leaves plant^{-1} recorded at all the critical growth stages were presented in Table 4. It was evident from the results that the number of functional leaves plant^{-1} of soybean was influenced due to individual seed treatment with *Bradyrhizobium* and PSB levels. The higher number of functional leaves plant^{-1} was observed with treatment A_2 (10ml of *Bradyrhizobium japonicum* kg^{-1} seed) at all the growth stages of soybean. The treatment A_2 recorded significantly highest number of functional leaves at branching (7.38), flowering (14.23), pod formation (18.53) and maturity (16.36) over the A_0 (control) and A_1 (5ml *Bradyrhizobium japonicum* kg^{-1} seed). The treatments A_0 (control) and A_1 (5ml *Bradyrhizobium japonicum* kg^{-1} seed) as well as A_2 (10ml

Table 4: Effect of liquid bio-fertilizers on number of functional leaves plant^{-1} of soybean

Treatments	Number of functional leaves plant^{-1}			
	Branching	Flowering	Pod formation	Maturity
***Rhizobium* levels (A)**				
A_0 (0ml)	5.30	11.82	15.79	13.75
A_1 (5ml)	5.91	12.49	16.65	14.76
A_2 (10ml)	7.38	14.24	18.53	16.36
A_3 (15ml)	6.77	13.69	18.01	15.83
S.E.±	0.22	0.30	0.43	0.41
C.D. (P=0.05)	0.65	0.87	1.19	1.18
PSB levels (B)				
B_0 (0ml)	5.57	11.63	15.66	13.59
B_1 (5ml)	5.94	12.51	16.73	14.66
B_2 (10ml)	7.00	14.28	18.56	16.49
B_3 (15ml)	6.85	13.80	18.00	15.96
S.E.±	0.22	0.30	0.41	0.41
C.D. (P=0.05)	0.65	0.87	1.19	1.18
Interaction (A×B)				
S.E.±	0.45	0.60	0.82	0.82
C.D. (P=0.05)	NS	1.74	NS	NS

NS= Non-significant

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 significantly lower number of functional leaves plant^{-1} was observed in treatment A_0 (control). It might be due to greater availability of nitrogen with *Bradyrhizobium* seed treatment which responsible for atmospheric nitrogen fixation.Similarly Gupta and Thomas (2003) revealed that positive improvement in number of leaves plant^{-1} under *Rhizobium* seed treatment.

PSB levels had remarkable positive effect on number of functional leaves plant^{-1}. Among the PSB levels, significantly highest number of functional leaves plant^{-1} were recorded with treatment B_2- 10 ml of PSB kg^{-1} seed at all the growth stages of soybean (Table 4). The treatment B_2 observed significantly highest number of functional leaves plant^{-1} at branching (7.00), flowering (14.28), pod formation (18.56) and maturity (16.49) over the B_0 (control) and B_1 (5 ml of PSB kg^{-1} seed). The treatment B_0 (control) and B_1 (5 ml of PSB kg^{-1} seed) as well as B_2 (10 ml of PSB kg^{-1} seed) and B_3 (15 ml of PSB kg^{-1} seed) were at par with each other. At all the growth stages significantly lower number of functional leaves plant^{-1} was observed in treatment B_0 (control). It might be due to greater availability of phosphorus with PSB seed treatment which responsible for solubilization of P, activity of phosphatase enzyme by PSB leading to greater apical growth. Similarly Dubey (1997) revealed that positive improvement in number of leaves plant^{-1} under PSM seed treatment.

The interaction effect of liquid *Bradyrhizobium* and PSB (A×B) was also found to be significant only at flowering stage (Table 5). Significantly higher number of functional leaves plant^{-1} was observed in the treatment

Table 5: Interaction effect of liquid bio-fertilizers on number of functional leaves plant^{-1} of soybean at flowering stage

A×B	A_0 (0ml)	A_1 (5ml)	A_2 (10ml)	A_3 (15ml)
B_0 (0ml)	10.04	10.50	12.50	13.40
B_1 (5ml)	11.39	13.15	13.60	13.55
B_2 (10ml)	12.80	14.26	15.35	13.60
B_3 (15ml)	12.01	13.40	14.93	13.98
S.E.±		0.60		
C.D. (P=0.05)		1.74		

Table 6: Effect of liquid bio-fertilizers on root length of soybean

Treatments	Mean root length (cm)			
	Branching	Flowering	Pod formation	Maturity
***Rhizobium* levels (A)**				
A_0 (0ml)	7.32	9.57	15.79	18.32
A_1 (5ml)	7.93	10.32	16.54	18.93
A_2 (10ml)	9.40	12.61	18.82	20.40
A_3 (15ml)	8.79	12.01	18.23	19.79
S.E.±	0.22	0.32	0.33	0.36
C.D. (P=0.05)	0.65	0.93	0.97	1.04
PSB levels (B)				
B_0 (0ml)	7.59	9.85	16.07	18.59
B_1 (5ml)	7.96	10.63	16.85	18.96
B_2 (10ml)	9.02	12.06	18.28	20.03
B_3 (15ml)	8.87	11.97	18.19	19.87
S.E.±	0.22	0.32	0.33	0.36
C.D. (P=0.05)	0.65	0.93	0.97	1.04
Interaction (A×B)				
S.E.±	0.45	0.65	0.67	0.72
C.D. (P=0.05)	NS	1.87	1.95	NS

NS= Non-significant

combination A_2B_2 (15.35) than the rest of the treatments but at par with the A_1B_2, A_2B_3 and A_3B_3 treatments and the lower number of functional leaves observed in treatment combination of A_0B_0 (control).

Greater availability of nutrients with the application of microbial inoculants (Rz + PSB) seems to have promoted various physiological activities in plant which are considered to be indispensible for proper growth and development.

Similarly significantly improvement in number of leaves plant^{-1} and overall growth of soybean plants due to inoculation with Rz + PSB was in close great agreement with finding of (Dubey, 1998) in soybean.

Root length (cm) :

The result regarding root length of soybean recorded at all the critical growth stages were presented in Table 6. It was evident from the results that the root length of soybean was influenced due to individual seed treatment with *Bradyrhizobium* and PSB levels. The higher root length was observed with treatment A_2 (10ml of *Bradyrhizobium japonicum* kg^{-1} seed) at all the growth stages of soybean. The treatment A_2 recorded significantly longer root length at branching (9.40 cm), flowering (12.61 cm), pod formation (18.82 cm) and maturity (20.40 cm) than the A_0 (control) and A_1 (5ml *Bradyrhizobium japonicum* kg^{-1} seed). The 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 on par with each other. At all the growth stages significantly shorter root length was observed in treatment A_0 (control).The root length increased might be due to greater availability of N with application of *Bradyrhizobium* which responsible for free atmospheric N fixation and nitrate reductase enzyme activity. Similarly Kalhapure *et al*. (2003) studied the varietal response of soybean to different strains of *Bradyrhizobium japonicum* and observed the *B. japonicum* inoculation increased the seed germination, root length, nodulation, growth and yield of soybean varieties over uninoculated control.

PSB levels had remarkable positive effect on root length. Among the PSB levels, significantly longer root length were recorded with treatment B_2 (10 ml of PSB kg^{-1} seed) at all the growth stages of soybean (Table 6). The treatment B_2 observed significantly longer root length at branching (9.02 cm), flowering (12.06 cm), pod formation (18.28 cm) and maturity (20.03 cm) than the B_0 (control) and B_1 (5 ml of PSB kg^{-1} seed). The treatment B_0 (control) and B_1 (5 ml of PSB kg^{-1} seed) as well as B_2 (10 ml of PSB kg^{-1} seed) and B_3 (15 ml of PSB kg^{-1} seed) remained at par with each other. At all the growth stages significantly shorter root length was observed in treatment B_0 (control). Increase in root length might be due to seed treatment with PSB which responsible for solubilization of applied and native soil phosphorus. Selvakumar *et al*. (2012) the investigation

Table 7: Interaction effect of liquid bio-fertilizers on root length of soybean at flowering stage

A×B	A_0 (0ml)	A_1 (5ml)	A_2 (10ml)	A_3 (15ml)
B_0 (0ml)	7.70	7.91	12.47	10.88
B_1 (5ml)	8.47	10.69	12.49	11.11
B_2 (10ml)	11.76	11.50	13.87	12.18
B_3 (15ml)	10.35	11.19	12.67	12.79
S.E.±		0.65		
C.D. (P=0.05)		1.87		

Table 8 : Interaction effect of liquid bio-fertilizers on root length of soybean at pod formation stage

A×B	A_0 (0ml)	A_1 (5ml)	A_2 (10ml)	A_3 (15ml)
B_0 (0ml)	13.92	14.13	18.89	17.33
B_1 (5ml)	14.69	16.91	18.71	17.10
B_2 (10ml)	17.98	17.72	20.09	18.40
B_3 (15ml)	16.57	17.41	18.69	19.01
S.E.±		0.67		
C.D. (P=0.05)		1.95		

was aimed at determining the effects of biofertilizers and their pure cultures on phytohormones production, plant growth and yield. Biopower inoculation also resulted in an increase in nodule numbers, root length, shoot length, seed weight and yield

The interaction effect of liquid *Bradyrhizobium* and PSB (A×B) was also found to be significant at flowering (Table 7) and pod formation stages (Table 8). Significantly longer root length of plant was observed in the treatment combination A_2B_2 (*Bradyrhizobium* 10ml and PSB 10ml/ kg seed) at flowering (13.87 cm) and at pod formation (20.09 cm) over the rest of the treatments but at flowering and pod formation stages were on par with the A_2B_0, A_2B_1, A_2B_3 and A_3B_3 treatments and the shorter root length observed in treatment combination of A_0B_0 (control).

This increase in root length might be due to higher atmospheric nitrogen fixation and activity of nitrobacter by *Rhizobium* seed inoculation and improved solubilization of P, activity of phosphatase enzyme by PSB. Individual and co-inoculation of *Rhizobium* and PSB significantly enhanced root length which might be due to greater P solubilization and atmospheric N fixation (Molla *et al*., 2001). Similar finding also reported by Sheikh *et al*., (2012).

Dry matter yield :

The data with respect to dry matter yield recorded at all the critical growth stages were presented in Table 9. The dry matter yield of soybean increased with advanced stages of growth upto maturity but it was decreased at harvesting stage due to leaf shrading. The

Table 9: Influence of liquid bio-fertilizers on dry matter yield of soybean

Treatments	Dry matter yield (qt. ha^{-1})				
	branching	flowering	pod formation	maturity	harvest
***Rhizobium* levels (A)**					
A_0 (0ml)	14.12	21.41	28.14	36.38	32.19
A_1 (5ml)	14.23	21.63	28.62	37.02	32.84
A_2 (10ml)	15.06	22.68	30.39	39.33	35.14
A_3 (15ml)	14.86	22.95	29.88	38.78	34.59
S.E.±	0.21	0.30	0.52	0.61	0.61
C.D. (P=0.05)	0.60	0.87	1.50	1.77	1.77
PSB levels (B)					
B_0 (0ml)	14.03	21.40	28.12	36.36	32.18
B_1 (5ml)	14.20	21.62	28.60	37.29	33.10
B_2 (10ml)	15.09	22.57	30.20	39.20	35.02
B_3 (15ml)	14.75	22.29	29.70	38.60	34.47
S.E.±	0.21	0.30	0.52	0.61	0.61
C.D. (P=0.05)	0.60	0.87	1.50	1.77	1.77
Interaction (A×B)					
S.E.±	0.42	0.60	1.04	1.22	1.22
C.D. (P=0.05)	1.20	NS	NS	NS	NS

NS= Non-significant

Table 10: Interaction effect of liquid bio-fertilizers on dry matter yield (qt. ha^{-1}) of soybean

A×B	A_0 (0ml)	A_1 (5ml)	A_2 (10ml)	A_3 (15ml)
B_0 (0ml)	13.52	14.04	14.22	14.33
B_1 (5ml)	14.24	13.93	14.19	14.43
B_2 (10ml)	14.39	14.56	16.93	14.47
B_3 (15ml)	14.32	14.38	14.90	15.74
S.E.±		0.42		
C.D. (P=0.05)		1.20		

data revealed that dry matter accumulation affected significantly due to individual seed treatment with *Bradyrhizobium* and PSB levels. The maximum dry matter yield was observed with treatment A_2 (10ml of *Bradyrhizobium japonicum* kg^{-1} seed) at all the growth stages of soybean. The treatment A_2 recorded significantly higher dry matter yield at branching (15.06 qt/ha), flowering (22.68 qt/ha), pod formation (30.39 qt/ ha), maturity (39.33 qt/ha) and at harvest (35.14 qt/ha) than the A_0 (control) and A_1 (5ml *Bradyrhizobium japonicum* kg^{-1} seed). The 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 on par with each other at all the growth stages. Significantly lower dry matter yield was found with treatment A_0 (control). This increase in dry matter accumulation might be reasons for increasing the growth parameters *i.e.* plant height, branches, leaf area, number and dry weight of root nodules.

The above results are in line with many researchers. Islam *et al*., (1999) carried out a field experiment on soybean inoculation with individual *Bradyrhizobium* inoculums and observed that inoculated seed gave higher dry matter yield over uninoculated control. Similar results were found by Bhuiyan *et al*. (1998) in soybean.

Dry matter yield of soybean recorded at all the critical growth stages were significantly influenced due to different PSB levels. Among the PSB levels, significantly higher dry matter yield were recorded with treatment B_2- 10 ml of PSB kg^{-1} seed at all the growth stages of soybean (Table 9) The treatment B_2 recorded significantly higher dry matter accumulation at branching (15.09 qt/ha), flowering (22.57 qt/ha), pod formation (30.20 qt/ha) maturity (39.20 qt/ha) and at harvest (35.02 qt/ha) as compared to B_0 (control) and B_1 (5 ml of PSB kg^{-1} seed). The treatment B_0 (control) and B_1 (5 ml of PSB kg^{-1} seed) as well as B_2 (10 ml of PSB kg^{-1} seed) and B_3 (15 ml of PSB kg^{-1} seed) were at par with each other at all the growth stages. Significantly lower dry matter yield was observed with treatment B_0 (control).

The above results are in line with many researchers. Raut *et al*. (2003) observed that maximum dry matter accumulation with the application of PSB made P available in soluble form in plant growth. This might be reasons for increasing the growth parameters *i.e.* dry matter accumulation, height, branches, leaf area, number and dry weight of root nodules.

Interaction effect between liquid *Bradyrhizobium* and PSB (A×B) was also found to be significant only at branching stage as presented in Table 10. Significantly higher dry matter yield was observed in the treatment combination A_2B_2 (16.93 qt/ha) as compared to rest of the treatments but it was at par with the A_3B_3 treatment. The lower dry matter yield was recorded with treatment combination of A_0B_0 (control). Similar results were recorded by Tran *et al*. (2007) in soybean.

Pawar *et al*. (2008) studied the combined effect of bioagents on growth and yield parameters of red gram and result revealed that the treatment T_{13} (*Rhizobium* + VAM + PSB + *Bacillus substilis*) recorded significant increase in dry matter by 33.33% and grain yield 24.22% over control.

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