

Original Research Article

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## Effect of Microbial Consortia on Growth, Nodulation, Yield and Nutrient Uptake of Soybean in Vertisol of Central India

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### ABSTRACT

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A field experiment on “Effect of microbial consortia on growth, nodulation, yield and nutrient uptake of soybean” was carried out during *Kharif* 2018-19 under the Department of Soil Science & Agricultural Chemistry. The experiment was laid out under randomized block design (RBD) with 3 replications and 9 treatments comprising beneficial microorganisms of Actinomycetes, *Arthrobacter* and PGPR (*P. fluorescens*) in possible combinations applied as seed treatments and additionally *P. fluorescens* was applied as foliar application at 20, 40 and 60 DAS of the crop growth stages. The crop was supplemented with recommended dose of fertilizers 20:80:20 (N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O kg ha<sup>-1</sup>) at basal application. Besides these, two types of control plots were maintained as fertilized uninoculated control (FUI) and unfertilized uninoculated control (UFUI). Results revealed that the significant improvement were noticed in plant growth attributes of nodulation (57 and 43.5%), over control (9.5 and 33.4 nodule plant<sup>-1</sup>) and its biomass, (71 and 43%), over the control (0.38 and 1.12 g plant<sup>-1</sup>) plant height 47, 38, 32% over the control (16.3, 35 and 45.4 cm) and its biomass, (39, 57 and 65%), over the control 1.22, 3.41 and 6.07 g plant<sup>-1</sup> leaf chlorophyll content (32 and 31.0 %) over the control (2.65 and 2.92 mg g<sup>-1</sup> leaf) all at 25, 45 and 65 DAS, nutrient contents (N, P and K seed and stover respectively) 58 and 122%, 65 and 101%, 70 and 86% over the control 98.5, 63.8, 5.2, 7.4, 24.9 and 44.4 kg ha<sup>-1</sup>, yields 44 and 61% over the control 1636 and 3345 kg ha<sup>-1</sup> respectively (seed and stover) at harvest of the crop.

### Introduction

Soybean is the most important oil seed crop in India which contains 35-40% protein, 19% oil, 35% carbohydrate, 5% minerals and several other components including vitamins (Liu, 1997). In Madhya Pradesh the area under soybean cultivation is 54.100 lakh ha. with 1,094 kg ha<sup>-1</sup> yield and 59.170 lakh MT

production (SOPA, 2018). Soybean rhizosphere harbors vast proportions soil microorganisms, whose activities largely determine the biological condition of the soil and influence the plant growth right from seed germination to maturity (Egamberdiyeva, 2005). Among nitrogen fixing microorganisms in soybean rhizosphere *Arthrobacter* is a typical diazotroph.

The microbe is a rod shaped aerobic Gram-positive becomes cocci at stationary growth phase that favours the crop with nutrient supplements including indeterminate way of N fixation and tolerance at moisture stress condition. Some species of *Arthrobacter* have been acknowledged for oxygen independent growth strategies under limited oxygen.

These species also under restriction of oxygen use nitrate as an electron. A number of evidence has been established that PGPR comprising *Pseudomonas* plays a major role in functioning of the biosphere. These bacteria stimulate the growth of plants through direct and indirect beneficial effects viz., enhancing diazotrophy, nutrient solubilization, siderophore formation for Fe availability, excretion of growth promoting enzymes (IAA, GA, ABA, cytokinin, etc.), vigorous growth via ACC-deaminase activity, plants systemic resistance (ASR and ISR(acquired and induced systemic resistance), and antioxidants (Bharadwaja *et al.*, 2008 and Kumar *et al.*, 2013) acceptor at the end of their respiratory chain, reducing it to ammonia via nitrite.

Actinomycetes are versatile group of microorganism habitually aerobic, performing important activities in soil like production of growth promoting substances, phosphorus solubilization, decomposition of organic matter, antibiotic production for suppression of soil borne plant pathogens etc. (Franco and Valencia, 2001).

*Arthrobacter*, actinomycetes and *P. fluorescens* individually are found beneficial but their co-inoculation in the form of a consortium acts as reinforced source to augment diazotrophy, nutrient solubilization, plant growth promoter and protectant against soil borne pathogens especially under moisture stress condition encountered by the crop.

## Materials and Methods

The experiment was carried out during *Kharif* 2018 at the Research field Department of Soil Science and Agricultural Chemistry, JNKVV, Jabalpur. Under the project AINP on Soil Biodiversity & Biofertilizers (ICAR), JNKVV, Jabalpur.

The recommended dose of fertilizer @ 20:80:20 kg ha<sup>-1</sup>(N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O) for soybean crop was applied in the form of urea, single super phosphate (SSP) and murate of potash (MOP). SSP and MOP were supplemented as basal applications to each plot as per recommendation.

One ml of gum acacia sticker solution was poured on the seed of each polythene bag followed by one ml of liquid formulations of different isolates and its consortium. By holding the mouth of polythene bags seeds were enough shaken to get mixed with the sticker and inoculants formulation so that each seed receive proper coating.

## Nodulation

Nodulation studies were done at 25 and 45 days of sowing by uprooting 3 plants plot<sup>-1</sup> very carefully taking sufficient care to avoid any losses or damage of nodules. After proper washing nodules of plants per plot were counted. After counting, the nodules were detached from the roots and were kept in small paper bags. Then the nodule fresh weight was taken. Nodules were oven dried in hot air oven at 60<sup>0</sup>C for (18-20 hrs) 3-4 days (till constant weight) to record their oven dried weight.

## Plant height and plant dry biomass

Plant height and plant dry biomass was measured at 25, 45 and 65 DAS. Three plants from each plot were taken and their heights dry weight was measured.

### Chlorophyll content

Leaf chlorophyll (a, b and total) content was estimated by acetone extraction method in fresh plant leaves at 25 and 45 DAS.

### Digestion of plant samples

The plants samples were subjected to wet digestion for estimation of various nutrients in grain and straw Mixture of HNO<sub>3</sub> and HClO<sub>4</sub> was added in 2.5:1 ratio (v/v) for estimation of major nutrients.

### Total nitrogen

The nitrogen content of soybean plant was estimated on dry weight basis by micro-kjeldahl method as per procedure suggested by AOAC (1995).

### Total phosphorus and potassium

The phosphorus contents in grain and straw of soybean were estimated on dry weight basis by vanado-molybdate yellow colour method as suggested by Bhargava and Raghupathi (1984). The potassium content in the digested material was directly estimated. Nutrients uptake by soybean was calculated in kg ha<sup>-1</sup> in relation to dry with a flame photometer using the procedure of Bhargava and Raghupathi (1984).matter production by using the following formula.

$$\frac{\text{Nutrient uptake (kg ha}^{-1}\text{)} \times \text{content (\%)} \times \text{yield (kg ha}^{-1}\text{)}}{100}$$

### Results and Discussion

#### Nodulation studies

The data on Nodulation of soybean is given in Table 1. the maximum Nodulation at 25 DAS was increased with the microbial consortium of PGPR+*Arthrobacter*+ Actinomycetes

recorded the significantly higher nodules number (14.3 No. plant<sup>-1</sup>) by 57% response, followed by PGPR+ *Arthro*, PGPR+Actino, *Arthro*+Actino, and PGPR with number of nodules 13.7, 13.2, 12.3 and 11.7 along with response of 44.2, 42.1 29.4 and 23.2%, respectively over FUI (9.5 nodules plant<sup>-1</sup>). Similarly, the maximum number of nodules of 48 No. plant<sup>-1</sup> at 45 DAS was recorded by treatment combination of PGPR+ *Arthro*+Actino with 43.7% increment, followed by PGPR+*Arthro* and PGPR+Actino with nodule 41.3 and 40.8 No. plant<sup>-1</sup> by 23.65 and 22.15% response, respectively over FUI (33.4 nodules No. plant<sup>-1</sup>). Jakhar *et al.*, (2018) Treatment P80+LRh (80 kg P<sub>2</sub>O<sub>5</sub> + liquid inoculum of *Rhizobium*) for enhanced the nodulation attributes, over the control at 45 DAS. The treatment P80+LRh gave maximum nodules number (81.1%), weight (89.1% fresh and 78.5% dry) and N content (64.4%) over control (6.9 number/plant, 103 mg/plant, 65 mg/plant and 2.03%), respectively.

The data related to nodule dry weight at 25 and 45 DAS of soybean were recorded and revealed that the consortium of PGPR+ *Arthro*+Actino gave the significantly higher nodule dry wt. 0.65 g with an increment 71% over FUI (0.38 g), followed by PGPR+*Arthro*, PGPR+Actino, *Arthro*+Actino and PGPR with nodule dry wt. 0.54, 0.53, 0.51 and 0.49 g along with percent response 71, 42, 39, 34 and 29 %, respectively over FUI (0.38 g nodules plant<sup>-1</sup>). Similarly, nodule dry weight plant<sup>-1</sup> of soybean at 45 DAS recorded maximum with consortium PGPR+*Arthro*+Actino as significantly highest (1.60 g) compared to FUI (1.12 g) by 43% response followed by PGPR+*Arthro*, PGPR+Actino and *Arthro*+Actino with nodule dry weight of 1.38,1.36,1.33 and 1.30 g plant<sup>-1</sup> these treatment responded 23, 21, 19 and 16% over FUI. The actinomycetes consortium (consortium of different strains of actonomycetes) and *Rhizobium* consortia along with PGPR consortia was found most

effective among microbial inoculants, in respect of symbiotic parameters including nodule number, nodule dry weight Gopalakrishnan *et al.*, (2015). The consortia of bradyrhizobia (*Bradyrhizobium japonicum*) and phosphate solubilizing bacteria (*Pseudomonas* sp.) as liquid inoculants on soybean enhanced the nodule number, fresh weight and dry weight of nodules Amule *et al.*, (2018).

### **Plant height and biomass**

The data on Plant height and its biomass of soybean is given in Table 2 and 3.

plant height of 23.9 cm at 25 DAS was responded maximum with the treatment combination of PGPR+*Arthrobacter*+Actinomycetes and responded by 46.62% over the FUI (16.3 cm) followed by PGPR+*Arthro*, PGPR+Actino, *Arthro* +Actino with plant height of 22.4 cm, 21.9 cm and 21.5 cm along with 37.42, 34.29 and 31.90% response, respectively.

Similarly at 45 DAS the plant height (48.3 cm) was significantly influenced by the treatment combination of PGPR+*Arthro*+Actino with an increment 38%, over FUI (35 cm) followed by PGPR+*Arthro*, PGPR+ Actino, *Arthro*+Actino, with plant height of 45 cm, 44.3 cm, 43 cm and 42.3 cm and response increase by 28.57, 26.57, 22.85 and 20.85%, respectively.

The plant height (59.8 cm) of soybean at 65 DAS exhibited of the significantly higher plant height (59.8 cm) was found associated with PGPR+ *Arthro*+Actino with an increment 31.7% over FUI (45.4 cm). This was followed by PGPR+*Arthro*, PGPR+ Actino, *Arthro*+Actino with plant heights of 57.5 cm, 57.1 cm, and 55.5 cm along with response increase by 26.6, 25.7, and 22.2 %, respectively. It is well documented that soil microorganisms exert a beneficial effect

on plant growth and development. In fact, many microorganisms are being commercialized to be used in agriculture Bashan *et al.*, (2014).

The dry biomass 1.70 g plant<sup>-1</sup> of soybean plant at 25 DAS was gained maximum by the consortium PGPR+*Arthro*+Actino with 39% response over the control FUI (1.22 g plant<sup>-1</sup>) followed by PGPR+*Arthro* and PGPR+Actino with plant dry biomass of 1.63 and 1.56 along with 34 and 28% response, respectively.

Similarly the dry biomass at 45 DAS the treatment combination of PGPR+*Arthro*+Actino increased the plant dry biomass by 5.14 g plant<sup>-1</sup> with 51% response over FUI (3.41 g plant<sup>-1</sup>) followed by the consortium PGPR+*Arthro* with plant biomass of 4.52 g plant<sup>-1</sup> by 33% increment over FUI (3.41 g plant<sup>-1</sup>).

The highest plant biomass at 65 DAS of 10 g plant<sup>-1</sup> recorded by application of PGPR+*Arthro*+Actino with an increment of 65% over the control FUI (6.07 g plant<sup>-1</sup>) followed by PGPR+*Arthro* and PGPR+Actino with plant dry biomass of 8.86 and 8.48 g plant<sup>-1</sup> by 43 and 40% response, respectively. Jha and Saraf (2012) also reported that the root and shoot biomass were maximized with microbial consortia compared to both control and individual trials of microorganisms.

Linu (2009) also confirmed the findings that the seed inoculation in cowpea by phosphate solublizers improved nodulation, root and shoot biomass, stover and seed yield and phosphorous and nitrogen uptake by crop. Co-inoculation of *G. fasciculatum*, *P. fluorescens* and *A. chroococcum* enhanced shoot and root biomass of tomato (Kavatagi *et al.*, 2014).

### **Chlorophyll content**

The chlorophyll content in the leaf were presented in Table 4. The maximum total

chlorophyll content ( $3.51 \text{ mg g}^{-1}$  of leaf) was obtained by the application of PGPR+*Arthro*+*Actino* consortium which gives 32% response over FUI ( $2.65 \text{ mg g}^{-1}$  of leaf), followed by PGPR+*Arthro* and PGPR+*Actino* with chlorophyll content of  $3.38$  and  $3.23 \text{ mg g}^{-1}$  of leaf by 28 and 23% response, respectively. Similarly, the data on chlorophyll content at 45 DAS all the treatment combinations, the consortium of PGPR+*Arthro*+*Actino* performed significantly better for the leaf chlorophyll content of  $3.85 \text{ mg g}^{-1}$  with 31% increment over the control of FUI ( $2.92 \text{ mg g}^{-1}$ ), followed by PGPR+*Actino* and *Arthro*+*Actino* with total chlorophyll content of  $3.55$ ,  $3.50$  and  $3.45 \text{ mg g}^{-1}$  of leaf by 22, 20 and 18% response, respectively. The PGPR had profound effect on the pigment contents on all the sampling days (25, 50, 75 and 100 DAS).

Similar finding suggested that the highest chlorophyll 'a', chlorophyll 'b' and total chlorophyll ( $0.805$ ,  $0.740$  and  $1.545 \text{ mg g}^{-1}$  of leaf) were recorded in 75 days old crop plants grown with *Rhizobium*+*Pseudomonas*+*Bacillus* and declined in 100 DAS (Mathivanan *et al.*, 2017).

The PGPR (*Azospirillum*, *Azotobacter* and *Pseudomonas*) application increased Chlorophyll 'a', Chlorophyll 'b' and total chlorophyll. Al-Erwy *et al.*, (2016) reported that the *A. globiformis* enhanced plant biomass, uptake of iron and phosphate, protein and chlorophyll contents. Iron plays an important role in chlorophyll biosynthesis pathway.

### **Nitrogen, phosphorus and potassium uptake by crop**

The nitrogen, phosphorus and potassium

uptake by the soybean seed and stover were presented in Table 5. The consortium of isolates PGPR+*Arthro*+*Actino* was recorded maximum nitrogen uptake of  $155.7 \text{ kg N ha}^{-1}$  by seed and  $142.0 \text{ kg N ha}^{-1}$  by stover of soybean over FUI of seed ( $98.5 \text{ kg N ha}^{-1}$ ) and stover ( $63.8 \text{ kg N ha}^{-1}$ ).

It was interesting to note that the percent increment were computed 58 and 122%, by seed and straw, respectively next to PGPR+*Arthro*, PGPR+*Actino*, *Arthro*+*Actino* and PGPR with N uptake by seed of  $133.2$ ,  $130.3$ ,  $123.7$  and  $121.1 \text{ kg N ha}^{-1}$  as well as N uptake by stover of  $107$ ,  $106$ ,  $95.9$  and  $94.0 \text{ kg N ha}^{-1}$ .

Similarly, studied that the effectiveness of *B. japonicum* strains on soybean gave significant positive effect on N content in shoot, N uptake by shoot and seed with inoculation by *B. japonicum* or the mixed culture of strains *B. japonicum*. Solaiman and Hossain (2006). The consortium of PGPR+*Arthro*+*Actino* were obtained significantly maximum P uptake of  $8.6 \text{ kg P ha}^{-1}$  by seed and  $14.9 \text{ kg P ha}^{-1}$  by stover of soybean as compare to FUI of seed ( $5.2 \text{ kg P ha}^{-1}$ ) and stover ( $7.4 \text{ kg P ha}^{-1}$ ).

The percent responses were calculated 65 and 101%, P uptake by seed and stover, respectively followed by PGPR+*Arthro*, PGPR+*Actino*, *Arthro*+*Actino* and PGPR with P uptake by seed of  $7.1$ ,  $7.0$ ,  $6.6$  and  $6.4 \text{ kg P ha}^{-1}$  as well as P uptake by stover of  $11.7$ ,  $10.7$ ,  $10.5$  and  $10.5 \text{ kg P ha}^{-1}$  due to the stimulatory effects of bacterial species such as *Pseudomonas*, *Bacillus* and *Arthrobacter* were observed on growth, yield, nitrogen and phosphorous uptake of cotton (*G. hirsutum*) by Egamberdiyeva *et al.*, (2005).



**Table.1** Effect of microbial consortia on nodulation of soybean at different growth stages

Treatment	(Nodules Plant <sup>-1</sup> )				Dry weight ( g plant <sup>-1</sup> )			
	25 DAS	sem	45 DAS	sem	25 DAS	sem	45 DAS	sem
<b>F+Actino</b>	10.7	1.15	37.0	5.85	0.43	0.21	1.23	0.37
<b>F+Arthro</b>	10.1	2.25	36.8	5.23	0.47	0.13	1.25	0.17
<b>F+PGPR</b>	11.7	1.21	38.9	12.6 6	0.49	0.17	1.30	0.42
<b>F+Arthro+Actino</b>	12.3	1.76	39.9	8.00	0.51	0.08	1.33	0.27
<b>F+PGPR+Actino</b>	13.2	2.98	40.8	11.3 5	0.53	0.05	1.36	0.38
<b>F+PGPR+Arthro</b>	13.7	1.41	41.3	11.0 2	0.54	0.03	1.38	0.14
<b>F+PGPR+Arthro+Actino</b>	14.3	1.15	48.0	5.13	0.65	0.08	1.60	0.17
<b>FUI</b>	9.5	1.5	33.4	7.79	0.38	0.07	1.12	0.53
<b>UFUI</b>	9.1	1.21	31.6	6.93	0.32	0.18	1.05	0.23
<b>Mean</b>	11.6		38.6		0.48		1.29	
<b>SE<sub>m</sub> ±</b>	0.62		2.52		0.04		0.09	
<b>LSD (p=0.05)</b>	1.87		7.57		0.12		0.26	

**Table.2** Effect of microbial consortia on plant height and dry biomass of soybean at different growth stages

Treatment	Plant height (cm)			Plant biomass(g plant <sup>-1</sup> )		
	25 DAS	sem	45 DAS	sem	65 DAS	sem
<b>F+Actino</b>	17.2	4.50	40.1	7.19	46.8	13.91
<b>F+Arthro</b>	19.2	3.04	41.0	10.63	47.4	7.04
<b>F+PGPR</b>	19.9	6.51	42.3	4.35	48.7	17.67
<b>F+Arthro+Actino</b>	21.5	3.77	43.0	13.91	55.5	6.49
<b>F+PGPR +Actino</b>	21.9	1.86	44.3	7.57	57.1	6.33
<b>F+PGPR+Arthro</b>	22.4	5.94	45.0	6.28	57.5	7.15
<b>F+PGPR+Arthro+Actino</b>	23.9	4.99	48.3	5.72	59.8	5.87
<b>FUI</b>	16.3	2.78	35.0	4.13	45.4	9.68
<b>UFUI</b>	15.5	4.02	32.0	4.33	44.8	5.10
<b>Mean</b>	19.5		36.8		51.1	
<b>SE<sub>m</sub> ±</b>	1.22		2.05		3.25	
<b>LSD (p=0.05)</b>	3.67		6.15		9.76	

**Table.3** Effect of microbial consortia on plant dry biomass of soybean at different growth stages

Treatment	Plant biomass(g plant <sup>-1</sup> )					
	25DAS	sem	45DAS	sem	65DAS	sem
<b>F+Actino</b>	1.31	1.3	3.51	3.10	6.40	1.33
<b>F+Arthro</b>	1.33	0.16	3.63	1.44	6.55	1.08
<b>F+PGPR</b>	1.40	1.35	3.70	0.71	6.91	1.07
<b>F+Arthro+Actino</b>	1.45	0.57	3.81	3.80	7.30	1.80
<b>F+PGPR +Actino</b>	1.56	0.87	3.87	0.96	8.48	1.26
<b>F+PGPR+Arthro</b>	1.63	1.76	4.52	1.23	8.86	1.47
<b>F+PGPR+Arthro+Actino</b>	1.70	1.60	5.14	2.54	10.00	1.58
<b>FUI</b>	1.22	1.13	3.41	0.87	6.07	0.95
<b>UFUI</b>	1.17	1.41	3.37	2.36	5.63	0.98
<b>Mean</b>	1.42		3.88		7.36	
<b>SE<sub>m</sub> ±</b>	0.09		0.33		0.455	
<b>LSD (p=0.05)</b>	0.27		0.98		1.35	

**Table.4** Effect of microbial consortia on chlorophyll content of soybean at different growth stages

Treatment	Total chlorophyll content (mg g <sup>-1</sup> leaf tissue)			
	25 DAS	sem	45 DAS	sem
<b>F+Actino</b>	2.72	±0.80	3.06	±1.39
<b>F+Arthro</b>	2.89	±0.63	3.11	±1.09
<b>F+PGPR</b>	3.06	±0.81	3.31	±1.40
<b>F+Arthro+Actino</b>	3.18	±1.32	3.45	±2.29
<b>F+PGPR +Actino</b>	3.23	±0.66	3.50	±1.14
<b>F+PGPR+Arthro</b>	3.38	±0.66	3.55	±1.14
<b>F+PGPR+Arthro+Actino</b>	3.51	±0.35	3.85	±0.61
<b>FUI</b>	2.65	±1.13	2.92	±1.97
<b>UFUI</b>	2.63	±0.78	2.72	±1.35
<b>Mean</b>	3.03		3.27	
<b>SE<sub>m</sub> ±</b>	0.18		0.19	
<b>LSD (p=0.05)</b>	0.55		0.58	

**Table.5** Effect of microbial consortia on NPK uptake ( $\text{kg ha}^{-1}$ ) by seed and stover.

Treatment	N uptake		P uptake		K uptake	
	Seed	Stover	Seed	Stover	Seed	Stover
<b>F+Actino</b>	107.0	79.6	5.6	8.8	27.1	50.9
<b>F+Arthro</b>	112.4	81.8	5.8	9.0	28.9	54.1
<b>F+PGPR</b>	121.1	94.0	6.4	10.5	30.9	59.8
<b>F+Arthro+Actino</b>	123.7	95.9	6.6	10.5	33.2	63.6
<b>F+PGPR +Actino</b>	130.3	106.3	7.0	10.7	35.0	64.6
<b>F+PGPR+Arthro</b>	133.2	107.0	7.1	11.7	35.2	68.9
<b>F+PGPR+Arthro+Actino</b>	155.7	142.0	8.6	14.9	42.3	82.3
<b>FUI</b>	98.5	63.8	5.2	7.4	24.9	44.4
<b>UFUI</b>	86.0	45.9	4.5	6.4	22.0	39.2
<b>Mean</b>	118.6	90.6	6.3	9.9	31.1	59.1
<b>SE<sub>m</sub> ±</b>	7.47	6.30	0.35	0.79	1.60	5.40
<b>LSD (p=0.05)</b>	22.4	18.9	1.03	2.38	4.79	16.7

**Table.6** Effect of microbial consortia on seed and stover yields of soybean.

Treatment	Yield ( $\text{kg ha}^{-1}$ )			
	Seed	sem	Stover	sem
<b>F+Actino</b>	1781	± 280	3679	± 779
<b>F+Arthro</b>	1839	± 322	3912	± 351
<b>F+PGPR</b>	1947	± 456	4272	± 833
<b>F+Arthro+Actino</b>	1978	± 384	4253	±1056
<b>F+PGPR +Actino</b>	2037	± 388	4162	± 688
<b>F+PGPR+Arthro</b>	2102	± 390	4369	± 1369
<b>F+PGPR+Arthro+Actino</b>	2350	± 160	5381	± 1604
<b>FUI</b>	1636	± 163	3345	± 685
<b>UFUI</b>	1545	± 315	3064	± 1260
<b>Mean</b>	1913		4547	
<b>SE<sub>m</sub> ±</b>	97.9		315.7	
<b>LSD (p=0.05)</b>	293.7		946.6	

The responses of the consortium of PGPR+*Arthro*+Actino were calculated 70 and 86% K uptake by seed and stover over FUI, respectively followed by PGPR+*Arthro*, PGPR+ Actino, *Arthro*+Actino and PGPR with K uptake by seed of 35.2, 35.0, 33.2 and 30.9  $\text{kg K ha}^{-1}$  as well as K uptake by stover of 68.9, 64.6, 63.6 and 59.8  $\text{kg K ha}^{-1}$  might be

attributed due to the potential K improvement and P nutrition by application of PGPR as biofertilizers for sustainable solution to improve plant nutrient status and production (Vessey, 2003). Higher K uptake may be attributable to the mobilization of nutrients from the soil because of the secretion of organic acids mediated by soil



microorganisms (Basak and Biswas., 2010)

### Seed and stover yield of soybean

The data on grain yield and biomass production of soybean is given in Table 6. The grain yield of soybean differed significantly among all the treatments. The consortium of PGPR+ *Arthro*+Actino gave the significantly maximum grain yield of 2350 kg ha<sup>-1</sup> that was responded 44% over FUI (1636 kg ha<sup>-1</sup>) followed by PGPR+*Arthro*, PGPR+ Actino, *Arthro*+Actino and PGPR with grain yield of 2102, 2037, 1978 and 1947 kg ha<sup>-1</sup> along with the increment of 28, 25, 21 and 19%, respectively. This increment in yields of soybean with the treatments of inoculation fertilization might be attributed to better nodulation, N<sub>2</sub> fixation and crop growth as against uninoculated control (Brahmaprakash *et al.*, 2004 and Gupta, 2005). Moreover, the co-inoculation of *Bradyrhizobium* and *Pseudomonas* strains along with P<sub>2</sub>O<sub>5</sub> enhanced the grain yield of soybean by 38% in pot experiments and 12% in the field experiment, over P<sub>2</sub>O<sub>5</sub> alone (Afzal *et al.*, 2010).

Similarly, the highest stover yield of soybean (5381 kg ha<sup>-1</sup>) was recorded with the treatment combination of PGPR+*Arthro*+Actino by 61% response over the control FUI (3345 kg ha<sup>-1</sup>) followed by the treatment combination of P GPR+*Arthro* with stover yield of 4369 kg ha<sup>-1</sup> by 31% which has been supported by the findings of Amule *et al.*, (2018) the inoculation of microbial consortium (actinomycetes, *Rhizobium* and PGPR) supplemented with recommended dose of fertilizer gave the significant improvement in seed and stover yield of soybean over fertilized uninoculated.

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