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Effect of Microbial Consortia Inoculation and Chemical Fertilizers on Growth Parameter and Nodulation of Soybean (*Glycine max* L. merill.) and Chickpea (*Cicer arietinum* L.)

Syed Javed [a++ *], Syed Ismail [a#], Dhamak A. L. [a†] and More S. S. [a†]

[a] *Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Agricultural University, Parbhani 431 402, Maharashtra, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Microbial consortia inoculation and chemical fertilizers significantly impact plant growth parameters. Microbial consortia contribute to soil health by enhancing nutrient availability and promoting plant growth, while chemical fertilizers provide essential nutrients. In this study, an Field Experiment was conducted during two successive years in Kharif and Rabi 2020-21 and 2021-22 consecutively on effect of microbial consortia inoculation and chemical fertilizers on productivity and soil properties in soybean chickpea sequence on vertisol at research farm of department soil science and agricultural chemistry Vasantrao Naik Marathwada Agricultural University, Parbhani (MAH) India. The Soil of

[++] *Phd Scholar and Senior Research asst.;*
[#] *Associate Dean and Principal;*
[†] *Associate professor;*
**Corresponding author: E-mail: jsyed0402@gmail.com;*

experimental site was classified as vertisol (Typic Haplustert) dominant montmorillonite type with kaollinite and illite mineral alkaline in reaction. Experimental treatments consist of four levels of laboratory evaluated microbial cultures (Bradyrhizobium, Mesorhizobium, Bacillus megaterium, Pseudomonas striata, Thiobacillus thioxidant) and uninoculated control and four levels of chemical fertilizers (100 % RDF, 75 % RDF, 50 % RDF and Control i.e. (without fertilizers)). Seed treatment of soybean and chickpea was done with microbial consortia immediate before sowing and chemical fertilizers were applied at the time of sowing as per treatments. The results revealed that the application of microbial inoculants with chemical fertilizers showed significant effect on biometric attributes and nodulation of soybean and chickpea. The microbial consortia Rhizobium spp.+ Pseudomonas striata inoculation has highest plant height, shoot weight, root length, number of nodule, fresh weight of nodules, and dry weight of noduels in both crops as compared to uninoculated control. However, the application of chemical fertilizer i.e. N,P and K 100% RDF obviously increased the height, shoot weight, number of nodulation, and fresh weight of nodules in respect of both soybean and chickpea crops. The chemical fetilizers N,P and K are applied in the form of Urea, single super phosphate and muriate of potash respectively.

Keywords: Microbial consortia inoculation; chemical fertilizers; growth parameters; nodulation soybean; chickpea.

1. INTRODUCTION

Beneficial microorganisms having the multifarious plant growth promoting attributes could be used as inoculants as single cell or as consortia for agricultural sustainability Kaur et al. [1]; Rana et al. [2]; Rastegari et al. [3]. Application of PGPMs used as consortium inoculants is various benefits over chemical fertilizers / biochemical pesticides and fertilizers. It promotes growth of the host plant along with its associative microbiota, PGPMs degraded very quickly as compared to conventional fertilizers and pesticides, development of resistance is negligible, and it can be also applied in conventional or integrated management system. Berg [4]; Kaur et al. [5]; Rana et al. [2]. The participating microbial consortium bacteria, fungi, actinomycetes and yeast among others. it enhancing productivity, sustainable and ecofriendly approach. It have positive effect on several crop growth parameters. It enhances productivity, biomass augment tress elements contents, root and shoot weight, nodulation and pod number and biomass of soybean and root, shoot growth, leaf number, fungal disease resistance in groundnut Naik et al., [6]. Improving use of mineral nutrients is a must to securing higher yield and productivity in a sustainable manner therefore continuously desiring, developing and testing innovative integrated plant nutrient management systems based on relevant biological resources (crops and microorganisms) is highly required. Several reports indicated that dual or triple inoculation of *Rhizobium* PSB (Phosphate solubilizing Bacteria), PGPR is better than inoculation with *Rhizobium* alone in different pulse crops Gupta, [7]. Bacteria is most plentiful microbial community in soil followed by fungi Kaur et al. [5]; Rana et al. [2]. Microorganisms bacteria, fungi inoculants are improve plant growth and various physiological parameters of plants Shah et al. [8]. Symbiotic *Rhizobium* species associated with soybean root nodules benefit plant growth via mediating biological N fixation Jaiswal et al. [9]. Soybean (*Glycine max* (L.) *Merill*.) is grown mainly in tropical, sub-tropical and temperate regions FAO [10]. It is a water intensive crop, requiring substantial water to grow and produce Bhardwaj, [11]. Consequently, rising global temperatures and changing precipitation patterns pose a significant threat to soybean production, specially in under irrigated or rainfed areas Jin et al. [12].

Soybean is an annual leguminous species cultivated mainly for its seed. Soybean seed consists of 35 % carbohydrate, 5 % ash, 40 % protein and 20 % oil and is a major source of protein and oil for commercial products. Soybean are native to China and there seeds are rich in protein (64%) and oil (30%) Kumawat et al. [13]. In 2019, the annual global soybean production was estimated to be above 333 million tones FAOSTAT, [14]. The different vegetable oil imported the soybean oil (22 %) after the palm oil of 60 % share and sunflower oil 17 % Anonymous, [15]. Soybean ranks first among the major oil seed crops of the world and has now found a prominent place in India Mahana, et al. [16]. Chouhan et al. [17] reported that soybean has occupied first rank among oilseed in India 2005 onwards. In India production of soybean dominated by maharashtra and madhya pradesh and it contributes 89 per cent of total production. Area of soybean in India is 11.8 million ha, production is 11.94 million tonnes with average productivity 1050 kg ha^{-1} Anonymous [15]. According to (FAS) Foreign Agricultural Survey (USDA) estimate soybean production is 12.4 tonnes of marketing year 2023.

Further, chickpea (*Chicer arietinum L.*) is the second most important pulse crop globally, after common bean (*Phaseolus vulgaris*). Chickpea is quality food source rich in proteins, minerals, vitamins and fibers that benefit the health of domestic stock and humans Bohra et al., [18]. The global area of chickpea average 13.0 million tonnes across 56 countries (2015-17) FAOS, [19]. According USDA, Foreign Agricultural Survey 2023 the globally average production of chickpea 24.2 million tones. India is the largest global producer, consumer and importer of chickpea whereas Australia is the main exporter of desi type (outlined later) chickpea to India. India mostly imports Desi chickpea but also emerges as an exporter to some Kabuli type over the past decade.

The progress on increasing chickpea yields has stagnated in India and Australia average around 1.0 to 2 t ha^{-1}. Moreover, the estimated realizable potential is over 2 t ha^{-1}. The current yields of chickpea are insufficient for meeting the growing demand of plants-based food specially dietary protein Jha et al*.* [20]. In addition, chickpea may not be able to absorb enough N from the soil, specially under drought to influence yield due to its low N-fixation ability and low nutrient used efficiently Sadras et al*.* [21]. Chickpea and soybean contribute a significant amount of residual nitrogen to the soil and adds organic matter thereby improving soil health and fertility. Chickpea also play important role in maintaining soil fertility by fixing nitrogen at the rate up to 140 kg ha^{-1} $year^{-1}$ Flowers et al*.* [22]. Thus, keeping this in the view present study was undertaken to evaluate the effect of microbial consortia along with chemical fertilizers on biometric attributes and nodulation in soybean and chickpea crops in sequence to promote the use of consortia in these dominant crops of Maharashtra State of India.

2. MATERIALS AND METHODS

2.1 Experimental Site

Present investigation was carried at Research Farm, Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Agicultural University, Parbhani (MAH) on Vertisol (*TypicHaplusterts*). The initial soil pH 8.29, organic carbon 4.86 per cent, available N 159.94 kg ha-1, available phosphorus 10.71 kg ha-1 and available potassium 578 kg ha-1. The soil was clayey in texture, medium in organic carbon, available nitrogen was low, medium available P2O5 and available K2O was very high 578 kg ha^{-1}.

2.2 Experimental Design

The experiment comprise four treatments of microbial consortia inoculation *Rhizobium* species + *Bacillus megaterium*, *Rhizobium* species + *Pseudomonasstriata*, *Rhizobium* species + *Thiobacillus thiooxidant* and Uninoculated control and four levels of chemical fertilizers (N, P2O5 and K2O) viz urea, single super phosphate and muriate of Potash,100 % RDF, 75 % RDF, 50% RDF and control i.e. without fertilizer treatment. The experiment was laid out in Factorial Randomized Block Design with three replications.

2.3 Seed Inoculation and Sowing

The Rhizophos (Consortia of *Rhizobium spp* and Phosphate solubilizing bacteria) and microbial Consortia inoculation *Rhizobium spp* + *Bacillus megaterium* inoculation (Consortia I), *Rhizobium spp* + *Pseudomona Striata* inoculation (Consortia II) and *Rhizobium spp* + *Thiobacillus thiooxidant* inoculation (Consortia III) for soybean and chickpea was obtained from ICAR - All India Network Project on Soil Biodiversity – Biofertilizers and used for seed treatment @ 5 ml per kg of soybean seed and chickpea seed. Seed treatment was done before sowing. Seeds were dried in shed and used for sowing The variety of soybean Cv. MAUS 162 and chickpea Cv. Phule Vikram. The recommended dose of fertilizer (RDF) as basal dose was applied $N:P_2O_5:K_2O$ 30:60:30 kg ha^{-1} for soybean and $N:P_2O_5:K_2O$ 25:50:0 kg ha^{-1} for chickpea, through urea, single super phosphate and muriate of potash respectively at the time of sowing soybean in kharif and chickpea in rabi season. Irrigation is given as per crop need and of chickpea crop only and package of practices were followed for both soybean and chickpea crops. The biometric observations were recorded at 60 and 90 DAS of both soybean, chickpea and average were computed.

2.4 Plant Sampling and Measurement of Growth Parameters

Five plants sampling technique were adopted and randomly selected from each plot tagged and biometric observations viz., plant height, shoot weight, root length, root weight and nodulation i.e. number of nodules (plant^{-1}), fresh weight of nodules (g plant^{-1}), dry weight of nodules (g plant^{-1}). The total number of nodules were recorded from five plants in each plot of soybean and chickpea. Fresh weight of nodules of soybean and chickpea was taken (g plant^{-1}) on digital electronic balance. The dry weight of nodules of soybean and chickpea were air dried, after air drying oven drying was carried out at 65C^0. Dry weight of nodules was recorded (g plant^{-1}) on a digital electronic balance. Statistical analysis of the data of field experiment was analyzed using FRBD (Factorial Randomized Block Design) as per the method described in "Statistical Methods for Agricultural Workers" by Panse and Sukhatme [23]. Appropriate Standard Error (S.E.) and critical differences (C.D.) at 5% level were worked out wherever necessary.

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm palnt^{-1}) of Soybean and Chickpea

Plant height was increased with effect of microbial consortia inoculation and chemical fertilizers during the years 2020-21 and 2021-22 and pooled mean of experiment Tables 1 and 2. Plant height of soybean and chickpea was significantly highest at 60, 90 days with treatment *Rhizobium* species + *Pseudomonasstriata* inoculation II (S3) 69.31, 74.79 and 46.38, 71.95 and lowest was noted in uninoculated control (S1) during both the years of experimentations and pooled mean, respectively. Treatment after (S3) consortia (II) found at par with *Rhizobium* species + *Bacillus megaterium* inoculation (consortia I) (S2) at both the stages during 2020-21, 2021-22 and pooled data. The treatment chemical fertilizers with 100 % RDF (T4) was found significant to increase plant height of soybean and chickpea. Significantly highest at 60 and 90 DAS with treatment 100 % RDF 61.45, 66.38and 43.54, 64.22 and lowest was found without fertilizers (T1) during both the years of experiment and pooled mean respectively.

3.2 Shoot Weight (g plant^{-1}) of Soybean and Chickpea

Shoot weight was increased with treatment microbial inoculants and chemical fertilizers Tables 3 and 4. Shoot weight of soybean and chickpea crop was significantly highest at 60 and 90 DAS 40.95, 57.66 and 55.12, 86.11, respectively with treatment *Rhizobium* species + *Pseudomonas striata* (S3) and lowest was observed in treatment Uninoculated control (S1) during both the experimentation years and pooled data. Chemical fertilizer with 100 % RDF

Table 1. Effect of microbial consortia inoculation and chemical fertilizers on plant height (cm plant^{-1}) of soybean (Pooled results of two years experiments)

Treatments	60 DAS	90 DAS
Microbial consortia inoculation (S)		
S_1- Uninoculated control	44.38	49.04
S_2-*Brady Rhizobium*+ *Bacillus megaterium* inoculation (Consortia-I)	61.73	66.50
S_3-*Brady Rhizobium* + *Pseudomonas striata* inoculation (Consortia-II)	69.31	74.79
S_4-*Brady Rhizobium* + *Thiobacillus thiooxidant* inoculation (Consortia-III)	56.64	62.05
S.E.m$\pm$	0.73	1.68
C.D. at 5%	2.11	4.87
Chemical fertilizers (T)		
T_1- Control (without fertilizer)	55.29	59.77
T_2- 50% RDF	56.47	61.78
T_3- 75% RDF	58.86	64.45
T_4- 100% RDF	61.45	66.38
S.E.m$\pm$	0.73	1.68
C.D. at 5%	2.115	4.87
Interaction (S x T)		
S.E.m$\pm$	1.46	3.37
C.D. at 5%	NS	NS

NS = Non-Significant

Table 2. Effect of microbial consortia inoculation and chemical fertilizers on plant height (cm plant^{-1}) of chickpea (Pooled results of two years experiments)

Treatments	60 DAS	90 DAS
Microbial consortia inoculation (S)		
S_1- Uninoculated control	33.79	42.77
S_2-*Mesorhizobium*+ *Bacillus megaterium* inoculation (Consortia-I)	41.82	61.475
S_3-*Mesorhizobium* + *Pseudomonas striata*i noculation (Consortia-II)	46.385	71.95
S_4-*Mesorhizobium* + *Thiobacillus thiooxidant* inoculation (Consortia-III)	38.57	63.925
S.E.m$\pm$	0.51	1.26
C.D. at 5%	1.50	3.66
Chemical fertilizers (T)		
T_1- Control (without fertilizer)	36.605	54.79
T_2- 50% RDF	38.965	59.11
T_3- 75% RDF	41.445	62
T_4- 100% RDF	43.545	64.22
S.E.m$\pm$	0.51	1.26
C.D. at 5%	1.50	3.66
Interaction (S x T)		
S.E.m$\pm$	1.03	2.53
C.D. at 5%	NS	NS

Table 3. Effect of microbial consortia inoculation and chemical fertilizers on shoot weight (g plant^{-1}) of soybean (Pooled results of two years experiments)

Treatments	60 DAS	90 DAS
Microbial consortia inoculation (S)		
S_1- Uninoculated control	30.00	41.10
S_2-*Brady Rhizobium*+ *Bacillus megaterium* inoculation (Consortia-I)	35.76	49.16
S_3-*Brady Rhizobium* + *Pseudomonasstriata*inoculation (Consortia-II)	40.95	57.66
S_4-*Brady Rhizobium* + *Thiobacillus thiooxidant* inoculation (Consortia-III)	33.22	51.41
S.E.m$\pm$	0.60	0.65
C.D. at 5%	1.72	0.90
Chemical fertilizers (T)		
T_1- Control (without fertilizer)	32.59	46.61
T_2- 50% RDF	33.92	47.96
T_3- 75% RDF	35.98	49.10
T_4- 100% RDF	37.44	50.67
S.E.m$\pm$	0.60	0.65
C.D. at 5%	1.72	0.90
Interaction (S x T)		
S.E.m$\pm$	1.19	1.04
C.D. at 5%	NS	NS

improved shoot weight of both soybean and chickpea crops at 60 and 90 DAS 37.44, 50.67 and 50.37, 72.21 with treatment (T4) and lowest in treatment without fertilizers (T1). The plant height and shoot weight of both soybean, chickpea crops was increased with 100 % NPK along with consortium of bioinoculants might be due to easily available all nutrients to plant roots and improve the plant height and shoot weight and crop growth. Our results are in line with Naik et al. [6], when applied EM formulations reported have positive effect on several crop growth parameters. Solanki et al. [24] reported enhancement of P availability increased better root growth, plant vegetative growth also. Saini et al. [25] reported similar results.

3.3 Root Weight (g palnt^{-1}) of Soybean and Chickpea

The highest root weight (g plant^{-1}) of soybean and chickpea Tables 5 and 6 was recorded in

Rhizobium species + *Pseudomonas striata* (S3) 10.58, 11.54 and 9.97, 11.05 g plant^{-1} at 60 and 90 DAS of pooled. Treatment S3 was found at par with *Rhizobium* species + *Bacillus megaterium* (S2) and lowest root weight was in Uninoculated control. Further chemical fertilizers 100 % RDF also increase root weight at 60 and 90 DAS 9.51, 10.46 and 8.01, 9.74 g plant^{-1} in pooled, and it was at par with treatment 75 % RDF and lowest root in treatment control (without fertilizer) (T1).

Table 4. Effect of microbial consortia inoculation and chemical fertilizers on shoot weight (g plant^{-1}) of chickpea (Pooled results of two years experiments)

Treatments	60 DAS	90 DAS
Microbial consortia inoculation (S)		
S_1- Uninoculated control	33.16	45.62
S_2-*Mesorhizobium*+ *Bacillus megaterium* inoculation (Consortia-I)	50.28	76.90
S_3-*Mesorhizobium* + *Pseudomonas striata* inoculation (Consortia-II)	55.12	86.11
S_4-*Mesorhizobium* + *Thiobacillus thiooxidanst* inoculation (Consortia-III)	46.20	60.55
S.E.m$\pm$	0.75	5.24
C.D. at 5%	2.18	2.16
Chemical fertilizers (T)		
T_1- Control (without fertilizer)	40.02	64.46
T_2- 50% RDF	45.56	64.87
T_3- 75% RDF	48.81	67.64
T_4- 100% RDF	50.37	72.21
S.E.m$\pm$	0.75	5.24
C.D. at 5%	2.18	2.16
Interaction (S x T)		
S.E.m$\pm$	1.51	1.49
C.D. at 5%	NS	NS

Table 5. Effect of microbial consortia inoculation and chemical fertilizers on root weight (g plant^{-1}) of soybean

Treatments	60 DAS	90 DAS
Microbial consortia inoculation (S)		
S_1- Uninoculated control	7.13	7.91
S_2-*Brady Rhizobium*+ *Bacillus megaterium* inoculation (Consortia-I)	9.27	10.11
S_3-*Brady Rhizobium* + *Pseudomonas striata*inoculation (Consortia-II)	10.58	11.54
S_4-*Brady Rhizobium* + *Thiobacillus thiooxidanst* inoculation (Consortia-III)	8.39	9.79
S.E.m$\pm$	0.14	0.23
C.D. at 5%	0.40	0.68
Chemical fertilizers (T)		
T_1- Control (without fertilizer)	8.00	9.05
T_2- 50% RDF	8.69	9.65
T_3- 75% RDF	9.18	10.19
T_4- 100% RDF	9.51	10.46
S.E.m$\pm$	0.14	0.23
C.D. at 5%	0.40	0.68
Interaction (S x T)		
S.E.m$\pm$	0.30	0.47
C.D. at 5%	NS	NS

Table 6. Effect of microbial consortia inoculation and chemical fertilizers on root weight (g plant^{-1}) of chickpea (Pooled results of two years experiments)

Treatments	Pooled	
	60 DAS	**90 DAS**
Microbial consortia inoculation (S)		
S_1- Uninoculated control	6.07	6.86
S_2-*Mesorhizobium*+ *Bacillus megaterium* inoculation (Consortia-I)	7.40	8.92
S_3-*Mesorhizobium* + *Pseudomonas striata* inoculation (Consortia-II)	9.97	11.05
S_4-*Mesorhizobium* + *Thiobacillus thiooxidant* inoculation (Consortia-III)	7.3	8.24
S.E.m$\pm$	0.10	0.15
C.D. at 5%	0.31	0.43
Chemical fertilizers (T)		
T_1- Control (without fertilizer)	7.38	7.83
T_2- 50% RDF	7.54	8.23
T_3- 75% RDF	7.80	9.26
T_4- 100% RDF	8.01	9.74
S.E.m$\pm$	0.10	0.15
C.D. at 5%	0.31	0.43
Interaction (S x T)		
S.E.m$\pm$	0.21	0.3
C.D. at 5%	NS	NS

3.4 Root Length (cm plant^{-1}) of Soybean and Chickpea

Tables 7 and 8 indicates the effect of microbial inoculants on root length of soybean and chickpea crops during the years 2020-21, 2021-22 and pooled were highest root length 31.80, 35.23 and 18.77, 20.36 cm palnt^{-1} at 60 and 90 DAS and maximum root length was noted in treatment *Rhizobium* species + *Pseudomonas striata* (S3) and least was noticed treatment Uninoculated control (S1) during both the years of and pooled. Chemical fertilizers showed significantly highest root length 27.84, 32.79 and 17.13, 17.62 cm palnt-1 at 60 and 90 DAS in1 00 % RDF treatment of both soybean and chickpea crop respectively, and was minimum root length was in treatment without fertilizer application (T1).

Shoot weight and root length of soybean and chickpea plants significantly increased might be due to *Brady Rhizobium*, *Mesorhizobium* and *Pseudomonasstriata*, *Bacillus megaterium* is able to synthesized growth regulators Indole Acetic Acid (IAA), Gibberellins, Auxins, Vitamins and Cytokines antagonistic metabolites such as HCN and siderophore through its ability to provide nutrients through biological nitrogen fixation and phosphorus solubilization / mobilization and ion chelation [26-28]. reported that single inoculation with AM (*Arbuscular mycorrhiza*) fungus and *R. irregularis* significantly increased shoot weight of chickpea over Uninoculated control. Elcoka et al. [29] observed on chickpea seed inoculants with *Rhizobium* N2 fixing *Bacillus subtilis* and P solubilizing *Bacillus megaterium* was highest plant height, shoot weight over control treatment.

3.5 Nodulation in Soybean and Chickpea

The number of nodules in soybean and chickpea were significantly improved by microbial consortia inoculants and chemical fertilizers Tables 9 and 10. Maximum nodules, fresh weight of nodules were recorded in treatment (S3) *Rhizobium* species + *Pseudomonas striata* 100.30, 897.84, 570.87 and 41.79, 478.55, 309.37 respectively and lowest number of nodules plant^{-1}, fresh weight of nodules mg plant^{-1} and dry weight of nodules mg plant^{-1} were recorded in treatment (S1) uninoculated control. Chemical fertilizer increased nodule number plant^{-1}, fresh weight mg palnt^{-1} and dry weight mg plant^{-1} of nodule in both soybean and chickpea i.e. 80.29, 741.88, 492.58 and 35.54, 417.09, 291.89 significantly maximum in treatment (T4) and minimum was in control (without fertilizer) and treatment (T1) both the soybean and chickpea crop.

Application of dual or more inoculants i.e. *Rhizobium* species, PSB, phosphate solubilizing and mobilizing bacteria might be due to greater availability of nitrogen and phosphorus in soil which results in better nodulation, increase number of nodules improves fresh weight and dry weight of nodules growth and development of plant growth. Our results are similar in line with Hungria et al*.* [30] ,they reported that the application of *Brady Rhizobium* + strains of *Azospirillum* and PSM the nodulation of soybean plants were promoted. Masciarelli et al. [31]. found that co-inoculation of *Brady Rhizobiumiaponicum* with PSB has better nodulation and could be due to phyetohormone production which resulted in increased nodule number and its dry biomass. Co-inoculation of rhizobia with PGPR enhanced nodulation in pigeonpea and other legumes Gupta et al. [32]; Sekar et al*.* [33]. Nasimento et al*.* [34]. Sibpankrung et al. [35] also reported the similar results. Inoculation of *bradyrhizobium japonicum* application with P and K fertilizer increased nodules number, dry weights of nodules and yield of soybean Wanling et al. [36]; Obey et al. [37].

Table 7. Effect of microbial consortia inoculation and chemical fertilizers on root length (cm) of soybean (Pooled results of two years experiments)

Treatments	60 DAS	90 DAS
Microbial consortia inoculation (S)		
S_1- Uninoculated control	21.60	25.82
S_2-*Brady Rhizobium*+ *Bacillus megaterium* inoculation (Consortia-I)	25.52	31.80
S_3-*Brady Rhizobium* + *Pseudomonas striata* inoculation (Consortia-II)	31.80	35.23
S_4-*Brady Rhizobium* + *Thiobacillus thiooxidanst* inoculation (Consortia-III)	22.78	29.14
S.E.m$\pm$	0.40	0.51
C.D. at 5%	1.17	1.49
Chemical fertilizers (T)		
T_1- Control (without fertilizer)	23.36	27.85
T_2- 50% RDF	24.31	29.90
T_3- 75% RDF	26.18	31.46
T_4- 100% RDF	27.84	32.79
S.E.m$\pm$	0.40	0.51
C.D. at 5%	1.17	1.49
Interaction (S x T)		
S.E.m$\pm$	0.81	1.03
C.D. at 5%	NS	NS

Table 8. Effect of microbial consortia inoculation and chemical fertilizers on root length (cm) of chickpea (Pooled results of two years experiments)

Treatments	Pooled	
	60 DAS	**90 DAS**
Microbial consortia inoculation (S)		
S_1- Uninoculated control	11.74	13.75
S_2-*Mesorhizobium*+ *Bacillus megaterium* inoculation (Consortia-I)	15.77	18.04
S_3-*Mesorhizobium* + *Pseudomonas striata* inoculation (Consortia-II)	18.77	20.36
S_4-*Mesorhizobium* + *Thiobacillus thiooxidanst* inoculation (Consortia-III)	14.98	16.92
S.E.m$\pm$	0.42	0.29
C.D. at 5%	1.20	0.74
Chemical fertilizers (T)		
T_1- Control (without fertilizer)	13.85	16.70
T_2- 50% RDF	14.51	17.14
T_3- 75% RDF	15.76	17.61
T_4- 100% RDF	17.13	17.62
S.E.m$\pm$	0.42	0.29
C.D. at 5%	1.20	0.74
Interaction (S x T)		
S.E.m$\pm$	0.83	0.59
C.D. at 5%	NS	NS

Table 9. Effect of microbial consortia inoculation and chemical fertilizers on nodules of soybean (Pooled results of two years experiments)

Treatments	No. of nodules	Fresh wt (mg/pl)	Dry wt (mg/pl)
Microbial consortia inoculation (S)			
S_1- Uninoculated control	39.46	372.83	345.75
S_2-*Brady Rhizobium+ Bacillus megaterium* inoculation (Consortia-I)	77.04	805.79	505.12
S_3-*Brady Rhizobium + Pseudomonastriata*inoculation (Consortia-II)	100.30	897.84	570.87
S_4-*Brady Rhizobium + Thiobacillus thiooxidant* inoculation (Consortia-III)	73.00	768.13	451.5
S.E.m$\pm$	2.63	2.41	8.60
C.D. at 5%	8.82	6.95	24.82
Chemical fertilizers (T)			
T_1- Control (without fertilizer)	64.58	683.50	443.08
T_2- 50% RDF	70.84	701.38	464.41
T_3- 75% RDF	74.09	717.84	473.17
T_4- 100% RDF	80.29	741.88	492.58
S.E.m$\pm$	2.63	2.41	8.60
C.D. at 5%	8.82	6.95	24.82
Interaction(SxT)			
S.E.m$\pm$	3.05	2.41	17.19
C.D. at 5%	8.82	6.95	NS

Table 10. Effect of microbial consortia inoculation and chemical fertilizers on nodules of chickpea (Pooled results of two years experiments)

Treatments	No. of nodules	Fresh wt (mg/pl)	Dry wt (mg/pl)
Microbial consortia inoculation (S)			
S_1- Uninoculated control	23.66	278.71	209.67
S_2-*Mesorhizobium+ Bacillus megaterium* inoculation (Consortia-I)	33.17	445.34	290.29
S_3-*Mesorhizobium + Pseudomonastriata*inoculation (Consortia-II)	41.79	478.55	309.37
S_4-*Mesorhizobium + Thiobacillusthiooxidant* inoculation (Consortia-III)	32.46	420.63	253.28
S.E.m$\pm$	0.34	1.64	4.93
C.D. at 5%	1.56	4.73	14.26
Chemical fertilizers (T)			
T_1- Control (without fertilizer)	29.29	392.79	240.57
T_2- 50% RDF	27.42	402.29	256.78
T_3- 75% RDF	33.83	411.05	273.78
T_4- 100% RDF	35.54	417.09	291.89
S.E.m$\pm$	0.33	1.64	4.93
C.D. at 5%	1.56	4.73	14.26
Interaction(SxT)			
S.E.m$\pm$	0.67	3.28	9.94
C.D. at 5%	1.94	9.47	NS

4. CONCLUSION

The growth parameter character viz., plant height, shoot weight, root length, root weight and nodulation of both soybean and chickpea crop were improved with consortia of *Rhizobium* species + *Pseudomonas striata* (Consortia II) inoculation over other inoculation treatments along with 100 % RDF).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kaur N, Sharma P, Sharma S. Coinocualtion of Mesorhizobium sp. And plant growth promoting rhizobacteria Pseudomonas sp. As bio enhancer and biofertilizer in chickpea (*Cicer arietinum* L.). Legume Research. 2015;38:367-374.
2. Rana Lata Kusam, Divijot Kour, Tanvir Kaur, Rubi Devi, Yadav Ajarnath, Yadav Neelam, Dhaliwal Harcharan Singh and Saxena Anil Kumar. Enophyticmicrobes: Biodiversity, palntgrowth-promoting mechanisms and potential applications for agricultural sustainability. Antonie Van Leeuwenhoek. 2020;113:1075-1107.
3. Rastegari AA, Yadav AN, Yadav N. Trends of microbial biotechnology for sustainable agriculture and bio mededince systems: diversity and functional perspectives. Elsevier, Amsterdam; 2020.
4. Berg G. Plantmicrobe interactions promoting plant growth and health: Perspective for controlled use of microorganisms in agriculture. Applied Microbial Biotechnology. 2009;(84):11-18.
5. Kaur Divijot, Rana Kumum, Lata Kusam, Yadav Ajasnath, Kumar Manish, Kumar Vinod, Vyas Pritesh, Dhadiwal Harcharan Singh and Saxena Anil Kumar. Microbiol biofertilizers bio sources and eco friendly technologies for agricultural and environmental sustainability. Biocatalysis and Agricultural Biotechnology. 2020;23: 10487.
6. Naik Kalyani, Mishra Snehashih, Srichandan Hargabinda, Singh Puneet Kumar and Choudhary Abhishek. Microbial formulation and growth of cereals, pulses, oilseed and vegetable crops. Sustainable Environmental Research; 2020. Available:https://doil.org/10.1186
7. Gupta SC. Effect of combined inoculation on nodulation, nutrient uptake and yield of chickpea in Vertisol. Journal of Indian Society of Soil Science. 2006;54(2):251-254.
8. Shah KK, Tripathi S, Shreshtha J, Modi B, Paudel N, Das BD. Role of soil microbes in sustainable crop production and soil health: A review. Agricultural Science and Technology. 2021;13(2):109-118.
9. Jaiswal SK, Mohammed M, Ibny FYI, Dakora FD. Rhizobia as a source of plant growth-promoting molecules: Potential applications and possible operational mechanisms. Front Sustainable. Food System. 2021;4:311.
   DOI: 10.3389/fsufs.2020.619676
10. FAO. Land & Water [Online]; 2021.
    Available:http://www.fao.org/landwater/databasesandsoftware/cropinformation/soybean/en/
    [Accessed on 12, August 2021]
11. Bhardwaj SF. Consumptive use and water requirement of soybeans. Journal of Irrigation Drainage Engineering. 1986;112: 157-163.
    DOI: 10.1061/(ASCE)0733-9437(1986) 112:2(157)
12. Jin Z, Zhuang Q, Wang J, Archontoulis SV, Zobel Z, Kotamarthi VR. The combined and separate impacts of climate extremes on the current and future US rainfed maize and soybean production under elevated CO2. Global Change in Biology. 2017; 23:2687-2704.
    DOI: 10.1111/gcb.13617
13. Kumawat K, Sing I, Nagpal S, Sharma P, Gupta R, Sirari A. Co-inoculation of indigenous pseuodomonas oryzihabitans and *Brady Rhizobium spp.* Modulate the growth symbiotic efficiency, nutrient acquisition and grain yield of soybean pedosphere. 2022;32:438-451.
    DOI: 101016/51002-0160(21) 60085-1
14. FAOSTAT. Crops and livestock products; 2019.
    Available:http://www.fao.org
15. Anonymous. Agricultural statistics at Glance. Government of India, Ministry of agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers Welfare, Directorate of Economics and Statistics; 2019.
16. Mahana SK, Meghavansi MK, Prasad Kamal. Identification of pH tolerant *Brady Rhizobium* japonicum strains and their symbiotic effectiveness in soybean

(*Glycine max* (L.) Merr.) in low nutrient soil. African Journal of Biotechnology. 2005;4:1-107.
17. Chauhan PG, Shinde VS, Kote GM, Solanke PS, Bhandve AA. Response of sources and levels of phosphorus with and without PSB inoculation on growth, yield and quality of soybean. Research on Crops. 2008;9(2):286-289.
18. Bohra A, Pandey MK, Jha UC, Singh B, Singh IP, Datta D, Chaturvedi SK, Nadarajan N, Varshney RK. Genomics assisted breeding in four major pulse crops of developing countries: present status and prospects. Theoretical and Applied Genetics. 2014;127:1263–1291.Cross Ref Google Scholar Pub Med
19. FAOSTAT. Crops and livestock products [Online]; 2020. Available:http://www.fao.org/faostat/en/#data/QCL [Accessed on 12, August 2021]
20. Jha K, Doshi A, Patel P, Shaha M. Comprehensive review on automation in agriculture using artificial; intelligence. Artificial Intelligence in Agriculture. 2019;2:1-12.
21. Sadras Vietor O, Lake Lachian. Screening chickpea for adaptation to water stress : Association between yield and crop growth rate. European Journal of Agronomy. 2016;81:86-91.
22. Flowers TJ, Gaur PM, Laxmipathigowda CL, et al. Salt sensitivity in chickpea. Plant Cell Environment. 2010;33(4):490-509.
23. Panse UG, Sukhatme PV. Statistical methods for agricultural workers, ICAR Pub., New Delhi. 1985;600-603.
24. Solanki RL, Sharma M, Sharma SK, Kumar A, Jain BK. Effect of phosphorus, sulphur and phosphate solubilizing bacteria on oil and protein quality of mustard (*Brassica juncea* L.). Indian Journal of Fertilizer. 2017;13(3)P:48-51.
25. Saini Lakhan Bharti, George PJ, Singh Swai Bhadana Effect of nitrogen management and biofertilizers on growth and yield of rapeseed *(Brassica Campestris*var.toria*).* Internanal Journal Current Microbiology and Applied Science. 2017;6(8):2652-2658.
26. TufenkciSefic, Sonmez Ferit, RuhanIlknur, Gaziogu Sensoy. Effect of Arbuscularmicorrhiza fungus and phosphorus and nitrogen fertilization on some plant growth content of chickpea. Journal of Biological Science. 2005;5 (6):738-743.
27. Rui Oliveira S, Patricia Carvalho, Guil Hermina Marques, Luis Ferreira, Mafalda Nunes, Ines Rocha, Ying Ma, Maria Carvalho F, Miroslav Vosatica, Helena Freitas. Increased protein content of chickpea (*Cicer arietinum* L.) inoculated with arbuscular mycorrhizal fungi and nitrogen fixing bacteria under water deficient conditions. Journal of Toxical Environmental Health A. 2012;320-328.
28. Bashan Y, Bashan LE, Prabhu SR, Hemandez JP. Advances in plant growth promoting bacterial inoculants technology.Formulations and practical perspectives (1998-2013); Plant Soil. 2014;378:1-33.
29. Elkoca E. Influence of nitrogen fixing and phosphorus solubilizing bacteria on the nodulation, plant growth and yield of chickpea. Journal of Plant Nutrition. 2007;31(1).
30. Hungria M, Ribeiro RA, Noguera MA. Draft genome sequences of Azospirillumbrasiliense strains Ab-V-5 and Ab-V-6 commercially used in inoculants for grasses and legumes in Brazil. Genome Announce 6; 2018.
31. Masciarelli O, Llanes A, Luna VA. New PGPR co-inoculated with *Brady Rhizobium* japonicum enhances soybean nodulation. Microbiological Research. 2014;169(7-8):609-615.
32. Gupta R, Bisaria VS, Sharma S. Effect of agricultural amendments on *Cajanuscajan* (pigeonpea) and its rhizospheric microbial communities – A comparison between chemical fertilizers and bioinoculants. PLOS One. 2015;13-16.
33. Sekar Jagan, Raj Rengalakshmi, Prabhavati VR. Microbial consortia products for sustainable agriculture : Commercialization and regulatory issues in India. Agriculturally Important Microorganisms; 2016. DOI: 10.1007/978-981-10-2576-1-7
34. Nascimento FX, Tavares MJ, Franck J, Ali S, Glick BR, Rossi MJ. ACC deaminase plays a major role in Pseudomonas fluorescens YsS6 ability to promote the nodulation of Alpha-and Betaproteobacteriarhizobial strains. Arch. Microbiology. 2019;201:817-822.
35. Sibponkrung S, Kondo T, Tanaka K, Tittabutr P, Boonkerd N, Yoshida KI,

Teaumroong N. Co-inoculation of Bacillus velezensis strain S141 and *Brady Rhizobium* strains promotes nodule growth and nitrogen fixation. Microorganisms. 2020;8:678.

36. Wanling Wei, Dawei Guan, Mingchao Ma Xin Jiang, Fenliang fan fangang Meng Li Li, Baisua Zhao, Yubin Zhao, Fengming Cao, Huijun Chen and Jun Li Long-term fertilization Coupled with *Rhizobium* inoculation promotes soybean yield and alters soil bacterial community composition. Frontiers of Micro biology. 2023;14.
Available:http://doi.org/10.3389/fmicb.2023.1161983

37. Obey Kudakwashe Zveushe, Victor Rescode Dios, Hengxing Zang, Fang Zeng, Siqin Liu, Songrong Shen, Qiamlin Kang, Yazhen Zang, Miao Huang, Ahmed Sarfaraz, Matina prajapati,Leizhou, Wei Zang, Ying Han and Faqin Dong. Effects f co-inoculating Saccharomyces spp with *Bardy rhizabium* on Atmospheric nitrogen fixation in soybean (Glycin max (L)) Plant. 2023;12(3):681
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