Original Research Article

Influence of Microbial Consortia Inoculation and Chemical Fertilizers on Growth Parameter and Nodulation of Soybean (*Glycine max* L. merill.) and Chickpea (*Cicerarietinum*L.) Crop

ABSTRACT

Field experiments were conducted during kharif seasons of 2020 and 2021 at Research Farm of Department of Soil Science and Agricultural Chemistry, VasantraoNaikMarathwadaKrishiVidyapeeth, Parbhani to study the influence of microbial consortia inoculation and chemical fertilizer on growth parameters and nodulation of soybean (*Glycine max* L. Merill.). The experimental site of present investigation was classified as Vertisol soil order belonging to Parbhani soil series. The soils were dominant in montmorillonite Mineral followed by moderate amount of kaolinite type and traces of illite mineral. Soil was clayey with alkaline in reaction (pH 8.29), low in salt content (0.29 dSm^{-1}) with high calcium carbonate content (132.3 g kg^{-1}). The organic carbon status of soil was medium (4.86 per cent). The soil available nitrogen was low (159.94 kg ha^{-1}), available phosphorus was medium (10.71 kg ha^{-1}), available potassium was very high (578 kg ha^{-1}). The experiments were laid out in factorial randomized block design with three replications. Results obtained from the study indicated that growth parameters like plant height, shoot weight, root length, root weight, number of branches and nodulation was significantly improved with combined effect of microbial consortia inoculation *Rhizobium* species + *Pseudomonas striata*, *Bacillus megaterium* and *Thiobacillusthiooxidant* along with chemical fertilizers 100 % RDF as compared to uninoculated control and control (without fertilizers) treatment.

Key words : Microbial consortia inoculation, chemical fertilizers, growth parameter, nodulation soybean.

INTRODUCTION

Modern agriculture has to be more productive sustainable and environmentally friendly. While macronutrients such as nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) supplied by mineral fertilizers are vital to crop production, etc. or indirectly (i.e. antimicrobial compounds biosynthesis and elicitation of induced systemic resistance, etc.) to crop improvement fertilizers efficiency, microbial based bioformulations that increase plant performance are greatly needed and in particular bioformulations that exhibit complementary and synergistic effects with mineral fertilization. Such an integrated soil fertility management strategy has been demonstrated through several controlled and non controlled experiments, but more efforts have to be made in order to thoroughly understand the multiple functions of beneficial microorganisms with in the soil microbial community itself and in interaction with plants and mineral resources. In fact, the combined usage of microbial (i.e. beneficial microorganisms: nitrogen fixing (NF), P-solubilizing and P-mobilizing, etc.) and mineral resources is an emerging research area that aims to design and develop efficient microbial formulations which are highly compatible with mineral resources is an emerging research area that aims to design and develop efficient microbial formulations which are highly compatible with mineral inputs with positive impacts on both crops and environment. This novel approach is likely to be of a global interest, especially in most N and P deficient agro-ecosystems. In this review, we report on the importance of NF bacteria and P solubilizing / mobilizing microbes as well as their interactions with mineral fertilization in improving crop productivity and fertilizers efficiency. 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, PGPR is better than inoculation with *Rhizobium* alone in different pulse crops (Gupta, 2006). Bacteria is most plentiful microbial community in soil followed by fungi (Kaur*et al.*, 2020; Rana*et al.*, 2020).

Soybean (*Glycine max* (L.) Merill.)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. About 40 % of the worlds edible vegetable oil comes from soybean (Hildebrand *et al.*, 1986). Soybean ranks first among the major oil seed crops of the world and has now found a prominent place in India (Mahana, *et al.*, 2005). Chouhan*et al.* (2008) reported that soybean has occupied first rank among oilseed seed in India 2005 onwards. In India production of soybean dominated by Maharashtra and Madhya Pradesh and its 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, 2019). Symbiotic *Rhizobium* species associated with soybean root nodules benefit plant growth via mediating biological N fixation (Jaiswal*et al.*, 2021). However, it has been demonstrated that extenuation of premature senescence is mediated by the induction of high glutiathionereductase in soybean roots and nodules. Glutathione reductase activity likely exerts its influence by reducing oxidative damage to biomolecules (Porcel and Ruiz Lozano, 2004; Prabbha and Sharadamma, 2019; Meena*et al.*, 2021).

Further, chickpea (*Cicerarietinum*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 helith of domestic stock and humans (Graham and Vance, 2003; Jukanti*et al.*, 2012; Bohra*et al.*, 2014). The global area of chickpea average 13.0 million tonnes across 56 countries (2015-17) (Food and Agricultural Organization of the United Nationals, FAOSTAT, 2020). India is the largest global producer, consumer and importer of chickpea whereas Asutralia 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 insufifcinet for meeting the growing demand of plants based food specially dietary protein

(Millan*et al.*, 2006; Jha*et al.*, 2019). Overall, legumes are more sensitive to environmental stress than cereals, with chickpea often exposed to terminal drought and high temperature. In addition chickpea may not be able to absorb enough from the soil, specially under drought to influence yield due to its low N-fixation ability and low nutrient used efficiently (Sadras*et al.*, 2016). Chickpea and soybean contributes a significant amount of residual nitrogen to the soil and adds organic matter thereby improving soil health and fertility. On the basis of seed colour and geographical distribution, chickpea is grouped into two types :desi (Indian origin) and Kabuli (Mediterranean) and middle eastern origin (Bampidisa and Christodolu, 2011). Chickpea also play important role in maintaining soil fertility by fixing nitrogen at the rate upto 140 kg ha^{-1} year-1 (Flowers *et al.*, 2010).

MATERIAL AND METHODS

Present investigation was carried at Research Farm, Department of Soil Science and Agricultural Chemistry, VasantraoNaikMarathwadaKrishiVidyapeeth, Parbhani 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 P_2O_5 and available K_2O was very high 578 kg ha^{-1}. The experiment comprising four treatments of microbial consortia inoculation *Rhizobium* species + *Bacillus megaterium*, *Rhizobium* species + *Pseudomonastriata*, *Rhizobium* species + Thiobacillusthiooxidans and uninocualted control and four levels of chemical fertilizers (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. Seed inoculation was alone with consortia *Rhizobium* species, *Bacillus megaterium*, *Pseudomonas striata*, *Thiobacillusthiooxidant* @ 100 ml for each 10 kg^{-1} seed as seed treatment before sowing. The variety of soybean Cv. MAUS 162 and chickpea Cv. *PhuleVikram*. The recommended dose of fertilizer (RDF) as basal dose was applied N:P2O5:K2O 30:60:30 kg ha^{-1} for soybean and N:P2O5:K2O 25:50:0 kg ha^{-1} for chickpea, through urea, SSP and MOP 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. 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 number of branches 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.

RESULTS AND DISCUSSION

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 (Table 1 and 2). Plant height of soybean and chickpea was significantly highest at 60, 90 days with treatment *Rhizobium* species + *Pseudomonastriata* 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, 66.38a nd 43.54, 64.22 and lowest was found without fertilizers (T1) during both the years of experiment and pooled mean respectively.

Shoot weight (g plant^{-1}) of soybean and chickpea

Shoot weight was increased with treatment microbial inoculants and chemical fertilizers (Table 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 + *Pseudomonastriata*(S3) and lowest was observed in treatment uninocualted control (S1) during both the experimentation years and pooled data. Chemical fertilizer with 100 % RDF 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 fertilziers (T1).

Significantly highest shoot weight was recorded 108.40 g in *Mesorhizobium* + *Pseudomonastriata* along with 100 % RDF treatment at 90 DAS stage and it was at par with *Mesorhizobium* + *Pseudomonastriata* with 75 % RDF. The plant height and shoot weight of both soyvbean, 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. Results are in line with Naik et al. (2020), when applied EM formulations reported have positive effect on several crop growth parameters. Solanki*et al.* (2017) reported enhancement of P availability increased better root growth, plant vegetative growth also. Saini*et al.* (2017) reported similar results.

Root weight (g palnt-1) of soybean and chickpea

The highest root weight (g plant^{-1}) of soybean and chickpea (Table 5 and 6) was recorded in *Rhizobium* species + *Pseudomonastriata* (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).

Root length (cm plant^{-1}**) of soybean and chickpea**

Table 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 31.80,3 5.23 and 18.77, 20.36 cm palnt-1 at 60 and 90 DAS and maximum root length was noted in treatment *Rhizobium* species + *Pseudomonastriata* (S3) and least was noticed treatment uninocualted control (S1) during both the years of and pooled. Chemical fertilziers 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 *BradyRhizobium*, *Mesorhizobium* and *Pseudomonastriata*, *Bacillus megaterium* is able to synthesized growth regulators IAA, Gibberellins, Auxins, Vitamins and Cytokinins antagonistic metabolites as HCM and siderophore through its ability to provide nutrients through biological nitrogen fixation and phosphorus solubilization / mobilization and ion chelation (Bashan *et al.*, 2014; Tufenkci*et al.*, 2005). Rui*et al.* (2012) reported that single inocualtionwith AM (*Arbuscularmicorrhiza*) fungus and *R. irregularis* significantly increased shoot weight of chickpea over uninouclated control. Elcoka*et al.*, 2007) 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.

Nodulation in soybean and chickpea

The number of nodules in soybean and chickpea were significantly improved by microbial consortia inoculants and chemical fertilizers (Table 9 and 10). Maximum nodules, fresh weight of nodules were recorded in treatment (S3) *Rhizobium* species + *Pseudomonastriata* 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 ind 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) andtreatment (T1) both the soybean and chickpea crop.

Application of dual or more inoculantsi.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 improve fresh weight and dry weight of nodules growth and development of plant growth. These results are finding with Hungria*et al.* (2018) application of *BradyRhizobium* + strains of Azospirillum and PSM the nodulation of soybean plants were promoted.Masciarelli*etal.*(2014) found that coinoculation of *BradyRhizobium*japonicum with PSB has better nodulation could be due to photohormone production resulted increased nodule number and its dry biomass. Coinocualtion of rhizobia with PGPR enhanced nodulation in pigeonepa and other legumes (Gupta *et al.* 2015; Sekar*et al.*, 2016. Nasimento*et al.*, 2019).Sibpankrung*et al.* (2020) also reported the similar results.

Table 1. Effect of microbial consortia inoculation and chemical fertilizers on plant height (cm $plant^{-1}$) of soybean

Treatments	2020-21		2021-22		Pooled	
	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS
Microbial consortia inoculation (S)						
S_1- Uninoculated control	44.08	49.60	44.68	48.48	44.38	49.04
S_2-*BradyRhizobium+ Bacillus megaterium* inoculation (Consortia-I)	63.75	69.28	59.71	63.72	61.73	66.50
S_3-*BradyRhizobium + Pseudomonastriata*inoculation (Consortia-II)	73.58	74.85	65.05	74.74	69.31	74.79
S_4-*BradyRhizobium + Thiobacillusthiooxidant* inoculation (Consortia-III)	57.75	63.72	55.54	60.39	56.64	62.05
S.E.m±	0.79	2.49	0.67	0.88	0.73	1.68
C.D. at 5%	2.29	7.19	1.94	2.55	2.11	4.87
Chemical fertilizers (T)						
T_1- Control (without fertilizer)	56.75	62.06	53.00	57.48	55.29	59.77
T_2- 50% RDF	57.58	62.67	56.20	60.90	56.47	61.78
T_3- 75% RDF	60.92	66.08	56.80	62.82	58.86	64.45
T_4- 100% RDF	63.92	66.65	58.98	66.12	61.45	66.38
S.E.m±	0.79	2.49	0.67	0.88	0.73	1.68
C.D. at 5%	2.29	7.19	1.94	2.55	2.115	4.87
Interaction (S x T)						
S.E.m±	1.58	4.98	1.34	1.76	1.46	3.37
C.D. at 5%	4.58	NS	NS	NS	NS	NS

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

Treatments	2020-21		2021-22		Pooled	
	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS
Microbial consortia inoculation (S)						
S_1- Uninoculated control	35.34	44.14	32.24	41.40	33.79	42.77
S_2-*Mesorhizobium*+ *Bacillus megaterium* inoculation (Consortia-I)	42.01	62.19	41.63	60.76	41.82	61.475
S_3-*Mesorhizobium + Pseudomonastriata*inoculation (Consortia-II)	46.92	72.86	45.85	71.04	46.385	71.95
S_4-*Mesorhizobium + Thiobacillusthiooxidant* inoculation (Consortia-III)	38.53	63.36	38.61	64.49	38.57	63.925
S.E.m$\pm$	0.73	0.90	0.30	1.63	0.51	1.26
C.D. at 5%	2.13	2.62	0.87	4.71	1.50	3.66
Chemical fertilizers (T)						
T_1- Control (without fertilizer)	36.81	56.58	36.40	53.00	36.605	54.79
T_2- 50% RDF	39.75	59.18	38.18	59.04	38.965	59.11
T_3- 75% RDF	41.98	61.88	40.91	62.12	41.445	62
T_4- 100% RDF	44.25	64.91	42.84	63.53	43.545	64.22
S.E.m$\pm$	0.73	0.90	0.30	1.63	0.51	1.26
C.D. at 5%	2.13	2.62	0.87	4.71	1.50	3.66
Interaction (S x T)						
S.E.m$\pm$	1.47	1.81	0.60	3.26	1.03	2.53
C.D. at 5%	NS	NS	NS	NS	NS	NS

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

Treatments	2020-21		2021-22		Pooled	
	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS
Microbial consortia inoculation (S)						
S_1- Uninoculated control	29.28	38.36	30.71	43.83	30.00	41.10
S_2-*BradyRhizobium+ Bacillus megaterium* inoculation (Consortia-I)	35.34	47.55	36.18	50.77	35.76	49.16
S_3-*BradyRhizobium + Pseudomonastriata*inoculation (Consortia-II)	39.24	57.01	42.65	58.31	40.95	57.66
S_4-*BradyRhizobium + Thiobacillusthiooxidant* inoculation (Consortia-III)	32.60	43.03	33.84	59.78	33.22	51.41
S.E.m$\pm$	0.46	0.73	0.72	0.56	0.60	0.65
C.D. at 5%	1.33	0.20	2.10	1.60	1.72	0.90
Chemical fertilizers (T)						
T_1- Control (without fertilizer)	32.07	44.20	33.10	49.01	32.59	46.61
T_2- 50% RDF	33.16	45.55	34.68	50.36	33.92	47.96
T_3- 75% RDF	34.86	46.88	37.09	51.31	35.98	49.10
T_4- 100% RDF	36.36	49.33	38.51	52.01	37.44	50.67
S.E.m$\pm$	0.46	0.73	0.72	0.56	0.60	0.65
C.D. at 5%	1.33	0.20	2.10	1.60	1.72	0.90
Interaction (S x T)						
S.E.m$\pm$	0.92	1.46	1.45	0.61	1.19	1.04
C.D. at 5%	NS	NS	NS	NS	NS	NS

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

Treatments	2020-21		2021-22		Pooled	
	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS
Microbial consortia inoculation (S)						
S_1- Uninoculated control	32.82	45.69	33.50	45.56	33.16	45.625
S_2-*Mesorhizobium*+ *Bacillus megaterium* inoculation (Consortia-I)	49.73	64.23	50.83	89.58	50.28	76.905
S_3-*Mesorhizobium* + *Pseudomonastriata*inoculation (Consortia-II)	53.41	69.91	56.83	102.32	55.12	86.115
S_4-*Mesorhizobium* + *Thiobacillusthiooxidant* inoculation (Consortia-III)	45.23	58.46	47.17	62.64	46.2	60.55
S.E.m±	0.89	0.56	0.62	9.93	0.75	5.24
C.D. at 5%	2.58	1.64	1.79	2.68	2.18	2.16
Chemical fertilizers (T)						
T_1- Control (without fertilizer)	39.38	56.33	40.67	72.60	40.025	64.465
T_2- 50% RDF	44.45	58.33	46.67	71.42	45.56	64.875
T_3- 75% RDF	48.05	60.33	49.58	74.96	48.815	67.645
T_4- 100% RDF	49.32	63.30	51.42	81.12	50.37	72.21
S.E.m±	0.89	0.56	0.62	9.93	0.75	5.24
C.D. at 5%	2.58	1.64	1.79	2.68	2.18	2.16
Interaction (S x T)						
S.E.m±	1.78	1.13	1.24	1.86	1.51	1.49
C.D. at 5%	NS	NS	NS	5.37	NS	NS

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

Treatments	2020-21		2021-22		Pooled	
	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS
Microbial consortia inoculation (S)						
S_1- Uninoculated control	7.17	7.31	7.10	8.51	7.135	7.91
S_2-*BradyRhizobium+ Bacillus megaterium* inoculation (Consortia-I)	9.00	9.66	9.54	10.57	9.27	10.115
S_3-*BradyRhizobium + Pseudomonastriata*inoculation (Consortia-II)	10.25	10.96	10.92	12.12	10.585	11.54
S_4-*BradyRhizobium + Thiobacillusthiooxidant* inoculation (Consortia-III)	7.78	9.44	9.00	10.14	8.39	9.79
S.E.m$\pm$	0.18	0.11	0.09	0.36	0.14	0.23
C.D. at 5%	0.52	0.31	0.29	1.05	0.40	0.68
Chemical fertilizers (T)						
T_1- Control (without fertilizer)	7.58	9.10	8.43	9.00	8.005	9.05
T_2- 50% RDF	8.49	9.25	8.89	10.06	8.69	9.655
T_3- 75% RDF	9.01	9.44	9.35	10.94	9.18	10.19
T_4- 100% RDF	9.13	9.59	9.89	11.34	9.51	10.465
S.E.m$\pm$	0.18	0.11	0.09	0.36	0.14	0.23
C.D. at 5%	0.52	0.31	0.29	1.05	0.40	0.68
Interaction (S x T)						
S.E.m$\pm$	0.36	0.21	0.25	0.73	0.30	0.47
C.D. at 5%	NS	NS	NS	NS	NS	NS

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

Treatments	2020-21		2021-22		Pooled	
	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS
Microbial consortia inoculation (S)						
S_1- Uninoculated control	6.12	7.09	6.02	6.64	6.07	6.865
S_2-*Mesorhizobium+ Bacillus megaterium* inoculation (Consortia-I)	7.25	8.85	7.55	8.99	7.4	8.92
S_3-*Mesorhizobium + Pseudomonastriata*inoculation (Consortia-II)	9.73	10.67	10.22	11.43	9.975	11.05
S_4-*Mesorhizobium + Thiobacillusthiooxidant* inoculation (Consortia-III)	7.11	7.91	7.49	8.57	7.3	8.24
S.E.m±	0.11	0.12	0.10	0.18	0.10	0.15
C.D. at 5%	0.33	0.35	0.29	0.51	0.31	0.43
Chemical fertilizers (T)						
T_1- Control (without fertilizer)	7.28	7.75	7.49	7.91	7.385	7.83
T_2- 50% RDF	7.49	8.24	7.59	8.23	7.54	8.235
T_3- 75% RDF	7.66	8.95	7.95	9.57	7.805	9.26
T_4- 100% RDF	7.77	9.58	8.25	9.91	8.01	9.745
S.E.m±	0.11	0.12	0.10	0.18	0.10	0.15
C.D. at 5%	0.33	0.35	0.29	0.51	0.31	0.43
Interaction (S x T)						
S.E.m±	0.23	0.24	0.20	0.36	0.215	0.3
C.D. at 5%	NS	NS	NS	NS	NS	NS

Table 7. Effect of microbial consortia inoculation and chemical fertilizers on root length (cm) of soybean

Treatments	2020-21		2021-22		Pooled	
	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS
Microbial consortia inoculation (S)						
S_1- Uninoculated control	20.50	24.90	22.70	26.75	21.60	25.82
S_2-*BradyRhizobium+ Bacillus megaterium* inoculation (Consortia-I)	24.98	29.44	26.07	34.17	25.52	31.80
S_3-*BradyRhizobium + Pseudomonastriata*inoculation (Consortia-II)	31.17	34.97	32.43	35.50	31.80	35.23
S_4-*BradyRhizobium + Thiobacillusthiooxidant* inoculation (Consortia-III)	22.33	26.21	23.24	32.08	22.78	29.14
S.E.m±	0.33	0.74	0.48	0.29	0.40	0.51
C.D. at 5%	0.95	2.13	1.39	0.85	1.17	1.49
Chemical fertilizers (T)						
T_1- Control (without fertilizer)	22.83	26.54	23.90	29.17	23.36	27.85
T_2- 50% RDF	23.71	28.13	24.92	31.67	24.31	29.90
T_3- 75% RDF	25.15	29.75	27.21	33.17	26.18	31.46
T_4- 100% RDF	27.29	31.09	28.40	34.50	27.84	32.79
S.E.m±	0.33	0.74	0.48	0.29	0.40	0.51
C.D. at 5%	0.95	2.13	1.39	0.85	1.17	1.49
Interaction (S x T)						
S.E.m±	0.66	1.48	0.96	0.58	0.81	1.03
C.D. at 5%	0.91	NS	NS	NS	NS	NS

Table 8. Effect of microbial consortia inoculation and chemical fertilizers on root length (cm) of chickpea

Treatments	2020-21		2021-22		Pooled	
	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS
Microbial consortia inoculation (S)						
S_1- Uninoculated control	10.87	13.23	12.60	14.26	11.74	13.75
S_2-*Mesorhizobium*+ *Bacillus megaterium* inoculation (Consortia-I)	14.11	17.76	17.43	18.31	15.77	18.04
S_3-*Mesorhizobium* + *Pseudomonastriata*inoculation (Consortia-II)	17.31	20.28	20.22	20.44	18.77	20.36
S_4-*Mesorhizobium* + *Thiobacillusthiooxidant* inoculation (Consortia-III)	13.22	16.30	16.73	17.53	14.98	16.92
S.E.m±	0.52	0.37	0.31	0.21	0.42	0.29
C.D. at 5%	1.50	0.86	0.90	0.62	1.20	0.74
Chemical fertilizers (T)						
T_1- Control (without fertilizer)	12.31	16.31	15.38	17.08	13.85	16.70
T_2- 50% RDF	12.82	16.62	16.20	17.65	14.51	17.14
T_3- 75% RDF	14.19	17.38	17.33	17.83	15.76	17.61
T_4- 100% RDF	16.18	17.27	18.08	17.97	17.13	17.62
S.E.m±	0.52	0.37	0.31	0.21	0.42	0.29
C.D. at 5%	1.50	0.86	0.90	0.62	1.20	0.74
Interaction (S x T)						
S.E.m±	1.04	0.75	0.62	0.43	0.83	0.59
C.D. at 5%	NS	NS	NS	NS	NS	NS

Table 9. Effect of microbial consortia inoculation and chemical fertilizers on nodules of soybean

Treatments	2020-21			2021-22			Pooled		
	No. of nodules	Fresh wt (mg/pl)	Dry wt (mg/pl)	No. of nodules	Fresh wt (mg/pl)	Dry wt (mg/pl)	No. of nodules	Fresh wt (mg/pl)	Dry wt (mg/pl)
Microbial consortia inoculation (S)									
S_1- Uninoculated control	37.75	375.83	340.375	41.17	369.83	350.75	39.46	372.83	345.75
S_2-*BradyRhizobium*+ *Bacillus megaterium* inoculation (Consortia-I)	73.42	795.08	468.58	80.67	816.50	541.67	77.04	805.79	505.12
S_3-*BradyRhizobium* + *Pseudomonastriata*inoculation (Consortia-II)	95.92	889.42	563.67	104.68	906.25	578.08	100.30	897.84	570.87
S_4-*BradyRhizobium* + *Thiobacillusthiooxidant* inoculation (Consortia-III)	70.08	763.25	407.08	75.92	773.00	495.92	73.00	768.13	451.5
S.E.m$\pm$	0.84	1.56	8.32	4.41	3.25	8.88	2.63	2.41	8.60
C.D. at 5%	4.90	4.50	24.02	12.74	9.40	25.63	8.82	6.95	24.82
Chemical fertilizers (T)									
T_1- Control (without fertilizer)	63.42	676.08	420.92	65.75	690.92	465.25	64.58	683.50	443.085
T_2- 50% RDF	66.42	700.08	442.83	75.25	702.67	486.00	70.84	701.38	464.41
T_3- 75% RDF	70.00	711.00	451.67	78.17	724.67	494.67	74.09	717.84	473.17
T_4- 100% RDF	77.33	736.42	464.67	83.25	747.33	520.50	80.29	741.88	492.58
S.E.m$\pm$	0.84	1.56	8.32	4.41	3.25	8.88	2.63	2.41	8.60
C.D. at 5%	4.90	4.50	24.02	12.74	9.40	25.63	8.82	6.95	24.82
Interaction(SxT)									
S.E.m$\pm$	1.69	1.56	16.63	4.41	3.25	17.25	3.05	2.41	17.19
C.D. at 5%	4.90	4.50	NS	12.74	9.40	NS	8.82	6.95	NS

Table 10. Effect of microbial consortia inoculation and chemical fertilizers on nodules of chickpea

Treatments	2020-21			2021-22			Pooled		
	No. of nodules	Fresh wt (mg/pl)	Dry wt (mg/pl)	No. of nodules	Fresh wt (mg/pl)	Dry wt (mg/pl)	No. of nodules	Fresh wt (mg/pl)	Dry wt (mg/pl)
Microbial consortia inoculation (S)									
S_1- Uninoculated control	25.17	278.75	208.29	22.17	278.67	210.61	23.66	278.71	209.67
S_2-*Mesorhizobium*+ *Bacillus megaterium* inoculation (Consortia-I)	33.17	439.17	281.36	33.17	451.50	299.53	33.17	445.34	290.29
S_3-*Mesorhizobium* + *Pseudomonastriata*inoculation (Consortia-II)	40.25	475.83	297.66	43.35	481.25	321.08	41.79	478.55	309.37
S_4-*Mesorhizobium* + *Thiobacillusthiooxidant* inoculation (Consortia-III)	31.50	389.17	233.66	33.42	452.08	273.34	32.46	420.63	253.28
S.E.m±	0.42	0.98	5.20	0.25	2.29	4.67	0.34	1.64	4.93
C.D. at 5%	2.4	2.83	15.02	0.73	6.62	13.51	1.56	4.73	14.26
Chemical fertilizers (T)									
T_1- Control (without fertilizer)	28.25	384.25	232.34	30.33	401.33	249.62	29.29	392.79	240.57
T_2- 50% RDF	32.92	392.25	246.29	21.92	412.33	266.47	27.42	402.29	256.78
T_3- 75% RDF	33.83	400.17	263.65	33.83	421.92	283.32	33.83	411.05	273.78
T_4- 100% RDF	35.08	406.25	278.33	36.00	427.92	304.56	35.54	417.09	291.89
S.E.m±	0.42	0.98	5.20	02.5	2.29	4.67	0.33	1.64	4.93
C.D. at 5%	2.4	2.83	15.02	0.73	6.62	13.51	1.56	4.73	14.26
Interaction(SxT)									
S.E.m±	0.84	1.97	10.43	0.50	4.59	9.44	0.67	3.28	9.94
C.D. at 5%	2.42	5.68	NS	1.46	13.25	NS	1.94	9.47	NS

CONCLUSION

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

REFERENCES

Anonymous (2019).Agricultural Statistics at Glance 2019. Government of India, Ministry of agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers Welfare, Directorate of Economics and Statistics.

Badiger Narayan, M., Jagdeesh, K.S., Krishnaraj, P.U. and Mogali Suma (2019).Effect of inoculation of microbial consortia on growth parameters of green gram (*Vigna radiate* L.).*International Journal of Crurent Microbiology and Applied Science*, 8(10):562-567.

BampidisaVasilelos and Vladimiros Christo Doulou (2011). Chickpeas (*Cicerarietinum*L.) in animal nutrition : A review Animal Feed Science and Technology, 168:1-20.

Bashan, Y., De-Bashan, L.E., Prabhu, S.R., Hemandez, J.P. (2014).Advances in plant growth promoting bacterial inoculants technology.Formulations and practical perspectives (1998-2013).*Plant Soil*, 378:1-33.

Bohra, A., Pandey, M.K., Jha, U.C., Singh, B., Singh, I.P., Datta, D., Chaturve di, S.K., Nadarajan, N. and Varshney, R.K. (2014) Genomics assisted breeding in four major pulse crops of developing countries: present status and prospects. *Theoretical and Applied Genetics* 127:1263–1291.CrossRefGoogle ScholarPubMed

Chauhan, P.G., Shinde, V.S., Kote, G.M., Solanke, P.S. and Bhandve, A.A. (2008).Response of sources and levels of phosphorus with and without PSB inoculation on growth, yield and quality of soybean.*Research on Crops*, 9(2):286-289.

Elkoca, E. (2007). Influence of nitrogen fixing and phosphorus solubilizing bacteria on the nodulation, plant growth and yield of chickpea. *Journal of Plant Nutrition*, 31(1).

FAOSTAT (2020). *Crops and livestock products* [Online]. Available at: http://www.fao.org/faostat/en/#data/QCL (Accessed 12, August 2021).

Flowers, T.J., Gaur, P.M., Laxmipathigowda C.L., *et al.* (2010) Salt sensitivity in chickpea.*Plant Cell Environment* 33(4), : 490–509.

Graham, P.H. and Vance, C.P. (2003) Legumes: importance and constraints to greater use. *Plant Physiology* 131:872–877.

Gupta, R., Bisaria, V.S. and Sharma, S. (2015). Effect of agricultural amendments on *Cajanuscajan* (pigeonpea) and its rhizospheric microbial communities – a comparison between chemical fertilizers and bioinoculants. PLoS One, pp 13-16.

Hilderbrand, D.F., Phillips, G.C. and Collins, G.B. (1986). Soybean (*Glycine max* (L.) Merr.).In : Bajaj, Y.P.S. (es.) Crops I. *Biotechnology in Agriculture and Forestry,* Vol. 2, Springer, Berlin, Heidelberg.

Hungria, M., Ribeiro, R.A. and Noguera, M.A. (2018). 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.

Jaiswal, S. K., Mohammed, M., Ibny, F. Y. I., and Dakora, F. D. (2021). Rhizobia as a source of plant growth-promoting molecules: potential applications and possible operational mechanisms. *Front Sustainable. Food System,* 4:311. doi: 10.3389/fsufs.2020.619676

Jha, K., Doshi, A., Patel, P. and Shaha, M. (2019).Comprehensive review on automation in agriculture using artificial intelligence.*Artificial Intelligence in Agriculture*., 2 :1-12

Jukanti, A.K., Gaur, P.M. and Gowda, C.L.L. (2012).Nutritional quality and health benefits of chickpea (*Cicerarietinum*L.).*British Journal Nutrition,* 108 Supplement, 1(51):511-526.

Mahana, S.K., Meghavansi, M.K. and Prasad Kamal (2005).Identification of pH tolerant *BradyRhizobium*japonicum strains and their symbiotic effectiveness in soybean (*Glycine max* (L.)Merr.)in low nutrient soil. *African Journal of Biotechnology*, 4:1-107.

Masciarelli, O., Llanes, A. and Luna, V. (2014). A new PGPR co-inoculated with *BradyRhizobium*japonicum enhances soybean nodulation. *Microbiological Research*, 169(7-8):609-615.

Millan, T. Cobos, M.J.; Rubio, J.; Strange, R.N.; Moreno, M.T. and Gil, J.A.(2006). New QTL for Ascochyta blight resistance in an RIL population derived from an interspecific cross in chickpea. *Euphytica,* 149:105–111.

NaikKalyani, Mishra Snehashih, SrichandanHargabinda, Singh Puneet Kumar and ChoudharyAbhishek (2020).Microbial formulation and growth of cereals, pulses, oilseed and vegetable crops.*Sustainable Environmental Research*, https://doil.org/10.1186.

Nascimento, F.X., Tavares, M.J., Franck, J., Ali, S., Glick, B.R., Rossi, M.J. (2019). ACC deaminase plays a major role in Pseudomonas fluorescens YsS6 ability to promote the nodulation of Alpha-and Betaproteobacteriarhizobial strains. *Arch. Microbiology*, 201:817-822.

Rokhzadi, AsadToashihVofa (2011) Nutrient uptake and yield of chickpea (*cicerarientinum L*) inoculated with plant growth-promoting rhizobacteria.*Asian Journal of Current Science*5 (1) ; 44-48 .

SadrasVietor, O. and Lake Lachian (2016). Screening chickpea for adaptation to water stress : Association between yield and crop growth rate. *European Journal of Agronomy*, 81:86-91.

SainiLakhanBharti, George P.J. and Singh SwaiBhadana (2017) Effect of nitrogen management and biofertilizers on growth and yield of rapeseed *(Brassica Campestris*var.toria*).Internanal Journal Current Microbiology and Applied Science* 6 (8):2652-2658

SekarJagan, Raj Rengalakshmi and Prabhavati, V.R. (2016). Microbial consortia products for sustainable agriculture : Commercialization and regulatory issues in India. *Agriculturally Important Microorganisms*, DOI 10.1007/978-981-10-2576-1-7.

Sibponkrung, S., Kondo, T., Tanaka, K., Tittabutr, P., Boonkerd, N., Yoshida, K.I., Teaumroong, N. (2020). Co-inoculation of Bacillus velezensis strain S141 and *BradyRhizobium* strains promotes nodule growth and nitrogen fixation. *Microorganisms*, 8:678.

Solanki, R.L., Sharma, M., Sharma, S.K., Kumar, A. and Jain, B.K. (2017).Effect of phosphorus, sulphur and phosphate solubilizing bacteria on oil and protein quality of mustard (*Brassica juncea* L.).*Indian Journal of Fertilizer*, 13(3)P:48-51.

Suliasih and Widawati, S. (2018). The effect of biofertilizer combined with organic or inorganic fertilizer on growth of Caesalpiniapulcherrima and bacterial population in soil. IOP Conference Series.*Earth Environmental Science*, 166. 7th International Symposium for A Sustainable Human Sphere, 1-2 Nov.

TufenkciSefic, SonmezFerit and RuhanIlknur and GazioguSensoy (2005).Effect of Arbuscularmicorrhiza fungus and phosphorus and nitrogen fertilization on some plant growth content of chickpea.*Journal of Biological Science*, 5(6):738-743.