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Effect of Microbial Consortia Inoculation on N, P and K Content, Uptake and Yield of Soybean (*Glycine max* L. merill.) and Chickpea (*Cicer arietinum* L.) on Vertisol

Syed Javed*, Syed Ismail, Waikar S.L. and More S.S.
Department of Soil Science and Agricultural Chemistry,
Vasantrao Naik Marathwada Agricultural University Parbhani (Maharashtra), India.

(Corresponding author: Syed Javed)*
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ABSTRACT: Tomorrow's agriculture, challenged by increasing global demand for food, scarcity of arable lands, and resources alongside multiple environment pressures, needs to be managed smartly through sustainable and eco-efficient approaches. Modern agriculture has to be more productive, sustainable, and environmentally friendly. Microbial-based bioformulations that increase plant performance are greatly needed, and in particular bioformulations that exhibit complementary and synergistic effects with mineral fertilization. While macronutrients such as nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) supplied by mineral fertilizers are vital to crop production, agriculturally beneficial microorganisms may also contribute directly (i.e., biological N_2 fixation, P solubilization, and phytohormone production. Capacity of legumes to fix atmospheric nitrogen through symbiotic association, with rhizobia root nodule bacteria that comprise *Rhizobium*, *Bradyrhizobium*, *Sinorhizobium*, *Azorhizobium* and *Mesorhizobium* could be used to increase agricultural productivity (Kebede, Kebede, 2021). Meanwhile a sum of the findings may have been expected, the complex biological process underlying microbial consortia inoculants strengthing remains challenging. Our research has been focused on microbial consortia inoculation in future study's to extends the potential of various beneficial bacterial inoculants the combination of two or more microbes together i.e consortium. Field experiments were conducted during kharif seasons of 2020-21 and 2021-22 at Research Farm of Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Agricultural University, Parbhani, Maharashtra to investigate the effect of microbial consortia inoculation and Chemical fetilizers on productivity and soil properties in soybean-chickpea sequence on Vertisol. The treatments detailed in kharif for soybean were microbial inoculants (S1), uninocualted control (S2), *Rhizobium* species + *Bacillus megaterium* (S3), *Rhizobium* species + *Pseudomonas striata* and (S4) *Rhizobium* species + *Thiobacillus thiooxidant*. Chemical fertilizers (T1) control i.e. without fertilizers, (T2) 50% RDF, (T3) 75 % RDF and (T4) 100 % RDF. After harvest of soybean, on the same plots were cultivated chickpea in rabi season with same treatments. The results indicated that the treatment combination of microbial inoculation (S3) *Rhizobium* species + *Pseudomonas triata* along with 100 % RDF was observed that the statistically highest nutrient content, uptake and yield of soybean and chickpea.

Keywords: Microbial consortia, chemical fertilizers, yield, nutrient, soybean-chickpea, Vertisol.

INTRODUCTION

Soybean (*Glycine max* (L.) Merill.) is an annual leguminous species cultivated mainly for its seed. It is sued in a variety of industries, providing products for human consumption, livestock feed and industrial purpose. 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. It is also used to produce a high protein animal feed. 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). India ranks fifth in area and production of soybean after USA, Argentina, brazil and China. The area, production and productivity of Maharashtra is 4.04 million ha, 4.55 million tonnes and 1125 kg ha^{-1}, respectively (Anonymous, 2019). Out of different vegetable oil imported, the palm oil constituted the share of 60 % followed by soybean oil (22 %) and sunflower oil (17 %) (Anonymous, 2020). The effect of microbial consortia on growth, nodulation, yield and nutrient uptake of soybean. significantly improvement and also investigate N, P and K nutrients contents in seed and stover of soybean (Yaduwanshi *et al.*, 2019). Inoculation of *Bradyrhizobium* in soybean resulted in mean increase of 8.4 per cent in grain yield compared with the control treatment (Santos *et al*. 2019). The highest stover yield of soybean was recorded with treatment combination microbial inoculants of PGPR + Arthro + Actino by 61% response over control treatment (Yaduwanshi *et al.*, 2019). Application of microbial consortium of Rizo + PSB + Strepto + Rhodo

+ Lacto + Sacchro + Aspergil as seed inoculation performed the best consortium for enhancing seed and stover yield of soybean (Singh *et al*., 2021). Application of various combination and doses of chemical fertilizers and bioinoculants and results showed that treatment T6P7 was highest yield as compared to other treatments of lower, higher and control with green gram (*Vigna radiata*) (Dhakne and Tiple 2021). Soybean is grown mainly in tropical, subtropical and temperate regions (FAO, 2021). Symbiotic *Rhizobium* species associated with soybean root nodules benefit plant growth via mediating biological N fixation (Jaiswal *et al.*, 2021).

Chickpea (*Cicer arietinum* L.) is a cool season legume crop grown wordwide as food crop. The seed is the main edible part of the plant. It is also called garbanzo gram or Bengal gram. Chickpea is an important food legume commodity and have a diverse use with specific consumer preference in global market. According to national agricultural Research system (NARS) policy makers chickpea production of India was 13.75 million tones from and acreage of 10.91 million ha during 2021-22. With a productivity of 12.6 q/ha (DES 2023 MOAF & W GOI) Ministry of Agriculture and Farmers Welfare, GOI. Chickpea solely contributes nearly 50% of the Indian pulse production. Therefore, this crop requires relatively low inputs of nitrogen as it derives 70 % of its N through symbiotic N2 fixation and benefits other cereal crops as well (Siddique *et al.*, 2005). India rank first both in area and production of chickpea in the word as it contributes 70.57 % to the total word area and 69.21 % to the total word production followed by Australia (Sharma *et al.,* 2020). Chickpea is highly nutritious pulse crop and placed 3rd in the list of the food legumes that are cultivated throughout the world it contains 25 % proteins and 60 % carbohydrates. Chickpea has significant amounts of all the essential amino acids except the sulfur containing types, which can be complemented by adding cereals to daily diet as cereals are rich in sulphur containing amino acids. Chickpea also plays an important role in maintaining soil fertility by fixing nitrogen at rates of upto 140 kg ha^{-1} year-1 (Flowers *et al.*, 2010). Chickpea as an affordable source of protein, carbohydrates, minerals and vitamins, dietary fiber, folate, *B*-carotene, and health promoting fatty acids (Jukanti *et al.*, 2012). PSB enhanced the nodulation and growth of chickpea through increasing P concentration in the *Rhizosphere* as well as plant P uptake (Anteneh Argow 2021). Rizobial inoculation combined with P fertilization resulted in a higher nodulation, biomass and yield of chickpea as compared to single inoculation with rhizobium or single use N or P (Imane *et al.,* 2021). Dual *Pseudomona* ssp. And *Mesorhizobium* sp. Inoculants with PGP and bio-control potential with appropriate formulations can be useful as integrated approach in nutrient and disease management for chickpea cultivation (Nagpal *et al.,* 2021). Microbial inoculants consortium of *Mesorhizobium, Bassiluss* species *and providencia vermicola* perform growth promotion as well as substantial nodulation characteristics in chickpea to enhance there grain yield under drought stress (Aulakh *et al.*, 2023).

Bioinoculant is a product which contains living microorganisms that, when applied to soil, seed or surfaces of plant colonize the *rhizosphere* on the plant internal tissues and induce plant growth. The main purpose of using microbial inoculants to improve the soil quality, to substitute inorganic fertilizers, to increase productivity and to promote an eco-friendly a sustainable agriculture (Bargaz *et al*., 2018). Coinoculation of *Pseudomonas* and *Bacillus* at various stages of plant growth promoted the yield, growth and nutritional status of plants. The coinoculation in the form of consortium with *Pseuodomonas fluorescens* (PGPR), *Actinomycetes* and *Arthrobacter* was found beneficial in enhancing yield of soybean (Yaduwanshi *et al* 2021). Microbial inoculants are artificial proportions of soil microbiomes which can be used as inoculants to improve the fertility and texture of soil, results in the increased productivity of crops (Sharma *et al*., 2022). Bioinoculant are not only responsible for enhancing soil physiochemical properties, but also affecting the structure and function of microorganisms via changes in the microbial carbon, microbial diversity and the community level physiological profiling (Aponte *et al*., 2022). Growth parameters and yield parameters of rice enhanced by using biofertilizers in addition to chemical fertilizers (Amrutha *et al.,* 2022). Dual inoculation of *Azotobacter* and PSB in noticeably superior yield attributes and yield production of linseed (Yadav *et al.*, 2023). The different VAM species and locally available biofertilizer to enhance the seedling growth of citrus (Kumar *et al.,* 2023). *Bradyrhizobium* sp. Enhanced phosphorus use efficiency and take up of N and P by soybean (Fituma *et al.*, 2015). Microbial inoculants contain living microorganisms that colonize the *rhizosphere* and helps in the promotion of plant growth. Bioinoculants are ready to use products consisting of live microbial inoculants which are capable of fixing atmospheric nitrogen, solubilizing phosphorus, potassium and zinc bring about organic matter decomposition in the soil. Therefore, bioinoculants consisting of biofertilizer strains capable of mobilizing N, P and K nutrients as a single inoculant with enhanced shelf life will be useful technology in present agriculture (Ashwini and Patil 2021). Combined application of nitrogen fixing, phosphate solubilising and mobilizing microbes i.e. microbial inoculants had positive effect on crop growth and yield (Syed Ismail, 2021). Hence, the present investigation was carried out to study the effect of different microbial inoculants and chemical fertilizers on nutrient content, uptake and yield of soybean-chickpea sequence.

MATERIAL AND METHODS

The field experiment was conducted during *kharif* and *rabi* seasons of 2020-21 and 2021-22 at Research Farm, Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Agricultural Univesity, Parbhani, Maharashtra, India, to study the effect of microbial consortia inoculation and chemical fertilizers on productivity and soil properties in soybean-chickpea sequence on Vertisol (*Typic haplusterts*), belonging to Parbhani soil series with comprise of fine montmorillonite isohyperthermic family of *Typic haplusterts* (Malewar, 1976). The soils were dominant kaolinite type of mineral and traces of illite minerals. The initial experimental soil was alkaline (pH 8.29), having EC 0.29 dsm^{-1}, calcareous ($CaCO_3$ 7.50 %), clayey in texture with bulk density of 1.31 (mg M^{-3}) soil available N, P and K contents were low, medium and high respectively. The experiment was laid out in factorial randomized block design in both *rabi* and *kharif* season. The treatments details for the study during *kharif* for soybean and *rabi* for chickpea are given in following Table 1. The treatment combinations of microbial consortia seed treatment and fertilizer application in soybean-chickpea cropping system.

Table 1: Treatment details for soybean and chickpea.

Treatments	
Soybean	**Chickpea**
Factor 1: microbial Consortia inoculation (s)	
S_1 – Uninoculated control	S_1 – Uninoculated control
S_2 – *Brady Rhizobium* + *Bacillus megaterium* inoculation (Consortia I)	S_2 – *Mesorhizobium ciceri* + *Bacillus megaterium* inoculation (Consortia I)
S_3 –*Brady Rhizobium*+ *Pseudomonas triata* inoculation (Consortia II)	S_3 – *Mesorhizobium ciceri* + *Psudomonas triata* inoculation (Consortia II)
S_4 – *Brady Rhizobium* + *Thiobacillus thiooxidant* inoculation (Consortia III)	S_4 – *Mesorhizobium ciceri* + *Thiobacillus thiooxidant* inoculation (Consortia III)
Factor 2 : Chemical fertilizers (T)	
T_1 – Control (Without fertilizers)	T_1 – Control (Without fertilizers)
T_2 – 50% RDF	T_2 – 50% RDF
T_3 – 75% RDF	T_3 – 75% RDF
T_4 – 100% RDF	T_4 – 100% RDF

The treatment details of study during *kharif* and *rabi* of both the soybean and chickpea crops are factorial randomized block design with twelve treatments and three replications. The microbial consortia inoculation *Rhizobium* spp + *Bacillus megaterium* (Consortia I), *Rhizobium* spp + *Pseudomonas triata* inoculation (Consortia II) and *Rhizobium* spp + *Thiobacillus thiooxidant* inoculation (Consortia III) for soybean and chickpea seeds @ 5 ml per kg of soybean and chickpea seed. Seed treatment was done before sowing. Seed were dried in shed and used for sowing, rest of control treatment.

The chemical fertilizers applied as treatment wise except control i.e. without fertilizer treatment. The recommended dose of fertilizer (RDF) $N:P_2O_5:K_2O$ 30:60:30 kg ha^{-1} for soybean at the time of sowing crops. After harvest of soybean the same plots were sowing to chickpea. The applied chemical fertilizer as similar as pattern and control i.e. without fertilizer treatment. The recommended dose of fertilizer $N:P_2O_5$: K_2O 25:50:0 kg ha^{-1} before sowing of chickpea crop respectively.

Table 2: Composition of fertilizers used.

Sr. No.	**Name of manure/fertilizer**	**Total Nutrient content(%)**			
1.	Fertilizers	**N**	P_2O_5	K_2O	S_4
2.	Urea	46	00	00	
3.	Single super phosphate	0	16	00	12
4.	Muriate of potash	0	00	64	

The nutrient content in different chemical fertilizers is presented in Table 2. The treatment wise fertilizers was applied to soybean and chickpea crops through soil application at the time of sowing respectively. Fertilizers were applied as per the treatments prior to sowing of soybean and chickpea.

RESULTS AND DISCUSSION

Nutrient content, uptake and seed and straw yield of soybean

Nutrient content. The nutrient N, P and K in seed and straw of soybean was significantly increased by effect of microbial consortia inoculation over control indicated in Table 3 that higher values of nitrogen content in soybean after harvest were noted in *Brady Rhizobium* + *Pseudomonas triata* (S3) of both experimentation years and pooled (Table 3). The treatment (S2) *Brady Rhizobium* + *Bacillus megaterium* was found at par with. The nutrient uptake also increased in treatment receiving (S3) *Brady Rhizobium* + *Pseudomonas triata*. Our results are similar in line with, the coinoculated of different plant growth promoting *Rhizobium ciceri* in chickpea crop significantly increased the N and P content in grain and straw (Bhat, 2007). The dual inoculation with PSB + VAM significantly improved N, P and K content in grain and Stover of black gram and their total uptake over untreated control plot (Yadav *et al.,* 2017). The highest response of N, P and K by soybean seed and straw with treatment *Rhizobium* + *Pseudomonas* striata (S3) with 100 % RDF over uninocualted control treatment (S1).

Highest total nitrogen uptake (260.87 kg ha^{-1}) was recorded with treatment *Rhizobium* spp. + *Pseudomonas stratia,* it was found significantly higher over uninocualted control during 2020-21, 2021-22 both the years and pooled mean. Amongst chemical fertilizers application of 100 % RDF showed highest (seed straw) i.e. total uptake (227.00 kg ha^{-1}) and was found statistically significant over other treatment values.

Pooled mean of two years data on chickpea observed that the seed, straw and total uptake was significantly more in treatment *Mesorhizobium* + *Pseudomonas stratia* (157.66 kg ha^{-1}) and minimum value (78.94 kg ha^{-1}) was observed in uninoculated control. Similarly, the chemical fertilizers application also increased seed, straw and total nitrogen uptake. Highest in treatment (S3) *Mesorohizobium* +*Pseudomonas stratia* with 100 % RDF and values were (131.66 kg ha^{-1}) followed by *Mesorhizobium* + *Bacillus megaterium* with 100 % RDF (125.44 kg ha^{-1}) during the years 2020-21, 2021-22 respectively. Similar results was observed Mohammed *et al.* (2017). The nitrogen, phosphorus and potassium content and uptake in grain + straw of green gram was enhanced with application of *Rhizobium* + PSB significantly over control. The similar results were reported by Bodkhe *et al.* (2014) Total nutrient uptake (NPKS) increased significantly with each successive increase of fertilizer upto RDF with *Rhizobium* and PSB on Vertisol in soybean. Bhande *et al.* (2002) also reported similar results with application of 100 % RDF and seed treatment with biofertilizer have resulted in more and easy availability of nutrient and recorded higher uptake of NPK. These results are in agreement with those obtained by Allito *et al.* (2020). They indicated that the inoculation of faba bean with diverse rhizobial strain significantly improvement nitrogen uptake as compared to uninocualted control Gou *et al.* (2020).

Data pertaining potassium uptake by soybean is presented in Table 4 indicates significant effect of microbial consortia inoculation showing significantly highest seed, straw and total uptake of potassium 91.08 kg ha^{-1} in pooled mean and significantly lower seed, straw and total uptake of potassium per plot (47.92 kg ha^{-1}) was noted in uninoculated control. Similarly chemical fertilizer also showed highest seed, straw and total uptake of potassium by soybean crop 100 % RDF applied plots (76.97 kg ha^{-1}) whereas lowest was observed in control (without fertilizer treatment plots) (66.79 kg ha^{-1}) in pooled data of two years experiments.

Pooled mean of two years experiment data on chickpea crop indicates seed, straw and total potassium uptake was significantly more in *Mesorhizobium* + *pseudomonas* striata (78.56 kg ha^{-1}) and lowest was found in uninocualted control (36.90 kg ha^{-1}) respectively. Further chemical fertilizer application also increased seed, straw and total potassium uptake in chickpea crop and highest was found in treatment 100 % RDF (63.76 kg ha^{-1}) and lowest (55.58) was noted in control, respectively.

A similar result was reported by Gajbhiye and Mane (2021), they observed that total uptake nutrients was significantly increased due to application of different biofertilizers treatment. Similarly, Auti *et al.* (2013) found that the dual inoculants i.e. *Rhizobium* + *Gluconacetobacter* and showed maximum N and K uptake in grain and stover respectively.

Nutrient content in soybean. Significantly higher pooled total N, P and K content in soybean was recorded was found lowest in treatment uninocualted control over other treatments (Table 3). Application of *Bradyrhizobium* + *Pseudomonas striata* treatment recorded the higher pooled total N, P and K content by soybean crop and was at par with *Bradyrhizobium* + *Bacillus megaterium*. Significant increase in the content of nutrients by soybean was recorded under application of 100 % RDF along with *Bradyrhizobium* + *Pseudomonas striata*. It might be due to greater growth of multiplication of microbial population with application of different microbial consortium and dilute the nutrients with action of microbial inoculants at growth stage of soybean crop. These results are in accordance with recent studies of Kumar and Ismail (2017). They found nutrient content and uptake was highest with microbial inoculants as compared to uninoculated control and they also reported more uptake of nutrients with treatment RDF + *Rhizobium* + *Burcholderia cepacea* and RDF + *Rhizobium* + *Pseudomonas striata* in soybean. Similarly, Yadav (2017) also reported dual inoculation with PSB + VAM significantly improved N, P and K content in grain and stover of black gram and their total uptake over uninoculated control.

Nutrient content in chickpea. The significantly higher total pooled N, P and K content in chickpea was recorded in application of *Mesorhizobium* + *Pseudomonas* striata in chickpea crop as compared to the rest of the treatments (Table 3). Application of 100 % RDF significantly higher pooled content N, P and K over other treatments. Interaction between microbial inoculant and chemical fertilizers (S xT) on content N, P and K in seed of chickpea was found significant of N, P and K in seed straw and total content is found statistically significant during both the years of pooled mean. It might be due to the treatment application of microbial inoculation consortia *Rhizobium* sp. + *Pseudomonas striata* and *Bacillus megaterium* secretion of organic acid and it was increased N, P and K availability ins oil and the content and uptake of N, P and K in chickpea crop. Similar results were reported Sonboir and Sarwagi (2000) in respect of N and P content and uptake by chickpea crop.

Yield of soybean two years (pooled). Data presented in Table 5, significant maximum seed (3234.63 kg ha^{-1}) and straw yield (3903.81 kg ha^{-1}) of soybean was recorded in treatment *Bradyrhizobium* + *Pseudomonas straita* and was lowest in treatment uninocualted control. Further, chemical fertilizer also increases seed and straw yield of soybean with treatment 100 % RDF (3035.74 kg ha^{-1}). The control treatment without fertilizers was found having lowest yield of seed and straw (2852.83 kg ha^{-1}) and (3505.46 kg ha^{-1}) pooled data of two year experiment, respectively.

Significantly highest chickpea yield were recorded under application of *Mesorhizobium* + *Pseudomonas* striata (Table 6). Data clearly showed that chickpea seed and straw yield of constantly increased and was recorded (2324.63 kg ha^{-1}) and straw yield (3086.50 kg ha^{-1}) and was minimum yield were noted in treatment S1 uninoculated control pooled of two years data. Significantly maximum seed yield of chickpea was recorded the value (2076.95 kg ha^{-1}) and straw was (3000.79 kg ha^{-1}) with treatment 100 % RDF and lowest was found in treatment (T1) control i.e. without fertilizer treatment.

The highest and increased seed, straw yield of soybean chickpea with application of microbial consortia inoculation and chemical fertilizers can be attributed might be due to improvement in growth and yield and yield parameters *viz*., N fixation, number of nodules per plant, fresh weight of nodules per plant, root weight, shoot weight, number of pods per plant and number of seeds per pods and 100 seed weight (g), it is might be due that nitrogen played important role in increased vegetative growth parameters. Similarly, Rafi *et al.* (2016), reported that increased yield was due synergistic effect of *Azospirillum* and PSB inoculation. Jagga and Sharma (2015) reported coinoculation of *Bradyrhizobium* and PSB along with P_2O_5 enhanced seed yield of soybean. Bodkhe *et al.* (2014) indicated that chemical fertilizer and microbial inoculant of N fixer and PSB gave maximum grain and straw yield of soybean and safflower (Shaikh *et al.*, 2017).

Table 3: Effect of microbial consortia inoculation and chemical fertilizers on nutrient content in soybean and chickpea (pooled data of 2 years).

Treatments	Nutrient content (%)					
	Soybean			Chickpea		
	N	P	K	N	P	K
Microbial consortia inoculation (S)						
S_1- Uninoculated control	5.87	0.56	2.06	5.29	0.85	1.96
S_2- *Rhizobium* spp. + *Bacillus megaterium* inoculation (Consortia-I)	7.14	0.28	3.22	6.33	1.03	2.42
S_3- *Rhizobium* spp.+ *Pseudomonas triata* inoculation (Consortia-II)	7.75	1.03	3.56	7.17	1.18	2.94
S_4- *Rhizobium* spp.+ *Thiobacillus thiooxidant* inoculation (Consortia-III)	7.08	0.75	3.12	6.17	0.99	2.38
S.E.m$\pm$	0.04	0.05	0.04	0.04	0.08	0.05
C.D. at 5%	0.10	0.06	0.13	0.12	0.02	0.16
Chemical fertilizers (T)						
T_1- Control (without fertilizer)	6.56	0.70	2.82	5.99	0.94	2.32
T_2- 50% RDF	6./78	0.76	2.99	6.21	0.99	2.33
T_3- 75% RDF	7.04	0.79	3.30	6.33	1.05	2.48
T_4- 100% RDF	7.18	0.88	3.10	6.44	1.08	2.58
S.E.m$\pm$	0.09	0.02	0.04	0.04	0.008	0.05
C.D. at 5%	0.25	0.06	0.13	0.12	0.021	0.16
Interaction (S x T)						
S.E.m$\pm$	0.08	0.05	0.09	0.07	0.014	0.10
C.D. at 5%	0.20	NS	NS	0.18	0.021	NS

***NS**- Non Significant

Table 4: Effect of microbial consortia inoculation and chemical fertilizers on nutrient uptake by soybean and chickpea (pooled data of 2 years).

Treatments	Nutrient uptake (kg ha^{-1})					
	Soybean			Chickpea		
	N	P	K	N	P	K
Microbial consortia inoculation (S)						
S_1- Uninoculated control	148.63	13.49	47.92	78.94	12.63	36.90
S_2- *Rhizobium* spp. + *Bacillus megaterium* inoculation (Consortia-I)	217.57	23.88	76.97	131.45	21.55	61.19
S_3- *Rhizobium* spp.+ *Pseudomonas triata* inoculation (Consortia-II)	260.87	32.33	91.08	157.66	27.47	78.56
S_4- *Rhizobium* spp.+ *Thiobacillus thiooxidant* inoculation (Consortia-III)	201.54	20.64	71.47	124.07	20.40	59.34
S.E.m$\pm$	3.81	0.38	0.86	1.16	0.52	1.39
C.D. at 5%	11.01	1.11	2.47	3.38	1.04	4.01
Chemical fertilizers (T)						
T_1- Control (without fertilizer)	199.5	19.33	66.79	114.55	18.07	55.58
T_2- 50% RDF	199.00	21.50	70.09	120.47	19.89	56.07
T_3- 75% RDF	212.00	23.61	73.59	125.44	21.20	60.30
T_4- 100% RDF	227.00	25.89	76.97	131.66	22.45	63.76
S.E.m$\pm$	3.81	0.38	0.86	1.16	0.52	1.39
C.D. at 5%	11.01	1.11	2.47	3.38	1.04	4.01
Interaction (S × T)						
S.E.m$\pm$	7.68	0.77	1.71	2.33	0.60	2.78
C.D. at 5%	NS	2.24	NS	6.76	1.75	NS

Table 5: Effect of microbial consortia inoculation and chemical fertilizers on seed and straw yield (kg ha^{-1}) of soybean.

Treatments	Seed yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Microbial consortia inoculation (S)						
S_1- Uninoculated control	2506.16	2529.88	2518.02	2978.14	3445.90	3212.02
S_2-*Bradyrhizobium* + *Bacillus megaterium* inoculation (Consortia-I)	3011.97	3047.08	3029.52	3606.11	3833.54	3719.82
S_3-*Bradyrhizobium* + *Pseudomonas triata* inoculation (Consortia-II)	3231.49	3237.78	3234.635	3777.35	4030.27	3903.81
S_4-*Bradyrhizobium* + *Thiobacillus thiooxidant* inoculation (Consortia-III)	2965.29	2982.03	2973.66	3497.30	3672.45	3584.875
S.E.m$\pm$	11.37	10.35	10.86	7.69	7.17	7.43
C.D. at 5%	32.83	29.88	31.36	22.20	20.71	21.46
Chemical fertilizers (T)						
T_1- Control (without fertilizer)	2842.01	2863.65	2852.83	3400.22	3610.70	3505.46
T_2- 50% RDF	2884.10	2908.37	2896.235	3454.42	3689.46	3571.94
T_3- 75% RDF	2968.13	2973.93	2971.03	3489.94	3818.82	3654.38
T_4- 100% RDF	3020.66	3050.83	3035.745	3514.32	3863.18	3688.75
S.E.m$\pm$	11.37	10.35	10.86	7.69	7.17	7.43
C.D. at 5%	32.83	29.88	31.36	22.20	20.71	21.46
Interaction (S × T)						
S.E.m$\pm$	22.74	20.35	21.55	15.37	14.34	14.86
C.D. at 5%	65.66	59.76	62.71	44.39	41.42	42.91

Table 6: Effect of microbial consortia inoculation and chemical fertilizers on seed and straw yield (kg ha^{-1}) of chickpea.

Treatments	Seed yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Microbial consortia inoculation (S)						
S_1- Uninoculated control	1337.60	1338.78	1338.20	2643.84	2630.06	2636.92
S_2-*Mesorhizobium* + *Bacillus megaterium* inoculation (Consortia-I)	2049.46	2055.28	2052.38	2991.41	2984.80	2988.10
S_3-*Mesorhizobium* + *Pseudomonas triata* inoculation (Consortia-II)	2323.75	2325.52	2324.63	3082.02	3091.05	3086.50
S_4-*Mesorhizobium* + *Thiobacillus thiooxidant* inoculation (Consortia-III)	1948.35	1960.83	1954.60	2806.88	2811.28	2809.08
S.E.m$\pm$	7.61	7.28	7.45	16.03	14.40	15.22
C.D. at 5%	21.98	21.02	21.50	46.31	41.57	43.94
Chemical fertilizers (T)						
T_1- Control (without fertilizer)	1729.21	1733.92	1731.50	2767.53	2767.52	2767.53
T_2- 50% RDF	1872.08	1872.08	1872.08	2840.93	2825.62	2833.28
T_3- 75% RDF	1984.27	1994.10	1989.18	2917.66	2920.51	2919.08
T_4- 100% RDF	2073.60	2080.31	2076.95	2998.03	3003.55	3000.79
S.E.m$\pm$	7.61	7.28	7.45	16.03	14.40	15.22
C.D. at 5%	21.98	21.02	21.50	46.31	41.57	43.94
Interaction (S × T)						
S.E.m$\pm$	15.22	14.56	14.89	32.07	28.79	30.75
C.D. at 5%	43.96	42.05	43.00	92.62	83.14	87.88

CONCLUSIONS

As the above discussion, it can be concluded that, the yield nutrient content and uptake of soybean and chickpea were improved with consortia of *Rhizobium* species + *Pseudomonas striata* (Consortia II) inoculation over other inoculant treatments along with 100 per cent recommended dose of fertilizers. Pooled data of seed and straw yield significantly increased in treatment (S3) *Pseudomonas triata* + *Bradyrhizobium* + *Pseudomonas striata* and lowest was found in uninocualted control.

FUTURE SCOPE

Thus, keeping this in the undertaken to evaluate the effect of Microbial consortia inoculation along with application of inorganic fertilizers on N, P and K content uptake and yield of soybean and chickpea crops in sequence to promotes the use of microbial consortia inoculants in these pulse and legume crops of Maharashtra state of India.

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Conflict of Interest. None.

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