Influence of Different Microbial Cultures and their Consortia on Yield and Nutrient Uptake in Soybean Grown on Vertisol

**ABSTRACT**

The present field experiment was undertaken at Research Farm, Department of Soil Science**,** College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. Ten different treatment combinations were used in the experiment which included different microbial cultures and their consortia *i.e* *Rhizobium spp.* + *Bacillus megaterium* (Consortia -I), *Rhizobium spp.* + *Frateuria aurantia* (Consortia-II), *Rhizobium spp.* + *Thiobacillus thioxidans* (Consortia-III), *Rhizobium spp.* + *Pseudomonas strita* (Consortia-IⅤ), *Rhizobium spp.* + *Bacillus megaterium* + *Frateuria aurantia* (Consortia-Ⅴ), *Rhizobium spp.* + *Bacillus megaterium* + *Thiobacillus thioxidans* (Consortia- ⅤI ), *Rhizobium spp.* + *Bacillus megaterium* + *Pseudomonas strita* (Consortia- ⅤII ), and control replicated thrice in RBD (Randomized Block Design). Seed treatment of soybean was done with microbial consortia @ 10 ml kg -1 seed before sowing with recommended dose of fertilizers. Among all the treatments, *Rhizobium spp.* + *Bacillus megaterium* + *Frateuria aurantia* (Consortia- Ⅴ) higher seed and straw yield of soybean (1863.26 and 2999.84 kg ha -1 respectively). Furthermore, total uptake of NPK was found significantly higher (130.65, 24.71 and 57.81 kg ha -1) with consortia -V. Study concludes that recommended dose of fertilizers with microbial consortia helped in improving yield and nutrient content in plants and seeds of soybean grown in Vertisol.

**Keywords: Microbial consortia; soybean; yield; nutrient uptake; vertisol.**

**INTRODUCTION**

Soybean (*Glycine max*) annual legume of the pea family *Fabaceae* with the subfamily *Papilionaceae*. It is also known as the “wonder bean” and “gold of the 21st century”. The origins of the soybean plant are obscure, but many botanists believe it was first domesticated in central China as early as 7000 BCE. An ancient crop, the soybean has been used in China, Japan, and Korea for thousands of years as food and a component of medicines. Soybean is also known as an oilseed crop. It contains 20% oil with 40% protein content. It is common knowledge that soybean, as a legume crop, fixes atmospheric nitrogen into the soil and it also adds roughly 32 to 35 Qt/ha of crop residue at harvest season, which not only increases soil fertility but also keeps the soil in good shape. In India, during *Kharif* 2023, the area under soybean was 118.54 lakh hectares with a production of 118.74 lakh MT. Among the states, Madhya Pradesh stood first with 52.647 Lakh MT production followed by Maharashtra with 46.91 Lakh MT. The average yield was higher in Maharashtra and Madhya Pradesh at 1028 and 1008 kg/ha during the same period SOPA [1]. The increase in the human population is expected to lead to an increase in global crop demand in the future, however, agricultural production cannot be sufficient for the estimated demand Tilman et al. [2]. Soybean is used to make a variety of fresh, fermented and dried foods such as milk, bean sprouts, and soy sauce. Additionally, soybean oil is extracted and used in several industrial and food-related operations.

 For agricultural sustainability, beneficial microorganisms with a variety of traits that promote plant growth could be employed as consortia or as single-cell inoculants. Kaur et al*.* [3]; Rana et al. [4]; Rastegari et al*.* [5]. There are various benefits of applying PGPMs as consortia inoculants as compared to chemical or biochemical insecticides and fertilizers. It encourages the growth of the host plant and its associated microorganisms; in contrast to conventional fertilizers and pesticides, PGPMs breakdown extremely quickly; resistance development is minimal; and it can be used in conventional or integrated management systems.Berg [6]; Kaur et al*.* [7]. The microbial consortium that is  actinomycetes, yeast, and bacteria among others, improves eco-friendliness, sustainability, and productivity. It improves a number of crop growth indices. It increases groundnut productivity and resistance to fungus-related diseases. Naik et al. [8]. Based on a number of studies, inoculating various pulse crops with two or three doses of *Rhizobium* and PSB (Phosphate Solubilizing Bacteria) is better than inoculating with *Rhizobium* alone. Gupta, [9].

**2. MATERIALS AND METHODS**

**2.1 Experimental site**

The field experiment was carried at Research Farm, Department of Soil Science, Vasantrao Naik Marathwada Agicultural University, Parbhani (MAH) on Vertisol (Typic Haplusterts). The initial soil pH 7.79, organic carbon 4.44 per cent, available N 154.07 kg ha-1, available phosphorus 9.85 kg ha-1 and available potassium 449.34 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 .

**2.2 Experimental design**

 Ten treatments were used in the experiment, viz. T1 Absolute control, T2 Recommended Dose of Fertilizer (RDF), T3 Recommended Dose of Fertilizer (RDF) + *Rhizobium spp.*, T4 Recommended Dose of Fertilizer RDF + *Rhizobium spp.* + *Bacillus megaterium* (PSB), T5 Recommended Dose of Fertilizer (RDF) + *Rhizobium spp.* + *Frateuria aurantia* (KSB), T6 Recommended Dose of Fertilizer (RDF) + *Rhizobium spp.* + *Thiobacillus thiooxidans* (SSB), T7 Recommended Dose of Fertilizer (RDF) + *Rhizobium spp.* + *Pseudomonas striata* (ZnSB ), T8 Recommended Dose of Fertilizer (RDF) + *Rhizobium spp.* + *Bacillus megaterium* (PSB) + *Frateuria aurantia* (KSB), T9 Recommended Dose of Fertilizer (RDF) + *Rhizobium spp.* + *Bacillus megaterium(* PSB) + *Thiobacillus thiooxidans* (SSB), T 10 Recommended Dose of Fertilizer (RDF) + *Rhizobium spp.* + *Bacillus megaterium* (PSB) + *Pseudomonas striata* ( ZnSB ), the experiment was laid out in a Randomized Block Design (RBD) with ten treatments and three replications. Seeds were sown at the rate of 65 kg ha -1 for soybean. The fertilizers were applied @ N: P2O5 : K2 O 30:60:30 kg ha -1 respectively. Urea, single super phosphate and muriate of potash were used as fertilizer sources.

**2.3 Seed inoculation and sowing**

 *Rhizobium spp.* with *Bacillus megaterium* (Consortia-I), *Rhizobium spp.* with *Frateuria aurantia* (Consortia-II), *Rhizobium spp.* with *Thiobacillus thiooxidans* (Consortia-III), *Rhizobium spp* with *Pseudomonas striata* (Consortia-IV), *Rhizobium spp.* with *Bacillus megaterium* and *Frateuria aurantia* (Consortia-V), *Rhizobium spp.* with *Bacillus megaterium* and *Thiobacillus thiooxidans* (Consortia-VI), *Rhizobium spp.* with *Bacillus megaterium* and *Pseudomonas striata* (Consortia-VII) were obtained from ICAR - All India Network Project on Soil Biodiversity – Biofertilizers, Parbhani Center and used for seed treatment @ 10 ml per kg of soybean seed. Seed treatment was done before sowing. Seeds were dried in shed and used for sowing as dibbling. The variety of soybean is MAUS-158.

**3. *RESULTS* AND DISCUSSION**

**3.1 Seed and straw yield**

 The seed yield of soybean was observed maximum *ie.,* 1863.26 kg ha -1 in treatment T8 RDF + *Rhizophos* + KSB , (Consortia-V). followed by treatment T9 RDF + *Rhizophos* + ZnSB, (Consortia-VII), (1840.00 kg ha-1 ). Significantly lowest seed yield was observed in T1 (absolute control). And straw yield significantly highest (2999.84 kg ha-1) was obtained from treatment receiving T8 RDF + *Rhizophos* + KSB (Consortia-V) followed by treatment T10 RDF + *Rhizophos* + ZnSB (Consortia-VII), (2944.00 kg ha-1) (Table 1). Yadav et al. [10] stated that the pearl millet hybrid MLBH-308 showed the most stover output in the sandy soil and a 20.5% increase in grain yield when *Azotobacter* and PSB were applied. Co-inoculation of *Bradyrhizobium* and PSB provided the highest seed yield (20.1% and 22.4%), over sole inoculation of *Bradyrhizobium*. Meetu et al*.* [11]. The release of indole acetic acid, which aids in the mobilization of fixed phosphorus and improves the supply of nutrients to plants and root nodulation, may be the cause of the higher seed yield in biofertilizer-inoculated treatments. Jaybhay et al*.* [12] and Virk et al. [13]

**3.2 Major nutrient (NPK) uptake in seed and straw (kg ha -1 ) of soybean**

 Nutrient uptake (NPK) of soybean was significantly influenced by microbial inoculants and their consortia with RDF. The seed NPK uptake ranges from 57.33 to 102.04; 3.80 to 11.06 and 15.65 to 31.61 kg ha -1 during *Kharif* 24. However, the NPK uptake of straw varied from 10.96 to 29.60 ; 4.93 to 15.09 and 10.41 to 26.20 kg ha -1total uptake of NPK was ranged from 68.29 to 131.64; 8.73 to 26.15 and 26.06 to 57.81 kg ha -1 (Table-2) and statistically significant values in treatment T8 ( RDF + *Rhizophos* + KSB ), among the treatments showed the effect of microbial cultures and their consortia to increase both seed and straw of soybean. The length and quantity of plant roots, which may have been increased by microbes that produce phytohormones, are responsible for the improvement along with increased the concentration of nutrients in the soil. Qureshi et al. [14] and ultimately their uptake by the crop. Kumar et al*.* [15] also reported the impact of seed bacterization with PGPR on growth and nutrient uptake in a variety of cultivable varieties of green gram. Bagmare et al. [16] suggested that the rhizosphere, a zone of greatest microbial activity and the soil environment where plant roots are available, creates a limited nutrient pool from which vital macro- and micronutrients are taken. Synthetic compounds that mimic natural plant hormones are known as plant growth regulators, or plant external hormones. Plant growth regulator, or phyto stimulation, is one of the words used to describe one of the main mechanisms of action used by PGPR to promote growth. They are crucial tools for increasing agricultural output and are used to control plant development. Aechra et al. [17] stated that co - inoculation of *Rhizobium* and PSB improved phosphorous uptake. Sahu et al*.* [18] discovered that KSB seed inoculation enhanced crop growth, yield, plant height, and grain and shoot weight, all of which contributed to a superior crop's uptake of potassium from the soil.

**Table 1: Effect of different microbial cultures and their consortia on seed and straw**

 **yield of soybean.**

|  |  |  |
| --- | --- | --- |
| **Treatment detail** | **Seed yield (kg ha-1)** |  **Straw yield** **(kg ha-1)** |
| T1:Absolute control | 1117.67 |  1826.50 |
| T2:RDF | 1563.63 |  2345.44 |
| T3:RDF+ *Rhizobium* inoculation | 1640.02 |  2525.63 |
| T4:RDF+ *Rhizophos* inoculation | 1786.26 |  2822.29 |
| T5:RDF + *Rhizobium* + KSB inoculation | 1683.19 |  2608.94 |
| T6: RDF + *Rhizobium* + SSB inoculation | 1687.85 |  2633.04 |
| T7: RDF + *Rhizobium* + ZnSB inoculation | 1689.44 |  2652.42 |
| T8 :RDF + *Rhizophos* + KSB inoculation | 1863.26 |  2999.84 |
| T9: RDF + *Rhizophos* + SSB inoculation | 1825.00 |  2901.75 |
| T10 :RDF + *Rhizophos* + ZnSB inoculation | 1840.00 |  2944.00 |
| **SE(m) ±** | 7.30 |  13.55 |
| **C.D at 5%** | 21.68 |  40.27 |

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment detail**  | **N uptake (kg ha-1)**  | **P uptake (kg ha-1)** | **K uptake (kg ha-1)** |
| **Seed** | **Straw** | **Total** | **Seed** | **Straw** | **Total** | **Seed** | **Straw** | **Total** |
| T1:Absolute control | 57.33 | 10.96 | 68.29 | 3.80 | 4.93 | 8.73 | 15.65 | 10.41 | 26.06 |
| T2:RDF | 81.79 | 16.42 | 98.20 | 5.99 | 7.27 | 13.26 | 23.09 | 15.25 | 38.33 |
| T3:RDF+ *Rhizobium* inoculation | 86.76 | 19.19 | 105.95 | 6.95 | 8.84 | 15.79 | 24.93 | 17.34 | 42.27 |
| T4:RDF+ *Rhizophos* inoculation | 96.28 | 24.37 | 120.64 | 8.93 | 12.14 | 21.07 | 28.58 | 21.73 | 50.31 |
| T5:RDF + *Rhizobium* + KSB inoculation | 89.88 | 21.14 | 111.02 | 7.63 | 9.91 | 17.54 | 26.59 | 19.57 | 46.17 |
| T6: RDF + *Rhizobium* + SSB inoculation | 90.58 | 22.12 | 112.70 | 8.21 | 11.06 | 19.28 | 26.05 | 18.70 | 44.75 |
| T7: RDF + *Rhizobium* + ZnSB inoculation | 90.89 | 22.55 | 113.44 | 8.05 | 10.88 | 18.93 | 26.36 | 19.37 | 45.72 |
| T8 :RDF + *Rhizophos* + KSB inoculation | 102.04 | 29.60 | 131.64 | 11.06 | 15.09 | 26.15 | 31.61 | 26.20 | 57.81 |
| T9: RDF + *Rhizophos* + SSB inoculation | 99.61 | 26.50 | 126.11 | 10.55 | 14.80 | 25.35 | 30.25 | 23.79 | 54.04 |
| T10:RDF + *Rhizophos* + ZnSB inoculation | 101.58 | 29.15 | 130.73 | 9.88 | 13.84 | 23.72 | 30.73 | 24.73 | 55.46 |
| **SE(m) ±** | 0.88 | 0.20 | 0.96 | 0.20 | 0.20 | 0.31 | 0.22 | 0.19 | 0.26 |
| **C.D at 5%** | 2.63 | 0.60 | 2.85 | 0.59 | 0.59 | 0.91 | 0.65 | 0.55 | 0.77 |

**Table 2: Effect of different microbial cultures and their consortia on uptake of macronutrients by**

 **soybean**

**Table 3: Effect of different microbial cultures and their consortia on uptake of iron and**

 **manganese by soybean.**

|  |  |  |
| --- | --- | --- |
| **Treatment detail**  | **Fe uptake (kg ha-1)**  | **Mn uptake (kg ha-1)** |
| **Seed** | **Straw** | **Total** | **Seed** | **Straw** | **Total** |
| T1:Absolute control | 61.80 | 63.07 | 124.87 | 47.93 | 60.98 | 108.91 |
| T2:RDF | 92.85 | 90.56 | 183.41 | 71.65 | 85.16 | 156.81 |
| T3:RDF+ *Rhizobium* inoculation | 100.09 | 101.71 | 201.79 | 77.35 | 95.17 | 172.44 |
| T4:RDF+ *Rhizophos* inoculation | 115.25 | 123.48 | 238.72 | 91.50 | 117.77 | 209.28 |
| T5:RDF + *Rhizobium* + KSB inoculation | 103.80 | 106.71 | 210.50 | 79.74 | 98.80 | 178.55 |
| T6: RDF + *Rhizobium* + SSB inoculation | 104.65 | 108.55 | 213.20 | 84.39 | 106.64 | 191.03 |
| T7: RDF + *Rhizobium* + ZnSB inoculation | 107.50 | 113.93 | 221.44 | 85.85 | 109.60 | 195.45 |
| T8 :RDF + *Rhizophos* + KSB inoculation | 124.32 | 137.83 | 262.15 | 99.89 | 132.15 | 232.04 |
| T9: RDF + *Rhizophos* + SSB inoculation | 119.91 | 129.97 | 249.88 | 95.35 | 123.50 | 218.84 |
| T10:RDF + *Rhizophos* + ZnSB inoculation | 123.58 | 136.54 | 260.12 | 99.76 | 131.63 | 231.38 |
| **SE(m) ±** | 2.30 | 2.98 | 3.61 | 2.06 | 0.57 | 2.06 |
| **C.D at 5%** | 6.83 | 8.87 | 10.72 | 6.12 | 1.71 | 6.11 |

**Table 4: Effect of different microbial cultures and their consortia on uptake of zinc and**

 **copper by soybean.**

|  |  |  |
| --- | --- | --- |
| **Treatment detail**  | **Zn uptake (kg ha-1)**  | **Cu uptake (kg ha-1)** |
| **Seed** | **Straw** | **Total** | **Seed** | **Straw** | **Total** |
| T1:Absolute control | 34.27 | 35.38 | 69.65 | 30.58 | 25.63 | 56.11 |
| T2:RDF | 55.17 | 56.29 | 111.46 | 45.72 | 37.22 | 82.95 |
| T3:RDF+ *Rhizobium* inoculation | 63.96 | 69.96 | 133.92 | 50.18 | 43.54 | 93.73 |
| T4:RDF+ *Rhizophos* inoculation | 78.80 | 92.60 | 171.40 | 60.13 | 57.24 | 117.36 |
| T5:RDF + *Rhizobium* + KSB inoculation | 68.45 | 76.62 | 145.07 | 53.13 | 47.46 | 100.59 |
| T6: RDF + *Rhizobium* + SSB inoculation | 69.76 | 79.07 | 148.84 | 53.64 | 48.47 | 102.11 |
| T7: RDF + *Rhizobium* + ZnSB inoculation | 71.34 | 82.04 | 153.38 | 54.63 | 50.26 | 104.89 |
| T8 :RDF + *Rhizophos* + KSB inoculation | 88.27 | 107.65 | 195.92 | 72.78 | 74.79 | 147.57 |
| T9: RDF + *Rhizophos* + SSB inoculation | 82.76 | 98.41 | 181.17 | 68.81 | 72.33 | 141.14 |
| T10:RDF + *Rhizophos* + ZnSB inoculation | 87.58 | 106.87 | 194.45 | 72.11 | 73.96 | 146.07 |
| **SE(m) ±** | 1.03 | 0.88 | 1.28 | 1.35 | 0.30 | 1.25 |
| **C.D at 5%** | 3.06 | 2.61 | 3.80 | 4.00 | 0.88 | 3.72 |

**3.3 Iron and manganese uptake (g ha -1 )**

The highest uptake values of iron in soybean seed ie 124.32 g ha -1 , straw-137.83 g ha-1 and total- 262.15 g ha -1 were found statistically significantly high showing maximum values in treatment T8 ( RDF + *Rhizophos*+ KSB ) was at par with treatment T10 ( RDF + *Rhizophos* + ZnSB) has iron uptake seed-123.58 g ha -1 , straw-136,54 g ha -1 and total- 260.12 g ha -1. Whereas, uptake of iron noticed lowest in treatment T1 (absolute control) *ie* ., seed- 61.80 g ha-1, straw-63.07 g ha-1 and total-124.87 g ha-1 ,(Table-3). Kumar et al*.* [19] showed that co inoculation of *Rhizobium* and *Trichoderma viride* along with RDF enhanced the yield, nutrient content, nutrient uptake and quality of soybean crop. Bagmare et al.[20] reported that inoculation of *Pseudomonas spp.* and *Azospirillum spp.* produced the most siderophores, which enhanced uptake of iron in green gram. The maximum uptake of manganese in seed 99.89 g ha -1, straw- 132.15 g ha -1 and total 232.04 kg ha -1 by soybean were found statically significant showing maximum values in treatment T8 ( RDF+ *Rhizophos* + KSB ), was at par with treatment T10 ( RDF+ *Rhizophos* + ZnSB) seed- 99.76 g ha -1, straw- 131.63g ha -1 and total- 231.38 g ha -1. However, uptake of manganese recorded lowest value in treatment T1 (absolute control) ie, seed- 47.93 g ha -1, straw- 60.98 g ha -1 and total- 108.91 g ha-1 (Table-3). Gamit and Tank [21] reported that inoculating *Cajanas cajan* with *Pseudomonas pseudoalcaligenes* which produces siderophore, due to acidification of PGPR it enhances the uptake of Fe, Cu, Mn, Zn, Co, Ni and Al. The role of microbial isolates boosts the growth of plants. Soliman et al. [22]stated that the supply of Mn through organics as a result of mineralization may be responsible for the rise in Mn uptake.

**3.4 Zinc and copper uptake (g ha**-1**)**

The highest uptake of zinc in seed - 88.27 g ha-1, straw- 107.65 g ha-1 and total- 195.92 kg ha-1 by soybean were found statistically significant showing maximum values in treatment T8 ( RDF + *Rhizophos* + KSB ) which was at par with treatment T10 ( RDF *Rhizophos* + ZnSB) has zinc uptake in seed- 87.58g ha-1, straw- 106.87g ha-1 and total- 194.45 g ha-1. However, uptake of zinc was recorded lowest value in treatment T1 *ie* ., absolute control in seed 34.27g ha-1, straw- 35.38g ha -1 and total 69.65g ha-1 (Table-4). According to Jadhav [23] there was a statistically significant interaction between zinc solubilizers and zinc levels. The results showed that *Pseudomonas striata* treatment with 30 kg ZnSO4 ha -1 had the maximum seed, straw, and total Zn uptake of pigeon pea. Significantly highest uptake of copper seed 72.78 g ha-1, straw- 74.79 g ha-1 and total 147.57 kg ha-1 by soybean were found statistically significant showing maximum values in treatment T8 ( RDF + *Rhizophos*+ KSB ) was at par with treatment T10 ( RDF + *Rhizophos* + ZnSB) has copper uptake in seed – 72.11 g ha-1, straw- 73.96 g ha-1 and total- 146.07g ha-1. Whereas, uptake of copper recorded lowest value in treatment T 1 absolute control seed- 30.58 g ha-1, straw 25.63 g ha-1 and total- 56.11 g ha-1 (Table-4). According to Gurumurthy et al. [24], The PSB seed inoculation to soybean with N, P, and K treatment increased grain and straw Cu uptake. According to the results of Jayant Raman's [25] experiment, a combination of *Pseudomonas striata, Trichoderma viride*, and *Azotobacter chroococcum* inoculation produced the maximum quantity of copper.

**4. CONCLUSION**

The results of the investigation showed that the application of the *Rhizobium spp*. + *Bacillus megaterium + Frateuria aurantia* (Consortia -V) as seed inoculation along with 100 per cent recommended dose of fertilizers performed as the best consortium for enhancing seed and stover yield of soybean. Similarly for nutrient uptake of N, P and K, micronutrients viz. , Fe, Mn Cu and Zn.

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