International Journal of Environment and Climate Change

Volume 13, Issue 12, Page 919-924, 2023; Article no.IJECC.111200
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Response of Combined Application of Nutrient Levels with Microbial Strains on Crop Growth, Nodulation and Yield of Soybean

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Authors' contributions

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

Article Information

DOI: 10.9734/IJECC/2023/v13i123754

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/111200

Original Research Article

Received: 16/10/2023
Accepted: 21/12/2023
Published: 23/12/2023

ABSTRACT

The study focused to investigate the 'Response of combined application of nutrient levels with microbial strains on crop growth, nodulation and yield of soybean (*Glycine max* (L.) Merrill.)' at All India Coordinated Research Project (AICRP) on Integrated Farming System Research at College of Agriculture, Indore, Madhya Pradesh, India during *kharif*, 2019-20. The research was conducted

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in randomized block design (RBD) with 8 treatments, viz. Control with 75% RDF (T_1), Control with 100% RDF (T_2), 75% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment (T_3), 100% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment (T_4), 75% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as foliar application at 30 and 45 DAS (T_5), 100% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as foliar application at 30 and 45 DAS (T_6), 75% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment + foliar application of *Bacillus megaterium* and *Bacillus mucilaginosus* strains at 30 and 45 DAS (T_7) and 100% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment + foliar application of *Bacillus megaterium* and *Bacillus mucilaginosus* strains at 30 and 45 DAS (T_8). The seed yield of soybean increased to the tune of 14.26 and 19.72 per cent with application of 100% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment + foliar application of *Bacillus megaterium* and *Bacillus mucilaginosus* strains at 30 and 45 DAS compared to control. Among all the treatments, crop growth and yield (1139 kg/ha) were observed highest with 100% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment + foliar application of *Bacillus megaterium* and *Bacillus mucilaginosus* strains at 30 and 45 DAS.

Keywords: Bacillus megaterium; Bacillus mucilaginosus; crop growth; nodulation; soybean.

1. INTRODUCTION

Soybeans, scientifically known as *Glycine max* (L.) Merrill, are premier legumes with high protein and oil contents. This remarkable legume has a protein content of 40.5% and a high oil content of 18% to 22.5%. Additionally, it contains 20-30% extractable substances and a well-balanced amino acid profile [1]. The soybean is known by many names and credentials, including yellow beans and large beans in China, edamame in Japan, and miracle beans and golden beans in the United States [2]. As a result of their adaptability to diverse soil conditions and climates, as well as their nutritional value, soybeans are becoming increasingly popular in Central India. Approximately 6% of all agricultural land is devoted to soybean cultivation, making it the world's most widely cultivated oilseed crop [3]. It is estimated that India will produce over 13.79 million tons of soybeans in 2019-20 on a cultivation area of approximately 11.33 million hectares, according to [4]. Madhya Pradesh is called the "Soya State of India" because of its soybean production.

Microorganisms are beneficial to agriculture, and they are now being used to grow sustainable food crops [5]. The beneficial microorganisms have been shown to fix nitrogen in the atmosphere, decompose organic wastes and residues, detoxify pesticides, suppress plant diseases, enhance nutrient cycling, and produce bioactive compounds that enhance plant growth, such as vitamins, hormones, and enzymes [6]. Utilizing organic, inorganic, and bio-fertilizers together enhances various aspects of agriculture holistically. As a result of this integrated approach, soil productivity, sustainability, reclamation, and crop growth, development, setting, and quality are improved [7]. In addition, the production of microbial metabolites, which contain organic acids, can cause a decrease in soil pH, which facilitates the solubilization of certain nutrients and their availability to plants.

The widespread use of synthetic fertilizers, while addressing some challenges, also poses significant environmental and food production risks, as highlighted by Dahal and Bhandari [8]. To address these concerns, a promising solution lies in harnessing the potential of various bacterial species such as *Azotobacter, Azospirillum*, *Bacillus* sp., and *Pseudomonas* sp. These microbes fall under the category of plant growth-promoting rhizobacteria (PGPR). Leveraging these microorganisms as biofertilizers offers a viable and sustainable alternative to synthetic fertilizers. Notably, bacterial species like *Azotobacte*r and *Azospirillum* exhibit remarkable capabilities. They can effectively fix atmospheric nitrogen and enhance soil phosphorus solubilization, as demonstrated by Yasin et al. [9].

Based on these assumptions, the current study focused on evaluating the effects of *Bacillus megaterium* and *Bacillus mucilaginosus* strains on soybean aiming to achieve the effects of *Bacillus megaterium* and *Bacillus mucilaginosus* strains on crop growth and yield of soybean.

2. MATERIALS AND METHODS

The experiment was conducted during *kharif* season 2019-20 at Research Farm of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, College of Agriculture, Indore, Madhya Pradesh, India with soybean var. "JS 95-60". The experimental field has uniform topography with gentle slope. Indore is situated at an altitude of 555.5 m above mean sea level (MSL). It is located at latitude 22.43 ^{0}N and longitude of 75.66 ^{0}E. This climate of the region was sub-tropical and semi-arid type. The maximum and minimum temperature varied from 25.36^{0}C - 32.43^{0}C and 20.4^{0}C - 24.57^{0}C respectively. The soil of experimental site was predominantly clayey in texture, slightly alkaline in reaction (pH 7.5) with low organic carbon (0.45%) and available nitrogen (210 kg/ha), low in available phosphorus (11.5 kg/ha) and high in available potash (410 kg/ha).

2.1 Field and Crop Management

In order to get a good tilth of soil for sowing, the field preparation was started with summer ploughing by tractor drawn plough followed by cross harrowing. Final harrowing was followed by planking to level the field before sowing. All the fertilizers were applied as basal in the furrows and mixed with soil before placing the seeds. For ensuring better germination, healthy and good quality seeds were used. Seeds were treated by Bavistin @ 2g/kg seeds and after that inoculated with *Bacillus megaterium* and *Bacillus mucilaginosus* strains @ 3 g/kg seeds at the time of sowing. The treated seeds were sown in plots with 6 m x 4.5 m dimensions maintaining 30 cm x 5 cm row and plant distance @ seed rate of 80 kg/ha. For crop protection in soybean at early stage two sprays of Triazophos 40 EC 600 ml/ha was done at 30 and 45 days of crop growth. The insects, pests like girdle beetle, stem fly caterpillars, blue beetle etc. were common insects, pests in soybean.

2.2 Statistical Analysis

The statistical analysis was carried out according to the method given by Panse and Sukhatme [10] for Randomized Block Design and results was tested at 5% probability level of significance.

3. RESULTS AND DISCUSSION

3.1 Effect on Crop Growth

Growth parameters of soybean such as plant height and dry matter production/plant significantly improved by RDF and microbial strains over the control (Table 1). The highest values of above growth parameters were recorded when 100% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment + foliar application of *Bacillus megaterium* and *Bacillus mucilaginosus* strains at 30 and 45 DAS (T_8) followed by 75% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment + foliar application of *Bacillus megaterium* and *Bacillus mucilaginosus* strains at 30 and 45 DAS. (T_7). The reason might be due to sufficient nitrogen being released from the organic matter or biological antagonism from other micro-organisms indigenous to the soil used. Similarly, PSB can mineralize organic phosphorus into a soluble form and reactions take place in the rhizosphere and because the micro- organisms render more P into soil solubilization than is required for their own growth and metabolism, the surplus is available for plants to absorb. Seed inoculation with bio-inoculants also produce fungistatic and growth promoting substances which influenced the plant growth. Similar results were reported by Sarawa and Arma [11], Mekki et al. [12].

3.2 Effect on Nodulation

The significant increase in number of nodules/plants nodules dry weight/plant were observed with 100% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment + foliar application of *Bacillus megaterium* and *Bacillus mucilaginosus* strainsat 30 and 45 DAS (Table 1). The improved root growth could be due to the liquid organic fertilizers' abilities to supply soluble organic nutrients and biostimulants more quickly to the plant, which supported its growth. Phosphate solubilizing microorganisms in the consortium of Biofertilizers affect the formation of nodules because it can increase phosphate availability. The results were similar to the findings of Malhotra et al. [13].

3.3 Effect on Yield

The perusal of the data clearly indicated that foliar spray and seed treatment of microbial strains with RDF significantly influenced the seed yield of soybean (Table 2). The highest seed yield was obtained with the application of 100% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed

Table 1. Effect of nutrient levels with microbial strains on growth attributes and nodulation at 60 DAS of soybean

Symbol	Treatment	Plant height (cm)	Dry matter (g/ plant)	Number of nodules /plants	Nodules dry weight (g/ plant)
T_1	Control with 75% RDF	30.33	8.58	74.41	0.870
T_2	Control with 100% RDF	30.33	8.90	76.77	0.900
T_3	75% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment	30.44	9.02	79.44	0.937
T_4	100% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment	30.66	9.53	79.86	0.937
T_5	75% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as foliar application at 30 and 45 DAS	30.44	8.68	79.87	0.973
T_6	100% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as foliar application at 30 and 45 DAS	29.89	9.58	80.00	1.047
T_7	75% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment + foliar application of *Bacillus megaterium* and *Bacillus mucilaginosus* strains at 30 and 45 DAS	30.55	10.23	80.31	1.053
T_8	100% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment + foliar application of *Bacillus megaterium* and *Bacillus mucilaginosus* strains at 30 and 45 DAS	31.33	10.40	83.00	1.073
SEm (±)		0.33	0.105	2.28	0.039
C.D. at 5%		0.99	0.32	6.91	0.119

Table 2. Impact of *Bacillus megaterium* and *Bacillus mucilaginosus* strains on crop yield of soybean

Symbol	Treatment	Economic yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
T_1	Control with 75% RDF	786	1953	40.24
T_2	Control with 100% RDF	807	2070	38.9
T_3	75% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment	843	2131	39.52
T_4	100% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment	890	2240	39.68
T_5	75% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as foliar application at 30 and 45 DAS	900	2310	38.9
T_6	100% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as foliar application at 30 and 45 DAS	958	2390	40.1
T_7	75% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment + foliar application of *Bacillus megaterium* and *Bacillus mucilaginosus* strains at 30 and 45 DAS	1083	2620	41.3
T_8	100% RDF with *Bacillus megaterium* and *Bacillus mucilaginosus* strains as seed treatment + foliar application of *Bacillus megaterium* and *Bacillus mucilaginosus* strains at 30 and 45 DAS	1139	2706	42.08
SEm (±)		49	211	1.32
C.D. at 5%		149	640	NS

treatment + foliar application of *Bacillus megaterium* and Bacillus mucilaginosus strain at 30 and 45 DAS (T_8) which was statistically comparable with T_7, T_6 and T_5 and significantly superior to T_4, T_3, T_2 and T_1. Seed inoculated with microbial strains increased the availability of nutrients resulted into higher production of assimilates as well as their balanced partitioning between source and sink and ultimately increased the seed yield as well as straw yield. Phosphate solubilizing bacteria led to increased absorption of other elements by increasing the ability to access phosphorus and thereby can increase crop yield [14,15].

4. CONCLUSION

In conclusion, the study underscores the efficacy of integrating specific microbial strains, specifically *Bacillus megaterium* and Bacillus *mucilaginosus*, alongside optimized nutrient levels (100% RDF) as a means to significantly enhance soybean yield. The combined approach of seed treatment and foliar application at specific growth stages showcased remarkable improvements in crop growth parameters and ultimately led to substantial yield enhancement in soybean cultivation. This research offers valuable insights into potential strategies for sustainable agricultural practices, highlighting the practical benefits of employing microbial strains in combination with appropriate nutrient levels for improved soybean productivity. Further exploration and implementation of such integrated approaches could contribute significantly to enhancing crop yield and ensuring food security in soybean farming systems.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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