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Unraveling the Potential of Nutrient Solubilizing Microbial Consortium and Chemical Fertilizers in Enhancing the Productivity and Profitability of Wheat under Irrigated Condition

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ABSTRACT

Sustainable wheat production requires innovative and efficient nutrient management strategies that enhance productivity while reducing dependence on synthetic fertilizers. Nutrient-solubilizing microbial consortia (Bio-NPK) have emerged as promising inputs capable of enhancing nutrient availability, nutrient-use efficiency, and crop productivity. A field experiment was conducted during the rabi season of 2021–22 at ICAR-IARI Regional Station, Pusa, Samastipur Bihar, India, to evaluate the effect of a nutrient-solubilizing microbial consortium (Bio-NPK) and different levels of inorganic fertilizers on the growth, productivity, and profitability of wheat. The combined application of 100% recommended NPK + seed treatment with Bio-NPK produced the highest plant stand (470.2 plants m^{-2}), plant height (102.6 cm), earhead density (199.4 m^{-2}), spike length (34.8 cm), and grains per spike (64.7), grain yield (4.47 t ha^{-1}) and biomass production (10.50 t ha^{-1}) representing substantial improvements over the absolute control. The treatment receiving 75% recommended NPK + seed treatment with Bio-NPK produced a grain yield of 4.20 t ha^{-1}, which was statistically comparable with the yield obtained under 100% recommended NPK alone (4.36 t ha^{-1}), indicating the potential to reduce fertilizer application by 25% without significant yield loss. The highest gross return (126,247 ha^{-1}) and net return (86,636 ha^{-1}) were obtained with 100% recommended NPK + seed treatment with Bio-NPK. Our findings highlighted that integrating nutrient-solubilizing microbial consortia with balanced chemical fertilizers application can substantially enhance wheat productivity and profitability under irrigated conditions

Keywords: Bio-NPK, Fertilizers, Wheat, Productivity, Profitability

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INTRODUCTION

Wheat (Triticum aestivum L.) is one of the most extensively cultivated cereal crops globally and serves as a staple food for a significant portion of the world's population and also a vital source of food, feed, and fodder. It occupies a vital place in the national food security system of India, contributing around 35% to the total food grain production (FAO, 2022). After maize, it ranks second in global production and plays a critical role in food security, especially in developing countries like India (FAO, 2023). To meet the growing food demand and consumption driven by a burgeoning population, achieving sustainable intensification of wheat productivity is essential. However, wheat production in irrigated ecosystems is challenged by stagnating productivity, declining soil health, imbalanced fertilizer application, reduced nutrient use efficiency (NUE) and inefficient fertilizer use (Singh et al., 2018). Addressing these limitations, a strategic integration of chemical fertilizers with biological-based solutions, such as nutrient-solubilizing microbial consortia are requires that blend conventional and biological approaches to maximize productivity while ensuring long-term soil fertility.

Chemical fertilizers have played a critical role in boosting wheat yields under irrigated conditions, during the Green Revolution (Tilman et al., 2002). However, their indiscriminate and imbalanced application has resulted in deteriorating soil physical and biological properties, micronutrient deficiencies, reduced fertilizer use efficiency (FUE), soil acidification, groundwater contamination, and greenhouse gas emissions (Adesemoye and Kloepper, 2009; Singh et al., 2021; Tilman et al., 2002; Pathak et al., 2010). Hence, there is an urgent need to adopt approaches that combine the benefits of chemical fertilizers with environmentally sustainable alternatives such as biofertilizers and microbial inoculants.

In this context, microbial consortia comprising nutrient-solubilizing microbes have emerged as promising bio-inputs and offer an environmentally sound alternative or supplement to chemical fertilizers that can enhance nutrient availability, improve plant growth as well as soil health (Kumar et al., 2021). These microbes can convert insoluble

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forms of nutrients into plant-available forms through biological processes such as acidification, enzymatic transformation chelation, nitrogen fixation, phosphate solubilization, potassium mobilization, zinc solubilization, siderophore production, phytohormone secretion and production of organic acids (Sharma et al., 2013; Vessey, 2003; Bhardwaj et al., 2014). Phosphorus and potassium, remain unavailable to plants due to their fixation in insoluble forms. Phosphate-solubilizing bacteria (PSB), such as Bacillus, Pseudomonas, and Rhizobium spp., secrete organic acids that chelate the cations bound to phosphate and release it into a plant-available form (Rodríguez and Fraga, 1999). Similarly, potassium-solubilizing bacteria (KSB), like Frateuria aurantia and Bacillus mucilaginosus, enhance the dissolution of K-bearing minerals such as mica and feldspar, thereby improving potassium nutrition (Sharma et al., 2016). Additionally, these microbes contribute to the sustainability of the agro-ecosystem by improving soil structure, enhancing microbial diversity, and reducing dependence on chemical inputs (Patel et al., 2020). The combined inoculation of these functional microbes in the form of a microbial consortium can offer a broader spectrum of nutrient-solubilizing abilities and higher consistency in performance compared to single-strain inoculants (Rana et al., 2020). The adoption of microbial consortia tailored for specific agro-climatic conditions and cropping systems thus holds significant promise for sustainable wheat production under irrigated environments. Prasanna et al. (2013) reported that co-application of PSB and nitrogen fixers significantly improved wheat grain yield, N and P uptake, and soil microbial biomass. The effectiveness of microbial consortia is often influenced by factors such as soil type, irrigation regime, microbial compatibility, host crop genotype, and the method of inoculation (Kumar et al., 2022). The microbial consortia also contribute to soil biological health by improving microbial biomass, enzymatic activities, and organic matter decomposition, ultimately enhancing nutrient cycling and soil fertility (Adesemoye et al., 2009).

By reducing chemical fertilizer use and enhancing soil organic carbon, microbial technologies contribute to climate-resilient agriculture and reduced greenhouse gas emissions (Lal, 2020). The ecological benefits also include enhanced biodiversity, improved water-use efficiency, and reduced risks of nutrient runoff and eutrophication (Goswami et al., 2016). In the Indian context, where irrigated wheat accounts for nearly 85% of total wheat area, especially in the Indo-Gangetic Plains (IGP), the potential of microbial consortia remains largely untapped (Sharma et al., 2021b). These regions, characterized by intensive cropping and high fertilizer use, are witnessing nutrient imbalances, declining total factor productivity, and emerging concerns of soil degradation. This integrated approach not only boosts crop performance but also contributes to long-term soil health and environmental sustainability. Therefore, location-specific integration of nutrient solubilizing microbial consortia with balanced chemical fertilization can play a transformative role in enhancing wheat productivity and profitability.

MATERIALS AND METHODS

A field experiment was conducted at the ICAR- Indian Agricultural Research Institute, Regional Station, Pusa, Samastipur, Bihar, India during rabi season of 2021-22. The site is situated at latitude of 25°58'49'' N, longitude of 85°40'48'' E and had an even topography and good drainage condition. The total average annual rainfall received during 2021 was 1883.6 mm and during 2022 was 835.4 mm, respectively. The weather data (2021-2022) were collected from weather stations of the IARI, RS Pusa Bihar and it is presented in Fig. 1. The soil of the experimental site was alluvial in nature and sandy loam in texture (International Pipette Method). The soil of the experimental site was sandy loam in texture having low organic carbon (0.35 to 0.38%) and available N, medium range of available P2O5 and available K2O and the pH of the soil was 8.3 whereas, EC was in the range of 0.25 to 0.30 dS/m during the study year. tare.

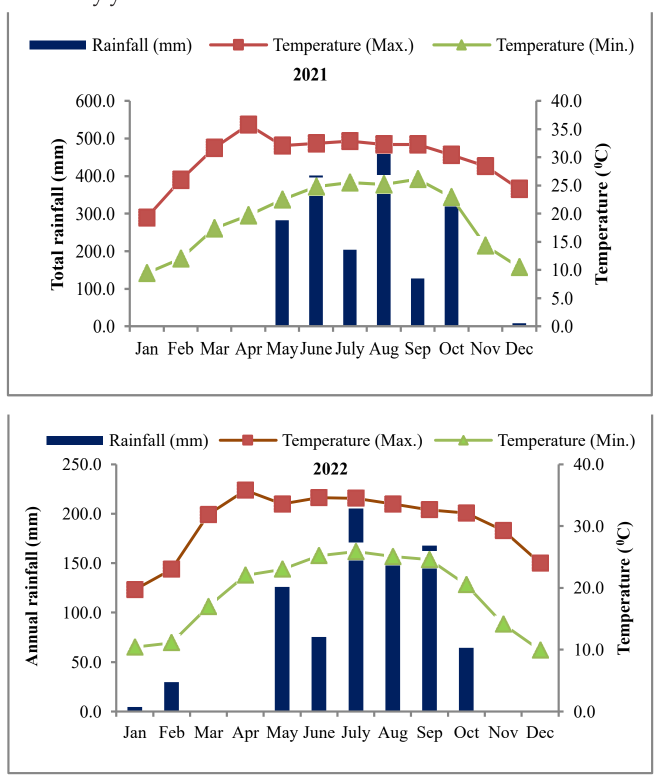

Fig. 1: Monthly average rainfall (mm), average maximum and minimum temperature (°C) in study locations (Pusa). Lines with filled triangles and squares represent the average minimum and maximum monthly temperatures, respectively, and bars represent the monthly average rainfall.

A total of eight treatments were tested, where three different doses of NPK with or without seed treatment with Bio NPK along with one absolute control and seed treatment with Bio-

NPK only were used (T1-T8). Treatment details are as follows: T1: Absolute control (no seed treatment and no NPK); T2: Control (No NPK) + seed treatment with Bio-NPK; T3: 50% NPK; T4: 50% NPK + seed treatment with Bio-NPK; T5: 75% NPK;T6: 75% NPK + seed treatment with Bio-NPK; T7: 100% NPK and T8: 100% NPK + seed treatment with Bio NPK. The source of inorganic fertilizer nitrogen was urea, the phosphate source was di-ammonium phosphate (DAP), and potassium source was muriate of potash (MOP). One third of nitrogen and full dose of phosphorous and potash were applied as basal dose and remaining 2/3rd N was top-dressed in two equal splits after first and second irrigation. Bio NPK Liquid Biofertilizer is a unique kind of bioformulation comprising nitrogen (N2) fixing (Azotobacter chroococum), P-solubilizing (Paenibacillus tylopili) and K-solubilizing (Bacillus decolorationis) bacteria. Bio-NPK was used as seed treatment @ 2.5ml/kg seed. For seed treatment 2.5 ml Bio NPK Liquid Biofertilizer to be diluted to 25 ml with water and a pinch of sugar is added to it. The suspension is then sprinkled on the seeds and the seeds are thoroughly mixed so as to have a uniform coating and leave the seeds for 30 minutes. Then the seeds are spread uniformly for drying on a gunny bag or cement floor in shade avoiding direct sunlight. The experiment was conducted using HD 2967 as the test variety, which was manually sown with a row spacing of 20 cm during the second week of November. All agronomic practices followed were in accordance with the standard recommendations for wheat cultivation in the eastern IGPs of India.

Growth and yield-attributing characters of wheat were recorded at periodic intervals and at harvest of crop. To compute spike length (cm) and number of grains per spike five panicles were selected randomly from each plot and averaged. The number of fertile tillers was assessed by placing a one-square-meter quadrate at three randomly selected places within each plot and the tiller count was averaged to estimate tiller density per unit area. At crop maturity, plants from net plot area were harvested manually and bundle weight was recorded separately for each plot and threshing was done with the help of mechanical power thresher. After threshing grains were thoroughly cleaned, and grain yield was recorded and expressed in tone per hectare (t ha^{-1}) after standardizing for moisture content. Yield data was recorded after threshing and cleaning of the grain and expressed in tone per hectare.

An economic assessment was done to evaluate the feasibility of various treatments based on total cost of cultivation, gross return (GR), net return (NR), and benefit-cost (B:C) ratio. The total cultivation cost included all necessary inputs and operations, such as land preparation, sowing, seed and seed priming, irrigation, intercultural activities, weed control, fertilizers, plant protection chemicals, harvesting, threshing, labor, and machinery usage. Gross returns (₹ ha^{-1}) were calculated by adding the income from wheat grain yield and the market price of the corresponding straw yield. Net returns (₹ ha^{-1}) were derived by subtracting the total cultivation cost from the gross returns. The benefit-cost ratio was estimated by dividing the net returns by the total cost of cultivation, providing insight into the economic efficiency of each treatment.

$$\text{Benefit: cost ratio} = \frac{\text{Net returns}}{\text{Cost of cultivation}}$$

For a randomized block design (RBD), the experimental data obtained during the study were subjected to statistical analysis using the Analysis of Variance (ANOVA) technique, following the standard procedures recommended by Gomez and Gomez (1984). The outcomes of the analysis were interpreted at a 5% probability level (P = 0.05). This level of significance was adopted to ensure scientific rigor in the comparison of treatment effects.

RESULTS AND DISCUSSION

Effect of integrated nutrient management on crop establishment and growth

The result indicated that the integrated application of inorganic fertilizers along with biofertilizers (Bio-NPK) as seed treatment significantly improved crop establishment and vegetative growth parameters compared with sole application of chemical fertilizers and the unfertilized control (Table 1). Plant population increased progressively with increasing levels of NPK, and the highest plant density (470.2 plants m^{-2}) was recorded under 100% Rec. NPK + Seed treatment with bio-NPK @ 2.5 ml kg-1 seed, representing a substantial improvement over the absolute control. Increasing in the number of plant population under integrated treatment management may be attributed to improved nutrient availability during early growth stages and better interactions between root-soil and microbe, which promote seedling vigor and survival over the period. Adesemoye et al. (2009) and Bhattacharyya and Jha, (2012) were also found same result.

Plant height also exhibited considerable responsiveness to treatment. The 100% recommended dose of NPK treatment alone reached 102.3 cm, while the combined application of 100% rec. NPK with bio-NPK seed treatment achieved 102.6 cm attaining a 26.9% increase over the absolute control. Earhead density followed a similar trend, it progressive increases in fertilizer levels consistently enhanced earhead formation, with the 50%, 75%, and 100% NPK treatments producing 154.7, 180.2, and 191.6 earheads/m², respectively. This proves that nutrient uptake efficiency enhanced with microbial consortia beyond the effect of mineral fertilizers alone. Bio-fertilizers stimulate hormone production in plants, root architecture improvement, and increase nutrient solubilization within the plant system, resulting in improved vegetative growth. Vessey (2003) and Bhardwaj et al. (2014) also reported similar results.

Yield attributes and yield

Yield-attributing characters also affected significantly due to integrated nutrient management in wheat crop. The number of grains per spike increased steadily from 36.2 in the absolute control to 64.7 under 100% rec. NPK + seed treatment with bio NPK, indicating improved reproductive efficiency (Table 1 and 2). The length of spike followed comparable patterns, ranging from 26.4 cm in the control to 34.8 cm under 100% rec. NPK with bio-NPK seed treatment. The 1000 grain weight also improved slightly with increasing nutrient inputs, reaching a maximum of 41.8 g under both 100% NPK and 100% Rec. NPK + seed treatment with bio NPK. However, the improvement in test weight was found non-significant, and it suggests that grain filling was not constrained under integrated nutrient supply. The higher doses of fertilizer (NPK) improved the soil fertility and bio-inoculants enhance nutrient cycling and reduce losses which created favorable environment for the overall growth and development of the plants, and thus improved the yield attributes and yield. Our results are in conformity with those reported by Mishra et al. (2013), Nath and Meena (2018), Pandey et al. (2018) and Rana et al. (2020).

Grain yield showed a strong positive response to integrated nutrient application to the wheat crop. The significantly highest grain yield (4.47 t ha-1) was obtained under 100% NPK + Bio NPK seed treatment, followed by 100% NPK (4.36 t ha^{-1}) and 75% NPK + Bio NPK seed treatment (4.20 t ha^{-1}). The yield obtained with the application of 75% NPK + Bio NPK were at par with the yield obtained in 100% NPK treatment, indicating the potential for reducing chemical fertilizer input by 25% without compromising the yield. Our findings have important implications for improving nutrient use efficiency and sustainability in intensive cereal systems. The yield improvement under integrated nutrient management can be attributed to cumulative improvements in plant population, spike length, no. of grains per spike, and biomass production. Bio-fertilizers in the form of Bio NPK likely improved nitrogen fixation enhance the phosphorus solubilizing bacteria leading to increase phosphorus solubilization, and potassium mobilization in the soil, leading to balanced nutrition and enhanced sink strength (Rodríguez and Fraga, 1999; Sharma et al., 2016). Similar yield advantages of integrated nutrient management in wheat crop have also been reported by Kumar et al. (2019) and Shukla et al. (2020) and Parewa et al., (2022). The superiority of the treatment involving rec. NPK + seed treatment with bio-NPK @ 2.5 ml/kg seed over non-inoculated treatments indicates a strong synergistic interaction between chemical fertilizer and microbial consortia. Finally, the performance of the treatment 75% rec. NPK + seed treatment with bio-NPK was at par with the performance of 100% NPK alone highlights the scope for reduction of fertilizer dose and cost, and also reduction of environmental risks associated with indiscriminate use of fertilizer. Integrated nutrient management (INM) and judicious use of fertilizer along with biological consortium not only enhances crop productivity but also contributes to long-term soil health and sustainability by improving nutrient use efficiency (Tilman et al., 2002; Sharma et al., 2021a).

Table 1: Effect of different nutrient management practices on growth and yield attributes of wheat

Treatment	Stand count/m²	Earhead/ m²	Plant height (cm)	Spike length (cm)	Grains/ spike	1000 grains weight (g)
Control (no seed treatment and no NPK)	283.2[e]	134.6[e]	80.8[c]	26.4[c]	36.2[d]	39.6[a]
No NPK + Seed treatment with bio NPK @ 2.5 Ml/kg seed	306.0d[e]	144.9[d]	82.7[c]	26.4[c]	37.8[d]	40.4[a]
50% Rec. NPK	329.7[d]	154.7[c]	93.5[b]	30.4[b]	44.2[c]	40.7[a]
50% Rec. NPK + Seed treatment with bio NPK @ 2.5 Ml/kg seed	373.8[c]	174.4[b]	97.8[ab]	31.6[ab]	50.5[bc]	41.2[a]
75% Rec. NPK	404.0[b]	180.2[b]	99.5[a]	33.0[a]	51.5[bc]	41.5[a]
75% Rec. NPK + Seed treatment with bio NPK @ 2.5 Ml/kg seed	426.3[ab]	187.1[ab]	100.5[a]	33.0[a]	55.0[b]	41.7[a]
100% Rec. NPK	431.7[ab]	191.6[ab]	102.3[a]	33.8[a]	59.8[ab]	41.8[a]
100% Rec. NPK + Seed treatment with bio NPK @ 2.5 Ml/kg seed	470.2[a]	199.4[a]	102.6[a]	34.8[a]	64.7[a]	41.8[a]
SEm±	26.46	9.62	2.35	0.31	3.60	1.01
CD 5%	88.49	32.16	7.85	1.05	12.05	NS

Economics of wheat crop as influenced by different nutrient management

Application of different nutrient treatment along with seed treatment with Bio-NPK significantly improved the GR and NR over the unfertilized control (Table 2). The cost of cultivation ranged from ₹32,325 ha^{-1} in the absolute control to ₹39,611 ha^{-1} in the treatment receiving 100% recommended NPK + Bio-NPK seed treatment and. The increase in cultivation cost with higher fertilizer doses was due to the higher expenditure incurred on fertilizer inputs and a little bit cost involved in microbial inoculants. Among all nutrient treatments, the highest gross return (₹126,247 ha^{-1}) and net return (₹86,636 ha^{-1}) were recorded with 100% rec. NPK + seed treatment with Bio-NPK, which remained statistically at par with 100% rec. NPK alone (₹123,191 and ₹83,937 ha^{-1}, respectively). The superior profitability enhancement of this treatment may be attributed to improved and adequate nutrient availability throughout the crop growth period, enhanced nutrient solubilization and mobilization by Bio-NPK inoculants, greater nutrient use efficiency and consequent improvement in yield and yield attributes resulting from synergistic interactions between chemical fertilizers and beneficial microorganisms. Treatments receiving 100% recommended NPK with or without Bio-NPK and 75% NPK combined with Bio-NPK were statistical at par, indicating comparable economic performance, suggesting the possibility of reducing fertilizer use by 25% without substantial loss in profitability. Therefore, integrated nutrient management involving recommended NPK fertilization along with Bio-NPK seed treatment can serve as an effective and economical viable nutrient management strategy for sustainable wheat production.

Table 2: Effect of different nutrient management practices on yield and economics of wheat

Treatment	Grain yield (t/ha)	Biomass Production (t/ha)	Cost of Cultivation (₹/ha)	Gross Return (₹/ha)	Net Return (₹/ha)
Control (no seed treatment and no NPK)	2.31^{c}	5.63^{d}	32325^{a}	66424^{c}	34099^{c}
No NPK + Seed treatment with bio NPK @ 2.5 Ml/kg seed	2.36^{c}	5.71^{d}	32682^{a}	67630^{c}	34949^{c}
50% Rec. NPK	3.39^{b}	8.06^{c}	35611^{a}	96365^{bc}	60755^{b}
50% Rec. NPK + Seed treatment with bio NPK @ 2.5 Ml/kg seed	3.40^{b}	8.14^{bc}	35968^{a}	96966^{bc}	60998^{b}
75% Rec. NPK	3.80^{ab}	9.00^{b}	37432^{a}	107697^{b}	70265^{ab}
75% Rec. NPK + Seed treatment with bio NPK @ 2.5 Ml/kg seed	4.20^{a}	9.92^{ab}	37789^{a}	118947^{ab}	81157^{a}
100% Rec. NPK	4.36^{a}	10.26^{a}	39254^{a}	123191^{a}	83937^{a}
100% Rec. NPK + Seed treatment with bio NPK @ 2.5 Ml/kg seed	4.47^{a}	10.50^{a}	39611^{a}	126247^{a}	86636^{a}
SEm±	0.11	0.31		3368	3368
CD 5%	0.37	1.03		11263	11263

Correlation between crop growth parameters, yield attributes, and yields of wheat

There is strong and positive correlation among crop growth parameters, yield attributes, and yields of wheat (Table 3). Grain yield showed a highly significant positive correlation with plant stand, plant height, spike length, grains per spike, and biomass production, indicating that yield enhancement was primarily driven by improved crop establishment, vegetative vigor, and sink capacity. Among yield attributes, grains per spike showed the strongest association with grain yield, followed closely by biomass accumulation, emphasizing the importance of assimilate production and partitioning in determining final yield. 1000 grain weight showed a comparatively weaker, and still significant, correlation with grain yield, suggesting that yield variation across treatments was governed more by sink size than by individual grain weight. These strong correlations among growth, yield attributes and yield indicate a coordinated response of wheat to integrated nutrient management practices including seed treatment with Bio-NPK, resulting into improved nutrient availability, enhanced crop growth, reproductive efficiency, and biomass production, ultimately it leads to higher economic yield.

Table 3: Pearson Correlation Coefficients (r) among Crop Growth, Yield Attributes and Grain Yield of Wheat

Parameters	Plant stand	Plant height	spike length	Grains/spike	Test weight	Biomass	Grain yield
Plant stand	1.00	0.99**	0.96**	0.97**	0.89**	0.97**	0.98**
Plant height		1.00	0.97**	0.98**	0.90**	0.98**	0.99**
Spike length			1.00	0.97**	0.88**	0.95**	0.96**
Grains/spike				1.00	0.91**	0.99**	0.99**
Test weight					1.00	0.90**	0.89**
Biomass						1.00	0.99**
Grain yield							1.00

CONCLUSION

This study demonstrated that the integration of nutrient-solubilizing microbial consortium (Bio-NPK) with chemical fertilizers significantly improved wheat growth, yield, and profitability under irrigated conditions of Indo-Gangetic Plain. The combination of 100% rec. NPK + Bio-NPK produced the highest productivity, while 75% NPK + Bio-NPK achieved yields comparable to 100% NPK alone, indicating a potential 25% reduction in fertilizer use without deteriorating the yield. It supports sustainable wheat production and contributes to SDGs 2, 12, 13, and 15 while aligning with India's National Mission for Sustainable Agriculture and soil health. Therefore, integration of Bio-NPK with optimized fertilizer application is a promising strategy for sustainable wheat production in the Indo-Gangetic Plains.

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REFERENCES

Adesemoye A O and Kloepper J W. 2009. Plant-microbes interactions in enhanced fertilizer-use efficiency. Applied Microbiology and Biotechnology 85(1): 1–12.

Adesemoye A O, Torbert H A and Kloepper J W. 2009. Plant growth-promoting rhizobacteria allow reduced application rates of chemical fertilizers. Microbial Ecology 58(4): 921–929.

Bhardwaj D, Ansari M W, Sahoo R K and Tuteja N. 2014. Bio-fertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. Microbial Cell Factories 13(1): 66. DOI: 10.1186/1475-2859-13-66.

Bhattacharyya P N and Jha D K. 2012. Plant growth-promoting rhizobacteria (PGPR): emergence in agriculture. World Journal of Microbiology and Biotechnology 28(4): 1327–1350. DOI: https://doi.org/10.1007/s11274-011-0979-9

FAO. 2022. FAOSTAT: Crops and livestock products. Food and Agriculture Organization of the United Nations.

FAO. 2023. FAOSTAT Statistical Database. Food and Agriculture Organization of the United Nations. Available at: http://www.fao.org/faostat.

Gomez K A and Gomez AA. 1984. Statistical procedures for agricultural research (2nd ed.). John Wiley & Sons.

Goswami D, Thakker J N and Dhandhukia P C. 2016. Microbial inoculants for sustainable agriculture: prospects and challenges. International Journal of Environmental Science and Technology 13: 183–206.

Kumar A, Singh R, Yadav A N, Kumar R, Saxena A K and Singh D P. 2021. Microbial consortia: promising tools for enhancing soil fertility and crop productivity. Frontiers in Microbiology 12: 703.

Kumar A, Verma J P and Singh R N. 2019. Synergistic effects of plant growth-promoting rhizobacteria and chemical fertilizers on wheat productivity. Agricultural Research 8(3): 332–341. DOI: https://doi.org/10.1007/s40003-018-0373-5

Kumar V, Yadav P, Verma S, Meena R S, Meena B L and Lal R. 2022. Field efficacy of microbial consortia for improved nutrient availability and wheat productivity. Indian Journal of Agricultural Sciences 92(1): 45–51.

Lal R. 2020. Regenerative agriculture for food and climate. Journal of Soil and Water Conservation 75(5): 123A–124A.

Mishra P K, Mishra S and Adhikari T. 2013. Role of microbial inoculants in nutrient use efficiency and crop productivity. Indian Journal of Fertilizers 9(8): 88–99.

Nath D and Meena V S. 2018. Mycorrhizae: A potential microorganism and its implication in agriculture. In: Meena VS (Ed.), Role of Rhizospheric Microbes in Soil. Springer, Singapore. pp. 251–276.

Panday S C, Choudhary M, Singh S, Meena V S, Mahanta D, Yadav R P, Pattanayak A and Bisht J K. 2018. Increasing farmer's income and water use efficiency as affected by long-term fertilization under rainfed and supplementary irrigation in a soybean-wheat cropping system of Indian mid-Himalaya. Field Crops Research 219: 214–221.

Parewa H P, Yadav J, Meena V S, Sarkar D, Meena S K, Rakshit A and Datta R. 2022. Improved nutrient management practices for enhancing productivity and profitability of wheat under Mid-Indo-Gangetic Plains of India. Agriculture 12(9): 1472. DOI: https://doi.org/10.3390/agriculture12091472.

Patel A, Patil N, Bhadekar R and Patil S. 2020. Role of phosphate solubilizing microorganisms in sustainable agriculture: A review. Journal of Pure and Applied Microbiology 14(3): 1885-1896.

Pathak H, Bhatia A, Jain N and Aggarwal P K. 2010. Greenhouse gas emission and mitigation in Indian agriculture: A review. Paddy and Water Environment 8(4): 315-332. DOI: https://doi.org/10.1007/s10333-010-0207-3.

Prasanna R, Nain L, Pandey A , Saxena A K and Babu S. 2013. Effects of co-inoculation of microbial consortia on wheat productivity and soil health. Soil Biology and Biochemistry 57: 86–91.

Rana A, Joshi M and Prasanna R. 2020. Formulation and delivery of microbial consortia. Current Developments in Biotechnology and Bioengineering 1:107-130. DOI: https://doi.org/10.1016/B978-0-444-64301-1.00006-7

Rodríguez H and Fraga R. 1999. Phosphate solubilizing bacteria and their role in plant growth promotion. Biotechnology Advances 17(4-5): 319–339. DOI: https://doi.org/10.1016/S0734-9750(99)00014-2.

Sharma R, Choudhary A K and Bhatt B P. 2021a. Nutrient use efficiency in Indian agriculture: Trends and strategies. Indian Journal of Fertilizers 17(4): 312–325.

Sharma S, Prasad R and Kumar V. 2016. Potassium-solubilizing bacteria and their effect on growth and yield of maize (Zea mays). Indian Journal of Agricultural Sciences 86(9): 1172–1177.

Sharma S, Yadav A, Tiwari M and Kumar V. 2021b. Enhancing wheat productivity in the Indo-Gangetic Plains through microbial inputs. Journal of Cereal Research 13(2): 123–132.

Sharma S B, Sayyed R Z, Trivedi M H and Gobi T A. 2013. Phosphate solubilizing microbes: sustainable approach for managing phosphorus deficiency in agricultural soils. SpringerPlus 2: 587.

Shukla L, Srivastava A and Yadav R S. 2020. Integrated nutrient management in wheat (Triticum aestivum L.) for sustainable productivity. Journal of Cereal Research 12(3): 230–235.

Singh R, Chauhan S K, Mehta S and Singh M. 2021. Impact of fertilizer use on soil health and productivity: A case study from northern India. Agricultural Reviews 42(1): 28-35.

Singh R P, Prasad B and Sharma A R. 2018. Strategies for improving fertilizer use efficiency in wheat. Indian Journal of Agronomy 63(3): 245-251.

Tilman D, Cassman K G, Matson P A, Naylor R and Polasky S. 2002. Agricultural sustainability and intensive production practices. Nature 418: 671–677. DOI: 10.1038/nature01014.

Vessey J K. 2003. Plant growth promoting rhizobacteria as biofertilizers. Plant and Soil 255(2): 571-586.

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