

Efficacy of *Trichoderma* spp. and plant growth promoting rhizobacteria (PGPR) as biofertilizer for wheat (*Triticum aestivum* L.) cultivation

**SUMMARY
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Summary

The population of the world is estimated to be eleven billion or more by 2100 which will require more than 70% of additional food compared to the current production level. It will be the greatest challenge to fulfill the needs of such a huge population with limited resources, declining water supplies to irrigate and other environmental concerns. Applications of conventional chemical fertilizers, pesticides and herbicides were started to enhance the yield and productivity of different food crops but excessive usage of these chemicals have overexploited the soil ecosystem. To minimize the negative effects of these chemicals on the environment, these should be substituted by suitable alternative that enhances the yield in sustainable and ecofriendly ways. In this regards, different advancements have been made in field of agricultural which have initiated the application of beneficial microorganisms. These are not only eco-friendly and sustainable but also cheaper than chemical fertilizers. These microorganisms are able to easily accelerate the absorption of nutrients from the soil and promote growth as well as productivities. These are technically termed as 'bio-fertilizers. Biofertilizers consists of various endophytic, symbiotic bacteria, fungi and other microorganism that promote growth and development of crops by various mechanism like nitrogen fixation, mineral solubilization, phytohormones (IAA, gibberellin and cytokinin etc.) production, secretion of antibodies and enzymes.

The present study focused on the application of biofertilizers composed of plant growth promoting rhizobacteria (PGPR) and plant growth promoting fungi (PGPF) on wheat plants to enhance its growth and productivity. Wheat (*Triticum aestivum* L.) is the most widely grown and major food crop all across the world including India. It provides about 20% of the daily proteins of the food calories for

4.5 billion people worldwide. The need of present time is to increase wheat yield and productivity for food security purpose to fulfill the needs of continuously growing their population. The native rhizospheric plant growth promoting microorganisms (PGPMs) were isolated from the wheat fields nearby Lucknow city and were characterized morphologically and biochemically for their application as efficient biofertilizer. Further, all the isolates were also screened through in-vitro for plant growth promoting activities (PGPAs) e.g. IAA, siderophore and ammonium production, phosphate solubilization, HCN test, and nitrogen fixation. On the basis of morphological, biochemical, PGPAs and molecular characteristic these isolates were identified as bacterial strains *Alcaligenes faecalis* (SDA₃) and *Microbacterium phyllosphaerae* strain (S5₁), and fungal strain *Trichoderma virens* (T₂)

These PGPMs were used as individual and in consortium to optimize the best formulations in earthen pots under net house conditions. The main growth parameters examined were root and shoot length, no. of root and leaves, fresh and dry weight wheat plants. The results indicated that selected isolates significantly ($p < 0.05$) improved all growth parameters of wheat in pot conditions when used as consortium. In initial 40 days after sowing (DAS), the growth parameters were less prominent and increased gradually till 80 DAS and became stagnant afterwards. It may be due to higher doings of microbes in initial days which augmented progressively and became static after reaching its peak. The maximum enhancement was recorded by synergetic effects of consortium of *A. faecalis*, *M. phyllosphaerae* and *T. virens*. The efficacies of best performing formulation of *Trichoderma* and PGPRs were also studied on growth and yield of wheat in experimental plots. The results were same as that of earthen pots which showed the highest increase in root and shoot length, no. of roots

and leaves and fresh and dry weight in comparison to control as 110.83 and 46.19; 127.03 and 181.82; and 164.60 and 79.39 %, respectively.

Further, studies on accessibility of nutrients and its distribution in plant parts during application of formulated treatments were also performed to observe nutrient (nitrate, nitrite, ammonium and phosphate) uptake and their accumulation in wheat. In this regards, physicochemical properties of pots and experimental field soils were observed to understand the natural characteristics of soil. The PGPR and PGPF used in the biofertilizers solubilized plant nutrients and make these available to plants. The results of present study were positive in enhancing N and P uptake in forms of nitrate, nitrite, ammonium and phosphates with the effect of different formulations of biofertilizers. It was observed that the concentration of nitrate, nitrite, ammonium and phosphate in wheat plants of control was 25.16, 0.43, 5.60 and 10.08 mg g⁻¹, respectively at harvesting time in earthen pots. But, in experimental field these were higher in comparison to pots which may be due availability of larger surface for interaction of isolated microbes. The highest increase of 297.03, 807.67 and 200.52 % in nitrate, nitrite, ammonium and phosphate was recorded with the effect of consortium of *A. faecalis*, *M. phyllosphaerae* and *T. virens*, respectively in experimental fields. Further, effect of biofertilizers containing isolated microorganisms on organic carbon, organic matter, alkaline phosphatase and dehydrogenase activity levels of pot and experimental field soils were also studied which were recorded highest by application of consortium of three isolates i.e. *A. faecalis*, *M. phyllosphaerae* and *T. virens* as 290.15, 204.40 and 60.59 % and 373.53, 156.44 and 62.91 %, respectively. For most of the time, increase in uptake and accumulation of nutrients was found in increasing order of examined treatments as Control < Commer. < Urea and DAP < *A. faecalis* < *M. phyllosphaerae* < *T. virens* <

consortium of *A. faecalis* and *M. phyllosphaerae* < consortium of *A. faecalis* and *T. virens* < consortium of *M. phyllosphaerae* and *T. virens* < consortium of *A. faecalis*, *M. phyllosphaerae* and *T. virens*.’

The productivity of control plants was 1.87 t ha⁻¹ which increased by 48.82, 53.84 and 54.67 % with the treatments of isolates *A. faecalis*, *M. phyllosphaerae* and *T. virens*, respectively in comparison to control. Whereas, the percentage increases in productivity of wheat in experimental fields were 55.12, 55.89, 65.86 and 67.80 %, respectively in comparison to control with co-isolation effect of consortium of *A. faecalis* and *M. phyllosphaerae*; *A. faecalis* and *T. virens*; *M. phyllosphaerae* and *T. virens*; and *A. faecalis*, *M. phyllosphaerae* and *T. virens*. Thus, it may be concluded that the best performing formulation were consortium of three isolates *A. faecalis*, *M. phyllosphaerae* and *T. virens* which may be recommended for commercial usage to enhance productivity and yield of wheat crops.

The last objective of the study was the cost benefit analysis to understand whether the cost involved in the manufacturing and applications of formulated biofertilizers provide benefits to the farmers and government or not. Treatment of control provided net benefit of about 10572 rs ha⁻¹ which was enhanced by application of chemical fertilizer (Urea and DAP) and become 29645 rs ha⁻¹. Whereas, market based commercial biofertilizer (Commer.) required about 22420 rs ha⁻¹ with net benefit of ~12930 rs ha⁻¹. The net benefit acquired by consortium of *A. faecalis* and *M. phyllosphaerae* (28310 rs ha⁻¹) and *A. faecalis* and *T. virens* (28485 rs ha⁻¹) were 4.50 and 3.93 % lesser than chemical fertilizers (29645 rs ha⁻¹). On the other hand, consortia of *M. phyllosphaerae* and *T. virens*; and *A. faecalis*, *M. phyllosphaerae* and *T. virens* achieved net benefit in terms of income as 31910 and 32480 rs ha⁻¹ which was 7.64 and 9.56 % higher in comparison to chemical fertilizers. The effects of these

native microbial biofertilizers were better and more consistent in comparison to the commercial biofertilizer (*Azoto plus*) obtained from Biotech Park, Lucknow. However, the chemical fertilizers Urea and DAP on recommended dose produced slightly more grain yield in comparison to control, commercial biofertilizer and newly prepared biofertilizers. But, net benefits in terms of manufacturing and environmental sustainability were more pronounced with the application of newly prepared biofertilizers used in this study. Therefore, application of these newly formulated biofertilizers should be encouraged over chemical fertilizers. These new formulated biofertilizers may be commercialized and promoted by governments over application of chemical fertilizers for sustainable and ecofriendly agricultural practices. The application of consortium of these PGPMs as commercial fertilizer in conventional wheat cultivation may be a means of improving yield and productivity with coping up with different environmental stresses. It may help in reduction of nutrient losses from agricultural ecosystems and therefore make partial savings on chemical fertilizers, although exterior N supply is still vital to maintain crop yield and quality integrities. Selection of microorganisms for specific crops and strains will perhaps be the chief forthcoming challenge in successful exploitation of PGP bacteria and fungi in the development of commercial bio-fertilizers.