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## IMPACT OF TINY MICROBES: A SUSTAINABLE WAY TO BOOST SOIL AND CROP PRODUCTIVITY

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Soil beneficial microorganisms have potential activity towards soil health and plant growth. Several research addressed that these microbes have roles in supporting plant growth with soil nutrient improvement. Single strains like *Pseudomonas* for phosphate solubilization, *Rhizobium* for nitrogen fixation gained importance as potential biofertilizer. By reducing chemical fertilizer application, microbial consortium enhances crop productivity in an economically feasible way. These findings support the big impact of tiny microbes towards sustainable agriculture to support global food security.

### Limitation of Conventional Farming

Recently agriculture is under increasing pressure to improve crop productivity while maintaining soil health. modern agricultural practices such as using large number of chemical fertilizers, excessive tillage and more along with improving yield, harms the soil quality. For long term these practices becoming harmful and that becomes the threat to food security. Food and Agricultural Organization (FAO), published a report that by 2030, about 600 million people worldwide are expected to be undernourished (FAO 2023). Along with soil health, application of chemical fertilizer leads to concerning environmental pollutions too (Wang and Li, 2019). Sustainable solution became emerging to solve this soil related and agricultural problems.

### Impactful Tiny Microbes

One promising approach to combat the situation is the application of impactful soil beneficial microorganisms as biofertilizer. Soil is a dynamic ecosystem where microbes play important functions like nutrient cycling, decomposition, and plant growth promotion. There are several groups of microorganisms, including bacteria, fungi, archaea, actinomycetes, capable of fixing nitrogen, solubilizing phosphate, potassium, sulfur and other macro and

micronutrients- essential for crop development (Pradhan et al. 2025). Application of these microbes as a consortium has the ability to reduce the dependency of chemical fertilizers to improve the crop productivity in a sustainable way (Shimada et al. 2024).

### **N, P, and K Fixation/Solubilization/Mobilization**

Nitrogen, one of the major nutrients for soil structure and crop productivity, required for synthesis of proteins, nucleic acids, and chlorophyll. Nitrogen is abundant in atmosphere, however gaseous nitrogen is unavailable to plants before it converted to available form like ammonia, nitrite or nitrate form by some nitrogen fixing bacteria. And in this way nitrogen fixer helps the soil to be nitrogen rich and support the plant growth. Symbiotic and free-living nitrogen fixers like *Rhizobium*, *Azospirillum* helps to fix nitrogen for legumes and cereals respectively (Aasfar et al. 2024). There are several other strains like *Pseudomonas*, *Azotobacter* and others helps as nitrogen fixers (Biswas et al. 2024). Along with nitrogen phosphorous and potassium, were solubilizing/ mobilizing by some phosphate solubilizing and potassium mobilizing bacteria from their insoluble form to soluble form. Several bacteria like *Enterobacter*, *Bacillus*, *Pseudomonas* has the potential to solubilize and mobilize these soil nutrients to support the plant growth while maintaining soil quality (Pandey and Saharan, 2025). Microbial consortium made up with these microbes is an impactful approach for the modern agriculture to be sustainable for soil health regeneration and crop production.

### **Micronutrients Solubilization**

Not only macronutrients, micronutrients like zinc (Zn), and manganese (Mn), iron (Fe), and sulfur (S), also has several roles in maintain soil health and plant growth. There are several microbes those helps in solubilizing these micronutrients to soil for the plants. Bacteria such has *Bacillus subtilis* has potential activity to plant growth by helping mobilizing zinc like micronutrients. *Pseudomonas*, *Enterobacter*, *Thiobacillus* like species has roles in solubilizing iron, zinc, sulfur like micronutrients through their enzymatic activities (Yadav et al. 2023a). Including these micronutrient solubilizing bacteria in a microbial consortium can be a sustainable solution towards agriculture.

### **Microbial Consortium and Economic Feasibility**

Traditional agriculture relies heavily on costly chemical fertilizers, which are environmentally unsustainable, and sometimes inefficient in nutrient-depleted soils. In contrast, microbial consortia can enhance nutrient availability in situ while minimizing

environmental impacts. Beyond agronomic benefits, microbial inoculants also have significant economic potential (Yadav et al. 2023b). The profitability of farming systems depends not only on yield but also on input costs and the efficiency of resource utilization. Application of microbes instead of chemical fertilizer cut the cost for purchase and application and improved productivity that increase the profit. In this way these tiny microbes help in global economic along with soil health and plant productivity.

### Future Perspective

Preparation of a microbial consortium with potential microbes with an improved shelf life will be beneficial for the agricultural sector. Complete study from preparation to application in field scale with different field conditions and crop will help to understand the consequences of the microbial formula. This can serve as a potential sustainable method to improve and maintain the soil quality to support the plant growth and economic stability.

### Conclusion

Tiny microorganisms have the potential to improve both the soil quality and structure, that helps the soil to function properly. Soil functionality of supporting plant growth, protecting it from several harmful diseases were lies on its structure, fertility, especially on biological load. So along with decreasing dependency over chemical fertilizer and pesticides microbial consortium helps to improve productive yield to combat the situation of food security. In other way bioaugmentation helps to reduce the cost of farming and hence helping in economic growth as well. Not only productivity it helps to improve the quality of crop as well. Therefore, it serves as a sustainable way to reduce cost of farming, improving soil health, productivity and quality of crops. Future studies focusing on all these aspects together will help researchers to find out the better sustainable and market available microbial consortium.

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