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## Role of Biofertilizers in Improving Maize Productivity and Soil Health: An Effective Step Towards Sustainable Agriculture

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India is an agricultural country where a continuous increase in agricultural production is essential to ensure food and nutritional security. Challenges such as a growing population, limited agricultural land, climate change, and the degradation of soil resources pose serious questions for the agricultural sector. Under such circumstances, the conservation of natural resources has become just as crucial as increasing production. Maize (*Zea mays* L.) is a crop that plays a vital role in the food, feed, and industrial sectors and possesses the potential to become the foundation of the future agricultural economy. Maize is known as the "Queen of Cereals" due to its high genetic yield potential. Globally, it ranks among the major cereal crops alongside wheat and rice. In India, it is the third most important cereal crop after wheat and paddy (rice). Currently, the utilization of maize is rapidly increasing in human food, animal feed, the poultry industry, the starch industry, food processing, ethanol production, and biofuel manufacturing. Following the Green Revolution, chemical fertilizers were used extensively to boost agricultural production. While this increased production in the short term, it had an adverse long-term impact on soil health, microbial diversity, and the environment. Presently, agricultural scientists are focusing on techniques that maintain soil fertility while simultaneously increasing production. Bio-fertilizers have emerged as a significant and sustainable alternative in this direction.

**Keywords:** Maize, Bio-fertilizers, Climate change, Natural resources, Nutrients.

### Importance of Maize in India

Maize is one of the fastest-growing crops in India. Although cultivated in almost all states, Karnataka, Madhya Pradesh, Bihar, Uttar Pradesh, Rajasthan, Maharashtra, and Telangana are the primary producing states. The major reasons behind maize's growing popularity include its high production capacity, the availability of short-duration improved varieties, multipurpose uses, escalating demand in the poultry and animal feed industries, increasing utilization in ethanol production, and relatively better adaptation to climate change. Maize grains contain approximately 70-72 percent carbohydrates, 8-12 percent protein, and 3-5 percent oil. Additionally, vitamins A, B, and essential minerals are present in adequate amounts. Consequently, it is considered a crucial crop from the perspective of food and nutritional security.

### Challenges in Maize Production

Despite a continuous increase in maize productivity in India, it remains low compared to developed countries. The primary reasons for this include unbalanced fertilizer application, depletion of organic carbon in the soil, micronutrient deficiencies, and a decline in soil biological activities, climate change, and low nutrient use efficiency.

The continuous application of chemical fertilizers deteriorates the physical, chemical, and biological quality of the soil. This escalates production costs and reduces fertilizer efficiency. In such a scenario, the importance of bio-fertilizers increases tremendously.



### What are Bio-fertilizers?

Bio-fertilizers are products containing living microorganisms. These microbes assist in making essential nutrients available to plants, enhancing root growth, and improving the biological activity of the soil. Upon reaching the soil, the microorganisms present in bio-fertilizers carry out various biochemical processes through which plants obtain nutrition. Unlike chemical fertilizers, they do not provide nutrients directly but rather convert nutrients into forms that are accessible to plants.

### Major Bio-fertilizers Used in Maize

- **Azotobacter:** This is a free-living nitrogen-fixing bacterium. It converts atmospheric nitrogen into a form usable by plants. Its application reduces the requirement for nitrogenous fertilizers.
- **Azospirillum:** This bacterium remains active around the root zones of grass family crops like maize. Alongside nitrogen fixation, it also produces growth hormones that stimulate root development.
- **Phosphate Solubilizing Bacteria (PSB):** Most of the phosphorus present in the soil exists in an insoluble form. PSB solubilizes this phosphorus, making it available to plants.
- **Potash Solubilizing Bacteria (KSB):** These bacteria make the potash available in the soil usable for plants and enhance the plants' resistance.
- **Mycorrhiza (VAM):** Mycorrhiza establishes a symbiotic relationship with plant roots. By increasing the effective surface area of the roots, it aids in the absorption of phosphorus, zinc, and other nutrients.
- **Zinc Solubilizing Bacteria:** Zinc deficiency is prevalent in many Indian soils. Zinc solubilizing bacteria assist in plant growth by increasing zinc availability.

### Impact of Bio-fertilizers on Maize Productivity

Numerous global and Indian research studies have proven that utilizing bio-fertilizers is highly effective in enhancing maize growth and productivity. According to research, the application of bio-fertilizers leads to:

- An increase in germination percentage.
- An increase in plant height.
- An expansion of leaf area.

- A more developed root system.
- Improved nutrient absorption.
- An increase in the number and weight of grains.
- An increase in total biological and grain yield.

Several studies have found that a 10–25 percent increase in maize yield is attainable through the combined application of *Azotobacter* and Phosphate Solubilizing Bacteria. Furthermore, a remarkable improvement in phosphorus use efficiency has been observed with the use of Mycorrhiza.

### Increase in Nutrient Use Efficiency

Currently, the most significant challenge facing agricultural scientists is enhancing Nutrient Use Efficiency. Generally, plants only utilize 30-50 percent of the applied nitrogen and 15–20 percent of the applied phosphorus. The usage of bio-fertilizers increases nitrogen use efficiency, boosts phosphorus availability, improves micronutrient absorption, and minimizes nutrient wastage. Thus, higher yields can be achieved even with reduced fertilizer application.

### Role of Bio-fertilizers in Soil Health Improvement

Soil health is the cornerstone of sustainable agriculture. Merely boosting production is insufficient; maintaining the long-term fertility of the soil is equally essential. Biofertilizers improve soil health in the following ways:

- **Increase in Organic Carbon:** Biofertilizer application accelerates the decomposition of organic matter in the soil, which elevates the organic carbon levels.
- **Increase in Microbial Activity:** The soil becomes biologically more active due to the proliferation of beneficial bacteria and fungi.
- **Improvement in Soil Structure:** Substances produced by microorganisms bind soil particles together, forming a stable structure that improves aeration and water-holding capacity.
- **Nutrient Availability:** Bio-fertilizers enhance the availability of nitrogen, phosphorus, potash, and micronutrients.
- **Environmental Protection:** Their use reduces the dependency on chemical fertilizers, thereby decreasing water and soil pollution.



## Climate Change and Bio-fertilizers

Climate change is leading to rising temperatures, irregular rainfall, and an increased frequency of droughts. Under these circumstances, bio-fertilizers help build plant tolerance. Research indicates that biofertilizer application results in better-developed root systems, enhanced water absorption capacity, improved drought tolerance, and better nutrient balance. Consequently, bio-fertilizers are becoming a critical component of climate-smart agriculture.

## Role of Bio-fertilizers in Integrated Nutrient Management (INM)

Integrated Nutrient Management (INM) is a system that involves the balanced application of chemical fertilizers, organic manures, and bio-fertilizers.

### Benefits of INM in Maize:

- Increased production.
- Reduced costs.
- Conservation of soil health.
- Nutrient balance.
- Environmental sustainability.

Several long-term experiments have demonstrated that maximum benefits are realized when bio-fertilizers are used in conjunction with the recommended dosage of fertilizers.

## Methods of Biofertilizer Application

- **Seed Treatment:** For 10 kilograms of maize seeds, 200–250 grams of biofertilizer culture are sufficient. Seeds should be treated, dried in the shade, and then sown.
- **Soil Application:** 2–5 kilograms of biofertilizer mixed with 50–100 kilograms of well-decomposed farmyard manure (FYM) can be applied per hectare in the field.
- **Application alongside Fertilizer Management:** For optimal results, biofertilizers should be applied in combination with recommended chemical fertilizers and organic manures.

## Suggestions for Farmers

- Use certified and high-quality bio-fertilizers.
- Do not use expired products.
- Do not expose treated seeds to direct sunlight.
- Store bio-fertilizers in a cool and shaded place.
- Adopt Integrated Nutrient Management.
- Conduct regular soil testing.

## Conclusion

Maize holds a crucial position in India's food, nutritional, and industrial economy. To meet its escalating future demand, relying exclusively on chemical fertilizers will not be viable. Bio-fertilizers provide a scientific, eco-friendly, and cost-effective alternative that plays a vital role in protecting soil health alongside boosting production. Various research studies have established that the use of bio-fertilizers like *Azotobacter*, *Azospirillum*, Phosphate Solubilizing Bacteria, and Mycorrhiza results in significant improvements in maize growth, nutrient use efficiency, crop yield, and soil fertility. The need of the hour is for farmers, scientists, and policymakers to collaborate in promoting the widespread adoption of bio-fertilizers to achieve the goals of sustainable agriculture and food security.

**"Healthy soil, balanced nutrition, and the proper utilization of bio-fertilizers form the foundation of a future sustainable maize production system."**