



Bio-Priming Seeds for Improved Soil-Microbe Interaction

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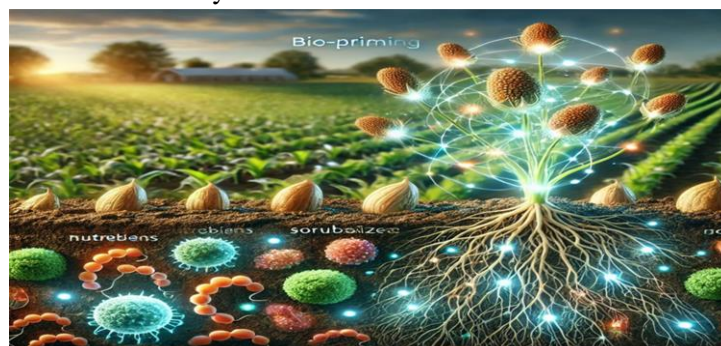
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INTRODUCTION

Bio-priming is an innovative and eco-friendly technology that inoculates seeds with beneficial microorganisms to upgrade their performance and develop mutualistic association with soil microbiota. This approach aligns with the principles of microbiology, seed technology, and sustainable agriculture toward improving seed germination and plant growth and stress tolerance. Bio-priming not only enhances crop productivity but also promotes a healthy and resilient soil ecosystem.



The Concept of Bio-Priming

Bio-priming can be defined as the process of applying beneficial microbes, such as bacteria or fungi or even both, to the seeds before their sowing. The process thus encapsulates three fundamental steps:

- Pre-imbibing of seeds.
- Inoculation with microbial strains.
- Incubation in a controlled environment to permit colonization by the microbes.

Well, the common beneficial microbes used are Rhizobium, Azospirillum, Pseudomonas fluorescens, Trichoderma harzianum, and mycorrhizal fungi. These microbes colonize the seed surface and provide various benefits including better uptake of nutrients, resistance against pathogens, and stimulation of growth.

Mechanisms of Promoting Soil-Microbe Interactions

1. Rhizosphere Colonization

Microorganisms applied through seed bio-priming will colonize the rhizosphere-the zone around the plant root-in a symbiotic relationship with mutual exchange in the forms of nutrients and signaling molecules. This then increases root functions, bringing about improved uptake of both water and nutrients.

2. Enhanced Availability of Nutrients

Bio-primed microbes make the essential nutrients like phosphorus and potassium soluble to be absorbed by the plant. Nitrogen-fixing bacteria convert atmospheric nitrogen into a usable form, and some release enzymes that degrade organic matter, thus aiding nutrient uptake.

3. Biocontrol Activity:

Antagonistic microorganisms added in the process of bio-priming combat soil-borne pathogens. They inhibit pathogens through the process of competition for spaces and nutrients, antimicrobial production, and/or sometimes by inducing plant's systemic resistance, which inhibits the happening of diseases.

4. Reducing Stress

Microorganisms involved in bio-priming seeds produce phytohormones, including auxins, gibberellins, and cytokinins, which enable plants to tolerate abiotic stresses like drought, salinity, and temperature fluctuations. These hormones regulate root architecture and water uptake efficiency.

5. Soil Health Enhancement:

Beneficial microorganisms contribute to the decomposition of organic matter, increasing the content of soil organic carbon and improving soil structure. Their activities enhance aeration, water retention, and microbial diversity, creating a healthy and resilient soil ecosystem.

Advantages of Bio-Priming

1. Improved Germination and Vigor:

Bio-priming maximizes uniformity and seed germination speed, promoting vigorous

seedling emergence. This vigor ensures that plants are established more rapidly and will be more competitive against weeds and tolerant of stress early in the growth phase.

2. Disease Resistance:

Seeds treated with beneficial microbes develop an inherent resistance to soil-borne pathogens like *Fusarium*, *Rhizoctonia*, and *Pythium*. This biocontrol activity minimizes crop losses by suppressing harmful organisms through mechanisms like antibiosis, competition, and induced systemic resistance.

3. Environmental Sustainability:

Bio-priming reduces reliance on synthetic chemical fertilizers and pesticides, thus reducing the environmental impact of agricultural practices. It supports the principles of sustainable farming by promoting natural interactions between plants and beneficial microbes.

4. Cost-Effectiveness:

The use of bio-priming provides an economical option for farmers, especially in resource-limited settings. By reducing the need for expensive agrochemicals and improving yield potential, it ensures higher returns on investment for agricultural inputs.

5. Climate Change Resilience:

Bio-primed seeds develop increased tolerance to drought, salinity, and temperature fluctuations. This resilience is achieved through enhanced soil-microbe interactions that support nutrient availability, water uptake, and stress mitigation under adverse climatic conditions.

Applications in Sustainable Agriculture

1. Cereal Crops:

Bio-priming has been effective in staple crops, such as wheat, rice, and maize. It increases the efficiency of nutrient uptake through the solubilization of critical nutrients and increases plant resistance to abiotic stresses like drought and salinity. This leads to higher yields and improved food security.

2. Horticulture:

In vegetables and fruit crops, bio-priming improves high transplant survival rates and

solid growth. Bio-priming ensures an early beginning of the root system by improving nutrition levels and lower susceptibility to disease, yielding better quality crop and acceptable yields.

3. Legumes:

The use of bio-priming enhances the nitrogen-fixing potential in leguminous crops, including soybean, lentil, and chickpea. The inoculation of symbiotic bacteria, like *Rhizobium*, increases soil nitrogen and promotes the crop and its succeeding crops in crop rotations.

4. Organic Farming:

Bio-priming is well in line with organic farming principles, providing an alternative to chemical inputs in a sustainable manner. This reduces the dependency on synthetic pesticides and fertilizers, improves soil health, and supports ecological balance, thereby making farming practices more environment-friendly.

Challenges and Future Perspectives

Bio-priming has been proven to have many benefits, but it still experiences inconsistent field performance, poor shelf life of microbial inoculants, and different effectiveness in different environmental conditions. The above issues can be addressed through the development of advanced microbial strains, optimal carrier materials, and improved delivery mechanisms. Future studies should focus on the following:

- Developing multi-strain consortia.
- Genomic studies to establish the most effective microbes.
- Integration of precision agriculture technologies.

CONCLUSION

Bio-priming is an excellent technology that bridges the gap between seed technology and soil microbiology. It promotes improvement in soil-microbe interactions, thereby giving sustainable ways to enhance crop productivity and soil health. Once more advanced and commonly practiced, bio-priming can transform modern agriculture into a more resilient and sustainable system.

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