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Biostimulants in Agriculture: Benefits and Applications

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Abstract

Biostimulants play a crucial role in modern agriculture by enhancing plant growth, improving stress tolerance, and promoting soil health. Unlike traditional fertilizers and pesticides, they stimulate natural physiological processes, leading to better nutrient absorption, increased crop yield, and improved quality. Biostimulants include various substances such as humic acids, seaweed extracts, protein hydrolysates, arbuscular mycorrhizal fungi, plant growth-promoting rhizobacteria, and silicon, each contributing uniquely to plant development. Their application supports sustainable farming by reducing chemical dependency and mitigating the effects of environmental stress.

1. Introduction

Agricultural productivity is increasingly challenged by soil degradation, climate change (Abbas et al., 2020), and the excessive use of chemical inputs. To address these issues, biostimulants have gained attention as natural solutions that enhance plant growth, improve stress tolerance, and promote soil health. Unlike fertilizers and pesticides, biostimulants stimulate physiological processes in plants, leading to better nutrient absorption, improved resistance to environmental stresses, and increased crop quality. They are classified either on mode of action or active ingredient origin. As sustainable agriculture becomes a priority, the use of biostimulants offers a promising approach to improving crop performance while reducing environmental impact. They are applied in small quantities supplementing fertilizers and increasing nutrient use efficiency, plant growth, and stress tolerance irrespective of their nutrient content. Standardization of formulations, regulatory frameworks, and economic feasibility assessments are also crucial for their broader adoption. Continued research and innovation will further optimize biostimulant use, making them an essential component of eco-friendly and resilient agricultural practices.

2. What are Biostimulants?

Plant biostimulants consist of those substances when applied

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to seed, plant, soil, or growing substrates in certain formulations, modify physiological processes increasing growth, development, stress responses excluding nutrients and pesticides. Another definition given by du Jardin (2015) defined plant biostimulant as any microorganism or substance applied to plant that enhances crop quality traits, nutrient efficiency, and stress tolerance regardless of its nutrient content. Biostimulants can be categorized as humic substances, seaweed extract, plant or animal-based protein hydrolysates, arbuscular mycorrhizal fungi (AMF), plant growth-promoting rhizobacteria (PGPR), chitosan, silicon (Figure 1) (Rouphael and Colla 2020).

Figure 1: Types of biostimulants

2.1. Humic substances

They are the natural components of soil organic matter formed by the decomposition of plant, animal, and microbial activity. Application of humic substances (humic and fulvic acid) causes some structural and physiological changes in root and shoot enhancing nutrient uptake (chelate formation), microbial activity, and overall soil ecosystem. Peat, lignite, and leonardite constitute some of its sources. According to some reports, it has auxin and cytokinin-like growth effects owing to the release of auxin-like biomolecules.

2.2. Seaweed extract

Brown, red, and green algae constitute the major macroalgae. However brown seaweed is the most popular comprising of *Laminaria, Ascophyllum*, and *Fucus.* They contain hormone-like substances, polysaccharides (30-40%) bioactive compounds (phloroglucinol, eckol), amino acids, fatty acids, phenolics along with trace elements like Zn, Fe, Mn, and Cu. IFFCO retails seaweed under the name of sagarika and sea secret composed of red and brown macroalgae having plant growth regulators like auxin, and gibberellins, along with essential amino acids, macro and micronutrients.

2.3. Protein hydrolysates

It can either be of plant or animal origin formed by enzymatic or chemical hydrolysis consisting of a mixture of amino acids and peptides (Moreno-Hernández *et al.*, 2020). They increase soil fertility affecting plant growth, while improving the quality of fruits and vegetables, through hormonal activity and primary and secondary metabolism regulation. The protein hydrolysate effect on the plant depends upon dose, timing of application along its composition. It is particularly useful to plants with limited water availability applied either as foliar application or side-dressed.

2.4. Arbuscular mycorrhizal fungi (AMF)

Arbuscular mycorrhizal fungi have symbiotic relationships with plants, from a dense network of hyphae in the root increasing uptake of water, nutrients as well as phosphorus. However, their susceptibility to management practices such as tillage, fallow period, and high rate of fertilizer and fungicide application limits their adoption. Another fungus the trichoderma spp. is also known to increase nutrient uptake through the release of metabolites.

2.5. Plant growth-promoting rhizobacteria (PGPR)

Bacteria such as *Bacillus, Pseudomonas, Azotobacter, Rhizobium, and Azospirillum* constitute the plant growth-promoting rhizobacteria (PGPR). Species such as *Rhizobium, Azotobacter,* and *Azospirillum* can fix atmospheric nitrogen supplementing plants. They also produce growth hormones such as auxin, cytokinin, and gibberlins. PGPR is known to produce siderophores (iron-chelating compounds) that reduce soil pathogen growth.

2.6. Chitosan

Chitosan is naturally found in the exoskeleton of insects, nematode eggshells and the fungal cell wall is a deacetylated chitin. They induce a defense response in plants making plants tolerant to disease and stresses. Moreover, they possess antifungal, antibacterial, and antiviral properties. Using it as a soil amendment controls soil-borne disease. Its efficacy depends upon the percentage of deacetylation, molecular weight along with dose and time of application.

2.7. Silicon

Silicon is second in abundance in the earth's crust. However, in soil, it is present in unavailable form. It renders resistance to diseases and pathogens along with

abiotic stress tolerance. It is essential to plants except rice and sugarcane. Some of its benefits include increasing nutrient uptake, water mobility, delayed senescence, etc.

3. Benefits of Biostimulants in Agriculture

• **Enhance Nutrient Uptake** – Biostimulants improve root development, allowing plants to absorb nutrients more efficiently. This leads to better growth, healthier foliage, and increased resistance to nutrient deficiencies.

• **Increase Stress Tolerance** – They help plants adapt to environmental stresses such as drought, salinity, and extreme temperatures. By strengthening natural defense mechanisms, biostimulants enhance plant survival and productivity in challenging conditions.

• **Boost Crop Yield and Quality** – By stimulating plant metabolism and improving nutrient efficiency, biostimulants contribute to higher yields and better-quality produce. They enhance fruit size, color, and shelf life, making crops more marketable.

• **Support Soil Health** – Biostimulants promote beneficial microbial activity, which helps break down organic matter and improve soil fertility. They also enhance soil structure, increasing water retention and aeration for better plant growth.

• **Stimulate Plant Metabolism** – These compounds activate key enzymes and hormones that regulate plant growth processes. This leads to improved germination, faster development, and stronger overall plant health.

• **Reduce Chemical Dependency** – By naturally enhancing plant growth and resilience, biostimulants reduce the need for synthetic fertilizers and pesticides. This lowers production costs for farmers and minimizes environmental pollution.

• **Promote Sustainable Agriculture** – Biostimulants support eco-friendly farming practices by improving soil fertility and reducing chemical runoff. Their use contributes to long-term agricultural sustainability while maintaining high crop productivity.

4. Future Prospects

The future of biostimulants in agriculture looks promising as research continues to enhance their effectiveness and application methods. With the growing demand for sustainable farming practices, biostimulants are expected to play a key role in improving crop resilience and reducing reliance on chemical inputs. However, challenges such as the lack of standardized regulations, variability in product efficacy, and limited farmer awareness hinder their widespread adoption. More scientific studies and field trials are needed to establish consistent results and gain trust among growers. Additionally, advancements in biotechnology and precision agriculture can further optimize the use of biostimulants, making them an essential tool for sustainable and productive farming in the years to come.

5. Conclusion

Biostimulants have emerged as a valuable tool in modern agriculture, offering numerous benefits for plant growth, stress resilience, and soil health. Their ability to enhance nutrient uptake, improve crop quality, and reduce dependence on chemical inputs makes them essential for sustainable farming. Various types of biostimulants, including humic substances, seaweed extracts, protein hydrolysates, beneficial microbes, chitosan, and silicon, contribute to improving plant metabolism and environmental adaptability. Despite their potential, challenges such as inconsistent regulations, limited research, and farmer awareness need to be addressed to ensure wider adoption.

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