NEW ERA AGRICULTURE MAGAZINE

# Biostimulants in Plants: Definition, Concepts, Key Categories, and Regulation

Patel Mrugesh M.[1], Shivam Dinkar[2], Yogita Lather[3], David Lalrochunga[4] and Nihar Ranjan Nayak[5]

**Abstract: -**

A plant biostimulant refers to any substance or microorganism applied to plants to improve nutrient efficiency, enhance tolerance to abiotic stress, and/or improve crop quality, independent of its nutrient content. Commercial products that contain mixtures of these substances and/or microorganisms are also considered biostimulants. The definition outlined in this article is based on scientific knowledge of the nature, modes of action, and effects of biostimulants on crops and horticultural plants. It also aims to facilitate the acceptance of biostimulants in future regulations, particularly in the EU, by distinguishing them from fertilizers, pesticides, or biocontrol agents. Many biostimulants enhance plant nutrition, regardless of their nutrient content. Biofertilizers, a subcategory of biostimulants, boost nutrient use efficiency and create new ways for plants to acquire nutrients. Microbial biostimulants, including mycorrhizal and non-mycorrhizal fungi, bacterial endosymbionts (such as Rhizobium), and Plant Growth-Promoting Rhizobacteria, play a role in this process. These microorganisms can act as both biocontrol agents and biostimulants, and their agricultural effects are critical in determining their regulatory classification. This review provides an overview of the definition and concept of plant biostimulants, as well as their key categories. It also briefly discusses their legal and regulatory status in the EU and US, and highlights the market drivers, opportunities, and challenges for their development.

***Patel Mrugesh M.[1], Shivam Dinkar[2], Yogita Lather[3], David Lalrochunga[4] and Nihar Ranjan Nayak[5]***

*[1]Research Scholar, Department of Microbiology, C. P. College of Agriculture, S. D. A. U., Gujarat*

*[2]Research Scholar, Department of Forestry, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh*

*[3]Research Scholar, Department of Agronomy, CCS Haryana Agricultural University, Hisar, Haryana*

*[4]Research Scholar, Centre for Management Studies, North Eastern Regional Institute of **Science** and Technology, Nirjuli, Arunachal Pradesh*

*[5]Lecturer, Department of Botany, Maa Manikeshwari University, Bhawani Kalahandi, Odisha*

**Introduction**

The term "biostimulant" was likely first coined by horticulture specialists to describe substances that promote plant growth without being classified as nutrients, soil improvers, or pesticides. The earliest known definition of biostimulants can be traced back to a 1997 article in *Ground Maintenance*, a web journal focused on turf management professionals. In this article, Zhang and Schmidt from Virginia Polytechnic Institute and State University defined biostimulants as "materials that, in minute quantities, promote plant growth." The term "minute quantities" was used to differentiate biostimulants from nutrients and soil amendments, which also promote plant growth but are applied in much larger amounts. The biostimulants mentioned in the article included humic acids and seaweed extracts. In later peer-reviewed publications by the same authors, the term "biostimulant" was not always used. For example, a study on the use of humic acids and seaweed extracts to increase drought tolerance in turfgrass did not use the term "biostimulant" but referred to the compounds as "hormone-containing products." This choice could be related to US regulatory rules, where the Environmental Protection Agency (EPA) exempts certain "vitamin-hormone horticulture products" from registration under specific conditions. The term "biostimulant" was first defined in the scientific literature by Kauffman *et al.* (2007) in a peer-reviewed paper, with an updated definition: "biostimulants are materials, other than fertilizers, that promote plant growth when applied in low quantities." Notably, the phrase "other than fertilizers" was added, aligning with Zhang and Schmidt's earlier description, though it was not explicitly stated in their original definition. Kauffman *et al.* (2007) further categorized biostimulants into three main groups based on their source and composition: humic substances (HS), hormone-containing products (HCP), and amino acid-containing products (AACP). They noted that HCPs, such as seaweed extracts, contain detectable amounts of active plant growth substances like auxins, cytokinins, or their derivatives. Over the years, the use of the term "biostimulant" grew in the scientific literature, expanding to encompass a wider range of substances and mechanisms of action (Calvo *et al.*, 2014). Biostimulant became a versatile term referring to any substance beneficial to plants, excluding nutrients, pesticides, or soil improvers. In this context, biostimulants were often defined by what they were not, distinguishing them from fertilizers and pesticides. As research progressed, it became clear that the positive effects attributed to chemical biostimulants (whether natural or synthetic) — such as promoting growth, modulating development, improving quality

traits, and increasing tolerance to environmental stress could also be achieved by bacteria and fungi. For example, plant growth-promoting rhizobacteria (PGPRs) are considered biostimulants due to their beneficial effects on plants, without being nutrients, pesticides, or soil improvers. PGPRs, like chemical substances, can vary widely in nature (e.g., their taxonomic status), and the PGPR category is defined by the agricultural and horticultural benefits they provide. The terms "biofertilizers" and "biocontrol agents" are also used to describe PGPRs, based on the expected outcomes.

**What Are Biostimulants?**

The term "biostimulants" refers to a broad class of substances or microorganisms that, when applied to plants, stimulate natural processes to enhance plant growth, development, and stress tolerance. Unlike fertilizers, which primarily provide essential nutrients to plants, biostimulants work by enhancing plant physiological processes. They are often used in agriculture to improve plant performance under suboptimal environmental conditions, such as drought, soil salinity, and nutrient deficiencies. Biostimulants can be composed of a variety of materials, including organic compounds, microorganisms, and natural extracts, each of which works in different ways to promote plant health. While their use is becoming more widespread, the lack of a universally accepted definition and regulation of biostimulants complicates their integration into commercial agricultural practices.

**Key Concepts of Biostimulants**

1. **Plant Growth Promotion**: Biostimulants can enhance plant growth by stimulating natural plant processes, such as nutrient uptake, enzyme activity, and root development. By improving these processes, plants can grow more efficiently, even under challenging conditions.
2. **Stress Resistance**: One of the key benefits of biostimulants is their ability to increase plant resilience to abiotic stresses, such as drought, extreme temperatures, and nutrient imbalances. They can also help plants withstand biotic stresses like diseases and pests by boosting the plant's natural defence mechanisms.
3. **Soil Health**: Many biostimulants, especially those based on microorganisms, contribute to soil health by enhancing microbial diversity and activity. These microorganisms can help improve soil structure, organic matter decomposition, and nutrient cycling, which benefits plant growth.
4. **Sustainable Agriculture**: The use of biostimulants is seen as a key component of sustainable agricultural practices. They

offer a natural alternative to synthetic chemicals, promoting healthier, more resilient crops with fewer environmental impacts. By improving plant health and yield, biostimulants can reduce the need for chemical fertilizers and pesticides.

**Main categories of plant biostimulants**

Despite ongoing efforts to define the regulatory status of biostimulants, there is currently no legal or regulatory definition of plant biostimulants worldwide, including in the European Union and the United States. This lack of definition prevents a comprehensive listing and classification of the substances and microorganisms that fall under this concept. However, certain major categories are broadly acknowledged by scientists, regulators, and stakeholders (Halpern *et al*., 2015), which include both substances and microorganisms. Microorganisms in this context encompass beneficial bacteria, primarily PGPRs, and beneficial fungi, which can be free-living, rhizospheric, or endosymbiotic. These categories are briefly introduced in the following section and will be further explored in the accompanying papers of this special issue on plant biostimulants in horticulture.

1. **Humic and fulvic acids:** Humic substances (HS) are natural components of soil organic matter, formed through the decomposition of plant, animal, and microbial residues, as well as the metabolic activity of soil microbes utilizing these materials. HS is a collection of diverse compounds, initially classified based on their molecular weight and solubility into humins, humic acids, and fulvic acids. These compounds also exhibit complex dynamics of association and dissociation into supra-molecular colloids, a process influenced by plant roots through the release of protons and exudates. As a result, humic substances and their complexes in the soil arise from the interaction between organic matter, microbes, and plant roots. To effectively use humic substances for enhancing plant growth and crop yield, it is crucial to optimize these interactions. This helps explain why applying humic substances—specifically the soluble fractions of humic and fulvic acids—often yields inconsistent but generally positive results on plant growth. A recent random-effect meta-analysis of HS applications (Rose *et al*., 2014) found an overall dry weight increase of 22 ± 4% for shoots and 21 ± 6% for roots.
2. **Protein hydrolysates and other N-containing compounds:** Amino acids and peptide mixtures are derived through chemical and enzymatic protein hydrolysis of agro industrial by-products, which come

from both plant materials (such as crop residues) and animal waste products (e.g., collagen, epithelial tissues) (Halpern *et al*., 2015). Chemical synthesis can also be used to create either single or mixed compounds. Other nitrogen-containing molecules include betaines, polyamines, and "non-protein amino acids," which are found in higher plants but are not well understood in terms of their physiological and ecological functions (Vranova *et al*., 2011). Glycine betaine, a derivative of an amino acid, is a notable example of well-established anti-stress properties (Chen and Murata, 2011). On a case-by-case basis, these compounds have been found to serve various roles as biostimulants, promoting plant growth (Calvo *et al*., 2014). Direct effects on plants include influencing nitrogen uptake and assimilation by regulating enzymes involved in nitrogen assimilation, their structural genes, and the signaling pathways for nitrogen acquisition in roots.

3. **Seaweed extracts and botanicals:** The use of fresh seaweeds as a source of organic matter and fertilizer dates back to ancient agricultural practices, but their biostimulant effects have only been recognized more recently. This has led to the commercial production of seaweed extracts and purified compounds, which include polysaccharides like laminarin, alginates, and carrageenans, as well as their breakdown products. Other compounds that contribute to plant growth promotion include micro- and macronutrients, sterols, nitrogen-containing compounds such as betaines, and hormones (Khan *et al*., 2009). Many of these compounds are unique to the algae from which they are derived, which explains the growing interest in these organisms from both the scientific community and the industry. Most algae used in these applications are from the brown algae phylum, with genera such as Ascophyllum, Fucus, and Laminaria being prominent, while carrageenans come from red seaweeds, which belong to a distinct phylogenetic group. Khan *et al*. (2009) have listed the product names of more than 20 seaweed-based biostimulants used to promote plant growth.
4. **Beneficial fungi:** Fungi interact with plant roots in various ways, ranging from mutualistic symbioses—where both organisms live in close contact and benefit from each other—to parasitism (Behie and Bidochka, 2014). Plants and fungi have co-evolved since the emergence of terrestrial plants, and the concept of a mutualism-parasitism continuum helps to describe the diverse range of relationships that have

developed over evolutionary time. Mycorrhizal fungi are a diverse group of organisms that form symbiotic relationships with more than 90% of plant species. Among the different types of interactions and taxa involved, Arbuscule-Forming Mycorrhizae (AMF) is a common form of endomycorrhiza found in crops and horticultural plants, where fungal hyphae from Glomeromycota species penetrate root cortical cells and form branching structures known as arbuscules. There is growing interest in using mycorrhiza to support sustainable agriculture, due to the well-recognized benefits of these symbiotic relationships, which enhance nutrient efficiency (particularly for macronutrients like phosphorus and micronutrients), water balance, and protection against both biotic and abiotic stresses in plants.

**Regulation of Biostimulants**

Despite the widespread use of biostimulants, their legal and regulatory status remains unclear. One of the main challenges facing the industry is the lack of a consistent global definition and regulatory framework. The regulatory status of biostimulants varies widely depending on the country and the specific product.

1. **European Union**

In the European Union, biostimulants are not classified under a specific legal category. However, they may fall under various regulations, such as those for fertilizers, plant protection products, or organic farming inputs. The European Commission's Regulation (EU) No. 1009/2019 on fertilizers includes a specific category for biostimulants, allowing their marketing as fertilizers if they meet specific criteria. This regulation, however, does not provide a clear definition of biostimulants, which complicates the establishment of reliable product registers and statistics.

2. **United States**

In the United States, biostimulants are not officially recognized under federal law. The U.S. Environmental Protection Agency (EPA) regulates pesticides, while the U.S. Food and Drug Administration (FDA) oversees food safety. Biostimulants are not directly regulated by these agencies unless they are intended for pesticidal purposes. Consequently, biostimulants are often categorized as "plant growth regulators" or "fertilizers," depending on their composition and claims.

3. **Global Variations**

Beyond the EU and the U.S., the regulation of biostimulants varies significantly across different countries. In some regions,

they are classified as agricultural inputs, while in others, they may be treated as novel products requiring specific approval. This regulatory inconsistency poses a challenge to manufacturers and stakeholders in the biostimulant sector, as it limits market access and creates barriers to international trade.

**Developing the market: opportunities and challenges**

Due to the lack of legal recognition of the concept of biostimulants, market data is limited and not very reliable. The regulatory status of biostimulants varies, depending on whether they are registered under the REACH regulation, classified as fertilizing materials under national laws, considered pesticides under European legislation, or authorized for use in organic farming, among other factors. Biostimulants fall under numerous regulations without being explicitly named, making it difficult to establish product registries or reliable usage statistics. Nevertheless, the European Biostimulants Industry Consortium (EBIC) has provided economic overviews of the biostimulants sector in Europe, based on surveys of its members (EBIC, 2013). While the data is more qualitative than statistical, as acknowledged by EBIC, it suggests that the market is growing steadily (around 10% or more per year), regardless of the indicator used (sales, treated hectares, number of users).

**Conclusion**

Biostimulants represent a promising and innovative approach to enhancing plant growth, stress tolerance, and overall crop quality through natural substances and microorganisms. Despite their potential, the lack of a clear, universally accepted definition and regulatory framework remains a significant challenge. The European Union and the United States, among other regions, have yet to establish a consistent regulatory classification for biostimulants, which complicates market access and hinders reliable product data. Nevertheless, the biostimulant market continues to grow steadily, driven by their role in sustainable agriculture, improving nutrient efficiency, and promoting environmental resilience. As research and regulatory frameworks evolve, biostimulants are poised to become an integral part of modern agricultural practices, offering both economic and environmental benefits.

**References:**

1. Behie, S.W., Bidochka, M.J., 2014. Nutrient transfer in plant-fungal symbioses. Trends Plant Sci. 19, 734–740.
2. Calvo, P., Nelson, L., Kloepper, J.W., 2014. Agricultural uses of plant biostimulants. Plant Soil 383, 3–41.
3. Chen, T.H.H., Murata, N., 2011. Glycine betaine protects plants against

abiotic stress: mechanisms and biotechnological applications. Plant Cell Environ. 34,1–20.

**4.** EBIC, 2013. Economic overview of the biostimulants sector in Europe. European Biostimulants Industry Council. http://www.biostimulants.eu/2013/04/2013-overview-of-the-european-biostimulants-market.

**5.** Halpern, M., Bar-Tal, A., Ofek, M., Minz, D., Muller, T., Yermiyahu, U., 2015. The use of biostimulants for enhancing nutrient uptake. In: Sparks, D.L. (Ed.), Advances in Agronomy, Vol. 129, pp. 141–174.

**6.** Kauffman, G.L., Kneivel, D.P., Watschke, T.L., 2007. Effects of a biostimulant on the heat tolerance associated with photosynthetic capacity, membrane thermostability, and polyphenol production of perennial ryegrass. Crop Sci. 47,261–267.

**7.** Khan, W., Rayirath, U.P., Subramanian, S., Jithesh, M.N., Rayorath, P., Hodges, D.M., Critchley, A.T., Craigie, J.S., Norrie, J., Prithiviraj, B., 2009. Seaweed extracts as biostimulants of plant growth and development. J. Plant Growth Regul. 28,386–399.

**8.** Rose, M.T., Patti, A.F., Little, K.R., Brown, A.L., Jackson, W.R., Cavagnaro, T.R., 2014. Ameta-analysis and review of plant-growth response to humic substances: practical implications for agriculture. In: Sparks, D.S. (Ed.), Advances in agronomy, Vol. 124, pp. 37–89.

**9.** Vranova, V., Rejsek, K., Skene, K.R., Formanek, P., 2011. Non-protein amino acids: plant, soil and ecosystem interactions. Plant Soil 342, 31–48.