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Ingevity: Biostimulants - The future of plant protection

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With a growing global population and declining arable land for crop production, manufacturers, farmers and governments are witnessing tremendous pressure to meet the increasing demand for food production while maintaining sustainable agriculture practices.[1] Extreme environmental conditions and dynamic changes in climatic conditions increase the chances of abiotic stresses and their impact on crop yields. These factors have led to the development of biostimulant products that provide a viable alternative to traditional plant protection offerings toward more sustainable agriculture by helping plants maintain crop nutrition sustenance throughout the plant growth cycle.

Biostimulants have emerged as innovative technical solutions, providing a viable alternative to plant protection products with the ability to effect significant change within the agricultural sector towards more sustainable agriculture. The term "plant biostimulant" has been in use since 1997, yet there is no globally accepted definition for legal, regulatory or commercial purposes. Recently, Europe published the European Fertilizer Regulation (EC) No. 2019/1009 which includes a definition for biostimulants and a regulatory path for registrations of these products across the European Union (EU) member states. Effective in 2022, the EU regulation will help kick off the development of new standards for processes and methods in European

regions.[2]

The EU defines plant biostimulants as substance(s) and/or microorganisms whose function when applied to plants or the rhizosphere is to stimulate natural processes to enhance nutrient uptake, nutrient efficiency, tolerance to abiotic stress and crop quality. The U.S. 18 H.R. 2: Agriculture Improvement Act of 2018 (formerly referred to as the Farm Bill) defines a biostimulant as "a substance or microorganism that, when applied to seeds, plants, or the rhizosphere, stimulates natural processes to enhance or benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress or crop quality and yield." 2 This definition is generally accepted in the U.S. by the Biological Products Industry Association (BPIA) and recognized by regulatory authorities and the general crop protection market. Biostimulants do not directly impact pests, pathogens or weeds, but improve plants' and soils' natural processes resulting in increased resilience to abiotic stressors and increased harvest yields.

Various types of biostimulants impact plants and rhizospheres, as seen in Figure 1. Biostimulants are typically divided into five groups: amino acids, microbials, plant extracts, organic acids and seaweed extracts. Although considered a separate group, biofertilizers are often linked with biostimulants. [3,4] The broad group of biostimulant products offer significant performance variability.

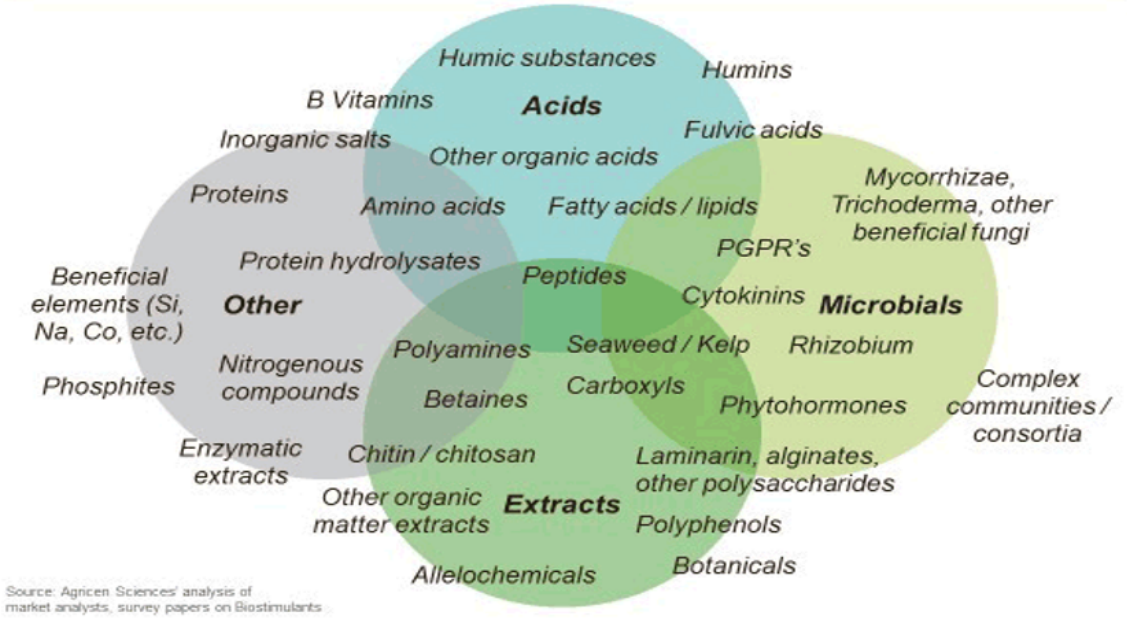

Figure 1. Sources of biostimulants[3]

Amino acids

Amino acid products (along with other protein-derived biostimulants based on peptides or protein hydrolysates) are derived from the chemical or enzymatic hydrolysis of animal, plant or microbial protein. The protein sources are often recycled waste products of agricultural crop residues or animal processing such as collagen, epithelial tissue, crustacean shells and other materials. Recycling these substances into useful agricultural products is a unique environmental benefit of protein-derived biostimulants. Performance benefits include improved soil fertility, better plant health and vigor, enhanced crop yields and quality, and increased stress tolerance.[5]

Microbials

Consisting of beneficial fungi and bacteria, microbials are considered the smallest category of biostimulants but are rapidly growing within the industry. Microbial products can include "pure strain" fermentation solutions, based on individual isolates, consortia of mixed or co-fermented isolates, or much more complex "natural" communities derived from organic matter processing. Microbial products have proven to enhance plant growth through various direct and indirect mechanisms. Some of the most well-known microbial biopesticides that also function as biostimulants are *Bacillus subtilis* and *Trichoderma harzianum*. Many newly discovered biofungicides provide both biofungal and biostimulant activities, impacting innate resistance system of plants.[4,6]

Plant extracts

Plant extracts (also known as "botanicals") are less represented by research but represent a fast-growing category of biostimulants. The use of allelochemicals—active plant compounds that can be extracted and concentrated—is an active area of both industry and academic investigation. Allelochemicals are chemical compounds released from the roots of plants into the soil that suppress or sometimes kill neighboring plants. Several plants produce allelochemicals, including common plants like English laurel, bearberry, sumac, rhododendron, elderberry, forsythia and garlic.[4.6]

Humic and fulvic acids

Humic substances, which include humic and fulvic acids, make up a majority of the organic matter in the world's soils. Humic and fulvic acids are complex organic molecules that form in the soil as byproducts of the decomposition and microbial metabolism of plant and animal residues. While materials can vary in molecular structure and weight, humic substances have been utilized for decades to improve soil structure and function (e.g., to chelate nutrients and improve cation exchange capacity), enhance plant nutrition, and contribute to improved crop yield and quality. The substances can be applied in multiple ways, including direct application to the soil, foliar application, incorporation into fertilizer and other products, and through irrigation water.[7,8]

Seaweed

Seaweed has been used in agriculture to improve fertility by augmenting soil organic content since the 14th century. Seaweed extracts, also referred to as kelp or sea kelp extracts, are currently used in more concentrated means to deliver specific benefits to soils and plants, such as improving soil structure, water retention and aeration, as well as helping to fix or chelate nutrients. Seaweed extracts also aid in the functioning of beneficial soil microorganisms, and improve the provisioning, uptake and utilization of plant nutrients. The effect is attributed to the presence of the plant growth hormones, as well as unique polysaccharides and polyphenols. Most commercial seaweed extracts are made from brown seaweed, including species of *Ascophyllum, Fucus, Laminaria, Sargassum* and *Turbinaria*. Extracts are active at low

concentrations suggesting a direct nutritional effect and as well as a systemic stimulation of the plant.[9]

Biofertilizer	Biostimulants				
Microbials	**Amino acids**	**Microbials**	**Plant extracts**	**Organic acids**	**Seaweed extract**
N fixing bacteria	Protein hydrolysate	Beneficial fungi	Botanicals	Humic acid	Brown seaweed
K, P mobilizers and solubilizers	Individual amino acids	Beneficial bacteria	Allelochemicals	Fulvic acid	
Micronutrient's mobilizers and solubilizers					

Figure 2. Types of biostimulants and biofertilizers[3]

Biofertilizer

Although considered a separate category, biofertilizers are often linked with biostimulants due to the current registration process of biostimulants through the fertilizer routes in many countries. Biofertilizers contain living microorganisms that colonize the soil, rhizosphere or the interior of the plant and promote growth by increasing the supply or availability of primary nutrients to the host plant. Biofertilizers are often divided into Plant Growth Promoting Bacteria (PGPB), Free Living Fungi and Arbuscular Mycorrhiza Fungi (AMF). [10,11,12,13]

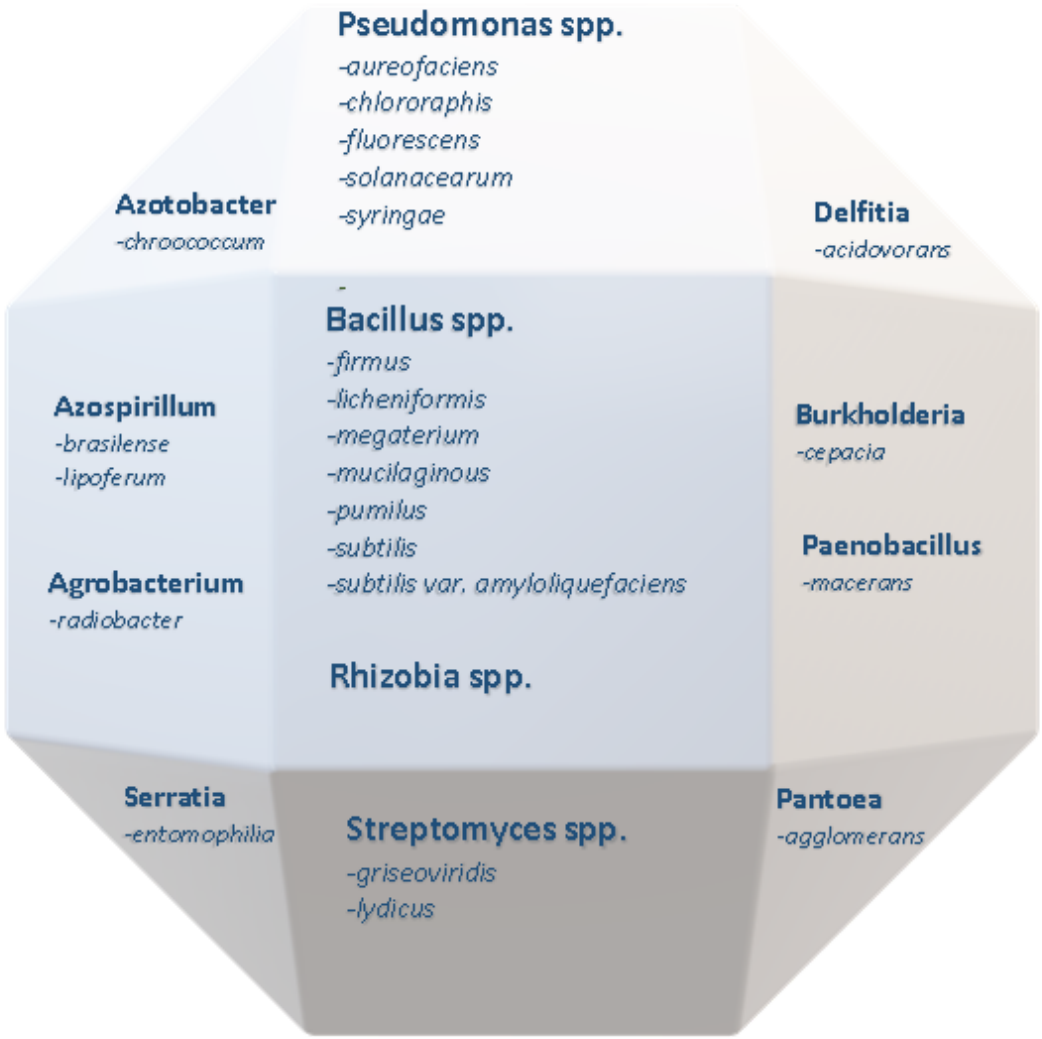

Figure 3. The most common plant growth promoting bacteria[9,10]

Increasing global market demands of biostimulants

The current global biostimulants market is estimated to be valued at $3 billion a year, with a projected annual growth rate of 12-15%.[3,6] However, the variety of the products used, lack of common nomenclature and complicated regulatory process make it difficult to identify the true market size. Humic substances and seaweed extracts currently lead the market, representing more than 50%, but other products like amino acids and microbials are gaining importance within the industry. In most countries, biostimulants are not required to be registered, causing consumer skepticism due to the lack of regulation. The need for more research to provide clearer guidance to farmers on which biostimulants prove most beneficial to specific crops in varied soil and climatic conditions is gaining importance, as well as how different growing practices impact product performance. Additionally, the industry shift toward more sustainable options underscores the value of biostimulants to positively influence holistic agriculture and promote organic practices.

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