Applications of Bio stimulants in Vegetable Production

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Vegetables are vital sources of essential nutrients like vitamins, dietary fibre and antioxidants. They also provide important minerals, folic acid, dietary fibre, and bioactive compounds such as phenolics and flavonoids, all of which play vital roles in supporting human metabolism (Abobatta, 2021). The rising awareness of the health benefits associated with vegetable consumption has driven a surge in demand. According to FAOSTAT, global production of vegetables nearly doubled between 2000 and 2021, increasing from 687 to 1115 million tons (FAO, 2023). This growth has necessitated an expansion of cultivated areas. However, the sustainability of these production methods warrants careful examination. Horticultural practices are predominantly characterized by open-field, seasonal, and intensive cropping systems that rely heavily on chemical inputs to achieve profitable yields. This approach, often implemented in water-scarce regions, raises concerns about the long-term viability of vegetable production. Key challenges include ensuring adequate water supply, maintaining soil fertility, and effectively managing pests and diseases (Melini et al., 2023).

In recent decades, the agricultural industry has increasingly sought sustainable solutions to address the growing global demand for food and the challenges posed by climate change (Del Buono, 2021). Biostimulants, a class of substances that stimulate plant growth and development, have emerged as a promising approach to enhance crop productivity and resilience. The global market for biostimulants is experiencing significant growth, driven by increasing awareness of their benefits and the need for sustainable agricultural practices. The biostimulant sector is projected to experience significant market growth, with an anticipated compound annual growth rate of 11.24%, reaching up to USD 4.9 billion by 2025 (Caradonia et al., 2019). Currently, six distinct categories of biostimulants are recognized in the agricultural sector. These include: Microbial inoculants, Humic substances, such as humic and fulvic acids, Protein hydrolysates and amino acids, Biopolymers, Inorganic compounds and Seaweed extracts. All of these biostimulants are commercially available and have a wide range of applications in agriculture. The use of biostimulants can be regarded as an effective and sustainable method for nutritional crop supplementation, potentially mitigating the environmental issues linked to excessive fertilization. Consequently, there is a growing interest within the agricultural sector for new biostimulant products, prompting extensive research in this rapidly evolving area of the industry. These products, derived from diverse sources such as microorganisms, plants, and minerals, can improve nutrient uptake, stress tolerance, and overall plant health (Shahrajabian et al., 2021). The major impacts of biostimulants on crops are illustrated in Figure 1.

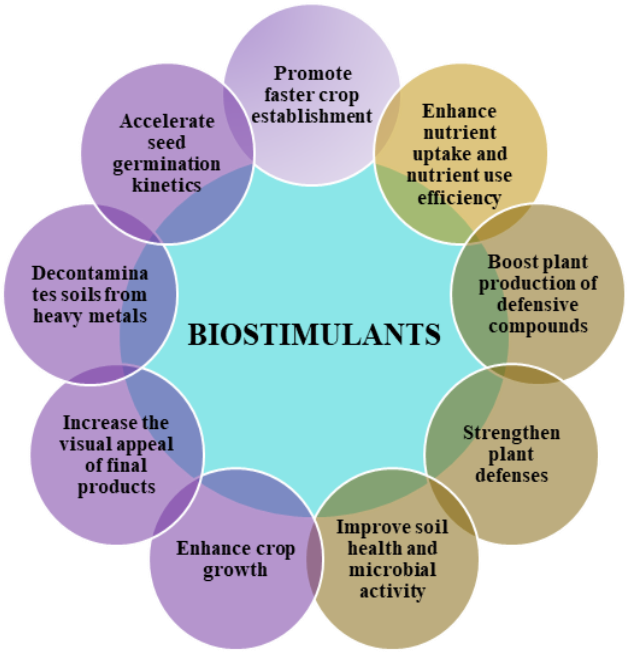

Fig 1: The key biostimulant effects on crops

Mechanisms of Action

Biostimulants exert their effects through various mechanisms (Fiorentino et al., 2018), including:

- **Hormonal Regulation:** Many biostimulants modulate the activity of plant hormones, such as auxins and cytokinins, to influence growth and development.

- **Nutrient Uptake and Utilization:** By enhancing root development and nutrient transport, biostimulants can improve nutrient uptake and use efficiency.
- **Stress Tolerance:** Biostimulants can help plants cope with abiotic stresses like drought, salinity, and extreme temperatures by inducing physiological and biochemical responses.
- **Soil Health Improvement:** Some bio stimulants can stimulate microbial activity in the soil, leading to improved soil structure and nutrient cycling.

Table 1 Biostimulants effect on vegetable crops

Crop	Biostimulant	Effects	Reference
Tomato	Application of plant growth promoting bacteria	Increased growth, yield and quality of tomato crop	Katsenios et al., 2021
Tomato	Incorporation of humic acids and/or ground maize grain	Enhanced shoot and root development, increased relative water content, improved membrane stability of transplants, and better uptake of macronutrients.	Rady et al., 2016
Eggplant	Foliar application of aqueous garlic bulb extract	A single application enhanced plant growth, improved photosynthetic parameters, and increased the activity of antioxidant enzymes.	Ali et al., 2019
Pepper	Application of a lipo-complex biostimulant primarily composed of polysaccharides, polypeptides, and vitamins	Improved levels of phenylalanine and metabolites associated with fruit ripening, including organic acids, monosaccharides, and carotenoids.	Barrajón-Catalán et al., 2020
Onion	Biostimulants composed of humic acids, organic substances, amino acids, carbon, boron, or algae extracts.	Increased plant growth and yield, as well as extended shelf life of bulbs.	Shehata et al., 2017
Amaranth	Combination of plant growth-promoting rhizobacteria (PGPRs) and extracts of Ecklonia maxima.	Enhanced plant growth and photosynthetic pigment content, along with stress alleviation.	Ngoroyemoto et al., 2020
Broccoli	Combination of foliar spraying with Ascophyllum nodosum extracts and watering with amino acids for broccoli plants exposed to water stress and subsequent re-watering.	Enhanced photosynthetic parameters under conditions of water stress.	Kałużewicz et al., 2017
Potato	Foliar application of biostimulants containing extracts of A. nodosum, E. maxima, or humic and fulvic acids.	Enhanced yield under drought stress and improved marketable yield.	Dziugieł et al., 2020
Lettuce	Application of endophytic fungi based biostimulant	Increased growth, yield and quality of lettuce under salinity stress	Saia et al., 2021
Cucumber	Application of salt-tolerant plant growth promoting bacteria	Increased plant growth, biomass, root length, root weight, chlorophyll, proline, total phenol, root and shoot N and P, and ascorbic acid under salinity stress	Kartik et al., 2021

Applications of Biostimulants in Vegetable Crops

Over the past two decades, the use of biostimulants has emerged as an effective and sustainable method for promoting plant growth in both optimal and stressful conditions. These products comprise various microorganisms and components that stimulate plant growth while reducing the need for fertilizers Shahrajabian et al., 2021). The applications and effects of biostimulants in different vegetable crops are listed in Table 1.

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