



Plant bio- stimulants in vegetable crops mechanism application and future prospects

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Abstract

Plant bio-stimulants are natural substances or beneficial microorganisms that enhance plant growth, nutrient uptake, stress tolerance, and crop productivity without acting as conventional fertilizers. Major bio-stimulants include seaweed extracts, humic and fulvic acids, protein hydrolysates, amino acids, beneficial microbes such as PGPR and arbuscular mycorrhizal fungi (AMF), and chitosan-based products. These compounds improve root development, photosynthetic efficiency, nutrient absorption, antioxidant activity, and resistance to abiotic stresses such as drought, salinity, and heat. In vegetable crops, bio-stimulants enhance seed germination, plant vigour, yield, quality, and shelf life while reducing dependence on chemical fertilizers. They can be applied through seed treatment, foliar spray, soil drenching, or fertigation. Despite their promising benefits, challenges such as inconsistent field performance, product standardization, and limited farmer awareness remain. crop-specific formulations, understanding molecular mechanisms, and integrating bio-stimulants into sustainable and climate-resilient vegetable production systems. (Du Jardin *et al.*, 2015)

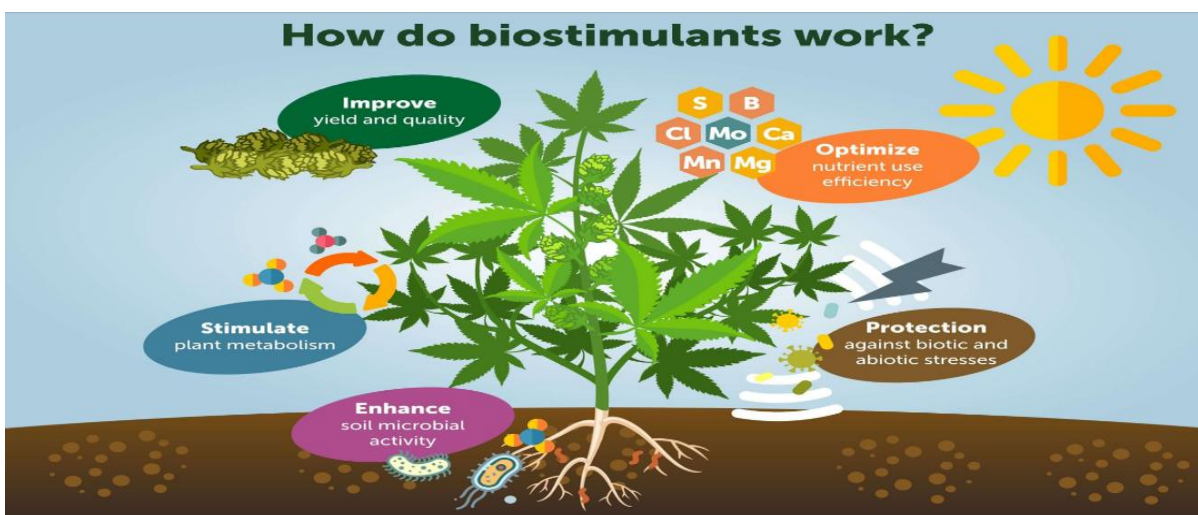
Keywords: Plant bio-stimulants, seaweed extract, humic acid, PGPR, AMF, vegetable crops

INTRODUCTION

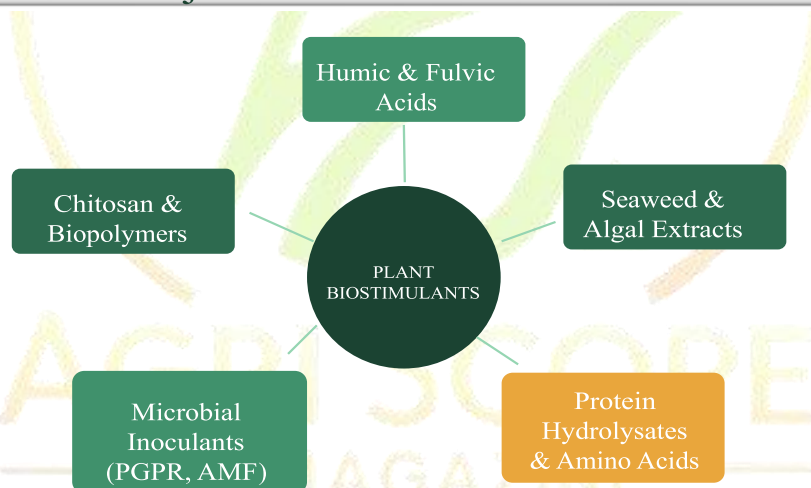
Vegetables are an essential component of the human diet, providing vital nutrients, vitamins and minerals. However, intensive cultivation practices, declining soil fertility and climatic challenges often limit vegetable productivity. Nowadays farmers are more inclined to get benefited by the various alternate. systems therefore indiscriminate use of chemicals is more popular. In recent years, bio-stimulants have gained importance as a sustainable tool to boost



growth and yield in vegetables while maintaining ecological balance. Biostimulants are the natural formulation extracted from different seaweeds, plants and other materials. According to the European Biostimulants Industry Council (EBIC), bio-stimulants are substances or microorganisms that stimulate natural processes in plants, improving nutrient uptake efficiency, abiotic stress tolerance and crop quality



Five Major Classes of Plant Biostimulants



Seaweed Extracts

Seaweed and algal extracts are bio-stimulant products obtained from marine algae. They contain various bioactive compounds, minerals, polysaccharides, and plant growth-promoting substances. They can stimulate several physiological processes in plants and are mainly used to improve seed germination, root development, shoot growth, nutrient uptake, stress tolerance, and fruit quality. (Du Jardin *et al.*, 2015)

Major effects:

- Improve seed germination and seedling establishment.



- Promote root and shoot development.
- Improve nutrient uptake and utilization.
- Support photosynthetic activity.
- Improve tolerance to environmental stresses.
- Enhance fruit and vegetable quality.

Humic and Fulvic Acids

Humic and fulvic acids are organic substances mainly derived from decomposed organic matter. They are important biostimulant substances that can improve the soil environment as well as plant nutrient acquisition. Their major role is to improve nutrient availability, nutrient uptake, root development and soil structure. Better root-zone conditions can help plants utilize available nutrients and water more efficiently.

Major effects:

- Promote root growth and development.
- Improve nutrient uptake.
- Improve soil structure.
- Enhance the root-zone environment.
- Support plant growth and development.
- Improve nutrient-use efficiency.

Protein Hydrolysates and Amino Acids

Protein hydrolysates are obtained through the breakdown of proteins into smaller peptides and amino acids. They can provide organic nitrogen and stimulate important physiological and biochemical processes in plants. Amino acids are involved in several metabolic processes, while protein hydrolysates can stimulate enzyme activity and support plant growth. (Du Jardin *et al.*, 2015)

Major effects:

- Provide organic nitrogen.
- Stimulate enzyme activity.
- Support chlorophyll synthesis.
- Promote plant growth and development.
- Improve nutrient-use efficiency.
- Support stress tolerance.
- Improve yield and crop quality.



Microbial Bio-stimulants

Microbial biostimulants contain beneficial microorganisms that interact positively with plants and their root-zone environment. Examples include *Azospirillum*, *Bacillus* and *Trichoderma*. These microorganisms can improve nutrient availability and contribute to plant health and disease resistance.

Major effects:

- Improve nutrient availability.
- Promote root development.
- Enhance rhizosphere activity.
- Support plant growth.
- Improve disease resistance.
- Support tolerance to environmental stresses.
- Improve beneficial soil microbial activity.
- Important groups: PGPR (Plant Growth-Promoting Rhizobacteria) and AMF (Arbuscular Mycorrhizal Fungi).

Chitosan and Other Natural Compounds

Chitosan is a natural biopolymer that can act as a plant biostimulant by stimulating the plant's natural defence responses. It is particularly useful in helping plants respond to environmental stresses such as drought and salinity. Chitosan can therefore contribute to improved plant resilience under unfavourable growing conditions. (Du Jardin *et al.*, 2015)

Major effects:

- Stimulates natural plant defence responses.
- Supports drought tolerance.
- Supports salinity tolerance.
- Enhances stress-response mechanisms.
- Supports plant growth and quality.
- Helps plants cope with environmental stresses.

Mechanisms of Action

Biostimulants Act Through Multiple Physiological And Biochemical Pathways:

Enhanced Nutrient Uptake: Stimulate root growth and nutrient absorption.

Improved Photosynthesis: Increase chlorophyll content and enzymatic efficiency.

Stress Tolerance: Activate antioxidant systems to combat drought, heat, and salinity.

Improved Soil Microbiome: Support beneficial microbial communities that enhance soil fertility.



Quality Enhancement: Improve flavor, color, vitamin content, and shelf life of vegetables (Colla *et al.*, 2017)

Seaweed Application in different crops

Seaweed Species	Crop	Concentration	Treatment Response
Ascophyllum nodosum	Tomato	0.2–0.5%	Improved germination 20–30%; root length 18–25%; shoot length 15–25%; seedling dry weight 20–35%
Ascophyllum nodosum	Onion	0.2–0.3%	TSS 8–10%; N, P & K uptake 8–15%; bulb weight 10–20%; yield 18–30%
Ascophyllum nodosum	Carrot	0.2–0.4%	Increase in soil microbial activity 20–35% and yield 15–25%

Application in Vegetable Crops

Crop	Bio-stimulant	Observed Effect
Tomato	Humic acid	Increased fruit yield 20–30% and lycopene content 15–25%
Cucumber	Microbial inoculants	Enhanced nutrient uptake 15–25% and disease resistance 20–30%
Onion	Protein hydrolysate	Improved bulb size 15–25% and shelf life 20–30%
Capsicum	Chitosan	Stress tolerance 20–35% and fruit firmness 10–20%
Spinach	Amino acid formulation	Higher chlorophyll content 20–35% and leaf area 15–30%

(Rouphael and Colla., 2020)

Advantages of Using Bio-stimulants

1. Environmentally friendly and biodegradable
2. Reduce dependence on chemical fertilizers and pesticides
3. Enhance soil health and fertility
4. Improve crop yield and quality
5. Compatible with organic farming practices

Challenges and Future Prospects

Bio-stimulants faces certain challenges such as product standardization, variable field performance, and limited awareness among farmers. Future research should focus on:

1. Molecular mechanisms of bio-stimulant action
2. Development of crop-specific formulations
3. Integration with precision agriculture technologies.



4. Regulatory frameworks to ensure quality and efficacy

Conclusion

Bio-stimulants represent a revolutionary approach in modern vegetable production, promoting sustainable and resilient farming systems. their integration into conventional and organic vegetable cultivation can significantly improve productivity, quality, and environmental sustainability. with continued. research and awareness, bio-stimulants can play a pivotal role in achieving the goals of climate-smart and eco-friendly agriculture

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