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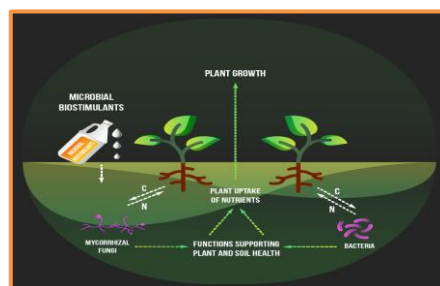
Biostimulants in Vegetable Crops: Types and Role

Balbir Singh Dogra, *Anjali Kumari and Shivali Dhiman

Department of Vegetable Science, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh), India

*Corresponding Author's email: anjalidrungal0055@gmail.com

Bioestimulants are natural substances or microorganisms that enhance plant growth and development by stimulating physiological processes rather than directly supplying nutrients. Biostimulants improve soil health and microbial activity, leading to better nutrient availability. They also promote physiological processes such as photosynthesis and enzyme activity, thereby increasing plant vigour.



Types of Biostimulants

Biostimulants are classified into several categories:

1. Seaweed Extracts

Seaweed extracts are obtained from marine algae (brown, red and green algae) and are among the most widely used biostimulants in horticulture. They are rich in minerals, vitamins, amino acids, polysaccharides (like alginates and fucoidans) and natural plant hormones such as auxins, cytokinins and gibberellins. These bioactive compounds stimulate seed germination, root growth, flowering and fruit development. They also enhance plant tolerance to abiotic stresses like drought, salinity and temperature extremes by improving water retention and activating stress-responsive genes.

Examples:

- Extracts of *Ascophyllum nodosum* are used in tomatoes to increase yield and improve fruit quality.
- *Kappaphycus alvarezii* extract applied in okra and brinjal enhances growth and nutrient uptake.

2. Humic Substances

Humic substances are natural organic compounds formed from the decomposition of plant and animal residues in soil. They are mainly classified into humic acids, fulvic acids and humin. They improve soil structure, aeration and water-holding capacity, making the soil more fertile. Humic substances also enhance nutrient availability by forming complexes with minerals and facilitating their uptake by plant roots. Additionally, they stimulate root growth and increase enzyme activity in plants.

Examples:

- Soil application in tomato and potato increases root development and yield.
- Foliar spray of fulvic acid in vegetable crops enhances micronutrient absorption like iron and zinc.

3. Protein Hydrolysates

Protein hydrolysates are derived from the breakdown of proteins from plant (soybean, alfalfa) or animal sources (collagen, fish waste). They contain free amino acids, peptides and small organic molecules. These compounds act as signaling molecules that stimulate plant metabolism. They enhance nutrient uptake, enzyme activity, chlorophyll synthesis and stress

tolerance. They are particularly useful under stress conditions such as drought, salinity and temperature stress.

Examples:

- Application in tomato and pepper increases fruit size, yield and sugar content.
- Use in lettuce and spinach enhances leaf area and chlorophyll content.

4. Beneficial Microorganisms

Beneficial microorganisms are living organisms that enhance plant growth by improving soil fertility and plant health. These include nitrogen-fixing bacteria, phosphate-solubilizing bacteria, mycorrhizal fungi and plant growth-promoting rhizobacteria (PGPR).

They promote plant growth through mechanisms such as:

- Nitrogen fixation (conversion of atmospheric nitrogen into usable form)
- Phosphate solubilization (making phosphorus available to plants)
- Production of plant hormones (auxins, cytokinins)
- Disease suppression through competition and antibiosis

Examples:

- *Rhizobium* in legumes (pea, beans) improves nitrogen fixation and yield.
- *Azotobacter* and *Azospirillum* enhance growth and yield in vegetables.
- Mycorrhizal fungi (*Glomus* spp.) improve phosphorus uptake in onion.

Modes of Action of Biostimulants

1. Enhancing Nutrient Uptake and Efficiency

Biostimulants improve the ability of plants to absorb and utilize nutrients from the soil. They stimulate root growth, increase root surface area and enhance root hair development, which allows better exploration of soil. Some biostimulants also activate membrane transport proteins that help in the uptake of nutrients like nitrogen, phosphorus, potassium, iron and zinc. Additionally, substances like humic acids form complexes with nutrients, making them more available to plants. As a result, plants use fertilizers more efficiently, reducing nutrient losses and improving growth.

2. Stimulating Hormone-like Activity

Many biostimulants contain natural plant growth substances or compounds that act like plant hormones. For example, seaweed extracts contain auxins, cytokinins and gibberellins. These compounds regulate important processes such as cell division, elongation, root initiation, flowering and fruit development. Even when actual hormones are not present, biostimulants can trigger the plant to produce its own hormones. This leads to balanced growth, improved crop development and better yield.

3. Improving Soil Microbial Activity

Biostimulants promote the growth and activity of beneficial soil microorganisms such as bacteria and fungi. These microbes help in nitrogen fixation, phosphate solubilization and decomposition of organic matter. They also produce growth-promoting substances and improve soil structure. For example, plant growth-promoting rhizobacteria (PGPR) enhance nutrient availability and protect plants from harmful pathogens. A healthy microbial population improves soil fertility and supports sustainable crop production.

4. Activating Plant Defense Systems

Biostimulants enhance the natural defense mechanisms of plants against diseases and pests. Certain compounds like chitosan and seaweed-derived substances act as elicitors, which trigger the production of defense-related proteins, enzymes and secondary metabolites. These include phytoalexins and pathogenesis-related proteins that help plants resist infections. This induced resistance reduces dependency on chemical pesticides and improves plant health.

5. Enhancing Photosynthesis and Metabolism

Biostimulants increase photosynthetic efficiency by improving chlorophyll content and enzyme activity in plants. They enhance the functioning of key enzymes involved in carbon fixation and energy production. This results in better conversion of sunlight into energy and increased production of carbohydrates. Improved metabolism also supports processes like

protein synthesis and nutrient assimilation, leading to vigorous plant growth and higher productivity.

6. Protecting Plants Against Oxidative Stress

Under stress conditions such as drought, salinity or extreme temperatures, plants produce harmful molecules called reactive oxygen species (ROS). These can damage cells, proteins and membranes. Biostimulants contain antioxidants or stimulate the production of antioxidant enzymes like superoxide dismutase, catalase, and peroxidase. These compounds neutralize ROS and protect plant cells from damage. This helps plants survive stress conditions and maintain growth and yield.