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Plant biostimulants in ornamentals: Enhancing growth and stress tolerance

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Abstract: Researchers have recently sought a comprehensive strategy to reduce the harmful effects of synthetic chemicals in agricultural production to improve productivity and quality. Biostimulants benefit plants by protecting soil and water resources and eliminating adverse environmental effects from pesticides and chemical fertilizers. Plant biostimulants, also called bioactivators, are becoming increasingly well-liked in the agricultural sector due to their capacity to boost a plant's growth rate and increase its resistance to stress. Biostimulants are frequently used because they can increase crop quality, nutrient assimilation, growth rate, and stress tolerance. This article thoroughly examines biostimulants' effects on ornamental plants, concentrating on their ability to withstand environmental stressors. Prior studies have demonstrated that a combination of non-pathogenic microbes, protein hydrolysates, humic and fulvic acids, and algal extracts benefits ornamental plants. This review's main aims are biostimulants' effects on raising agricultural yield, enhancing nutrient uptake, enhancing photosynthesis, and shielding plants from biotic and abiotic stress. The role of biostimulants in more resilient and sustainable farming practices is also covered.

1. Introduction

The ornamental industry contributes significantly to both the global economy and agribusiness. It covers various activities, such as cultivating, distributing, and consuming flowers and attractive plants. The ornamental sector's economic worth, environmental benefits, and cultural relevance demonstrate its significance. Worldwide, ornamental plant and flower production and trade produce significant money (Reis *et al.*, 2020; Krigas *et al.*, 2021). Employment opportunities are available in the sector, especially for small and family-run firms (Reis *et al.*, 2020). Additionally, the ornamental sector improves the aesthetic appeal of parks, gardens, and public places, contributing to the beauty of urban and natural landscapes (Rocha *et al.*, 2022). Additionally, ornamental plants have crucial environmental responsibilities as biological filters, wildlife habitats, and environmental purification agents (Rocha *et al.*, 2022). Ongoing innovation and developments in technology characterize the decorative industry. Digital tools and sensors are used in precision agriculture to monitor plant health, maximize resource utilization, and increase output efficiency. With the help of these technologies, producers can make better decisions, lessen their influence on the environment, and improve the quality of their decorative plants (Traversari *et al.*, 2021).

Plant biostimulants have drawn much interest in agriculture as a sustainable way to promote plant growth and raise crop output. Biostimulants containing organic materials and microbes have been discovered to improve stress tolerance, boost nutrient intake, and encourage growth crops (Parađiković *et al.*, 2019). Biostimulants present intriguing prospects to strengthen growth, quality, and stress tolerance in the context of ornamental plants, consequently enhancing the overall productivity of ornamental crops. Biostimulants can come from various sources, including non-pathogenic microorganisms, humic and fulvic acids, protein hydrolysates and algal extracts. These biostimulants have been shown to benefit plant growth in several ways, including higher yield, improved nutrient uptake and utilization, increased photosynthetic activity, and resistance to biotic and abiotic stresses (Calvo *et al.*, 2014). For biostimulants to be used effectively in horticulture, it is essential to understand the mechanisms underlying their impacts on ornamental plants. To thoroughly review the most recent studies on using biostimulants in cultivating ornamental plants, this study will examine their most recent findings. It will discuss the various biostimulants and how they affect ornamental crops' development and stress resilience. The evaluation will also examine how biostimulants might support resilient and sustainable horticulture.

2. Types of plant biostimulants

Microbial inoculants, such as arbuscular mycorrhizal fungi (AMF) and plant growth-promoting rhizobacteria (PGPR), are advantageous microorganisms that can boost nutrient uptake and increase stress tolerance in plants (Calvo *et al.*, 2014; González-González *et al.*, 2020). These biostimulants form symbiotic interactions with plants, which have several benefits, including increasing soil structure, nutrient availability, and plant defence systems. Organic molecules known as humic acids are produced when organic matter breaks down and are prized for their capacity to improve soil fertility, nutrient availability, and overall plant growth (Calvo *et al.*, 2014). They aid in forming roots, make nutrient absorption easier, and increase plant metabolism (Yakhin *et al.*, 2017). Fulvic acids, which are related to humic acids but have smaller molecules and better solubility, work in a manner comparable to that of humic acids. They help increase nutrient availability, root growth, and plant growth (Calvo *et al.*, 2014). Protein hydrolysates contain amino acids and peptides that help plants develop, absorb nutrients, and withstand stress. Amino acids are also created when proteins are broken down enzymatically (Calvo *et al.*, 2014; Ivankov *et al.*, 2021). These biostimulants increase plant vitality, encourage photosynthetic activity, and aid in root development. In agriculture, seaweed extracts, especially those from species like Ascophyllum nodosum, are frequently utilized as biostimulants (Calvo *et al.*, 2014; De Saeger *et al.*, 2019). Just a few of the bioactive components discovered in seaweed extracts that aid plants in growing, better-absorbing nutrients, and withstanding stress include hormones, polysaccharides, betaines, and phenolic compounds (De Saeger *et al.*, 2019; Boukhari *et al.*, 2020).

3. Molecular and physiological mechanism of plant biostimulants

Numerous studies have focused on the molecular and physiological processes of plant biostimulants. Several processes and routes are involved in how biostimulants positively affect plant growth, stress tolerance, and overall performance. One typical mechanism is the stimulation of crucial enzymes in nitrogen metabolism and the induction of hormone-like activity, such as auxin and gibberellin.

Biostimulants can modify a plant's root system and enhance its nutritional status. Increasing root biomass, density, and lateral root branching improves nutrient intake, assimilation, and translocation (Caruso *et al.*, 2019). It has been found that biostimulants can modulate phytohormones such as auxins, cytokinins, and gibberellins to affect plant growth and development. Additionally, they can boost photosynthesis, reduce aging, boost nutrition and water intake, and activate genes that defend against abiotic threats (Yakhin *et al.*, 2017). The metabolic changes caused by biostimulants have been better understood because of metabolomic studies. For instance, it has been shown that utilizing microbial biostimulants impacts metabolism, increasing the levels of tricarboxylic acid (TCA) intermediates, altering the amounts of amino acids, and changing the composition of phenolics and lipids. With these metabolic changes, plants are drought-resistant, have better defensive preconditioning, and promote growth. Additionally, biostimulants can modify redox homeostasis, strengthen plant cell walls, regulate osmoregulation, boost energy production, and remodel membranes, making plants more resilient and stress-tolerant (Nephali *et al.*, 2021). Plant biostimulants' molecular and physiological mechanisms involve several interactions and processes that enhance plant growth, stress tolerance, and overall performance. These techniques also control enzyme activity, metabolic adjustments, hormone-like effects, and the activation of genes and pathways related to development, stress response, and nutrient intake.

4. Mechanisms of action of plant biostimulants

The mechanisms of action of plant biostimulants are still not fully understood due to the complex nature of the raw materials used and the fact that the biostimulant products contain a variety of component mixtures (Yakhin *et al.*, 2017). However, research has shed light on some mechanisms that underlie specific biostimulants' action. Protein hydrolysate-based biostimulants have been discovered to promote plant development and mitigate the effects of abiotic stresses (Sorrentino *et al.*, 2021). The precise mechanisms of action of protein hydrolysates remain unknown. However, research has shown that they can affect specific metabolic pathways, including those involved in amino acid metabolism and phenolic chemical synthesis, enhancing plant growth and stress tolerance (Sorrentino *et al.*, 2021; Zhang *et al.*, 2023). The advantages of humic substances, such as humic and fulvic acids, have long been recognized in soil fertility and plant growth (Rouphael and Colla, 2018). The biostimulatory effects of humic chemicals are attributed to several mechanisms, including improved soil structure, increased nutrient availability, and nitrate assimilation (Rouphael and Colla, 2018). Microbial biostimulants, such as plant growth-promoting rhizobacteria (PGPR), have increased plant growth, nitrogen uptake, and stress tolerance (Kaushal *et al.*, 2023). Secondary metabolites, hormones, organic acids, and enzymes produced by microbial biostimulants help plant growth and activate defence mechanisms (Ma *et al.*, 2022; Kaushal *et al.*, 2023). Algal extracts and products made from seaweed have also been discovered to support plant development and stress tolerance (Mannino *et al.*, 2020). These biostimulants' possible modes of action include altering phytohormones, increasing photosynthetic activity, and inducing defensive responses (Yakhin *et al.*, 2017; Mannino *et al.*, 2020). Remembering that the type of plant and particular product can impact the biostimulant's mode of action is crucial. Mixing different biostimulants may have positive, negative, or cumulative effects (Giordano *et al.*, 2020). More research is needed to fully understand the biostimulants' mechanisms of action and maximize their use in sustainable farming practices.

5. Effects of plant biostimulants on growth and development

Improved growth and yield

Biostimulants have been proven to improve plant growth and raise agricultural production. Some examples are increased plant height, biomass buildup, and fruit production (Ertani *et al.,* 2014; Francesca *et al.,* 2020). Biostimulants can stimulate all elements of plant growth, such as root formation, shoot growth, and general vigour (Kocira *et al.*, 2020). Plant growth (germination rate, leaf area, chlorophyll and protein content, nitrogen content, root and stem development, root and stem weight biomass, yield, and drought resistance) has been shown to benefit from the application of biostimulants. Additionally, biostimulants can help with seed germination, increase crop production, and natural soil fertility, and decrease pollutant toxicity. These are just a few of the positive benefits of biostimulants.

Enhanced nutrient uptake and utilization

Plant biostimulants can enhance a plant's capacity to take in and utilize nutrients. Increasing nutrient assimilation and absorption can improve nutritional status and resource utilization (Paradikovic *et al.*, 2019; Mohamed *et al.*, 2021). Improved plant nutrition and general development may result from this.Plant development and health are impacted both directly and indirectly by bacteria having PGPR properties. By fixing nitrogen, aiding in the production of plant hormones like auxin, cytokinin, and gibberellin, promoting the uptake of iron and similar trace elements through the production of bacterial siderophores, dissolving mineral and organic phosphates, and converting other nutrients into forms that the plant can easily absorb, these bacteria can directly affect the growth of plants. Or, as previously indicated, they are known to indirectly encourage plant development by reducing elements that cause plant disease (Dobbelaere *et al.*, 2003; Çakmakçı *et al.*, 2006).

Activation of metabolic pathways

Biostimulants can activate many plants' metabolic processes, promoting better growth and development. They can alter the synthesis and metabolism of plant hormones such as auxins, cytokinins, and gibberellins, which are crucial for regulating plant growth (Nephali *et al.*, 2021; Sorrentino *et al.*, 2021). Although the effect of biostimulants on metabolic processes has not been fully revealed, biostimulant contents may be associated with the synthesis of molecules or precursors involved in these processes. For instance, protein hydrolisates may function as regulators for plant growth, as they contain short-chain peptides, and certain amino acids, such as phenylalanine, have been reported to increase the production of endogenous auxin by functioning as signaling molecules (Raguraj *et al.*, 2022). Additionally, biostimulants, such as phenolic compounds, may affect the production of secondary metabolites that enhance plant defence and stress tolerance (Nephali *et al.*, 2021).

Stress tolerance and resistance

One of the main benefits of biostimulants is their ability to boost plant stress tolerance. They can make plants more resilient to abiotic stresses such as heat, salt, and drought (Oosten *et al.*, 2017; Nephali *et al.*, 2021). Furthermore, biostimulants can increase resistance to biotic stresses like pests and illnesses (Godlewska *et al.*, 2021). They can strengthen the immune system, activate defence systems, and enhance the plant's overall stress response.

Improved fruit quality and nutritional value

Biostimulants have been shown to enhance the nutritional value and quality of fruits and vegetables. They can increase the amount of bioactive components in crops, such as vitamins, phenolic compounds, and antioxidants, enhancing their nutritional value and health-promoting properties (Francesca *et al.*, 2020; Godlewska *et al.*, 2021). Biostimulants can also improve the sensory characteristics of fruits, such as color, flavor, and shelf life.

Plant biostimulants improve a plant's capacity to grow, develop, and tolerate stress. They can promote crops' nutritional content and quality, nutrient uptake, metabolic activity, stress resistance, and other processes (Calvo *et al.*, 2014). Because of these effects, biostimulants are valuable tools in sustainable agriculture for increasing crop productivity and resilience.

Enhancing stress tolerance in ornamental plants

With positive findings, using plant biostimulants has increased the stress tolerance of ornamental plants. Using biostimulants, abiotic stressors such as drought, heat, and water scarcity can decrease and improve plant performance (Toscano *et al.*, 2019; Nephali *et al.*, 2021). By triggering antioxidant defence mechanisms, controlling reactive oxygen species (ROS) metabolism, and enhancing membrane integrity, they can improve plant responses to stress (Nephali *et al.*, 2020; Hasanuzzaman *et al.*, 2021). Studies have shown that biostimulants can help ornamental plants flower earlier, produce more flowers, and accumulate biomass (Toscano *et al.*, 2019). Furthermore, it has been discovered that biostimulants increase the tolerance of ornamental plants to drought stress, leading to more significant growth and survival rates (Toscano *et al.*, 2019; Leotta *et al.*, 2023). Promoting root growth, enhancing nutrition and water availability, and managing stomatal function can increase the plant's resistance to water scarcity (Clercq *et al.*, 2023; Leotta *et al.*, 2023). Some biostimulants have examined the resilience of ornamental plants. Studies, for example, have demonstrated that protein-rich seaweed extracts, such as *Chondrus crispus*, serve as biostimulants and improve drought tolerance in tomato plants (Domingo *et al.*, 2023). Seaweed extracts are known to increase several crops' resiliency to stress, especially ornamentals (Francesca *et al.*, 2020; Clercq *et al.*, 2023). It has also been investigated whether microbial biostimulants, such as rhizobacteria that promote plant development, can improve ornamental plants' resilience to stress (Nephali *et al.*, 2021).

Plant biostimulants throughout cultivation can considerably improve ornamental plants' performance and stress tolerance. Utilizing biostimulants enables plants to respond to abiotic challenges, develop, and grow more effectively, which enhances the quality of attractive crops. More investigation is required to comprehend the mechanisms of action and to improve administration strategies and biostimulant dosages for diverse species of ornamental plants.

6. Application methods and dosages of plant biostimulants

Application methods

Before planting, seeds can be treated with biostimulants to improve germination, seedling vigour, and early growth (Paradikovic *et al.*, 2019). Foliar application is another one to boost nutrient intake, spur growth, and increase stress tolerance; biostimulants can be sprayed into the leaves of ornamental plants (Mannino *et al.*, 2020; Cristiano and De Lucia, 2021). Spraying biostimulants on the substrate is another application method to promote root development, nutrient uptake, and overall plant growth. Biostimulants can be sprayed on the substrate or growing media surrounding the roots of ornamental plants (Lorenzo *et al.*, 2018; Santos *et al.*, 2019). Irrigation systems can also be used to apply biostimulants, which will then be delivered right to the root zone of ornamental plants (Paradikovic *et al.*, 2019).

Dosages

Different biostimulants may require different dosages depending on the product, plant type, and growth stage. Various research has evaluated a range of biostimulant application doses or rates. For instance, a biopolymer-based biostimulant was used in a study on melon plants at rates of 0.06, 0.12, 0.24, or 0.48 mL per plant (Lorenzo *et al.*, 2018). Compared to lower concentrations, the application at 0.12 and 0.24 mL per plant led to better plant growth and biomass. An animal-derived biostimulant was administered to potted snapdragon plants in a different investigation at concentrations of 0, 0.1, or 0.2 g L^{-1} (Cristiano *et al.*, 2018). The biostimulant application at both doses significantly increased plant height, shoot length, leaf area, flower number, and aboveground dry weight compared to the control. Depending on the particular needs of the ornamental plant species and the desired results, the dosage and frequency of biostimulant application may need to be changed. It is significant to note that depending on the biostimulant product, plant species, environmental factors, and growth stage, the best application techniques and dosages of biostimulants may change. As a result, it is advised that site-specific studies be carried out and that the manufacturer's instructions for the biostimulant product be adhered to.

7. Biostimulant application in ornamental plants

Biostimulant applications have recently started to be in high demand in ornamental plants. Many studies have demonstrated that it naturally promotes rooting and plant growth as an alternative to commercial hormone uses. In some ornamental plants with high commercial value, it has been stated that PGPR applications positively affect both rooting promotion and agronomic properties.Studies have been carried out on ornamental plants belonging to different families Asteraceace (*Chrysanthemum, Dahlia, Zinna*) and Geraniaceae (Göre and Altın, 2006); *Iridaceae* (Gladiolus) and *Oleaceae* (Jasmine) (Damodaran *et al.*, 2014) and *Solanaceae* (Petunia) (Hoda and Mona, 2014).

In the studies, it has been determined that biostimulants positively affect rooting in ornamental plants.It has been stated that *P. fluorescens* bacterial strain in *Zinnia* (Yuen and Schroth, 1986); *Azospirillum brasilense* strains in Photinia (Larraburu et al., 2007); *Agrobacterium rubi* and *Serratia liguefaciens* strains in *Forsythia intermedia* (Kır, 2010); *Bacillus megaterium* and *Pseudomonas flourescens* strains in *Rosa canina* (Kınık and Çelikel, 2017); *Bacillus subtilus* strain in *Ficus benjamina* L.

(Sezen *et al.,* 2014); different *Bacillius* strains in *Kalanchoe blossfeldiana* (Dalda-Sekerci and Unlu, 2023) have been shown to promote rooting.

The effects of biostimulants on the vegetative characteristics, flowering status, duration of flowering, and tuber formation of ornamental plants were also reported.Positive effects of biostimulants on agronomic properties were reported in anthurium (Padmadevi *et al.*, 2004); chrysanthemum and dahlia (Gore and Altın, 2006); geranium (Mishra *et al.*, 2010), tulip (Parlakova, 2014), gladiolus (Damodaran *et al.*, 2014), jasmine (Jayamma *et al.*, 2014); in petunia (Hoda and Mona, 2014); in the poinsettia (Parlakova Karagöz, 2018); and cyclamen (Girgin and Sezen, 2021) summary of reported beneficial effects of different biostimulant types and application techniques given Table 1.

8. Regulatory aspects and future perspectives

Clear definitions and rules controlling plant biostimulants are required because the regulatory framework for these substances is currently developing (Yakhin *et al.*, 2017). To promote the legalization of biostimulants and ensure their efficacy and safety, the European Union (EU) has tried to regulate them (Farkas *et al.*, 2022). Beyond necessary nutrients or plant growth regulators, the concept of biostimulants emphasizes their capacity to increase plant productivity through the unique features of their constituents (Yakhin *et al.*, 2017). Biostimulants must be regulated to maintain product quality, efficacy, and consumer confidence and support ecologically friendly and sustainable agricultural practices (Farkas *et al.*, 2022). The ability of plants to function better under stress and produce higher-quality plants overall is greatly enhanced by using biostimulants in the cultivation of ornamental plants (Farkas *et al.*, 2022). Additional research is required to comprehend further the mechanisms of action and the impacts of various biostimulants on ornamental plants (Nephali *et al.*, 2020). For the efficient and long-term use of biostimulants in agriculture, creating a science-based biostimulant industry and sound regulations are essential (Yakhin *et al.*, 2017). Application strategies, doses, and timing of biostimulant treatments in ornamental plants can all be improved to increase efficacy (Farkas *et al.*, 2022).

Combining biostimulants with environmentally friendly agriculture techniques like organic fertilizers and integrated pest management can produce more robust and sustainable systems for growing decorative plants (Farkas *et al.*, 2022). In conclusion, efforts are being made to assure the safety, effectiveness, and appropriate use of plant biostimulants in cultivating ornamental plants. Biostimulants' prospects include more study, method optimization, and integration with other sustainable practices to improve plant performance and resilience.

9. Conclusions

As a result, plant biostimulants have demonstrated significant promise for improving ornamental plants' growth and stress tolerance. The research that has been evaluated has shown that biostimulants can boost ornamental crop performance, yield, nutrient uptake, and stress tolerance.

The mechanisms of action of biostimulants include stimulating antioxidant defence systems, activating metabolic pathways, and modifying plant hormone levels. Using biostimulants to develop ornamental plants provides opportunities for resilient and sustainable horticulture techniques. By lowering the need for artificial fertilizers and pesticides, biostimulants can aid in developing more effective and ecologically friendly agricultural methods. They can also raise ornamental plants' aesthetic appeal and quality, increasing their marketability.

More study and development are required to maximize the utilization of biostimulants in the growth of ornamental plants. This includes examining the precise results of various biostimulant formulations and biostimulant kinds on various species of ornamental plants. The best biostimulant application strategies, doses, and timing for various growth phases and environmental circumstances also require further research. Specific definitions and regulations are required to guarantee product quality, efficacy, and consumer confidence. Regulatory aspects of biostimulants are also evolving. For biostimulants to be used effectively and sustainably in producing ornamental plants, a science-based biostimulant industry, and good laws are essential. To sum up, plant biostimulants have much potential to improve ornamental plants'

Table 1 - Different biostimulant agents and beneficial effects on ornamental plants

Biostimulant type	Applied species	Application	Beneficial effects	References
Spirulina and Klamath algae	*Portulaca grandiflora*	Mixing with the growing substrate	To improve seed germination, plant growth and flowering	Prisa (2019)
Animal-derived PH (hydrolysis of proteins from erythrocytes	*Antirrhinum majus* L.	0.1 and 0.2 gL^{-1} foliar spray and root drenching (150 ml/plant)	To increase plant morphological and qualitative traits, leaf and root-N content, photosynthetic rate, transpiration rate, and stomatal conductance	Cristiano *et al.* (2018)
Seaweed extract (*Ascophyllum nodosum*)	*Helianthus annus* L. cv. Pleno Sol	0, 5, 10 or 15-mLL^{-1} of seaweed extract (60 mL spray treatment during seed germination)	To enhances seed germination and seedlings development	Santos *et al.* (2019)
Animal derived PH (Hicure®)	*Dianthus caryophyllus* L.	Drenching with biostimulant concentrations of 2.0, 2.5 and 3.0 L ha^{-1}	Improvement of flower quality, such as stem length and flower head size	Niyokuri *et al.* (2017)
Chitosan nanoparticles	*Rosa hybrida* cv. Black magic	Applying as vase solution with the concentration of 5, 10, 15 mg L^{-1}	Reduction microbial growth in vase solution. Increase phenolics, total flavonoids, and amount of anthocyanin in treated petals and vase life of the flowers	Seyed Hajizadeh *et al.* (2023)
Plant derived Protein hydrolysates (PH)(Trainer® and Vegamin©)	*Chrysanthemum morifolium* cv. Pinacolada and Radost	Spraying the whole plant at the recommended concentration by the companies	Overall action; improved the status of plants, stimulating stem elongation and the apical flower diameter	Carillo *et al.* (2022)
Animal derived PH (Hydrostim®)	Petunia × *hybrida* Hort. cv. Potuniaand Dunnen	0, 0.1, 0.2 g L^{-1}foliar spray and root drenching	Enhance visual quality of the plants (increase leaves and flower numbers, leaf area, dry weight, shoots, flowers, and leaf fresh weight	Cristiano and De Lucia (2021)
Cyanobacterial hydrolysate (*Arthrospira platensis*)	*Petunia x hybrida*	5 g L^{-1} foliar spraying weekly under salinity stress conditions	Hydrolysate mitigates the negative effect of NaCl on *Petunia* x *hybrida* crops at an EC of 3.0 dS m^{-1}	Bayona-Marcillo *et al.* (2020)
Fermented alfalfa brown juice	Tagetes patula L. cv. Csemő	0.5%, 1.0%, 2.5%, 5.0%, or 10% of fermented alfalfa brown juice	0.5% fermented BJ improved seed germination root and shoot length, root and shoot dry mass and the number of leaves	Barna *et al.* (2021)
Vegetal extract and PH (Radifarm®)	Viola tricolor var. *hortensis* DC.	Applying to the plant rhizosphere at 0.3% solution	Improvement seedling quality and morphological parameters	Zeljković *et al.* (2021).
Microalgae (*Arthrospira platensis*) hydrolysate	*Pelargonium hortorum* L.H. Bailey	Foliar spraying at the 5 g/L concentration with 150 mg/L silicon	Stimulation root, shoot, leaf, and flower formation under salinity stress.	Tejada-Ruiz *et al.* (2020)

Table 1 - Different biostimulant agents and beneficial effects on ornamental plants

Biostimulant type	Applied species	Application	Beneficial effects	References
Seaweed extract (Acadian Seaplants™)	*Tagetes erecta*	Spraying to seeds daily with 70 ml solution at the 0, 5, 10, 15 ml L^{-1} concentrations	Enhancing seed germination and seedling growth and development (optimum concentration was 15 ml/L)	Tavares *et al.* (2020)
Microbial biostimulant (*Trichoderma sperellumand T. harzianum)*	*Passiflora caerulea*	Foliar application with spores at the concentration of 10^6 and 10^8 cfu mL^{-1}	Increase number and size of chloroplasts, improved plant physiology characteristics, and an increase yield	Şesan *et al.* (2020)
Vegetal extract (*Moringa oleifera*)	*Gladiolus grandiflorus*	5% (*v/v*) aqueous extract alone or in combination with 50 mg/L salicylic acid or gibberellic acid	Increase the yield and quality of cut spikes, prolong the vase life.	Zulfiqar *et al.* (2020)
Nitrophenolate based biostimulant (Atonik®)	*Calendula officinalis*	Plants irrigated by 3000 ppm saline water and sprayedwith 2 mlL^{-1}Atonik (0.196 Ug^{-1})	Tolerate the salt stress and promoted flowering growth	El-Ziat and Swaefy (2019)
Arbuscular mycorrhizal fungi (*Glomus mossease*)	*Gerbera jamesonii* cvs. Beaudine and Palm Beach	AMF spores were added to soil at a rate of 100 spore/1000 g of dried soil	AMF inoculation at seedling stage can significantly increase gerbera flower yield and longevity after harvesting (vase life)	Othman *et al.* (2022)
Arbuscular mycorrhizal fungi *(Funneli formis mosseae)*	*Hyacinths orientalis* L. Anna Marie	Approx. 1100 spores were added to 2 kg substrate with soils and sands (3:1, v/v)	Regulate early flowering and prolonging flowering time	Xie and Wu (2018)
Rhizobacteria (*Azospirillum brasilense*)	*Eustoma grandiflorum* (Raf) Shinn.	Inoculation with 106 and 107 cfu on seed surface at sowing	Improve morphological parameter of seedlings and lead to a shorter time production	Santos *et al.* (2022)
Humic acid and vermicompost	*Lavandula angustifoli*a L.	Adding vermicompost to the soil before planting, foliar application of humic acid	Increase flower yield and essential oil content, reduce the demand for chemical fertilizers	Sharafabad *et al.* (2022).
Humic acid	Lilium Oriental Hybrids *'Sorbonne'*	Adding 0.2, 2.0, and 20.0 mgL^{-1} humic acid directly to the medium	Promote *in vitro* bulblet growth increase in bulblet sucrose, total soluble sugar, and starch content	Wu *et al.* (2016)

growth, stress tolerance, and general performance. Future horticulture practices will be more resilient and sustainable thanks to the optimization of biostimulant use made possible by ongoing research and development in this area.

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