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Influence of biostimulants on growth and physiology of ornamental crops

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Abstract
The horticultural sector's rapid expansion, especially in ornamental plant cultivation, has prompted a surge in interest in sustainable practices. Ornamental plants in urban settings play a vital role in filtering airborne contaminants. To meet aesthetic standards and harvest timing, the industry is exploring holistic strategies, focusing on plant biostimulants. Biostimulants, enhancing plant nutrition efficiency and stress tolerance, offer promise for sustainable ornamental cultivation. Caution is vital to avoid potential negative effects, especially with substances like humic acids. Biostimulants, like protein hydrolysates and A*rbuscular mycorrhizal* fungi, positively impact nutrient absorption, plant development, yield, and stress resilience. They enhance metabolism, abiotic stress tolerance, nutrient assimilation, and produce quality. Seaweed extracts and chitosan show notable effects on ornamental crops, influencing plant traits and stress tolerance. *Arbuscular mycorrhizal* fungi improve nutrient and water absorption, enhancing drought stress tolerance. Plant growth-promoting bacteria, e.g., *Bacillus* and *Pseudomonas*, act as probiotics, enhancing nutrient use efficiency, disease resistance, and stress tolerance. In conclusion, judicious biostimulant application in ornamental plant cultivation provides a sustainable approach for growth, yield, and quality, mitigating environmental stressors.

Keywords: Biostimulants, ornamental plants, humic acid, sea weed extract and protein hydrolysates

Introduction
The horticultural sector is expanding quickly, and one notable area of expansion is the cultivation of ornamental plants. In urban environments, ornamental plants are becoming more and more important because they help to filter airborne contaminants (Sriprapat and Thiravetyan 2016) [31]. Growers' increased interest in natural materials and helpful microorganisms that can sustainably and environmentally increase ornamental plant yield is fuelling the desire for plant biostimulants.

The excellent aesthetic quality of ornamental items and the timing of their harvest are major factors influencing their competitiveness in the market. All the same, meeting these requirements frequently necessitates large energy and pesticide expenditures in the absence of a holistic and sustainable decorative horticultural strategy. When used singly or in combination, biostimulants offer a viable means of attaining notable rates of growth and yields in ornamental plants grown in solid media (De Silva *et al*. 2020) [12]. However, it's important to use biostimulants with caution because an overdose might have negative effects, especially when humic acids are involved (Yuan 2021) [36].

Biostimulants- A plant biostimulant is any substance or microorganism applied to plants or soils with the aim to enhance nutrition efficiency, abiotic stress tolerance and/or crop quality traits regardless of its nutrients content. They can also be referred to as 'positive growth regulators' or 'metabolic enhancers' (Schmidt 2003) [29]. The term 'plant biostimulants' was first used by (Zhang and Schmidt 1997) [37]. Biostimulants do not provide essential nutrients like fertilizers, but they stimulate natural processes within the plants when applied in low quantities. It can also be applied through foliar application and root drenching. Biostimulants divided into two categories namely non- microbial and microbial. Humic and fulvic acid, Protein hydrolysates, sea weed extract and chitosan comes under non-microbial biostimulants. Microbial biostimulants includes beneficial fungi and beneficial bacteria. Drought stress is one of the many factors that lead to decreased yield in both quality and quantity. Application of biostimulants increase a plant's resistance to this stress.

This method has an impact on several metabolic processes as well as important gas exchange parameters like stomatal conductance, internal CO_2 concentration, and cell membrane permeability (Yordanov *et al.* 2000) [35]. One of the first reactions of a plant to drought stress is stomatal closure, which lowers water loss. Because of reduced internal CO_2 concentration (Ci), decreased ribulose-1,5-bisphosphate carboxylase/oxygenase enzyme activity, and impaired ATP synthesis, the net photosynthetic rate decreases under drought stress conditions (Dulai 2006) [14]. Stressful events are constants for plants; they begin with seed germination and continue for the duration of their life cycle. Moreover, the negative effects of abiotic stress on plants can be mitigated through the application of biostimulants.

Biostimulants can change the antioxidant properties and activity of the enzymes. Lycopene, ascorbic acid, and phenolic compounds are examples of antioxidant compounds that are essential in neutralising reactive oxygen molecules like OH^-, O_2, and H_2O_2 (Abdalla 2014) [1]. Reactive oxygen species are deactivated by these antioxidant compounds as well as enzymes such as catalase, peroxidase, and superoxide dismutase (Exposito-Rodriguez *et al*. 2017) [17].

The phenylpropanoid biosynthesis pathway is activated by abiotic stressors such as UV radiation, high/low temperatures, salinity, heavy metals, and drought. The accumulation of various phenolic compounds that have the capacity to bind hazardous reactive oxygen species is the outcome of this activation (Sharma *et al*. 2019) [30]. Growth may be hampered by nutrient restriction or exposure to abiotic stress, which could over excite the photosynthetic electron transport chain and produce potentially harmful oxygen species. Early stress detection triggers defence and acclimatisation pathways, as well as the modification of plant growth. Among the biostimulants, due to their beneficial effects on boosting plant nutrient absorption, development, yield and fruit quality, and resilience to abiotic stresses, protein hydrolysates and arbuscularmycorrhizal fungi are widely used in greenhouse plant culture (Depascale *et al*. 2018) [13].

Roles of biostimulants in ornamental plants:

- Improving the efficiency of the crop's metabolism to increases yield and enhanced crop quality through plant health and vigor.
- Increasing crop tolerance and recovery from abiotic stresses.
- Facilitating nutrient assimilation, translocation and use.
- Enhancing quality attributes of produce, including sugar content, color etc.
- Rendering more efficient water use.
- Enhance uptake and efficient use of nutrients, both applied and existing.

Biostimulants mode of action on plants

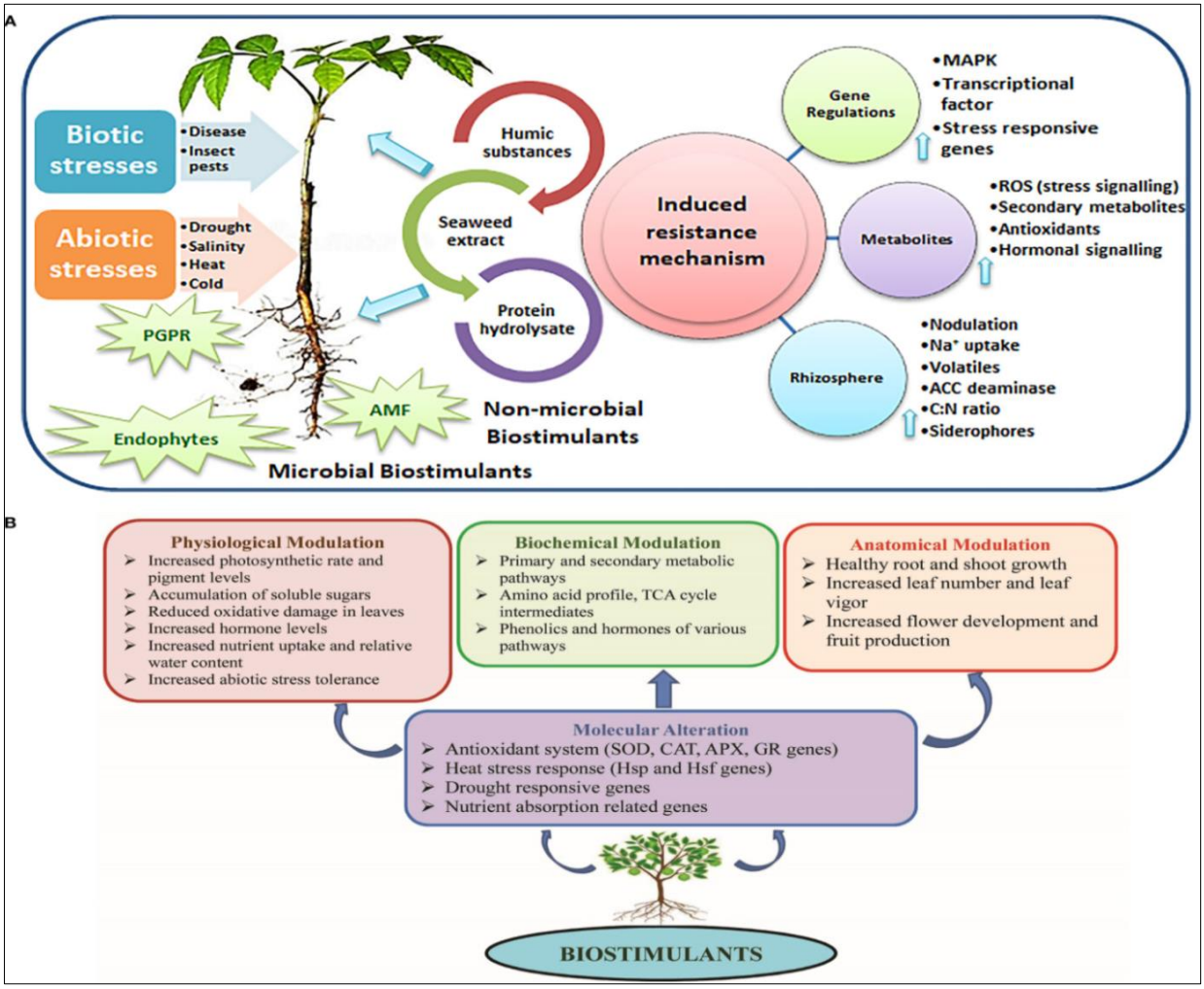


Fig 1: The role of biostimulants in mitigating the adverse effects of stresses on plants through several mechanisms (Physiological, biochemical and anatomical modulation.

Humic acid

Humic substances are naturally occurring by products of the chemical breakdown of plant and animal remains in the soil as well as the breakdown of microorganisms like bacteria and fungi. Together, fulvic and humic acids transform minerals into organic compounds that are more easily absorbed by plants (Kumar and Aloke 2020) [25], which can be split into three main categories: humic acid (HA), fulvic acid (FA) and humin. Most sources of humic substances used in horticulture are non-renewable and include natural humidified organic matter, such as peat and organic soils and mineral deposits. More sustainable, renewable sources are derived from compost and vermicompost. Mode of action involves activate the plasma membrane proton pumping ATPases, promote cell wall loosening and cell elongation.

Extraction procedure of humic acid: Kumada *et al*. 1967 [24]

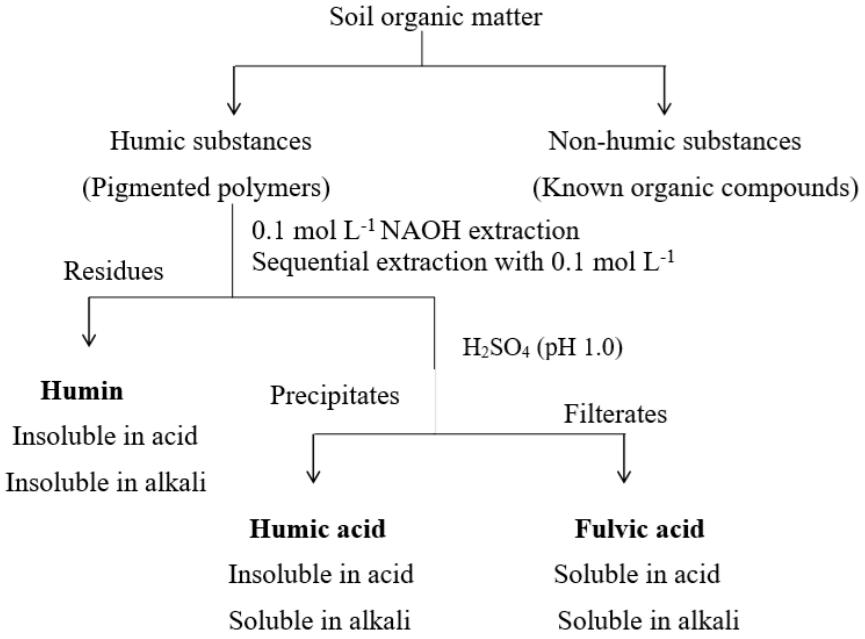


Table 1: Effect of humic Substances on ornamental Crops

Crop	Treatment	Effects	References
Gladiolus	Application of Humic acid along with NPK at different stages	Increases morphological parameters and leaf area $(cm)^2$. Total leaf chlorophyll content at 3 (at planting, 3 and 6-leaf) stages	Ahmad *et al*. 2014
Chrysanthemum	NPK fertilizer and organic foliar humic acid fertilizer- every 15 days.	The morphological indices, the net photosynthesis rate, chlorophyll content improved.	Fan *et al*. 2014 [18].
Calendula	Biochar (with soil) applied at 0, 20, and 40 g/Kg, HA (with irrigation water) at concentrations of 0, 250, and 500 mg/L.	BC and HA enhanced plant growth and morphological parameters, improved acquisition of macro- and micro-elements.	Karimi *et al*. 2020 [23].
Gerbera	Fulvic acid at 0, 50, 100 and 250 mg/L and iron nano chelate at of 0, 1, 2 and 4 g/L (15 days intervals for 4 months)	fulvic acid (50 mg/L) supplemented with iron nano chelate caused to early flowering and increased flower longevity.	Hajizadeh *et al*. 2021 [21].

Protein hydrolysates

Protein hydrolysates (PHs) are an important group of plant biostimulants, these are mixture of peptides and amino acids, mainly produced by enzymatic or chemical hydrolysis of proteins from animal or plant derived raw materials or agro industrial by-products (Calvo *et al*. 2014) [7]. Besides amino acids and peptides, protein hydrolysates contain other compounds that can contribute to the biostimulant action. These compounds include fats, carbohydrates, phenols, mineral elements, phyto-harmones and other organic compounds. Application of protein hydrolysates to leaves and roots increase Fe and N metabolism, nutrient uptake, water and nutrient use efficiencies for both macro and micro elements.

There are two types of protein sources derived from animal origin and plant origin. Animal origin includes leather by products, blood meal and fish by-products. Legume seeds, Alfalfa hey, Vegetable by-products comes under plant based protein sources. Protein hydrolysis production process is done with 2 methods. 1. Chemical hydrolysis (acid hydrolysis and alkali hydrolysis) 2. Enzymatic hydrolysis- it is most widely used method.

PHs are known to -Increase microbial biomass and activity, soil respiration and soil fertility, nutrients availability and acquisition by roots (Chelating and complexing activities of specific AAs and peptides), tolerance to abiotic stress.

Protein hydrolysates extraction procedure

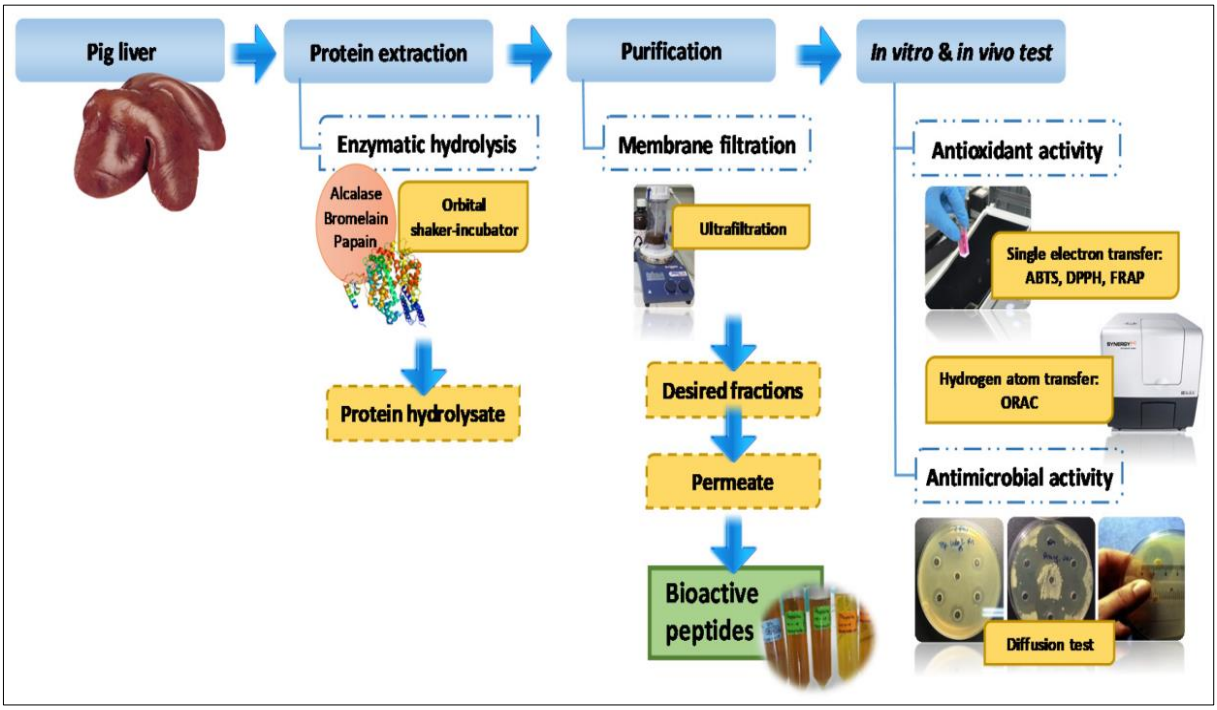


Fig 2: Protein hydrolysates extraction procedure

Modes of Action

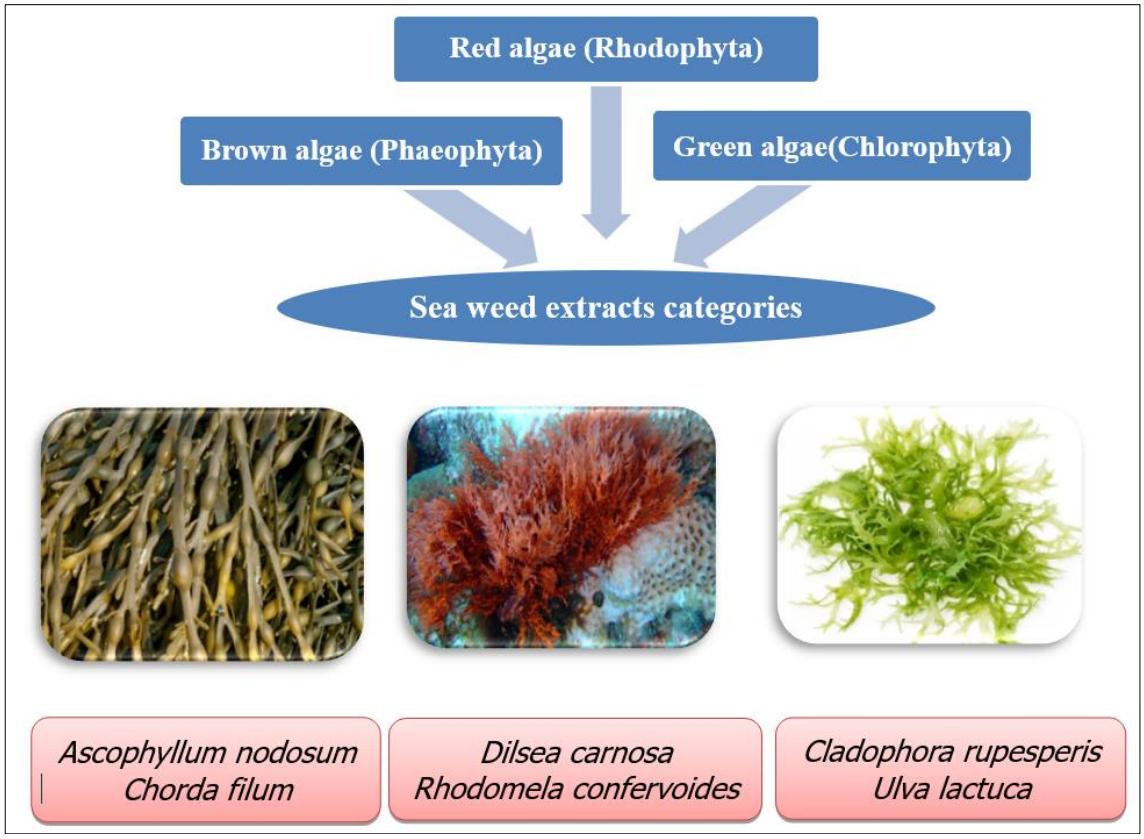
Protein hydrolysates have the power to improve soil microbial activity and soil fertility, which can subsequently improve plant productivity and growth. They directly affect both primary and secondary metabolism by regulating genes and enzymes involved in nitrogen assimilation and the tricarboxylic acid cycle (TCA cycle) as well as hormonal activities. Certain amino acids (Proline) have the ability to chelate, which shields them from the harmful effects of heavy metal stress. Glycine betaline is a special amino acid derivative with well- known anti- stress properties (Chen and murata 2011) [8]. Other amino acids also play a role in the uptake and transportation of micronutrients concurrently.

Table 2: Effects of Protein Hydrolysates on flower crops

Crop	Treatment	Effect	Reference
Petunia	At two doses ($D_{0.1}$ = normal and $D_{0.2}$ = high) or not treated (D_0) with an animal-based PH, Hydrostim, applied by foliar spray or root drenching.	foliar spray at 0.2 g/L helped to achieve extra-grade plants, increased dry biomass; leaf N, P, and K content; and root morphology. Increased net photosynthesis and stomatal conductance	Cristiano and De Lucia 2021 [9]
Antirrhinum majus L.	The plants were treated with PH (Hydrostim) by foliar spray or root drenching	Plant height, number of shoots, leaves, flowers, leaf area, total shoot length, were significantly increased regardless of the dose.	Cristiano *et al.* 2018 [10]
Lilium	Bio-stimulants, based on hydrolyzed protein coming from algae (M.A.E.), animal epithelium (A.P.H.), and lucerne origin (H.S.), were applied 8 times both at foliar and drenching level.	crop cycle came early, flower size, leaf area, root length, stem and bulb dry weights values were higher than the control.	De Lucia and Vecchietti 2012 [11]

Sea weed extract

Brown, red, and green marine macro algae are referred to as seaweeds. Of these, the most often used in horticulture are brown seaweeds, including species from the genera Ascophyllum, Fucus, and Laminaria. The raw material and extraction technique, which may include alkali extraction, acid extraction, or other technologies, have a significant impact on the biological efficacy of these extracts. Important constituents, comprising 30-40% of the dry weight, are polysaccharides, which comprise laminarins and alginates. These polysaccharides are known to trigger plant defence responses against bacterial and fungal pathogens and to exhibit activities that promote plant growth.



Extraction procedure

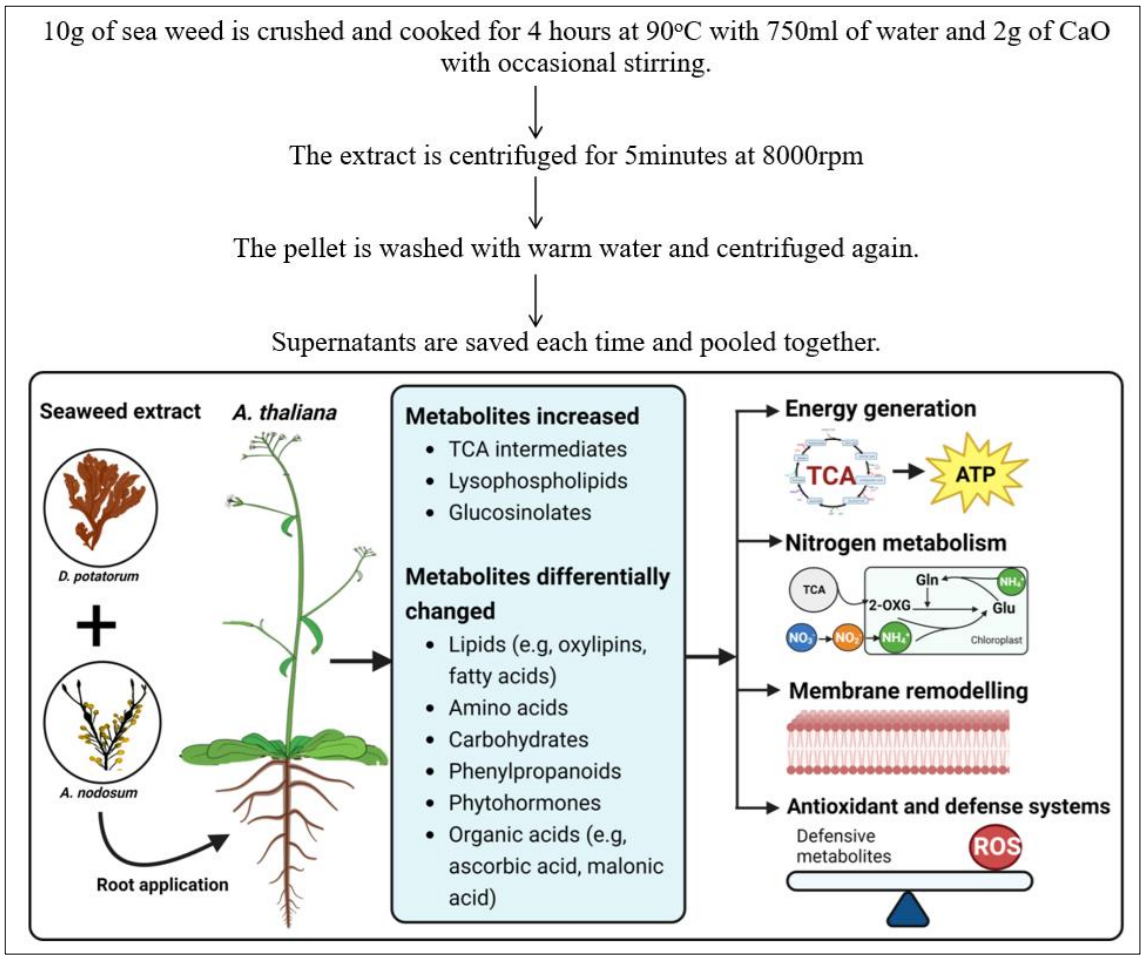


Fig 3: Seaweed extract mode of action on plants

Seaweed extracts (SWE) derived from *Durvillaea potatorum* and *scophyllum nodosum* were applied to Arabidopsis (Plant) roots, causing metabolic changes arise to include changes in lipids, amino acids, carbohydrates, and phytohormones, among other important metabolite groups. Additionally, SWE-treated leaves and roots had accumulations of vital growth and defense-related metabolites like glucosinolates, lysophospholipids, and TCA cycle. The production of energy, the metabolism of carbon and nitrogen, the remodelling of cell membranes, and the strengthening of antioxidant and defence systems are all potential benefits of these metabolic alterations.

Table 3: Effects of sea weed extracts on flower crops:

Crop	Treatment	Effect	Reference
Rose	7 treatments of seaweed liquid extract applications 10%, 20%, 30% once and twice a weak and distilled water were applied	Once a week application of 20% seaweed liquid extract increased the plant height, leaf area, plant biomass, number of flowers and dry weight of flowers.	Sumangala *et al.* 2019 [32]
Marigold	seeds of marigold were daily sprayed with 0 (control), 5, 10 or 15 mL/L commercial seaweed extract Acadian Seaplants™ (70 ml).	15 mL/L seaweed extract increased seed germination by two-fold marigold, seedling height, both fresh and dry shoot mass, root morphology.	Tavares *et al.* 2020 [33]
Dahlia	SWE 0.0, 0.5, 1 and 1.5% and the phosphorus element treatment through soil application technique at four levels 0.0, 100, 200 and 300 ppm.	seaweed extract at 1% and P at 200 ppm revealed significant increase in stem length, number of leaves leaf area, flower diameter, duration and dry weight of stem, leaves and flowers.	El-Alsayed *et al.* 2018 [15]
Gladiolus	Seaweed Extract of *Ascophyllum nodosum*, named Acadian, was added to the soil, by three levels (0,1,2)g	(2)g to the soil was significantly influenced qualities of vegetative growth, floral and corms yield	Al-Saad 2019 [4]
Turf grass (Creeping bent grass)	Foliar application of *Ascophyllum nodosum* (Utilize) at differents rates under heat and mild drought stress	Leaf photosynthetic rate, nitrogen reductase activity, cholorophyll and carotenoid was maximum at 58 µl.m^{-2}	Zhang *et al.* 2023 [38]

Chitosan

The naturally occurring material chitosan is the deacetylated form of chitin, which is present in the exoskeletons of insects and crustaceans, nematode eggshells, and fungal cell walls. Industrial methods and natural processes are both used to produce chitosan. Its physiological effects in plants are mediated through oligomers, which cause this polycationic compound to bind with different parts of the cell, such as DNA, the plasma membrane, and cell wall components. It also aids in the binding of particular receptors that are essential for the activation of defence genes.

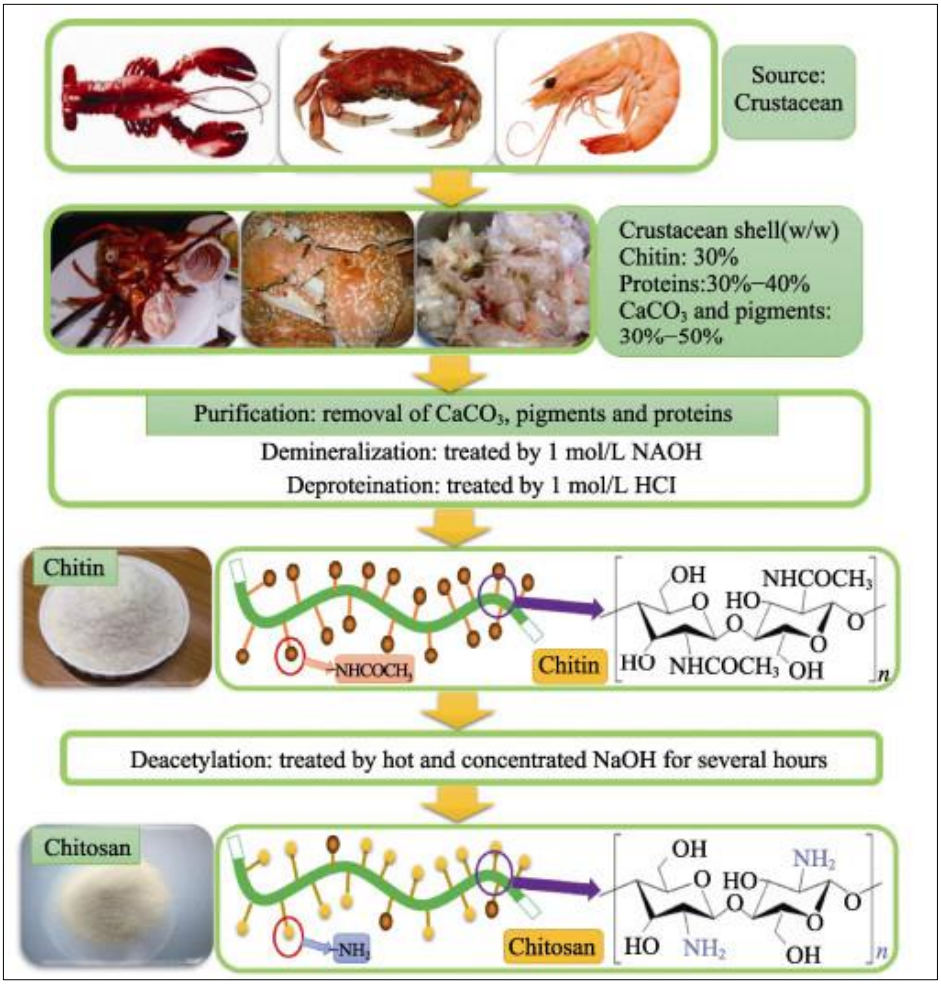


Fig 4: Extraction procedure for chitosan

Chitosan as biostimulant helps in - Protection against fungus, bacteria and virus, Tolerance to abiotic stress (drought, salinity and cold stress), Enhancement of quality traits related to primary and secondary metabolisms. Modes of action - Affects cell membranes, alters DNA and activates defense genes.

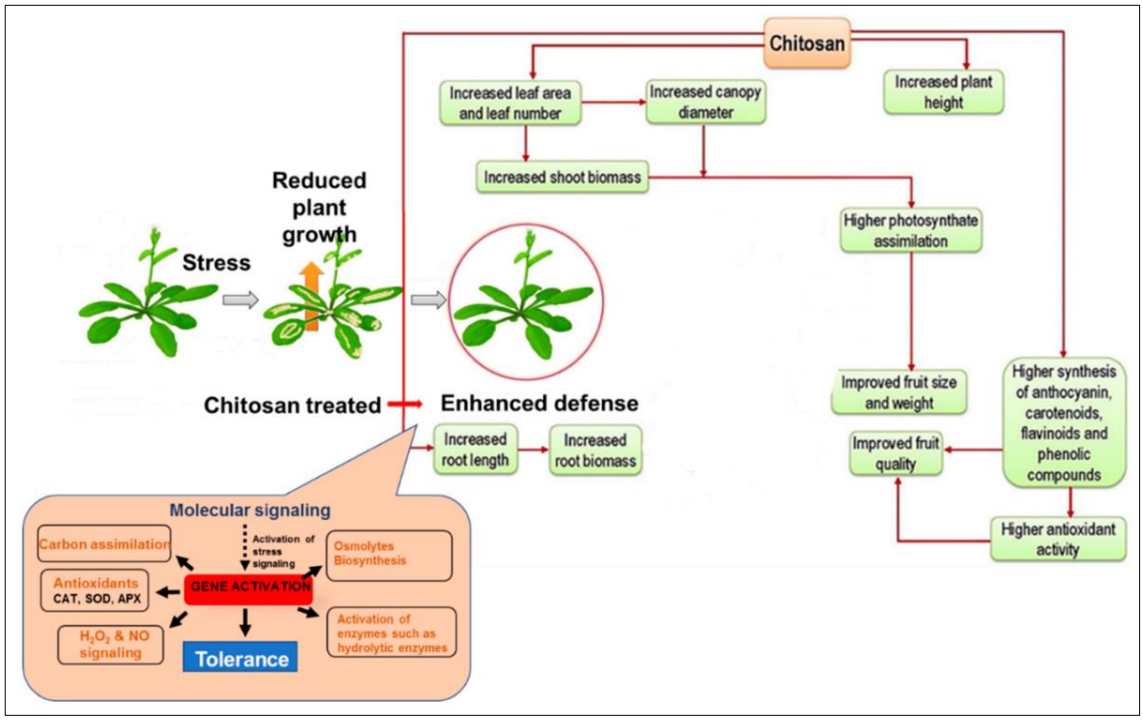
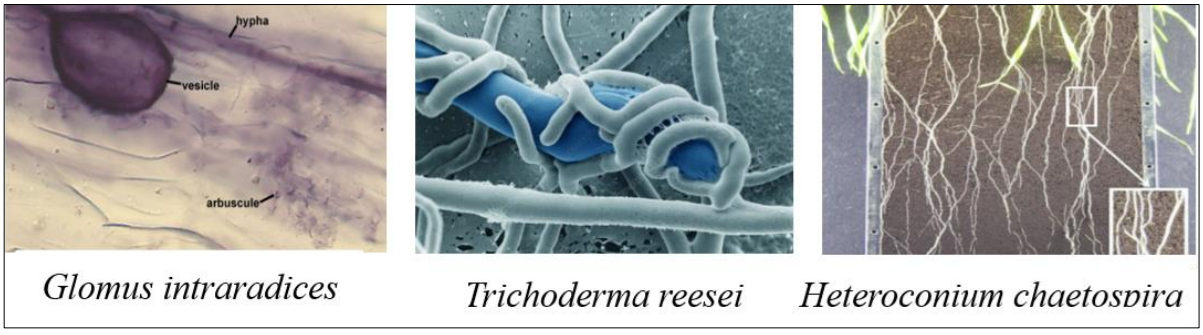


Fig 5: Chitosan mode of action

Crop	Treatment	Effect	Reference
Freesia	corms were soaked in 0.5% (20 min) chitosan solutions with low (2 kDa), medium (50 kDa) and high molecular weights (970 kDa).	Regardless of the molecular weight of the compound, the chitosan-treated plants had more leaves and shoots, flowered earlier, formed more flowers and corms.	Salachna and Zawadzinska 2014 [28]
Tuberose	first factor was storage of bulbs before planting at a degree of 5 C° for a period of 0, 1, 2 a week, and the second factor was sprayed with chitosan at a concentration of 0, 500, 1000 mg/L	two-week storage treatment exceeded the number of leaves, leaves area, and leaf. Spraying chitosan at a concentration of 1000 mg/L increased infloresence length, floret diameter	Alsanam and Salih 2021 [5]
Chrysanthemum	water solutions of robinin (25, 100, and 200 ppm) and/or foliar sprays of chitosan (0, 50, and 200 ppm) were applied to *Chrysanthemum morifolium* subjected to a 2 or 6 day irrigation intervals for 6 weeks.	Robinin + chitosan-treated plants showed increased morphological performance, stimulated the accumulation of carbohydrates, K^+, Ca^{+2}, proline, and chlorophylls to achieve osmotic adjustment and maintain turgor pressure, enhanced drought resistance	HO Elansary, 2020 [16]

Beneficial fungi: Among the symbiotic fungi are some that have beneficial plant biostimulant activity, particularly Arbuscular Mycorrhizal Fungi (AMF), which are found in the genus Glomus. These fungi enter plant roots and create a dense network of hyphae and roots that resembles a tree. By enabling plants to extend their root systems past the depletion zone, this network improves nutrient and water absorption and increases drought stress tolerance. AMF's effectiveness is hampered by their vulnerability to a number of crop management techniques, such as soil tillage, periods of bare fallow, and high fertiliser applications. Among the fungi used in the cultivation of plants- *Glomus intraradices*, *Trichoderma atroviride*, *Trichoderma reesei*, and *Heteroconium chaetospira*.



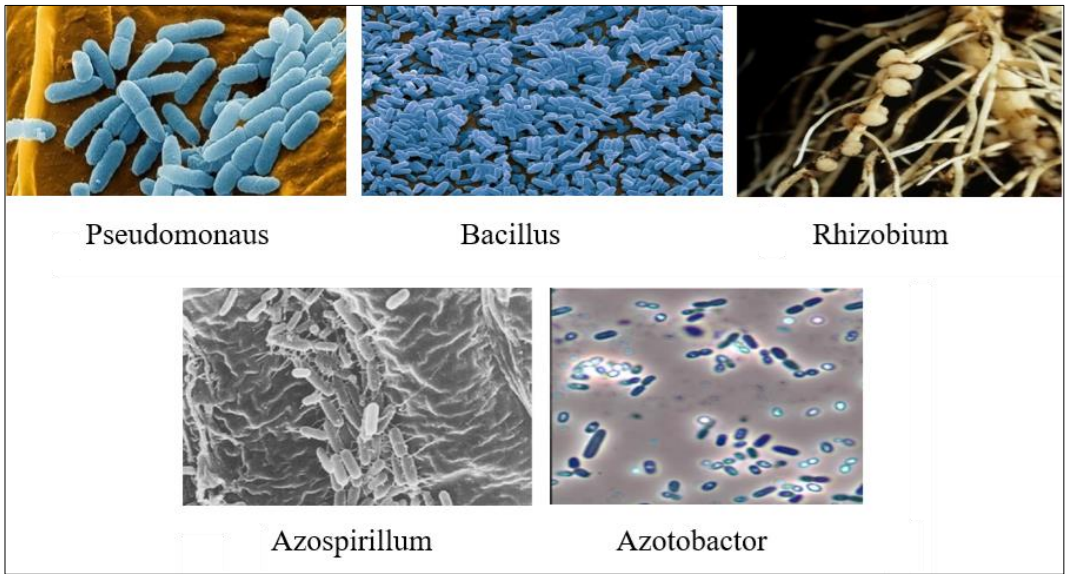
Fungal-based products applied to plants - As a biofertilizers. Enhance nutrient use efficiency (phosphorous deficient soil). Maintain phytohormone balance. Helps in organ growth and morphogenesis. Improve crop yield and product quality. Induce changes in secondary metabolism leading to improved nutraceutical compounds.

Crop	Treatment	Effect	Reference
Rose	Four levels of drought stress (100, 75, 50, and 25% FC) were examined on mycorrhizal and non-mycorrhizal plants in pots filled with sterilized soil.	The results obtained in this study provide a clear evidence that AMF colonization can enhance growth, flower quality and adaptation of rose plants under different drought stress levels via improving their water relations and photosynthetic status.	Abdel-Salam *et al.*, 2018 [2]
Begonia × *tuberhybrida*	Before planting, the tubers were soaked in water or a mixture of spore of *Trichoderma* spp. in the form of a suspension for 24 h.	*Trichoderma* spp. accelerated the flowering by 2-8 days, stimulated the development of buds and flowers in the plants and affected their size. *Trichoderma* spp. stimulated the production of chlorophyll and uptake of microelements (Zn, Fe, and B).	Andrzejak*et al.*, 2021 [6]

Beneficial bacteria

Concerning the horticultural applications of biostimulants that facilitate plant growth, known as Plant Growth-Promoting Bacteria (PGPBs), these include free-living bacteria inhabiting the root zone (rhizosphere), bacteria colonizing the root surface (rhizoplane), and bacteria residing within the roots (endo rhizosphere).

Bacteria exhibiting plant growth-promoting activity are prevalent in genera such as Bacillus, Rhizobium, Pseudomonas, Azospirillum, Azotobacter, and many others. One of the notable benefits of PGPBs on plants is their capacity to fix nitrogen and produce siderophores-small, iron-chelating compounds that impede the growth of detrimental soil-borne pathogens.



PGPR inoculants are now regarded as plant 'probiotics' - Supply of nutrients, increase in nutrient use efficiency, induction of disease resistance-Volatile organic compounds (VOCs) such as 2,3butanediol (2,3-BD), enhancement of abiotic stress tolerance.

Crop	Treatment	Effect	Reference
Chrysanthemum	Three strains of *Bacillus*, three strains of *Pseudomonas* and their combination were applied. In addition to above treatments, nitrogen @ 30 g/ m^2 or 150 ppm and phosphorus and potash each @ 20 g/m^2 or 100 ppm were also applied.	Results revealed that the inoculation of plants with strains of *Bacillus*, *Pseudomonas* significantly improved the growth and flowering parameters.	Kumari *et al.* 2016 [26]
Gerbera	100% RDF, Vermicompost, 75% RDF, PSB, *Azospirillum*, *Azotobacter*, and foliar application of macro and micro elements.	It was concluded that reducing level of chemical fertiliser to 75% RDF along with application of different organic source of nutrient improved flower yield of gerbera in open field condition.	Giri and Beura 2019 [20]
Ornamental crops	*Pseudomonas poae* 29G9 and *Pseudomonas fluorescens* 90F 12-2 batcerial strains were used for *Petunia X hybrida*, *Impatiens walleriana* and *Viola X wittrockiana* flowers production under green house.	Both the strains under drought stress 5 weeks after transplant increase the quality of ornamental crops grown under drought and nutrient limiting conditions.	Nordstedt *et al.* 2020 [27]

Conclusion

Biostimulants play crucial roles in enhancing ornamental plant growth, improving crop quality, and increasing resilience to abiotic stresses. It offers numerous benefits, from increased metabolic efficiency to enhanced nutrient assimilation and stress tolerance. However, careful application is essential to avoid adverse effects. These biostimulants contribute to the ornamental plant market by not only improving aesthetic quality but also promoting sustainable and holistic horticultural strategies. As the industry continues to evolve, the judicious use of biostimulants stands out as a promising approach for

achieving both economic competitiveness and environmental responsibility in ornamental plant production. In summary, the judicious application of biostimulants in ornamental plant cultivation presents a sustainable approach to boost growth, yield, and quality while mitigating the impact of environmental stressors.

References

1. Abdalla MM. Boosting the growth of rocket plants in response to the application of *Moringa oleifera* extracts as a biostimulant. Life Sciences. 2014;11(1):1113-21.
2. Abdel-Salam E, Alatar A, El-Sheikh MA. Inoculation with arbuscular mycorrhizal fungi alleviates harmful effects of drought stress on damask rose. Saudi Journal of Biological Sciences. 2018;25(8):1772-80.
3. Ahamad I, Saquib R, Qasim M, Saleem M, Khan AM, Yaseen M. Humic acid and cultivar effects on growth, yield, vase life and spike characteristics of gladiolus. Chilean Journal of Agricultural Research. 2014;73(4):339-344.
4. Al-Saad KG. Influence of seaweed extract of *Ascophyllum nodosum* on the growth, floral and corms yield of two gladiolus cultivars (*Gladiolus hybrida*). Plant Archives. 2020;20(2):6885-6894.
5. Alsanam MA, Salih ZK. Response of *Polianthes tuberosa* L. to cold storage time and chitosan on vegetative growth and floral characteristics. Earth and Environmental Science. 2021;761(1):012057.
6. Andrzejak R, Janowska B, Reńska B, Kosiada T. Effect of *Trichoderma* spp. and fertilization on the flowering of *Begonia* × *tuberhybrida* Voss. 'Picotee Sunburst'. Agronomy. 2021;11(7):1278.
7. Calvo P, Nelson L, Kloepper JW. Agricultural uses of plant biostimulants. Plant and Soil. 2014;383(1):3-41.
8. Chen TH, Murata N. Glycine betaine protects plants against abiotic stress: mechanisms and biotechnological applications. Plant Cell & Environment. 2011;34(1):1-20.
9. Cristiano G, De Lucia B. Petunia performance under application of animal-based protein hydrolysates: effects on visual quality, biomass and gas exchange. Frontiers in Plant Science. 2021;12:640608.
10. Cristiano G, Pallozzi E, Conversa G, Tufarelli V, De Lucia B. Effects of an animal-derived biostimulant on the growth and physiological parameters of potted snapdragon (*Antirrhinum majus* L.). Frontiers in Plant Science. 2018;9:861.
11. De Lucia B, Vecchietti L. Type of bio-stimulant and application method effects on stem quality and root system growth in LA Lily. European Journal of Horticultural Science. 2012;77(1):10.
12. Silva DTS, Silva APS, Almeida DSA, Ribeiro KG, Souza DC, Bueno PAA, *et al*. Cytotoxicity, genotoxicity, and toxicity of plant biostimulants produced in Brazil: subsidies for determining environmental risk to non-target species. Water Air Soil Pollution. 2020;231:233.
13. DePascale S, Rouphael Y, Cirillo C, Colla G. Plant biostimulants in greenhouse horticulture: recent advances and challenges ahead. Acta Horticulturae. 2018;1271:327-334.
14. Dulai S. Effects of drought on photosynthetic parameters and heat stability of PSII in wheat and in *Aegilops* species originating from dry habitats. Acta Biologica Szegediensis. 2006;50(1-2):11-7.
15. El-Alsayed SG, Ismail S, Eissa D. Impact of seaweed extract and phosphorus application on productivity of dahlia plants. Assiut Journal of Agricultural Sciences. 2018;49(1):159-88.
16. Elansary HO, Hamid AAM, Yessoufou K, Al-Mana FA, El-Ansary DO, Mahmoud EA, *et al*. Physiological and molecular characterization of water-stressed chrysanthemum under robinin and chitosan treatment. Acta Physiologiae Plantarum. 2020;42(1):1-14.
17. Rodriguez EM, Laissue PP, Durocher YG, Smirnoff N, Mullineaux PM. Photosynthesis-dependent H2O2 transfer from chloroplasts to nuclei provides a high-light signalling mechanism. Nature Communications. 2017;8:49.
18. Fan HM, Wang XW, Sun X, Li YY, Sun XZ, Zheng CS. Effects of humic acid derived from sediments on growth, photosynthesis and chloroplast ultrastructure in chrysanthemum. Scientia Horticulturae. 2014;177(1):118-123.
19. Galmés J, Carbo RM, Medrano H, Flexas J. Rubisco activity in Mediterranean species is regulated by the chloroplastic CO_2 concentration under water stress. Journal of Experimental Botany. 2011;62(2):653-65.
20. Giri B, Beura S. Impact of INM practices on vegetative growth and flowering of hybrid gerbera (*Gerbera jamesonii* B.) cv. Shimmer in open field condition. Progressive Horticulture. 2019;51(2):192-5.
21. Hajizadeh HS, Maani Z, Yari F, Vakilkandi FG. Comparison of vase life and quality of gerbera in preservative solutions including essential oils and chemicals. Journal of Crop Improvement. 2021;23:429-442.
22. Jardin P. Plant biostimulants: Definition, concept, main categories and regulation. Scientia Horticulturae. 2015;196:3-14.
23. Karimi E, Shirmardi M, Ardakani DM, Gholamnezhad J, Zarebanadkouki M. The effect of humic acid and biochar on growth and nutrients uptake of calendula (*Calendula officinalis* L.). Communications in Soil Science and Plant Analysis. 2020;51(12):1658-1669.
24. Kumada K, Sato O, Ohsumi Y, Ohta S. Humus composition of mountain soils in central Japan with special reference to the distribution of P-type humic acid. Soil Science and Plant Nutrition. 1967;13(5):151-158.
25. Kumar HD, Aloke P. Role of biostimulant formulations in crop production: An overview. International Journal of Applied Research in Veterinary Medicine. 2020;8:38-46.
26. Kumari A, Goyal RK, Choudhary M, Sindhu SS. Effects of some plant growth-promoting rhizobacteria (PGPR) strains on growth and flowering of chrysanthemum. Journal of Crop Weed. 2016;12(1):7-15.
27. Nordstedt NP, Chapin LJ, Taylor CG, Jones ML. *Pseudomonas* spp. increases ornamental crop quality during abiotic stress. Frontiers in Plant Science. 2020;10:1754.
28. Salachna P, Zawadzińska A. Effect of chitosan on plant growth, flowering and corm yield of potted freesia. Journal of Ecological Engineering. 2014;15(3):94-101.

29. Schmidt RE. Questions and answers about biostimulants. Davenport: Hi Tech Ag Solutions; c2003, p. 4.
30. Sharma A, Shahzad B, Rehman A, Bhardwaj R, Landi M, Zheng B. Response of phenylpropanoid pathway and the role of polyphenols in plants under abiotic stress. Molecules. 2019;24:2452.
31. Sriprapat W, Thiravetyan P. Efficacy of ornamental plants for benzene removal from contaminated air and water: Effect of plant-associated bacteria. International Biodeterioration and Biodegradation. 2016;113:262-268.
32. Sumangala K, Srikrishnah S, Sutharsan S. Roses growth and flowering responding to concentration and frequency of seaweed (*Sargassum crassifolium* L.) liquid extract application. Current Agriculture Research Journal. 2019;7(2):204-212.
33. Tavares AR, Santos DPLF, Zabotto AR, Nascimento DMVL, Jordão HWC, Boas RLV, *et al*. Seaweed extract to enhance marigold seed germination and seedling establishment. SN Applied Sciences. 2020;2(11):1792.
34. Teklić T, Paradiković N, Špoljarević M, Željković S, Lončarić Z, Lisjak M. Linking abiotic stress, plant metabolites, biostimulants, and functional food. Annals of Applied Biology. 2021;178(1):169-191.
35. Yordanov I, Velikova V, Tsonev T. Plant responses to drought, acclimation, and stress tolerance. Photosynthetica. 2000;38:171-186.
36. Yuan Y. Effects of biostimulants on ornamental plants grown in solid soil-less cultural systems [PhD Thesis]. Lincoln: Lincoln University; 2021.
37. Zhang X, Schmidt RE. The impact of growth regulators on alpha-tocopherol status of water-stressed *Poa pratensis* L. International Turfgrass Society Research Journal. 1997;8(1):1364-2137.
38. Zhang X, Taylor Z, Goatley M, Wang K, Brown I, Kosiarski K. Photosynthetic rate and root growth responses to *Ascophyllum nodosum* extract-based biostimulant in creeping bentgrass under heat and drought stress. HortScience. 2023;58(8):917-921.