Review Article

Efficacy of Eco-Friendly Biostimulants in Enhancing the Performance of Ornamental Crops: A Review

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Abstract

Biostimulants have been successfully used in agricultural and horticultural crops to enhance both qualitative and quantitative parameters. The main active substances of biostimulants includes seaweed extracts, botanicals, humic and fulvic acids, chitosan and compounds containing nitrogen, protein hydrolysates, beneficial fungi and bacteria. These are popularized in the recent years as an important alternatives to chemical fertilizers and are being used as an important agronomic tool since they are environment friendly and promotes sustainable crop production. The application of biostimulants like seaweed extracts and humic acid have been exploited on many fruit and vegetable crops with the aim to enhance crop quality, increase nutrition efficiency and abiotic stress tolerance. The application in ornamentals crops are comparatively lesser thus presenting a wide area of scope for research with the growing ornamental industry. This review aims to cover the concept of biostimulants, classification and their influence or efficacy with respect to quantity and quality of ornamental crops.

Keywords: Biostimulants, seaweed, chitosan, amino acid, botanicals, floriculture

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Introduction

The trends in crop production over the past years has imposed a huge challenge in sustaining an economic input and output. Advancement in technology has necessitated a relevant strategy with scientific approach that includes quality planting materials and improved production practices, especially with the evident impact of climate change on plant growth and development. The aim to enhance production and meet the global needs caused by an exponential growth of the population has resulted in an increased use of chemical fertilizers as agronomic practice over the past years [1, 2].

It is a known fact that overuse of chemical fertilizers and pesticides has a detrimental effects on the environment, human health as well as soil fertility creating an enormous interest in organic production. However, we are aware of the lower yield of organic production in comparison to conventional agriculture [3]. Thus the search for a reliable approach to achieving sustainable system that is eco-friendly, but at the same time gives quality produce and in the quantity that will suffice the demands of the population is highly crucial. A promising agronomic tool and sustainable approach considered in the recent years is the use of naturally derived biostimulants, which is gaining interest globally [4, 5].

Biostimulants

The word ‘biostimulant’ was first used by Zhang and Schmidt [6] and mentioned it as ‘‘materials that, in minute quantities, promote plant growth’’. Du Jardin [7] later gave a more comprehensible definition of biostimulant as ‘‘any substance or mixture of substances of natural origin or microorganism applied to crop or soils with the aim to enhance nutrition efficiency, abiotic stress tolerance and/or crop quality traits regardless of its nutrients content’’. The use of plant biostimulants have been reported to alter the biological, biochemical and physical properties of soil [5], improves nutrient use efficiency [8, 9] and increase crop yields [10]. It affects the root growth and root architecture [11, 12] and also enhances the performance of plants under abiotic stress [13].

In reality the use of biostimulants have been around for many years now, however due to the rising interest of their use as an environment friendly input has resulted in the expansion of its market in the recent years. The global market for these products was estimated at USD 2.6 billion in 2019 with a projected value in 2025 at over USD 4 billion [14]. The use of these biostimulants are thus emerging as a considerable crop management practice and its application can be considered as an innovative environmental friendly approach [15] and a sustainable strategy to enhance crop yield even under stress conditions [16, 17].

Classification and role of biostimulants on ornamental crops

Biostimulants are generally classified into some major categories which have been accepted as the official classification by a number of researchers [18-20].

Seaweed extracts

The bio-stimulatory effect of seaweed has been recorded recently although it has been reported to be used as a source of organic matter since many years back [7]. Seaweeds are green, brown and red marine macro-algae (**Table 1**) and are composed of a mixture of complex polysaccharides, fatty acids, vitamins, phytohormones and mineral nutrients that are known to stimulate plant growth and improved its productivity [21, 22] Brown algal seaweed (*Ascophyllum nodosum*) particularly has been extensively and successfully used in agriculture since the 12th century [23]. The use of seaweed extracts in recent years has gained popularity due to their potential use in organic and sustainable agriculture [24]. Seaweed liquids are often applied as foliar spray or as soil drench and are able to enhance plant growth and performance improving yield and productivity, increase tolerance to abiotic stresses, photosynthetic activity, and resistance to pathogenic attacks of several crops [25].

Table 1 Different classes of seaweed with important species

Class	Important species
Brown algae (Phaeophyceae)	*Ascophyllum nodosum, Cystoseira myriophylloides, Durvillea spp., Ecklonia maxima, Fucus spp., Hydroclathrus spp., Laminaria digitata, Padina pavonica, Ralfsia spp. Sargassum spp.*
Red algae (Rhodophyta)	*Acanthophora spicifera, Cyanidium caldarium, Gelidium serrulatum, Gracilaria spp., Kappaphycus alvarezii, Laurencia johnstonii, Macrocycstis pyrifera, Porphyra perforate, Nereocystis spp.*
Green algae (Chlorophyta)	*Caulerpa spp., Codium spp., Enteromorpha prolifera, Ulva spp.*

Seaweed extracts on ornamental crops

Few researches had been conducted to evaluate the efficacy of seaweed extracts on the performance of ornamental crops over the years with evidence of positive response. Seaweed extracts at 20 % resulted in maximum plant biomass, number of flowers and dry weight of rose flowers [26] and when sprayed at 5 %, it increased the plant height, number of primary and secondary shoots as well as number of productive shoot and leaf area of *Jasminum sambac* [27]. Chrysanthemum recorded high yield per hectare when treated with *Ascophyllum nodosum at* 5 ml/L [28]. The number of pseudobulb and pseudobulb perimeter of *Dendrobium nobile* Lindl var Sonia was found to increase with brown sea weed extract (Biovita) at 1% concentration [29]. Both vegetative and flowering characteristics were induced in annuals like amaranthus [30], pansy [31], *Tagetus* [32], *Dianthus* [33], petunia [34] and salvia [12]. The treated begonia plants had better nutrient uptake and higher free proline content in roots upon treatment with seaweed extracts at 0.25 % [35].

Botanicals

Plants extracts which are used in pharmaceutical or cosmetic products and also in plant production for its medicinal values are the botanicals having biostimulant activity [37]. They contain bioactive compounds which are known to enhance plant productivity as well as protection. Many plants like moringa leaf extracts, pongamia seed extract, lantana leaf extract, chrysanthemum leaf extracts, ginger extracts etc. are widely used by farmers.

Botanicals on ornamental crops

Botanical extracts had proven effective in several ornamental crops rendering their use as an efficient input for crop production. Leaf extracts like moringa leaf extracts at 5 % had resulted an increased corm diameter and biomass of gladiolus [38] whereas it led to rapid corm sprouting, high leaf chlorophyll and longest vase life of *Freesia hybrida* [39]. Application of ginger extracts at 15 mg/L had increased the total soluble sugars, phenol, anthocyanin content, and carotenoid content with higher volatile oil yield in *Rosa damascena* [40]. Higher percentage of chlorophyll with improved vegetative and floral characteristics was recorded when banana peel powder was applied at 10 g per plant on the flower *Narcissus daffodil* L. [41].

Figure 1 Marigolds 6 weeks after applying seaweed at transplanting. A = control; B = I cm seaweed concentrate applied to the soil; C = 2 cm seaweed concentrate applied as a foliar spray [36].

Humic acids and fulvic acids

Humic and fulvic acids have been used as an agricultural inputs many years for their effects on microbial communities, plant growth and nutrient availability [14, 42, 43]. Humic substances (HS) are the natural constituents of the soil organic matter, that is produced as a result of decomposition of plant, animal and microbial residues and are basically the end-products of microbial decomposition and chemical degradation of dead biota in soils [20, 44]. Humic substances in soils are divided into three main fractions: humic acids, fulvic acids, and humin. These substances improve the physical, physicochemical, chemical and biological properties of the soil thus increasing the soil fertility.

Humic acids and fulvic acids on ornamental crops

Application of humic acid recorded more number of spikes and flowers per plant with increased blooming period in *Antirrhinum majus* [45], better yield per plant in chrysanthemum [46], more branches and flowers per plant in petunia [47] and increased flowering duration in carnation [48]. The chlorophyll and chemical components of leaves like N, P, K were observed to be higher with humic acid application in gladiolus [49] and tuberose [50]. Foliar application of fulvic acid resulted in increased plant height, stem thickness and more number of shoots in the foliage plant *Dracaena* [51].

Chitosan and other biopolymers

Chitosan is a deacetylated form of the biopolymer chitin that is produced naturally and industrially [52]. These substances are used to induce resistance to abiotic stresses like drought, temperature and salinity by building defence against plant pathogens. Chitosan induces stomatal closure via ABA-dependent mechanism resulting in its ability to enhance stress tolerance in plants [53]. The common sources of raw materials for chitosan manufacturing are shrimps and crabs while lobsters, crayfishes and oysters have also been utilized [22].

Chitosan on ornamental crops

The efficacy of chitosan have been assessed for the pre and post-harvest performance of different ornamental crops. Its application has been reported to extend the vase life of cut carnations [54] and heliconia [55]. Chitosan is widely known for its function to increase stress tolerance in crops, thus evident by the enhanced proline, K^+, Ca^{+2}, phenols, leaf water potential, antioxidants, and leaf water content in *Chrysanthemum morifolium* [56] and increased stomatal index in tiger orchid [57]. It also enhanced the growth of protocorms and bulbs of orchid and tuberose [58, 59].The application also proved useful in increasing the number of leaves per plant of *Eucomis bicolor* [60].

Inorganic compounds

The beneficial elements like cobalt, silica, selenium and sodium promotes plant growth, improves the quality of produce and tolerance to abiotic stress. Their mechanism in enhancing crop growth is attributed by their ability to influence plant hormones and enzymes signalling, cell wall rigidification and protection against pathogens [52]. Silicon is a commonly used biostimulant and is known to alleviate abiotic stresses such as drought, salt and nutrient stress.

Inorganic compounds on ornamental crops

Elements like silica has substantiated its importance for postharvest treatment in many flower crops. Silica nanoparticles not only improved the longevity and postharvest quality of cut roses [61] but also increased the concentration of calcium, protein, pigment intensity and degree of transparency in gerbera [62]. The treatment of *Tagetes patula* with potassium silicate at 5 ml/L had also increased the percentage of essential oil [63]. Selenium has been found to be beneficial in increasing the phenolic content and antioxidant activity of *Narcissus* [64]. The senescence of rose was delayed by cobalt chloride application by increasing the water uptake and increasing the vase life [65].

Protien hydrolates and other N-containing compounds

Amino-acids and peptides mixtures are manufactured by chemical synthesis or enzymatic protein hydrolysis from agroindustrial by-products of plant sources (crop residues of corn, soyabean etc) and animal wastes (collagen, epithelial tissues etc). These products are used as effective plant biostimulants [7, 18, 19]. Amino acids are readily absorbed, transported, and utilized as a source of nitrogen and carbon for plants resulting in indirect effects on plant growth and development. They improves soil structure and increases the microbial activity thus enhancing the soil fertility.

Amino acids and protein hydrolysates on ornamental crops

Different types of amino acids are being in use for improving the quality and performance of several crops. Arginine and asparagine has positively affected the leaves and flower characters of nasturtium [66] while it caused increased number of shoots in wild rose [67]. Tryptophan and ascorbic acids increased the fresh and dry weight of leaves with more weight and length of *Spathiphyllum wallisii* spathe [68]. Amino acid application also significantly increased the number of floret and inflorescence in *Freesia hybrida* [69], increased chlorophyll and carotenoid content in gerbera [70] and proliferate the floral characters in carnation [71].

Animal derived protein hydrolysates enhanced leaf and root, nitrogen content, photosynthetic rate, transpiration rate and stomatal conductance of *Antirrhinum majus* L. hybrids [72] and also resulted in significant improvement in net photosynthesis and stomatal conductance of petunia [73].

Beneficial Fungi and bacteria

Beneficial fungi such as mycorrhizal fungi aids nutrient uptake and mineralization and assist with stress tolerance [74], whereas *Trichoderma* releases growth enzymes and increase nutrient use efficiency. These fungal-based products are applied to plants to promote nutrition use efficiency, tolerance to stress, enhance quality and crop yield [75]. Beneficial bacteria, specifically plant growth promoting rhizobacteria (PGPR) are also known to stimulate plant growth by improving soil structures, supplying nutrients and production of hormones thus enhancing plant response to biotic and abiotic stress [76, 77].

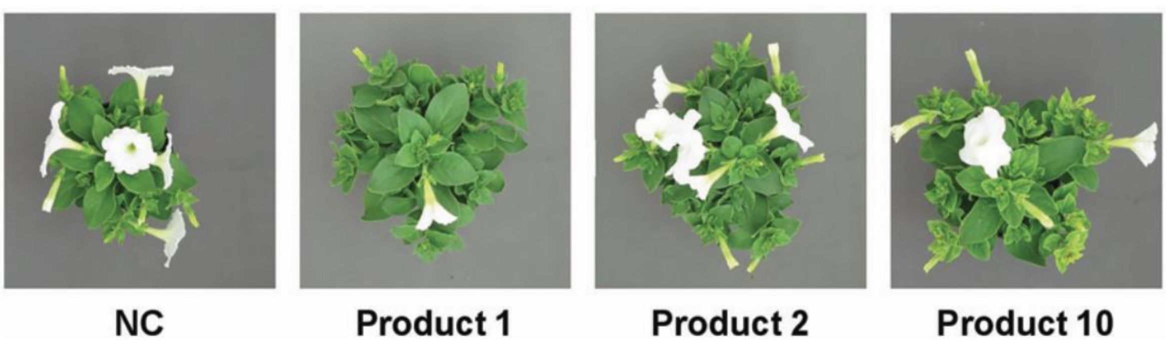

Figure 2 Plant size (Growth index) evaluations of petunia; negative control (NC) petunia treated with biostimulant products 1 and 2 containing multiple species of beneficial bacteria and fungi, and product 10 containing *Bacillus subtilis* [78].

Beneficial fungi and bacteria on ornamental crops

Arbuscular mycorrhizal fungi improved the flower characteristics of zinnia with increased fresh and dry shoot weight [79] when it was applied in combination with *Bacillus subtilis,* the total oil yield of geranium was significantly increased because of the increase in biomass production [80]. Tuberose when treated with phosphate solubilising bacteria (PSB) recorded high production of bulb per plant [81] and minimum days of bulb sprouting when treated with arbuscular mycorrhizal fungi in combination with GA_3 [82]. Plant growth promoting bacteria (PGPR) has been found to improve the phytochemical characteristics and increased the essential oil content of rose cv Black prince [83].

Conclusion

Biostimulants are now being considered as an effective environment friendly input in crop management and production. The use in ornamental crops, however is comparatively lesser compared to fruits and vegetable crops. A wide range of scope is available as they offer effective and sustainable approach to enhance crop productivity which could be incorporated in an integrated crop management system. More research prospects are also available in grasping the underlying mechanisms of biostimulants, their mode of action and plant responses at the physiological, biochemical, and molecular levels. Progressive precision farming in crop management and demands of farmers and consumers for alternatives to synthetic inputs are inevitable and could trigger more demands to the use of biostimulants in the years to come.

The general knowledge and awareness would help in commercialization and large scale application of biostimulants at farmer’s level. The idea is to ensue limited use of chemical fertilizers which as we know is becoming a threat to the environment each day. Improving crop performance and less contribution to soil, air and water pollution is the consistent impact we are currently striving to achieve in the farming community.

References

[1] Mannino G, Campobenedetto C, Vigliante I, Contartese V, Gentile C, Bertea CM. The application of a plant biostimulant based on seaweed and yeast extract improved tomato fruit development and quality. Biomolecules. 2020, 10 (12): 1662.

[2] Campobenedetto C, Grange E, Mannino G, Van Arkel J, Beekwilder J, Karlova R, Garabello C, Contartese V, Bertea CM. A biostimulant seed treatment improved heat stress tolerance during cucumber seed germination by acting on the antioxidant system and glyoxylate cycle. Frontiers in Plant Sci. 2020, 11: 836.

[3] Dorais M, Alsanius B. Advances and trends in organic fruit and vegetable farming research. Hortic. Reviews. 2015, 43 (4): 185.

[4] Colla G, Rouphael Y. Biostimulants in horticulture. Scientia Hortic. 2015, 196: 1–2.

[5] Rouphael Y, Cardarelli M, Bonini P, Colla G. Synergistic action of a microbial-based biostimulant and a plant derived-protein hydrolysate enhances lettuce tolerance to alkalinity and salinity. Frontiers in Plant Sci. 2017, 8: 131.

[6] Zhang X, Schmidt RE. The impact of growth regulators on the α-tocopherol status in water-stresses Poa pratensis L. Int. Turfgrass Res. J. 1997, 8: 1364–1373.

[7] Du Jardin P. The Science of Plant Biostimulants–A bibliographic analysis, Ad hoc study report. European Commission. 2012.

[8] Vernieri P, Borghesi E, Tognoni F, Serra G, Ferrante A, Piagessi A. Use of biostimulants for reducing nutrient solution concentration in floating system. In III International Symposium on Models for Plant Growth, Environmental Control and Farm Management in Protected Cultivation. 2006, 718: 477-484.

[9] De Pascale S, Rouphael Y, Colla G. Plant biostimulants: Innovative tool for enhancing plant nutrition in organic farming. European J. Hortic. Sci. 2017, 82 (6): 277-285.

[10] Yakhin OI, Lubyanov AA, Yakhin IA, Brown PH. Biostimulants in plant science: A global perspective. Frontiers in Plant Sci. 2017, 7: 2049.

[11] Yazdani B, Nikbakht A, Etemadi N. Physiological effects of different combinations of humic and fulvic acid on gerbera. Soil Sci. Plant Analysis. 2014, 45 (10): 1357-1368.

[12] Zeljković S, Parađiković N, Babić T, Đurić G, Oljača R, Vinković T, Tkalec M. Influence of biostimulant and substrate volume on root growth and development of scarlet sage (Salvia splendens L.) transplants. J. Agri Sci. 2010, 55: 9-36.

[13] Van Oosten MJ, Pepe O, De Pascale S, Silletti S, Maggio A. The role of biostimulants and bioeffectors as alleviators of abiotic stress in crop plants. Chem. Biol. Technol. Agri. 2017, 4 (1): 1-12.

[14] Sible CN, Seebauer JR, Below FE. Plant biostimulants: A categorical review, their implications for row crop production, and relation to soil health indicators. Agron. 2021, 11 (7): 1297.
[15] Tejada M, Benítez C, Gómez I, Parrado J. Use of biostimulants on soil restoration: Effects on soil biochemical properties and microbial community. Applied Soil Ecol. 2011, 49: 11-17.
[16] Petropoulos SA, Fernandes Â, Plexida S, Chrysargyris A, Tzortzakis N, Barreira J, Barros L, Ferreira IC. Biostimulants application alleviates water stress effects on yield and chemical composition of greenhouse green bean (Phaseolus vulgaris L.), Agron. 2020,10 (2): 181.
[17] Campobenedetto C, Agliassa C, Mannino G, Vigliante I, Contartese V, Secchi F, Bertea CM. A biostimulant based on seaweed (Ascophyllum nodosum and Laminaria digitata) and yeast extracts mitigates water stress effects on tomato (Solanum lycopersicum L.). Agri. 2021, 11 (6): 557.
[18] Calvo P, Nelson L, Kloepper JW. Agricultural uses of plant biostimulants. Plant and Soil. 2014, 383 (1): 3-41.
[19] Du Jardin P. Plant biostimulants: Definition, concept, main categories and regulation. Sci. Hortic. 2015, 196: 3–14.
[20] Halpern M, Bar-Tal A, Ofek M, Minz D, Muller T, Yermiyahu U. The use of biostimulants for enhancing nutrient uptake. Advances in agron. 2015, 130: 141-174.
[21] Safinaz AF, Ragaa AH. Effect of some red marine algae as biofertlizers on growth of maize (Zea mays L.) plants. Int. Food Res. J. 2013, 20 (4):1629–32.
[22] Dedhia L. Bio Stimulants in Floriculture. 2022.
[23] Temple WD, Bomke AA. Effects of kelp (Macrocystis integrifolia) on soil chemical properties and crop responses. Plant and Soil. 1988, 105: 213-222.
[24] Russo RO, Berlyn GP. The use of organic biostimulants to help low input sustainable agriculture. J. Sustainable Agri. 1991, 1 (2): 19-42.
[25] Bulgari R, Franzoni G, Ferrante A. Biostimulants application in horticultural crops under abiotic stress conditions. Agron. 2019, 9 (6): 306.
[26] Sumangala K, Srikrishnah S, Sutharsan S. Roses growth and flowering responding to concentration and frequency of seaweed (Sargassum crassifolium L.) liquid extract application. Curr. Agri. Res. J. 2019, 7 (2): 236.
[27] Manimaran P, Ghosh S, Priyanka R. Bulb size and growth regulators on the growth and performance of bulbous ornamental crops-A Review. Chem. Sci. Rev. Letters. 2017, 6 (22): 1277-1284.
[28] Suchitha N, Babu KK, Kumar SP, Lakshminarayana D. Studies on the effect of biostimulants on growth and yield of cut flower of chrysanthemum (Dendranthema grandiflora) cv. Denjigar white. 2021.
[29] Hegde PP, Patil BC, Kulkarni MS, Hegde NK, Kukanoor L, Shiragur M, Harshavardhan M. Efficacy of biostimulants on growth and flowering of Dendrobium orchid (Dendrobium nobile Lindl.) var. Sonia-17 under protected cultivation. 2021.
[30] Abdel-Aziz NG, Mahgoub MH, Siam HS. Growth, flowering and chemical constituent performance of Amaranthus tricolor plants as influenced by seaweed (Ascophyllum nodosum) extract application under salt stress conditions. J. Appl. Sci. 2011, 1472-1484.
[31] Zeljković S, Parađiković N, Tkalec Kojić M, Mladenović E. Effect of biostimulant application on development of pansy (Viola tricolor var. hortensis dc.) seedlings. J. Central European Agric. 2021, 22(3): 596-601.
[32] Sridhar S, Rengasamy R. Effect of seaweed liquid fertilizer on the growth, biochemical constituents and yield of Tagetes erecta, under field trial. Journal of Phytol. 2010, 2 (6).
[33] Al-Hamzawi MK. Effect of seaweed extract and micronutrients mixture on some growth characters and flowering of Dianthus chinensis L. and Gazania splendens L. plants. In Journal of Physics: Conference Series. 2019, 1294 (9): 092001.
[34] Li Y, Mattson NS. Effects of seaweed extract application rate and method on post-production life of petunia and tomato transplants. Horti. Technol. 2015, 25 (4): 505-510.
[35] Parađiković N, Zeljković S, Tkalec M, Vinković T, Maksimović I, Haramija J. Influence of biostimulant application on growth, nutrient status and proline concentration of begonia transplants. Biol. Agri. Hortic. 2017, 33 (2): 89-96.
[36] Aldworth SJ, Van Staden J. The effect of seaweed concentrate on seedling transplants. South African J. Bot. 1987, 53(3): 187-189.
[37] Seiber JN, Coats J, Duke SO, Gross AD. Biopesticides: state of the art and future opportunities. J. Agri. Food Chem. 2014, 62(48): 11613-11619.
[38] Zulfiqar F, Younis A, Finnegan PM, Ferrante A. Comparison of soaking corms with moringa leaf extract alone or in combination with synthetic plant growth regulators on the growth, physiology and vase life of sword lily. Plants. 2020, 9 (11): 1590.

[39] Ahmad I, Tanveer MU, Liaqat M, Dole JM. Comparison of corm soaks with preharvest foliar application of moringa leaf extract for improving growth and yield of cut Freesia hybrida. Scientia Hortic. 2019, 254: 21-25.

[40] Ali EF, Al-Yasi HM, Issa AA, Hessini K, Hassan FAS. Ginger extract and fulvic acid foliar applications as novel practical approaches to improve the growth and productivity of damask rose. Plants. 2022, 11(3): 412.

[41] Altaee AH. In IOP Conference Series: Earth and Environmental Sci. 2019, 388: 012074.

[42] Celik H, Katkat AV, Aşık BB, Turan MA. Effect of foliar-applied humic acid to dry weight and mineral nutrient uptake of maize under calcareous soil conditions. Comm. Soil Sci. Plant Analysis. 2010, 42 (1): 29-38.

[43] Jindo K, Sonoki T, Matsumoto K, Canellas L, Roig A, Sanchez-Monedero MA. Influence of biochar addition on the humic substances of composting manures. Waste Management. 2016, 49: 545-552.

[44] Asli S, Neumann PM. Rhizosphere humic acid interacts with root cell walls to reduce hydraulic conductivity and plant development. Plant and Soil. 2010, 336 (1): 313-322.

[45] Memon SA, Khetran K. Effect of humic acid and calcium chloride on the growth and flower production of Snapdragon (Antirrhinum majus). J. Agri. 2014, 10 (6): 1557-1569.

[46] Gawade NV, Varu DK, Devdhara U. Response of biostimulants and biofertilizers on yield and quality of chrysanthemum cv. Ratlam Selection. Inter. J. Curr. Microbiol. Appl. Sci. 2019, 8 (9): 2732-2742.

[47] Memon SA, Baloch MH, Baloch RA. Influence of humic acid and macronutrients (mgso4+ s) application on growth and yield of petunia (Petunia milliflora). J. Agric. Technol. 2014, 10 (6): 1501-1516.

[48] Vidya A, Shivpure A, Hanumantharayya BG. Influence of biostimulants on growth and yield of China aster (Callistephus chinensis) cv. Poornima. 2022.

[49] Adam A. Studies the response of gladiolus plants to humic acid, potassium and water irrigation intervals. Scientific J. Agri. Sci. 2021, 3 (1): 23-37.

[50] El-Bably SM. Effect of some Natural Material Additives on Growth and Flowering of Tuberose (Polianthes tuberosa L.) Bulbs. J. Plant Prod. 2017, 8 (9): 895-906.

[51] El-Khateeb MA, Nasr AAM, Hassan NAA. Growth and quality improvement of Dracaena surculosa Lindl. by the foliar application of some bio-stimulants. Int. J. Envi. 2018, 7 (2): 53-64.

[52] Sharma P, Abrol A, Qureshi A, Sharma S. Role of biostimulants with special reference to Panchgavya and Jeevamrit in floriculture. Agri int. 2019, 6 (1): 23-32.

[53] Iriti M, Picchi V, Rossoni M, Gomarasca S, Ludwig N, Gargano M, Faoro F. Chitosan antitranspirant activity is due to abscisic acid-dependent stomatal closure. Environ. Exp. Bot. 2009, 66 (3): 493-500.

[54] Solgi M. The application of new environmentally friendly compounds on postharvest characteristics of cut carnation (Dianthus caryophyllus L.). Brazilian J. Bot. 2018, 41: 515–522.

[55] Bañuelos-Hernández KP, García-Nava JR, Leyva-Ovalle OR, Peña-Valdivia CB, Trejo C, Ybarra-Moncada MC. Chitosan coating effect on vase life of flowering stems of Heliconia bihai L. cv. Halloween. Postharvest Biol. Technol. 2017, 132: 179-187.

[56] Elansary HO, Abdel-Hamid AME, Yessoufou K. Physiological and molecular characterization of water-stressed chrysanthemum under robinin and chitosan treatment. Acta Physiologiae Plantarum. 2020, 42: 31.

[57] Pitoyo A, Hani MR, Anggarwulan E. Application of chitosan spraying on acclimatization success of tiger orchid (Grammatophyllum scriptum) plantlets. Nusantara Biosci. 2015, 7 (2).

[58] Kananont N, Pichyangkura R, Chanprame S, Chadchawan S, Limpanavech P. Chitosan specificity for the in vitro seed germination of two Dendrobium orchids (Asparagales: Orchidaceae). Sci. Hortic. 2010. 124 (2): 239-247.

[59] Abd-El-Hady WMF. Response of tuberose (Polianthes tuberosa L.) plants to chitosan and seaweed foliar application. Scientific J. Flowers Ornamental Plants. 2020, 7 (2): 153-161.

[60] Byczyńska A. Chitosan improves growth and bulb yield of pineapple lily (Eucomis bicolor Baker) an ornamental and medicinal plant. World Scientific News. 2018, 110: 159-171.

[61] El-Serafy RS. Silica nanoparticles enhances physio-biochemical characters and postharvest quality of Rosa hybrida L. cut flowers. J. Hortic. Res. 2019, 27 (1).

[62] Tofighi Alikhani T, Tabatabaei SJ, Mohammadi Torkashvand A, Khalighi A, Talei D. Effects of silica nanoparticles and calcium chelate on the morphological, physiological and biochemical characteristics of gerbera (Gerbera jamesonii L.) under hydroponic condition. J. Plant Nutrition. 2021, 44 (7): 1039-1053.

[63] Ayyat AM, Abdel-Mola MAM. Response of Tagetes patula plants to foliar application of potassium silicate and seaweed extract under various irrigation intervals. Scientific J. Flowers Ornamental Plants. 2020, 7 (4): 513-526.

[64] Bayat H, Moradinezhad F. Extending vase life of Narcissus tazetta L. cut flowers using selenium and 1-methylcyclopropene treatments. J. Appl. Horti. 2020, 22 (3).

[65] Aslmoshtaghi E, Jafari M, Rahemi M. Effects of daffodil flowers and cobalt chloride on vase life of cut rose. J.

Chem. Health Risks. 2014, 4 (2): 1-6.
[66] Zeljkovic S, Susak U, Tudorovic V. Influence of two biostimulants application on growth and development of Tropaeolum majus L. Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series. 2017, 46 (1): 308-313.
[67] Tkalec M, Parađiković N, Zeljković S, Vinković T. Influence of medium on growth and development of wild rose in vitro. In International Conference on Bioscience: Biotechnology and Biodiversity–Step in the Future. 2012, 104-107.
[68] Ibrahem HE. Effect of Tryptophan, Ascorbic Acids and Super Max Different Rates on Vegetative Growth and Flowering Spathiphyllum Wallsi. J. Plant Prod. 2016, 7 (8): 813-820.
[69] Abbass JA, AL-Zurfi MTH, Al-Abbasi AM, Swadi MJ, Kadhim ES. Effect of adding wheat organic residues and salicylic acid on growth and corms production of Freesia hybrida plants. Plant Archives. 2020, 20 (1): 574-578.
[70] Tavakoli M, Asadi-Gharneh HA. Assess effect of foliar application of seaweed extract and amino acids on morpho-physiological characteristics of Gerbera jamesonii var. Stanza cut flowers. J. Crop Nutrition Sci. 2020, 6 (1): 1-11.
[71] Niyokuri AN, Nyalala S, Mwangi M. Effects of bioslurry and plant biostimulant Hicure® on yield, flower quality and vase life of carnation (Dianthus caryophyllus L.). J. Appl. Hortic. 2017, 19 (1): 29-34.
[72] 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 Sci. 2018, 9: 861.
[73] Cristiano G, De Lucia B. Petunia performance under application of animal-based protein hydrolysates: effects on visual quality, biomass, nutrient content, root morphology, and gas exchange. Frontiers in Plant Sci. 2021, 12: 890.
[74] Rouphael Y, Franken P, Schneider C, Schwarz D, Giovannetti M, Agnolucci M, De Pascale S, Bonini P, Colla G. Arbuscular mycorrhizal fungi act as biostimulants in horticultural crops. Scientia Hortic. 2015, 196: 91-108.
[75] Dalpé Y, Monreal M. Arbuscular mycorrhiza inoculum to support sustainable cropping systems. Crop management. 2004, 3 (1): 1-11.
[76] Vacheron J, Desbrosses G, Bouffaud ML. Touraine B, Moënne-Loccoz Y, Muller D, Legendre L, Wisniewski-Dyé F, Prigent-Combaret C. Plant growth-promoting rhizobacteria and root system functioning. Frontiers in Plant Sci. 2013, 4: 356.
[77] Rybakova DG, Grube M, Köberl M. The plant microbiome explored: Implications for experimental botany. J. Exp. Bot. 2016, 67 (4): 995–1002.
[78] Lin Y, Jones ML. Evaluating the growth-promoting effects of microbial biostimulants on greenhouse floriculture crops. HortScience. 2022, 57(1): 97-109.
[79] Saini I, Aggarwal A, Kaushik P. Influence of biostimulants on important traits of Zinnia elegans Jacq. under open field conditions. Int. J. Agron. 2019.
[80] Alam M, Khaliq A, Sattar A, Shukla RS, Anwar M, Dharni S. Synergistic effect of arbuscular mycorrhizal fungi and Bacillus subtilis on the biomass and essential oil yield of rose-scented geranium (Pelargonium graveolens). Archives of Agron. Soil Sci. 2011, 57 (8): 889-898.
[81] Joginder S. Response of PSB inoculation and gibberellic acid on vegetative growth and flowering of tuberose (Polianthes tuberosa L.) cv. Double. Agriways. 2015, 3 (2): 103-106.
[82] Kumar J, Singh T, Pal K. Effect of GA3 and VAM on growth and flowering in Tuberose (Polianthes tuberosa L.) Cv. Double. Agric. Sci. Digest-A Res. J. 2011, 31 (4): 289-292.
[83] Araujo NAF, Brandao RM, Barguil BM, Cardoso MDG, Pasqual M, Rezende RALS, Pereira MMA, Buttros VHT, Doria, J. Plant growth-promoting bacteria improve growth and modify essential oil in rose (Rosa hybrida L.) cv. Black Prince. Frontiers in Sustainable Food System. 2020, 4: 606827.

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