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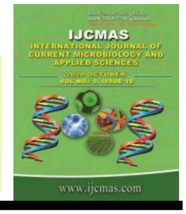

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Beneficial Effects of Biostimulants in Various Flower Crops and Ornamental Plants

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A B S T R A C T

Agricultural growing practices have been evolving towards organic, sustainable or environmentally friendly systems. The aim of modern agriculture is to reduce inputs without reducing the yield and quality. The identification of organic molecules able to activate plant metabolism may allow an improvement in plant performance in a short period of time and in a cheaper way. Biostimulants are plant extracts and contain a wide range of bioactive compounds that are mostly still unknown. These products are usually able to improve the nutrient use efficiency of the plant and enhance tolerance to biotic and abiotic stresses. In this review, the state of the art and future prospects for biostimulants are reported and discussed. Moreover, particular attention has been paid to intensive agricultural systems such as floricultural crops. In floriculture, biostimulants used in bedding plant production stimulated the growth of plants, which reached the blooming and commercial stages earlier, thus optimizing space in the greenhouse.

Introduction

The sustainability production of horticultural crops is essential to meet consumer's demand. This is best achieved by increasing the efficient use of resources to make and provide healthy products. In contemporary years, various technological upheavals have been proposed in order to boost the sustainability of production systems, through a remarkable reduction of agrochemicals. An optimistic practice would be the use of substances and/or microorganisms that strengthen plant growth, increase tolerance to unfavorable soil and environmental conditions, and it also increases resource use efficiency. The term "biostimulant" was proposed for these substances and microorganisms by (Zhang and Schmidt, 1997). Plant biostimulants are the materials which include substances and microorganisms which stimulate natural processes when applied to plants or the rhizosphere the main functions of plant biostimulants include nutrient uptake, nutrient efficiency, tolerance to abiotic stresses, increase crop quality. Jardin (2015) proposed seven classes of substances that act as biostimulant namely: Humic and fulvic acids (Canellas *et al.*, 2015), protein hydrolysates, seaweed extracts, chitosan (Pichyangkura and

Chandchavan, 2015), inorganic compounds, beneficial fungi and bacteria (Ruzzi and Aroca, 2015).

Main categories of biostimulants

Humic and fulvic acids

Humic substances (HS) are the natural elements of the soil organic matter, formed from the decomposition of plant, animal and microbial residues, also from the metabolic activity of soil microbes using these substrates. Sources of humic substances (HS) are extracted from naturally humified organic matter (e.g., peat or volcanic soils), from composts and vermicomposts, or from mineral deposits. Humic substances enhance soil fertility, acting on physical, physico-chemical, chemical and biological properties of the soil.

Protein hydrolysates and other N-containing compounds

Amino-acids and peptides mixtures are obtained by chemical and enzymatic protein hydrolysis from agro-industrial by-products. Other nitrogenous molecules include betaines, polyamines, and non-protein amino acids. These compounds have beneficial effects as biostimulants on plant growth. It regulates enzymes of the TCA cycle, Chelating effects are reported for some amino acids (like proline) which may protect plants against heavy metals but also contribute to micronutrients mobility and acquisition.

Seaweed extracts and botanicals

Use of fresh seaweeds as a source of organic matter and as fertilizer is ancient in agriculture, but effects of biostimulant have been recorded recently. This prompts the commercial use of seaweed extracts and of purified compounds, which include the polysaccharides laminarin, alginates and carrageenans, and their breakdown products. Other constituents contributing to the plant growth include sterols, micro and macronutrients, N-containing compounds, like betaines, and hormones. Their polysaccharides in soils, contribute to water retention, gel formation, and soil aeration.

Chitosan and other biopolymers

Chitosan is formed from chitin, a copolymer of N-acetyl-d-glucosamine and D-glucosamine. The physiological effects of chitosan oligomers in plants are the results of the capacity of this poly-cationic compound to bind a wide range of cellular components, including cell wall constituents, plasma membrane and DNA, but also to bind specific receptors involved in defense gene activation, in a similar way as plant defense elicitors. Chitosan used as a biostimulant to stimulate plant growth and abiotic stress tolerance, and as to induce pathogen resistance; however, these responses are complex and they depend on different chitosan-based structures and concentrations as well as the plant species and developmental stage.

Inorganic compounds

Chemical elements that promote plant growth and may be essential to particular taxa but are not required by all plants are called beneficial elements. The five main beneficial elements are Si, Al, Se, Na and Co, present in soils and in plants as different inorganic salts and as insoluble forms. These inorganic compounds influence pH, osmotic and redox homeostasis, hormone signaling and enzymes involved in stress response (e.g. peroxidase). Among five beneficial elements Si is used abundantly as biostimulants, Si alleviates salt, drought, and nutrient stress, as well as stress associated with climatic conditions, minimizes metal and metalloid toxicities.

Table.1

Sl No	Bio stimulant	Crop	Application ofbio stimulant	Effect of bio stimulants	References
1	Humic substances	Gladiolus	HA derived from composts is applied with different concentration doses; corms soaked for 24 h in treatment solutions	Growth is increased and promoted early flowering.	**Baldotto and Baldotto, 2013.**
		Chrysanthemum	HA derived from peat combined with NPK fertilizers is applied as foliar spray	Increased shoot and root fresh and dry weight and flower diameter by 33%.	**Fan *et al.*, 2014.**
		Croton and hibiscus	HA derived from vermicompost is applied as foliar spray with different concentration doses	It hastens rooting of cuttings.	**Baldotto *et al.*, 2012.**
2	Protein Hydrolysates	lily	Foliar application	Reduced the duration of crop and increased diameter of flower buds,stem and bulb dry weight	**De Lucia and Vecchietti, 2012.**
3	Sea weed extract	Amaranthus tricolor	*A. nodosum* extract applied as foliar spray	Increased stalk length of inflorescences, length, and number of inflorescences, the **fresh and dry weight of inflorescences under salt stress**	**Aziz *et al.*, 2011.**
		Marigold	*Ecklonia maxima* extract applied as foliar spray	Increased in **vegetative and reproductive growth**	**Van Staden *et al.*, 1994.**
		Petunia, Pansy and Cosmos	*A. nodosum* extract along with N-P-K fertilizer	Increased length of root, leaf area and development of root and shoot in response to drought stress	**Neily *et al.*, 2010.**
		Paper birch	Seaweed extract	Increased in **chlorophyll and carotenoids**	**Richardson *et al.*, 2004.**
		Tall fescue sod	*A. nodosum* extract in combination with humic acid	Increased root mass, and foliar content of tocopherol and zeatin riboside under drought stress	**Zhang *et al.*, 2010.**
		Turf and forage grasses	*A. nodosum* commercial extract	Enhanced ascorbic acid, ß-carotene content and increased antioxidant	**Kauffman *et al.*, 2007.**

				activity of **superoxide dismutase, glutathione reductase, and ascorbate peroxidase**	
4	Chitosan	Chrysanthemum	Chitosan at 0.01% to 0.05% sprayed Twice on symptomatic plants	Protected against *Oidium chrysanthemi* and *Puccinia horiana*.	**Wojdyła, 2004.**
		Gladiolus	Corm dippedbefore planting with Commercial chitosan (Biorend) at 1.5% combined with hot watertreatment	Accelerated corm emergence, increased number of flowers extended vase life and increased number of cormlets.	**García *et al.*, 2009.**
		Lisianthus	Chitosan flake at 1% Added to soil at sowing time	Enhanced growth, shortened flowering time increased number and weight of flowers.	**Ohta *et al.*, 1999.**
		Rose	Plant spraying twice weekly after rose powdery mildew symptoms Chitosan at 0.01–0.02% (w/v)	Protected against *Sphaerotheca pannosa* var. rosae, *Peronospora sparsa* and *Diplocarpon rosae*.	**Wojdyła, 2004.**
		Gloxinia	Seedling pretreatment and soil application Chitosan at 1% (w/v)	Promoted seedling growth and induced earlier flowering.	**Ohta *et al.*, 2004.**
5	Silicon	**Rose**	Two concentrations, i.e.,50 and 100 ppm by spraying for 6 s every 8 min for 16 h per day Si applied through the mist	Increased leaflet retention, the percentage of rooting, and new leaf emergence	**Gillman and Zlesak, 2000.**
		Carnation	Potassium silicate (K_2SiO_3) with 0, 50, or 100 $mg·L^{-1}$ in combination with 0, 50, or 100 mM sodium chloride (NaCl) in Invitro condition	Enhancement of growth and resistance to salinity by Si 50 $mg·L^{-1}$	**Soundarajan *et al.*,2015.**

In conclusion the application of biostimulants in flower crop cultivation allows higher levels of sustainability by the reduction of fertilizers and environmental contamination and, at the same time, increases plant tolerance to abiotic and biotic stresses enhancing internal and external quality. It can be concluded that application of biostimulants can lead to qualitative and quantitative increase in various flower crop production. Thus, biostimulants play a significant role in sustainable flower production.

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