

Editorial

Management of Abiotic Stress in Horticultural Crops: Spotlight on Biostimulants

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Abstract: Horticultural crops are currently exposed to multiple abiotic stresses because of ongoing climate change. Abiotic stresses such as drought, extreme temperatures, salinity, and nutrient deficiencies are causing increasing losses in terms of yield and product quality. The horticultural sector is therefore searching for innovative and sustainable agronomic tools to enhance crop tolerance towards these unfavorable conditions. In a recent review published in *Agronomy*, “*Biostimulants Application in Horticultural Crops under Abiotic Stress Conditions*”, Bulgari and colleagues discussed the main pieces of evidence of the use of biostimulants to manage abiotic stresses in vegetable crops. The intent of this editorial was to focus the attention on aspects related to the stress development in plants (i.e., timing and occurrence of multiple stress factors), in combination with the application of biostimulants. The large number of factors potentially involved in the enhancement of crop tolerance toward stress calls for an intensification of research activities, especially when conducted in field conditions and with well-defined protocols. This must be seen as a mandatory task for a successful implementation of biostimulant products among the available agronomic tools for the management of abiotic stresses in horticultural crops.

Keywords: drought; salinity; nutrient deficiency; climate change; stress tolerance; bio-solutions; fruit and vegetables

Agricultural crops are exposed to a large number of stress factors of both biotic and abiotic origin. Biotic stresses are caused by specific harmful living organisms (including bacteria, fungi, and insects), whereas abiotic stresses are due to unfavorable environmental conditions for plants growth and reproduction. The modification of the growing environment caused by climate change is constantly increasing the pressure upon horticultural crop production with seasonal climatic conditions characterized by a higher incidence of extreme events (i.e., heat waves, drought periods, heavy rainfalls, and excessive radiation) that are responsible for severe reduction of both yield and quality of fruit and vegetable produce [1,2]. The horticulture sector is therefore actively seeking for new agronomic tools that are able to contrast the negative effects of environmental stresses, while maintaining the overall sustainability and quality of the production. Among those new bio-technological innovations, biostimulants have gained increased attention in the last decade also because of their capability to exploit agricultural, urban, and industrial waste materials in a perspective of circular economy. The definition of plant biostimulants has been the object of an in-depth discussion mainly driven by regulatory purposes [3]. EU regulations [4] currently focus on a claim-based definition of biostimulants, and thus they are defined as substances able to improve one or more of the following plant or plant rhizosphere characteristics: (i) nutrient use efficiency, (ii) tolerance to abiotic stresses, (iii) quality traits, and (iv) availability of confined nutrients in the soil or rhizosphere. This legal definition includes many substances, which can be distinguished into two main categories: microbial and non-microbial biostimulants. The former includes beneficial bacteria (i.e., N-fixing bacteria) and fungi (i.e., arbuscular

mycorrhizal fungi), whereas the later defines several complex substances or mixtures of both organic and inorganic origin such as seaweed extracts, plant extracts, biopolymers, protein hydrolysates, amino acids, humic acids, and minerals.

In a recent interesting review published in *Agronomy* ("*Biostimulants Application in Horticultural Crops under Abiotic Stress Conditions*"), Bulgari and colleagues discussed several evidences about the use of biostimulants as an effective tool to contrast abiotic stress in vegetable crops. In this editorial, I restate the main aspects outlined in the review, adding further consideration regarding the future perspectives of a research area that has to give answers to several unexplained features of biostimulants efficacy and way of use.

In their review, Bulgari and collaborators [5] focused on the main sources of abiotic stresses for vegetable crops, such as cold, heat, salinity, drought, and nutrient deficiency. The literature about the use of biostimulants to reduce the negative consequences of these stresses is considered, highlighting the possible mechanisms of action of those compounds defined as "active ingredients" inside the biostimulant products. The critical evaluation of the available literature on this topic allows some considerations that I report below.

The timing of the biostimulant application with regard to the development of the stressful condition plays a crucial role for the successful application of these products. A plant biostimulant containing compounds that have an anti-stress effect can be applied when the stress occurs or immediately before (this is the case of proline-containing products, for instance). Differently, other biostimulants that are able to trigger a systemic defense response (i.e., against reactive oxygen species generated by stress) have to be applied in advance in order to achieve a so-called "priming" effect [3]. It is therefore possible to distinguish between preventive, curative, and recovery strategies for the effective use of biostimulants against abiotic/environmental stresses. The bottleneck of this methodological framework is the availability of reliable stress indicators that are able to depict the multiphasic evolution of a stress event in plant metabolism. Things become even more complicated when a possible plant adaptation to stress is also depending from growing and climatic conditions occurring year after year on open-field cultivation systems [6]. This is for instance the case of woody tree species (i.e., fruit trees) characterized by permanent organs (root, trunk, branches) whose structures and available metabolic reserves could affect the defense reaction mechanisms against abiotic stress after biostimulant application.

Abiotic stress is rarely caused by only one environmental factor, and is generally the effect of a combination of different stressful conditions [7]. This is particularly true for open field cultivation systems where crops are often exposed to multiple stresses with severe consequences on yield and quality of agricultural products. High temperatures, as an example, are responsible for heat stress, but are also frequently combined with drought or salinity [8]. Experiments conducted under controlled conditions, where a single stress factor is manipulated in order to create different stress intensity levels, might reach results that are unable to predict plant response when subjected to a combination of stressful factors. This highlight the relevance of trials conducted under real growing conditions, where multiple and combined biotic and abiotic stressors occurred, possibly repeated during different years in order to take also the effects of different seasonal conditions into consideration [6]. These types of experiments are currently lacking in the literature; nevertheless, they are unavoidable, especially for the group of perennial crops, before a confident implementation of biostimulant products among the agronomic tools for the management of horticultural systems.

As explained above, biostimulants are currently defined and classified by their effects on plants. The claim of "enhanced tolerance to abiotic stress" implies, therefore, that an objective evaluation of biostimulant efficacy in reducing the negative effects of stress in plants is achieved. Future research on this topic should therefore be based on methodologies and standardized protocols aiming at a precise characterization of plant stress conditions and degree of efficacy achieved after biostimulant applications in reducing stress intensity. This is a very ambitious task that could become a sort of "methodological nightmare" when many different factors have to be taken into consideration (combined effect of stresses of different origin in open field, variability of genotype response to stress

and to biostimulant application, variability of plant susceptibility to stress during the growing cycle and timing of biostimulant application, synergic and/or antagonistic effect of the many chemical components of biostimulant products). These challenging aspects nonetheless need to be tackled in the awareness that a *one-size-fits-all* answer does not exist and that biostimulants' successful use in horticultural systems will be achieved after an in-depth evaluation of the best genotype \times environmental stress \times biostimulants combination.

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