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Biostimulant: A Sustainable Strategy to Mitigate Stress in Horticultural Crops

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SUMMARY

In the present situation of rapidly changing climate, crop plants are increasingly exposed to both biotic and abiotic stress factors. These include unpredictable and extreme weather events, alterations in plant functions and growth cycles, increased risks from pests and diseases, and significant global losses of up to 30% to 50% in crop yields. In order to overcome this, it is necessary to develop a sustainable strategy to address these concerns. One potential method is, use of bioactive compounds that have the ability to modify plant metabolism pathways and enhance plant performance even under stress. A biostimulant is a substance derived from plants, microorganisms (such as beneficial fungi or yeasts), or other organic compounds that stimulate physiological and biochemical processes in crops, such as the ratio of leaf photosynthetic pigments (carotenoids and chlorophyll), enhanced antioxidant potential, tremendous root growth, improved nutrient use efficiency (NUE) and reduced fertilizers consumption, thereby enhances productivity and stress tolerance. Biostimulant preparations include protein hydrolysates, seaweed extracts, fulvic acids, humic acids, nitrogenous compounds, as well as beneficial bacteria and fungi, that can be effectively used in horticultural crops. The use of microbial biostimulants, represents a sustainable strategy to increase plant performances and productivity, under stresses due to climate changes. .

INTRODUCTION

Climatic records worldwide have revealed a rise in global temperature since 1970, along with changes in precipitation patterns, resulting in significant consequences for crop production. This change in climate exposes crop plants to more frequent and diverse stresses, both from the environment and from pathogens and pests. Estimates suggest that global crop production could suffer losses of 50 % and 30 % due to abiotic and biotic stress, respectively. Given the steady increase in human population, crop production needs to increase by 60 % to meet global demands. However, this would lead to extensive deforestation and loss of natural habitats. To address this challenge and ensure food security without expanding crop land, a sustainable approach is essential to enhance plant resistance and resilience to combat climate change-induced stress. Biostimulants offer a promising solution to achieve this objective. Biostimulants refer to plant materials, microorganisms, or other organic compounds that not only improve plant nutrition, vitality, and overall health but also enhance their performance under stressful conditions. Biostimulants encompass a wide range of compounds, including humic substances, protein hydrolysates, amino acids, seaweed extracts, chitosan, other biopolymers, and inorganic molecules. Within the category of biostimulants, microbial biostimulants consist of beneficial microorganisms such as fungi, yeast, and eubacteria, which have the ability to enhance plant growth, productivity, nutrient uptake, and effectiveness, as well as improve tolerance to biotic and abiotic stresses and crop quality.

Effect of Climate Change induced Stress and Role of Microbial Biostimulants on plant

High Temperature and Heat Waves

High temperatures have an impact on the physiology of plants by increasing the rates of leaf transpiration and respiration. This affects photosynthesis, especially in C_3 plants, and changes how the plant allocates its energy. At high temperatures, the enzyme Rubisco has a higher affinity for oxygen and a lower affinity for carbon dioxide. Additionally, the solubility of carbon dioxide decreases more than that of oxygen at high temperatures, resulting in a lower concentration of carbon dioxide relative to oxygen in the chloroplast. In response to high temperatures, plants tend to close their stomata to reduce water loss through evapotranspiration. However, this leads to a rapid decrease in carbon dioxide concentration, which becomes the main limiting factor for photosynthesis. At the same time, the concentration of oxygen increases due to the high rate of water photolysis in the presence of strong light. These conditions result in a significant reduction in photosynthetic efficiency, as the limited carbon dioxide concentration and increased activity of Rubisco in photorespiration can consume up to 25% of the fixed carbon. To help plants cope with heat stress, microbial biostimulants can be used. These biostimulants, found in bacteria such as *Pseudomonas* and *Bacillus* and in mycorrhizal fungi in tomato plants, promote heat stress tolerance by producing enzymes that degrade reactive oxygen species, reducing levels of hydrogen peroxide, and preventing lipid peroxidation.

Low Temperature and Frost

Cultivated plants experience significant stress when exposed to unusually low temperatures. These cold spells have led to damage and financial losses for horticulture crops. When temperatures are slightly above freezing, the plant's metabolism slows down, resulting in reduced levels of photosynthesis, less foliar growth, and premature aging. If temperatures drop below freezing, the development of buds can be hindered as the cold destroys buds that have started to sprout. Additionally, frost can dehydrate plant tissues and lead to an increase in osmolyte concentrations within the cell cytoplasm, which can disrupt the plasma membrane. Ice core formation, which can occur even at temperatures near zero, exacerbates the damage caused by the cold. This formation can be triggered by the presence of microorganisms known as INA+ with ice nucleating activity, which can reside on leaves, fruits, or roots of plants. These microorganisms have proteins in their cell walls or extracellular polymeric substances that act as ice nucleation centers, promoting the formation of ice crystals.

The use of microbial biostimulants that can outperform INA+ microorganisms has become a significant approach to decrease the losses resulting from frost damage. One effective method is through the use of *Pseudomonas syringae* mutants that have a deactivated ice nucleating gene, which has proven to reduce frost damage. Additionally, numerous bacterial strains have the ability to effectively compete with INA+ bacteria and prevent them from colonizing plants. Furthermore, microbial biostimulants can also alleviate the negative impact of temperatures above freezing. This is because certain microbial symbionts produce growth hormones like auxins or gibberellins, which can counteract the inhibition of plant growth caused by low temperatures.

Drought and Salinity Stress

Drought stress has negative effects on plants' structure and function, leading to the harmful buildup of ROS, the release of ethylene, and a decrease in the availability, assimilation, and transport of essential nutrients. However, the use of microbial biostimulants containing soil microorganisms can enhance plants' ability to withstand drought or salinity by employing various direct or plant-mediated processes.

Role of Microbial Biostimulants in Response to Biotic Stresses

Plant diseases cause significant losses, estimated at 20-40% of global crop production. The impact of climate change on plant-pathogen interactions is complex, as it affects various aspects such as plant susceptibility, parasite and pathogen cycles, and the interactions between hosts and pathogens. Factors like increased temperature, CO_2 levels, acid rain, and tropospheric O3 concentration can chronically stress plants, making them less able to defend against pathogen attacks. Additionally, while CO_2 increase may reduce the density of stomata, which serve as entry points for some pathogens, acid rain and O3 can weaken the protective cuticles of plants, making it easier for pathogens to penetrate. Climate change is also expected to lead to more frequent pesticide applications.

To mitigate the negative environmental, social, and economic effects of increased pesticide use, the use of microbial biological control agents, such as certain bacterial and fungal species, is becoming a crucial option. *Pseudomonas*, *Serratia*, *Bacillus*, *Trichoderma* spp., and *Piriformospora indica* are some of the most extensively studied organisms for their ability to induce resistance in plants.

Limitations in the Application of Microbial Biostimulants

- Commercial registration process is usually complex, and a harmonized international legislation is still lacking.
- Product efficacy is strictly dependent on the horticultural crop on which it is applied and on its phenological state.
- The development of phytostimulant products needs to evaluate the relationship microorganisms establish with the host plant.
- The significant expenses associated with manufacturing commercial biostimulants and the inconsistent effectiveness experienced in real-world settings are major obstacles to the advancement of biostimulant products. As a result, there are relatively few biostimulant products that have been brought to market and their use in horticulture is limited.

Table 1. Effect of biostimulants on the crop physiology.

Plant Species	Biostimulants	Developmental Stage	Expected Outcomes
Tomato (*Solanum lycopersicum* L.)	Radifarm ®	Transplants	Enhanced roots growth
	Radifarm ® + Megafol ®	Transplants	Improved nutrients uptake and distribution
Bell peppers (*Capsicum annuum* L.)	Radifarm ® + Megafol ®	Fruit bearing	Increased macro- and micronutrient, especially Ca^{2+} ion concentration in leaves and fruits
	Benefit ®; Megafol ®; Radifarm ®; Viva ®	From transplanting to harvest	Improved fruit yield
	Benefit ®; Megafol ®; Radifarm ®; Viva ®	7th day seedlings	Increased fruit yield
Garlic (*Allium sativum* L.)	Radifarm ®	After transplanting	Increased seedling after transplanting
Lettuce (*Lactuca sativa* L.)	Bio-algeenS-90 ®	After transplanting	Improved growth and yield characteristics; Increased ascorbic acid content and dry matter and reduced pH

CONCLUSIONS

Microbial biostimulants offer a promising and viable approach to mitigating the negative impacts of climate change-related stresses on plants and ecosystems. Additionally, their use could help maintain ecological balance in production systems by reducing the need for pesticides and heavy metals. However, it is important to address certain challenges, such as regulatory considerations and the need for further research and development, in order to maximize the effectiveness and widespread adoption of these biostimulants.

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