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REVIEW PAPER

Biostimulants and salinity: Crosstalk in improving growth and salt tolerance mechanism in Fennel (*Foeniculum vulgare*)

Mubashar Iqbal[1] and Abdul Ahad Qureshi[2]

[1]Department of Agriculture, Directorate of Pest Warning and Quality Control of Pesticides, Punjab, Pakistan
[2]Department of Horticulture, Faculty of Crop and Food Sciences, Pir Mehr Ali Shah, Arid Agriculture University Rawalpindi, Pakistan

*****Corresponding author's email: aoppctn@gmail.com

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Abstract

Crop development of various economically important horticultural crops faces substantial limitations due to various abiotic stresses. These pressures contribute to over 70% of the yield gap. Notably, salt stress has become increasingly significant in crop production in recent years. Salinity triggers ionic, osmotic, and oxidative disturbances, leading to the production of reactive oxygen species, decreased water potential, membrane dysfunction, reduced rates of photosynthesis, and lower nitrogen assimilation. All of these factors significantly impede crop growth and yield. A potential and effective approach to alleviate salt stress involves the use of plant extracts obtained from natural sources as an alternative to synthetic fertilizers. These extracts are rich sources of bioactive compounds such as carotenoids, flavonoids, and phenolics, which play pivotal roles in redox metabolism regulation and enhancing plant growth. Fennel (*Foeniculum vulgare*) with its diverse applications in food, cosmetics, and medicine, offers essential oil rich in beneficial properties, including antifungal, antibacterial, anticancer, and antioxidant effects. Humic acid is recognized for improving soil conditions and promoting plant growth. Saline soils present a major hindrance to plant development, impacting seed germination and seedling growth. Plants employ various adaptive mechanisms to endure challenging environmental conditions. Biostimulants, which consist of diverse compounds derived from microbial and plant sources, play a vital role in promoting plant growth and alleviating environmental stress. These products impact plant physiology, metabolic processes, and nutrient absorption, presenting an innovative method to address salinity issues. The article highlights the significance of seaweed extracts, humic acid, and vegetable extracts as valuable elements in augmenting both crop yield and quality. Furthermore, this assessment illuminates how plants react to different biostimulants, showcasing benefits such as amplified root growth, improved nutrient assimilation, and increased resilience to stress.

Keywords: *Foeniculum vulgare*, Humic acid, Plant biostimulants, Salt stress, Signaling signatures, Stress perception

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Introduction

The plant *Foeniculum vulgare* commonly referred to as fennel is a medicinal herb native to the Mediterranean region and belongs to the Apiaceae family. Fennel finds applications in diverse domains such as food, cosmetics, and medicinal practices. Its essential oil possesses advantageous properties including being antifungal, antibacterial, potentially anticancer, and holding antioxidant characteristics (El-Awadi & Hassan, 2010; Bahmani et al., 2012). The salinity of the soil has an impact on agricultural output in various parts of the world (Zorb et al., 2004). Several factors can contribute to salinity problems, which reduce productivity and product quality, including over-watering, sowing the same crops, imbalanced use of nutrients, and water with unwanted salt content (Cansev & Ozgur, 2010). Salt-affected soil impairs plant growth and productivity because of the increased uptake of various harmful ions like Sodium ions, which have negative effects on plant growth. Finding the best species that can tolerate the saline condition or biological compounds extracted from nature that can grow in damaging effects of salt affected soils will require more exploration (Yamaguchi & Blumwald, 2005). Humic acid was discovered to be the main source of soil contents of organic. It can boost plant growth by improving soil conditions. Improve soil qualities by pH modification soil aeration, water availability, water holding capacity, ionic movement in the soil, and better uptake of nutrients (Tan, 2003). Increased cell membrane absorption, exchange of oxygen, respiratory activity, photosynthetic process, phosphate uptake, enlargement of root cells, and balanced activity of the hormone, improved crop growth, and better tolerance of salty environment were among the direct benefits (Cimrin et al., 2010). According to Kulikova et al. (2005), these compounds may avoid such stress conditions by rapid plant growth.

The most important abiotic stress factors that decrease agricultural production and limit crop yield are water shortage, saline soils, and temperature fluctuations. Saline soil is a main abiotic factor that impairs plant development, growth, and finally crop yield (Jan et al., 2018; Syed et al., 2021). Saline soils' main contributors that limit plant growth and yield have been characterized as weak process of osmosis, excessive ions, and disturbance in nutrient supply, which lead to a decline in photosynthetic activity and other physical ailments (Mahajan & Tutija, 2005; Zhu, 2007). It appears reasonable to assume that many plant breeding initiatives will place an increasing emphasis on improving the salt tolerance of crops if global food production is to be sustained (Arzani, 2008). Recent studies have shown that numerous plants like coriander, black cumin and sweet Majorana, which have aromatic and medicinal properties, are affected by saline conditions on their oil and fatty acid contents (Baatour et al., 2012). The germination of seeds is one of the most critical parts of the life cycle of a plant. Water is consumed during seed germination for respiratory activities and all metabolic processes. This sums up all biological processes taking place there (Ouji et al., 2015). During unfavorable climates in soil like saline conditions osmotic pressure influences the seed's capacity to germinate by disturbing water absorption and then accumulation of sodium chlorine ionic toxicity (Yacoubi et al., 2013), which causes osmotic stress and the production of reactive oxygen species (ROS) (Grato et al., 2012).

Salt stress has been shown to affect several crops' germination rates and percentages. Two ways that soil salinity may impede seed germination include the osmotic pressure it generates, which stops seeds from absorbing water, and the toxic effects of Sodium ions and Chlorine ions on seed germination. Salt and osmosis pressure inhibit or delay seed germination and seedling growth (Welbaum et al., 1990; Khajeh-Hosseini et al., 2003). Salt stress limits plant growth by accumulating dangerously high levels of sodium and chloride, lowering the osmotic pressure of water, and decreasing nutrient absorption (Azarmi et al., 2016). Additionally, salinity damages stomata, reduces the amount of pigments used for photosynthesis, and prevents photosynthesis, all of which hinder the rate at which leaves grow (Sadak et al., 2010).

Short- and long-term adaptation tactics are typically used by plants to respond to unfavorable environmental conditions. This includes the activation and control of specific genes expression that belongs to avoidance from salty soil conditions (Hasanuzzaman et al., 2013; Xu et al., 2015). Because plants are sessile organisms that must struggle with unfavorable environmental conditions, they require all of these coping mechanisms to survive. These strategies work best when applied beforehand to develop a defense mechanism according to climate conditions which may induce stunted plant growth. Because energy through nutrients that would normally be used for production and development are instead used by stress-response mechanisms, plants pay a physical cost as a result of the trade-off between growth and acclimation metabolisms (Bechtold & Field, 2018). Technological and environmental changes, scientific advancement, and farmers' experiences have all contributed to changes in agronomic management techniques used to develop the adoption of plant normal growth even in physical stress conditions over time. The best variety, the ideal growth season, the spacing of the planting, and the delta of water or fertilizer supplied are factors to minimize the stress implications of all physical weather soil conditions (Mariani & Ferrante, 2017).

Biostimulants

Products made from various compounds, microbial organisms and plant origin that can help in plant growth regulation, and crop yield, and avoid the adverse impacts of growing environment are known as biostimulants (Du Jardin, 2015; Rouphael & Colla. 2018). A lot of studies are being done on the mechanisms that biostimulants activate (Paul et al., 2019). By enhancing soil conditions, they can directly influence plant physiology and metabolism (Bulgari et al., 2015; Caradonia et al., 2018). It can change several molecular processes by enhancing primary and secondary metabolism that help crops utilize water and nutrients more effectively, encourage plant development, and protect against abiotic challenges (Nardi et al., 2009; Van Oosten et al., 2017; Yakhin et al., 2017; Caradonia et al., 2018).

A major topic of discussion is using these substances under pressure and their role as nutrients rather than remedies. A product should specifically not be labeled as a biostimulant if it directly combats biotic stresses; instead, it should be categorized as a plant protection product. A novel method for lowering salinity by giving essential nutrients is to use biostimulants. To promote plant development, a variety of chemicals and microorganisms are used as plant biostimulants. It could improve nutrition and quality attributes, lessen abiotic stress, or boost development capacity (Du Jardin, 2015). Various seaweed extracts have been shown to affect plant development and play more significant roles in agribusiness and agriculture as natural excrements and manures (Craigie, 2011). Various quantities of these seaweed extracts have been used to increase plants' resilience to a variety of abiotic stimuli, including salt, dry spells, and extreme temperatures, lessen abiotic stress, or even improve nutrition and qualitative attributes (Bulgari et al., 2019). To increase yield and quality, seaweed extracts are also applied as foliar sprays to fruits, flowers, and trees (Haider et al., 2012). In place of fertilizer, humic acid (HA), an organic acid with a black colour, is used to increase crop productivity. Humic content has been shown to enhance plant growth, physiology, and metabolism (Ahmad et al., 2016). As a result of plant breakdown, microbial byproducts, and soil organisms using humic acid in their metabolic processes, humic substances are fundamentally composed of organic matter. It is used to increase crop output and plant growth (Eyheraguibel et al., 2008). Its application promotes processes related to plant development and nutrient uptake (Linehan, 1978). Additionally, it makes cells more permeable (Lee & Bartlett, 1976). Vegetable extract is just a locally prepared organic extract made from different vegetables with the help of glucose. Additionally, it supplied the plant with hormones, carbohydrates, and other essential components. It supports the enhancement of the plants' quality and output (Abbasi et al., 2019).

Effect of biostimulants on photosynthesis

Numerous authors have noted that seaweed extracts and plant-based biostimulants frequently intensify the colour of leaves by promoting chlorophyll formation or slowing theirbreakdown (Abbas & Akladious, 2013). Leaf colour influences the aesthetic attraction of the product. Additionally, leaves with higher chlorophyll concentrations can perform their photosynthetic processes more effectively. A huge proportion of leaf pigments (chlorophyll and carotenoids) were discovered in the process after biostimulant applications (Vernieri et al., 2005; Vernieri et al., 2006), lettuce, and endive (Bulgari et al., 2014). It boosted the titratable acidity, chlorophyll content, ascorbic acid concentration, weight, volume, and stiffness of tomato fruits (Ullah et al., 2019). The chlorophyll content and fresh weight of lettuce were dramatically increased by a variety of bioactive chemicals derived from plants, according to recent research by Luziatelli et al. (2019). In their studies into the activating properties of bioactive substances generated from smoke and seaweed in spinach, Kulkarni et al. (2019) found that growth, chlorophyll content, and carotenoid content were all positively impacted by morphological, physiological, and biochemical factors. The two products Goemar BM86 and Seasol had a substantial impact on broccoli plants. According to Mattner et al. (2013), the amount of micro- and macronutrients rose together with the leaf area, stem diameter, and biomass. Improvement in pepper plant productivity and fruit quality was observed after using four different commercial biostimulants (Radifarm, Megafol, Viva, and Benefit) with active components including amino acids, polysaccharides, and organic acids (Paradikovi'c et al., 2011). The Radifarm and Viva treatments stimulated the root system in optimal and drought conditions, respectively in pepper plant and had an impact on tomato plants as well (Petrozza et al., 2013a; 2013b).

Biostimulants and crop tolerance to abiotic stresses

Biostimulants' ability to reduce stress conditions depends on several factors, including how they work and when they are used. Applications of biostimulants are possible at various stages of the stress cycle, such as before, during, and even after the stress. They could be given to seeds, plants that are just beginning to grow, or fully matured crops, according to the desired results (Kunicki et al., 2010). When stress is present or when the circumstances are stressful, take into account employing biostimulants that consist of ingredients that can react against stress like proline or glutamic acid. On the other hand, before the stress occurs, the creation of bioactive molecules needs to be stimulated. Distinct species have different needs for the right timing of treatment throughout crop development depending on the most crucial stages for crop productivity. Identification of the optimal time and dose for biostimulant delivery is essential to avoid product loss, unnecessary production costs, and unexpected results. At the time of planting to safeguard the seedling during its early stages of growth, during osmotic uptake of a solution containing nutritional ingredients, or while the plant is blossoming or laying fruit, biostimulants can be applied as leaf surface of plants through stomata or via the root system. There isn't a fundamental mechanism that can be used for all types of plant species and in different environmental stress.

The advanced study aimed at saving crops by biostimulants as a protection agent in a difficult growing environment. These things can lessen environmental stresses such as a lack of water, salinized soil, and growing even in weather conditions that are not favorable in a variety of ways (Le Mire et al., 2016; Pokluda et al., 2016). They interact with several processes that are involved in how plants respond to stress, improve plant performance, development, and production, and promote the synthesis of antioxidant molecules that make plants less sensitive to stress. Some latest results especially in the matter of the adaptability of vegetable crops have been found after the administration of many external foliar applications. According to Cao et al. (2018), work of different light exposures to tomatoes proved that seedlings tolerated the saline environment by affecting light absorption and photosynthesis activity. Tomato plants growing in saline and heat benefited from the application of exogenous melatonin (Mertinez et al., 2018). To boost resistance to abiotic stresses, plant seeds can be soaked in a variety of chemicals, either synthetic or natural.

Botanicals as bio-stimulants in salinity

Botanicals are devoid of artificial chemicals, making their use to alleviate salinity an environmentally friendly and sustainable method for addressing abiotic stress. The composition of plant extract can include various plant components, such as phytohormones, minerals, photosynthetic pigments, amino acids, nucleotides or nucleosides, lipids, and other bioactive compounds, including flavonols, phenolics, betaines, amino-polysaccharides, sterols, glucosinolates, terpenoids, and more. These compounds exhibit detoxifying and reactive oxygen species (ROS) quenching characteristics, leading to widespread application in the pharmaceutical sector for protection against conditions like neurology, diabetes, developmental disorders, and chronic diseases such as cancer. Given the success of natural compounds in preventing oxidation in animal cells, it is reasonable to consider their potential benefits to plants against salinity-induced disruptions in redox balance (Pehlivan, 2018). Previous studies have demonstrated that plant extracts contribute to increased growth, development, yield, and resistance to diseases and stresses in plants, owing to the presence of the aforementioned chemicals (Howladar, 2014; Drobek et al., 2019; Desoky et al., 2020; Zulfiqar et al., 2020). However, further scientific evidence is needed to ascertain the functionality of the diverse spectrum of compounds in Plant Extracts. Additionally, investigating the viability and quality of plant extracts represents another potential area for exploration.

Conclusion

Several scientific researches have established the ability of various types of biostimulants to increase crop yield and lessen abiotic stresses such as soil salinity and drought. It will become clearer how certain humic chemicals affect plant development, nutrient uptake, and stress-tolerance responses with more research on the transcriptome and proteome effects of humic chemicals, from the perspective of fundamental research. The results of these investigations may also reveal biostimulant response markers that might be applied in the development of novel goods. Future research and development on biostimulants can be focused on by combining some of the various areas listed in this analysis. It is possible that adding humic substances or seaweed extracts to microbial inoculants will increase the repeatability of crop production benefits.

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