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Review Paper

Effect of Salinity Stress on Tomato (*Lycopersicon Esculentum* L.) and Mitigation Strategies

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***Abstract*— Tomato (*Lycopersicon esculentum* L.) belongs to the Solanaceae family. It is a crop of immense economic importance worldwide and salinity is one of the major abiotic factors limiting it's production and productivity globally. The amount of irrigation water and their evapotranspiration is the main reason that causes salinization. Salinity is an abiotic stress that affects agriculture by severely impacting crop growth and, consequently, final yield. Considering that sea levels rise at an alarming rate over year, it is clear that salt stress constitutes a top-ranking threat to agriculture. Among the economically important crops that are sensitive to high salinity is tomato one that is more affected by salt stress. Si plays the beneficial role of the quasi-essential metalloid silicon (Si), which increases the vigor and protects plants against a biotic stresses. The use of silicon fertilization can be used as sustainable practices in agricultural production to increase yield and quality of plants. Silicon fertilization also plays role in plant protection against various range of exogenous stresses especially, under changing environment. The use of appropriate irrigation method, amount and water quality to minimize the risk of salt accumulation around root zone of plants. Different plant growth regulators and amino acids could also play a great role in increasing yield and growth of tomato under salt stress.**

Keywords*— Chitosan, control mechanism, Growth Regulators, salinity stress, Tomato

I. INTRODUCTION

Salinity is an abiotic stress that has a significant negative impact on crop growth and, as a result, yield. Because they are sessile organisms, plants are constantly exposed to their environment. Plants must adapt to their changing environment in order to carry out essential functions like photosynthesis and to develop vegetatively and reproductively. They achieve this by triggering a wide range of physiological processes, including the synthesis of specialized metabolites through the activation of metabolic branches [1], [2], [3] and changes at the transcriptional and translational levels [4] [5]. For a certain period, the environment can remain constant, yet it can also abruptly alter. When this happens, living things must adjust to their new environmental circumstances if those circumstances prevent them from successfully completing their life cycle [6]. Such unfavorable conditions are collectively referred to as environmental stresses.

Depending on the kind of changed environmental condition, stress adaptation can take on a variety of forms. The plant will adjust to the new situation by non-permanent changes in its morphology or physiology if the stress is temporary and happens unexpectedly. As a result, if the environmental conditions return to normal, these modifications can be reversed to normal, and acclimatization then takes place [7].

On the other hand, if suboptimal conditions start to prevail in a particular area, plants will need to develop methods to make the most of their new environment and pass these changes on to their progeny. Evolutionary adaptation occurs in this situation [8]. Some plant species, for instance, can be specifically adapted to grow in soils from volcanoes [9], [10], littorals with high salt conditions [11], or regions that are contaminated with heavy metals [12].

Depending on whether they include interaction with a living thing or not, stresses are typically categorized into two categories. It comprises abiotic stresses brought on by environmental modifications, such as water stress, exposure to extremely high or low temperatures, an abundance or deficiency of nutrients, high salinity, the presence of heavy metals, and UV radiation. Interactions with other species, such as another plant that will compete for resources and space, animals, pathogenic bacteria or fungi, to mention a few, are a part of biotic stressors. It is very common for biotic and abiotic pressures to coexist. Abiotic stresses tend to erode a plant's defenses, leaving it more susceptible to infections and pests. However, when abiotic and biotic pressures coexist, plants may become more resistant to infections [13]. Salinity warrants special consideration among the abiotic stresses due to its detrimental impact on crop growth and yield [14].

II. SALINITY STRESS

Soil salinization is defined as the accumulation of salts in the soil solution that can be measured as the total dissolved solids (TDS) or the electrical conductivity. According to Corwin and [15] sodicity is the predominance of Na^+ ions that saturate the ion exchange sites in the soil rather than other ions like Mg^{2+} and Ca^{2+}. Na^+ ions harm soils because they prevent the production of macro-aggregates and encourage colloidal dispersion, both of which lead to the destruction of the macro-structure of the soil. Since it is one of the effects of climate change due to the rise in ocean levels, soil salinization has recently become a major worry for the entire world. It is true that saltwater intrusion in groundwater significantly raises the amount of salt in soils, rendering them salty and unsuitable for agricultural production [16]. One of the main sources of soil salinization is irrigation, particularly in soils with high evapotranspiration rates. Saline or brackish water irrigation may be the cause of this. Additionally, the issue may arise when soils are watered improperly, with non-saline water, during periods of minimal rainfall, or in regions with high evapotranspiration rates [17]. Salinity is currently one of the most hazardous abiotic stresses. [18] Claim that it has had an adverse influence on about one third of all irrigated land on the planet, which has a negative impact on plant performance.

Salinity is a significant stressor that limits plant growth [19]. It affects the nitrogen availability and soil composition. It also affects how effectively plants absorb nutrients and water [20]. Salinity affects the processes of mitosis, protein synthesis, DNA and RNA synthesis, lipid metabolism, seed germination, and plant growth [21]. One of the main factors causing a severe fall in plant growth, productivity, and yield is drought stress. Using chitosan encourages drought resistance and enhances water use quality [22].

A. Effect of Salinity on Germination and Growth of Plants

There are two effects of salts on plants. First, due to the osmotic impact, they initially contribute to water uptake. Because soluble salts reduce osmotic potential, roots have a harder time absorbing water. Therefore, despite the soil's low water potential, plants must develop unique techniques to absorb water from it. The potential for salts to be poisonous to plants is another effect, particularly for NaCl. Na^+ can compete with other cations, such Ca^{2+}, for binding sites in the root cell wall. This affects pectin cross-linking, which disrupts crucial physiological processes including primary growth [23]. Such changes are reflected at the level of the cell wall by a decline in stability and a subsequent rise in stiffness. In the conductive tissues of the plant, salt stress reduces the size of the xylem vessels at the morphological level. This discovery is related to the reduction in cavitations, which is expected to occur more frequently under salt stress [24].

Reactive oxygen species (ROS), such as the superoxide radicals responsible for DNA, RNA, and protein oxidation, are created as a result of oxidative stress brought on by salt stress. Additionally, they affect the lipids that make up the cell membrane, which may affect the stability and composition of the membrane [25]. When salt stress first occurs, one of the reactions of plants is the creation of antioxidant molecules and enzymes that scavenge ROS [26]. Examples of the former are phenolic compounds, whose chemical structure allows hydrogen atom transfer mechanisms (HAT) to occur via a pure H transfer, or an electron transfer followed by a proton release, or a proton loss followed by anelectron transfer [27].

Isoorientin, Orientin, Vitexin, Rutin, and Phenolic Acids are Among the Most Common Secondary Metabolites Found at Higher Levels in Plants Stressed by Salt [28]. When plants are under salt stress, anthocyanins frequently build up in the leaf epidermal cells. These cells are expected to help reduce the osmotic potential by increasing the solute content [29]. But it was demonstrated that acyanic species were able to modify their osmotic pressure to a level comparable to that of red-leafed evergreen species without manufacturing anthocyanins, indicating that these pigments constitute just a minor part of osmotic pressure [30]. In other words, these indices are rapidly decreased by an increase in salt concentration. This leads to the identification of a tolerant genotype with increased shoot length and fresh weight in environments with high salt concentrations. Primo early and chef flat amrica are regarded as the tolerant genotypes because they had greater growth indices throughout a range of salinity levels than the other cultivars, which showed less tolerance to salt under the same growing conditions as the others [31]. A significant reduction in germination percentage, germination speed, germination index, and seedling vigor index was seen in tomato cultivars when salinity was induced by NaCl solution. All germination parameters were considerably reduced as salt content increased, and the decreases were greater at higher salt concentrations [32].

B. Effect of Salinity on yield and physiology of plants

Salt stress also has a deleterious impact on the physiological and biochemical processes that occur in tomatoes [33]. Salt stress reduces plant water content or water potential, causing stomatal closure to avoid further water loss through transpiration [34]. Salt stress decreases net photosynthesis in addition to decreasing transpiration due to stomatal closure by creating ROS, lowering chlorophyll content, and decreasing rubisco activity [35] and [36]. Salinity decreases CO_2 availability due to diffusion restrictions and lowers the concentration of photosynthetic pigments, which impairs tomato physiological efficiency [37]. [38] reported that when compared to control treatments, tomato variety yield dropped by about 50% at the salinity level of $5dSm^{-1}$. This is most likely caused by fewer fruits, smaller fruits, and decreased accumulation of dry matter within the fruits, all of which directly affect fruit yields [32]. This result was in agreement with [39] findings, which showed that tomato production fell by 50% at moderate salinity levels ($5dSm^{-1}$). Tomato yield is diminished as a result of the detrimental effects of salt stress on tomato growth, including decreased plant water potential, disruption in mineral uptake, and increased plant respiration. This outcome was in line with what was found by [40], who observed that fruit yield is strongly negatively correlated with increasing salt. Increased saline levels decreased fruit yield significantly in irrigation water, which had a negative effect on tomato yield [41]; [42].

III. SALINITY STRESS

A. Chitosan

Chitosan is a naturally occurring, less harmful, and reasonably priced substance with several uses in agriculture. It is also biodegradable and environmentally benign [43]. Both plants and animals can benefit from its health and nutrition. D-glucosamine and N-acetyl-D-glucosamine are used to make chitosan. It is created when an amino group is added to the acetyl group of chitins [44]. It is the most widely used basic biopolymer and resembles cellulose structurally [45]. In addition to being utilized to increase growth and yield, chitosan is frequently employed as a post-harvest coating to extend shelf life [46]. Additionally, it strengthens a plant's defenses against biotic and abiotic stress [47]. Chitosan improves crops' qualitative and quantitative traits by encouraging the plant to absorb nutrients [48]. Inducing stress tolerance and enhancing plant performance, chitosan is applied to both soil and leaves [49, 62]. Chitosan plays a significant part in a plant's internal structure by triggering a number of enzymes to protect it from various pressures. Because of its organic makeup, environmental friendliness, and biodegradability, chitosan is now mostly employed as a growth stimulant. It increases the plants' ability to withstand stressors. Applying the right concentrations of chitosan could successfully lessen the hazardous effects of increasing saline levels and enhance tomato plant development and productivity by enhancing various morphological features and the caliber of chlorophyll. According to this study, chitosan at 150 mg L1 is advised for improved tomato growth and productivity when grown in saline conditions [50].

B. Soil texture

A significant contributing factor to salt buildup at the root zone and subsequently to plant uptake of salt is the various soil textures. Indeed, according to Li and co-authors, soils with layered textures can store more water than homogeneous soils (made up of a single layer) because they impede the vertical movement of water during infiltration (downward) and evaporation (upward) processes [51]. With the help of their thickness, composition, and spatial organization of the inner layers, stratified soils can influence water dynamics due to their hydraulic capabilities. Multi-layered soils can influence salt dynamics by reducing the concentration of salt ions among the layers [52]. Straw mulching, when paired with irrigation, dramatically lowers the saline levels near the plant root zone by fostering a more suitable environment for tomato growth, according to a paper by Zhai and co-authors. More specifically, the practice of mulching, or covering soil with an organic material, permits salt to travel vertically from the root zone to the mulch's edge [53]. Cations like Ca^{2+} and Mg^{2+} in soils produce solid aggregates with organic matter (specifically, humic acids), which control the soil's physical characteristics, including drainage and porosity. The replacement of other cations (Ca^{2+} and Mg^{2+}) by sodium in high concentrations can change how organic matter interacts with it and lead to soil particle dispersion. Gypsum ($CaSO_4$) application is thought to be a practical agronomic technique for replacing and removing Na^+ ions from the root zone [54]. Since salt stress prevents the uptake of crucial ions, such as K^+, Ca^{2+}, and NO_3, fertilizers and organic amendments are typically helpful in reducing the negative consequences of salinity [55].

C. Application of Appropriate Irrigation

In order to prevent salinization, irrigation must be applied frequently enough to leach the excess salt buildup in the topsoil. However, leaching should be at its best and irrigation water should be of high quality. Regarding the first issue, numerous expensive methods, such as inverted osmosis or electro dialysis, can be employed for water desalination or water recycling; however, these are still in development.

D. Fertilization

Since proline, chlorophyll, and antioxidant enzyme levels rise under stressful conditions, organo-mineral fertilizers made of $CaSO_4$, crushed rice bran, and humic acid are good choices to reduce yield loss in tomato grown in saline soils [56]. As a result, mixing organic and mineral fertilizers has a greater positive impact on crops than using the same fertilizers alone. According to Al-Yahyai and colleagues, blended fertilizers do in fact increase tomato fruit output and quality [57].

E. Application of Amino Acids and Growth Regulators

Under salinity, amino acids increased plant yield and growth. Amino acids, according to Neeraja et al. (2005) [58], improved the number of flowers, fruit setting, and fruit output. Previously, it was found that the application of amino acids enhanced plant yield and growth in saline environments [59].

F. Application of Silica

The quasi-essential metalloid silicon (Si), which boosts plant vigor and defends against abiotic stressors, has a large body of supporting evidence in the literature. This defense is achieved by opaline silica, which forms a mechanical barrier to phytopathogen entrance, precipitating in the cell walls. Similar to other nightshade family members like tobacco, tomatoes are categorized as non-accumulators (excluders) when it comes to Si accumulation. Even though tomato plants have a limited capacity for collecting silicon, the metalloid boosts growth under abiotic stress circumstances, for example, by increasing fruit output or by promoting vegetative growth through the manipulation of physiological parameters [60]. In tomato plants that were overexpressed, a larger buildup of Si was seen in the sap of the root cells and the roots, but not in the shoots. Despite being placed in the excluders category, tomato displays reduced stress symptoms when Si and silica nanoparticles are added (N-SiO_2). For example, Si together with salicylic acid activated the antioxidant systems of tomatoes stressed by a high pH (e.g., upregulating the genes peroxidase, ascorbate peroxidase, superoxide dismutase and catalase) and decreased the concentration of abscisic acid in the shoots and roots [61]. Surprisingly, Si supplementation reduced peroxidase activity while enhancing superoxide dismutase and catalase activity in tomato seeds subjected to dehydration during germination [62]. Under water stress, Si helped to increase photosynthetic metrics (PSII maximal photochemical efficiency, photosynthetic electron transport rate, and activation of photosynthesis-related genes) and minimize the decline in chlorophyll and carotenoids [63].

In addition, Si improved tomato's defense against the plant pathogenic bacterium Ralstonia solanacearum by enhancing gene-level immunity triggered by pathogen-associated molecular patterns, resistance to oxidation, and water deficits, as well as by raising the concentration of lignin-thioglycolic acid, which fortifies root cell walls [64]. Si (2 mM Na2SiO3) raised the level of K, Ca, and Mg and decreased that of Na and Cl in tomato roots, stems, and leaves during salt stress (150 mM NaCl). This was due to a better growth, namely a higher shoot biomass accumulated during salt stress and Si treatment, rather than a reduced translocation from root to stem or stem to leaves [65]. In salt-stressed tomato plants, a prior study found that the metalloid reduced the loss of dry biomass. It also demonstrated that the presence of Si increased the leaf turgor potential [66]. This final discovery is the result of Si precipitating as opaline silica within the cell walls of epidermal cells, which forms a barrier that prevents water loss under abiotic stress. The results demonstrate that Si fertilization can reduce the negative effects of high salinity on tomato plants and that post-harvest treatment with this metalloid is an intriguing method for extending the shelf life of the fruits while maintaining their quality characteristics.

IV. FUTURE PERSPECTIVES

Since the salinity stress in genetically controlled, screening of different varieties under stress environment could help to overcome the salinity stress problem. The use of silicon fertilization can be used as sustainable practices in agricultural production to increase yield and quality of plants. Silicon fertilization also plays role in plant protection against various range of exogenous stresses especially, under changing environment. The use of appropriate irrigation method, amount and water quality to minimize the risk of salt accumulation around root zone of plants. Different plant growth regulators and amino acids could also play a great role in increasing yield and growth of tomato under salt stress.

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