Review

Salinity Stress in Maize: Consequences, Tolerance Mechanisms, and Management Strategies

Mohammad Sohidul Islam [1, *], Md. Rafiqul Islam [2], Md. Kamrul Hasan [1], ASM Golam Hafeez [3], Md. Kaium Chowdhury [4], Moaz Hosen Pramanik [5], Muhammad Aamir Iqbal [6], Murat Erman [7], Celaleddin Barutcular [8], Ömer Konuşkan [9], Anamika Dubey [10], Ashwani Kumar [10], Ayman El Sabagh [11, 12, *]

1. Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh; E-Mails: islam.agn@hstu.ac.bd; kbdkhasan@gmail.com
2. Agronomy Division, Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Ishwardi, Pabna, Bangladesh; E-Mail: rafiq_bari2@yahoo.com
3. Department of Agricultural Finance and Banking, Faculty of Agricultural Economics & Rural Sociology, Bangladesh Agricultural University, Mymensingh, Bangladesh; E-Mail: ghkennedy01@yahoo.com
4. Department of Agricultural Extension, Agricultural Training Institute, Gaibandha, Bangladesh; E-Mail: kaium34bcs@gmail.com
5. Department of Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh; E-Mail: moazhosen42@gmail.com
6. Department of Chemical Engineering, Louisiana Technical University, USA; E-Mail: aamir1801@yahoo.com
7. Department of Field Crops, Faculty of Agriculture, Bursa Uludağ University, Bursa, Turkey; E-Mail: Merman56@hotmail.com
8. Department of Field Crops, Faculty of Agriculture, Çukurova University, Adana, Turkey; E-Mail: cbarutcular@gmail.com
9. Department of Field Crops, Faculty of Agriculture, Mustafa Kemal University, Hatay, Turkey; E-Mail: okonuskan@mku.edu.tr
10. Metagenomics and Secretomics Research Laboratory, Department of Botany, Dr. Harisingh Gour Central University, Sagar, MP 470003, India; E-Mails: anamikadubey909@gmail.com; ashwaniiitd@hotmail.com
11. Department of Field Crops, Faculty of Agriculture, Siirt University, Siirt, Turkey; E-Mail: ayman.elsabagh@agr.kfs.edu.eg
12. Department of Agronomy, Faculty of Agriculture, Kafrelsheikh University, Kafrelsheikh, Egypt

*   **Correspondences:** Mohammad Sohidul Islam and Ayman El Sabagh; E-Mails: islam.agn@hstu.ac.bd; ayman.elsabagh@agr.kfs.edu.eg

Academic Editors: Mohamed Farag Mohamed Ibrahim and Ahmed Abou El-Yazied

Special Issue: Molecular Plant Physiology under Abiotic Stress Conditions

Abstract

Maize, along with rice and wheat, is a popular staple food crop worldwide, and the most widely produced cereal crop. It is a versatile crop that may be utilized as a source of raw materials for human and animal fodders. Low agricultural yield and rapid population expansion significantly threaten future food security. Maize production is hampered by biotic and abiotic causes, with abiotic factors being the most critical limitation to agricultural output worldwide. Soil salinity is a key abiotic factor that reduces agricultural production by imposing negative impacts at several life cycle phases, including germination, seedling, vegetative, and reproductive development. Maize plants experience many physiological changes due to osmotic stress, toxicity of particular ions, and nutritional imbalance induced by salt stress. The degree and duration of stress, crop growth phases, genetic characteristics, and soil conditions influence yield reduction. Maize plants can tolerate salt stress involving a complex mechanism by changing their physiological, biochemical, and metabolic activities like stomatal functioning, photosynthesis, respiration, transpiration, hormone regulation, enzymes, metabolite generation, etc. After studying the salt tolerance mechanisms of maize plants under stress, integrated management techniques should be developed for maize agriculture in saline settings. Therefore, the study of plant responses to salt stress, stress tolerance mechanisms, and management strategies is one of the most imperative research fields in plant biology, and the study will focus on the effects of salt stress in different growth stages, plant tolerance mechanisms, and agronomic management practices for successful maize production all over the world.

Keywords

Salt stress; physiological changes; mitigation techniques; management practices; maize

1. Introduction

Globally, maize (*Zea mays* L.) ranks top position among cereals in terms of total cultivated area [1] as well as grain and fodder production [2]. Over 1147.7 million MT of maize is produced on 193.7 million hectares of land in 170 countries, with an average productivity of 5.75 t ha^{-1} [3]. Over 50 maize varieties are cultivated worldwide, and they can be divided into five broad groups based on their food, feed, and production needs, like popcorn, sweet corn, flour corn, flint corn, and field

corn or dent corn [4]. Among them, dent corn accounts for around 99% of the corn grown in the United States, and is mainly used for livestock feed and industrial items. Due to its higher starch content than sweet corn, dent corn has a bland flavor and a mealy texture [4]. Maize is the highest-yielding cereal crop, and holds a prominent position as one of the major crops in most countries. It occupies 24% of the farmlands worldwide [5, 6]. It is one of the most important cereals in the world, with a wide range of commercial and economic uses [1, 2, 7]. Cereals, such as maize, account for 52% of global human nourishment [8], and maize-derived products have been used in various aspects of our daily life due to their high-value nutrients [9, 10].

Maize is a major cereal in Southern and Eastern Africa, Central America and Mexico, and is a staple in Sub-Saharan Africa [11], where maize accounts for nearly a quarter of total calorie consumption. Maize is a staple food for 1.2 billion people worldwide, accounting for more than 20% of total calories in 21 countries [12]. The use of maize as food is expected to increase mainly in developing countries (72%) where growing populations and maize are becoming increasingly crucial in diets. Hence, the rising demand for animal-based protein sources will likely drive the trade and the market for maize globally. Maize is also used to produce ethanol fuel (ethyl alcohol) in alcoholic beverages, and is most often used as a motor fuel, mainly as a biofuel additive for gasoline. From a global perspective, the USA has been the leading consumer, followed by China, accounting for about 32% and 23%, respectively. However, the highest per capita consumption is noticed in southern Africa, such as Lesotho (120 kg/year) and Malawi (107 kg/year) [10]. From 2018 to 2027, maize output and area are predicted to expand by 1.2 billion MT and 3.2 percent due to rising demand [11].

Global food insecurity has become one of the most significant concerns, and land degradation due to abiotic pressures (environmental stresses) is causing poorer agricultural output, exacerbating the problem [13]. Moreover, high population growth puts pressure on increasing productivity to ensure food security and meet future needs [8]. Land degradation occurs mainly due to abiotic factors like salinity, drought, and pollution. Soil salinity is severe abiotic stress to agriculture worldwide [13-15], with considerable economic consequences due to the loss of arable area and lower agricultural production. Therefore, increasing food production per unit of cultivated land area with more sustainable production systems is a great challenge, given the exponential population growth [16] and adverse environmental conditions due to changing climate [17]. This chapter will delve into the intricacies of how maize responds to salt stress, examining its underlying causes, the effects it has on the plant, its ability to tolerate such stress, and the adaptive mechanisms it employs.

2. Maize and Salt Stress Effects

2.1 Germination & Seedling Growth Stages

The ability of a seed to germinate in saline soil is critical for many plant species' survival, and better crop production on salt-affected soils depends on successful seed germination. Since the seed and the soil surface are close together, seeds are more susceptible to salt stress [18]. Germination and seedling growth traits are the most critical factors for selecting salinity tolerance species/cultivars. Because the effective establishment of healthy seedlings depends on seed germination, the germination stage is susceptible to salinity compared to other vegetative stages [19]. Germination rate had the most critical effect on the stand establishment and plant density. The main harmful effects of salinity are reduced germination and emergence, stand, and

establishment of seedlings [20, 21]. Salinity stress mainly reduces the seed germination and seedling growth characteristics. It delays the onset of germination, and environmental factors like temperature and light interact with the germination and seedling growth properties [22, 23]. It has been reported that high salt concentration in soils limits seed germination and root proliferation, and impedes plant water and nutrient uptake, further reducing plant vegetative growth [24, 25]. Soil salinity amasses the toxic ions in plants, which imbalances essential ions following interference with the normal physiological functions of the plant. Sodium (Na^+) and chloride (Cl^-) ions induce hyperosmotic stress and toxic effects on germinating seeds under a saline environment, which may delay or reduce the speed of seed germination [26, 27]. Excess salinity slows the seed germination, while lower salinity provokes seed dormancy [28]. Seeds, on the other hand, develop a method for maintaining reduced water potential and dealing with the restrictions of nutritional imbalance [29], or they evolve other particular tolerance mechanisms for avoiding salt stress damage [30].

Imbibition of water is the first stage of seed germination, and salinity interrupts seed germination by decreasing the soil's osmotic potential, inhibiting the imbibition of water by seeds [28]. Salinity creates ionic toxicity that alters the enzymatic activity needed for nucleic acid metabolism. Salinity stress reduces seed germination rate by changing the metabolism of protein [21, 31]. Ionic pressure due to NaCl accumulation to a toxic level in soil decreases the germination rate [32, 33]. Water absorption by the seed is reduced because of lower water potential caused by salt stress, thus posing toxic effects on the developing embryo and delaying the germination process [34]. The reduction of seed germination due to salinity stress was noted by lowering the osmotic potential of the germinating media, increasing Na^+ and Cl^- toxicity to the embryo, or modifying protein synthesis. For example, salinity delays germination in maize [21, 33] and other crops such as soybean [27] and black gram [35]. Priming seeds with NaCl significantly improved germination and early seedling growth of maize under saline conditions [36]. However, the seed's mean germination time (MGT) depends on the strengths of salinity stresses and species/genotypes. The germination rate consistently decreases with increasing the trend of salinity stress [21, 37]. The imposition of salt stress reduced the germination index of maize cultivars [38, 39]. Salinity had a very distinct negative effect on germination, vigor index, seedling growth, and water uptake in maize [40]. A high value of germination index is recorded in small-sized seeds compared to large-sized seeds under saline conditions. Salinity stress reduced the germination percentage, index, germination speed, MGT, and seedling growth of maize genotypes [41]. Salinity stress reduced Zea mays' germination rate, plumule length, shoot length, root length, and seed vigor by 32, 78, 78, 80, and 95%, respectively [42].

2.2 Vegetative Stage

Maize vegetative development was greatly hampered by salinity. Soil salinity inhibited leaf initiation, expansion, and internode growth, reducing maize plant growth and enhancing leaf abscission [43, 44]. The reduction of growth caused by salinity is predominantly responsible for acidification in the apoplast and enzyme activity. Salt stress diminished cell division, the number of elongating cells, and cell elongation rate, resulting in rapidly reduced leaf growth and plant growth of maize. It has been reported in many studies that salt stress primarily reduces the shoot growth of maize [45-48]. Salinity remarkably reduces the leaf and stem biomass [49, 50], leaf area, shoot, and root dry weights of maize [51]. The activities of various enzymes that take part in nitrogen

metabolism in plants are reduced by salt stress; hence, plant nitrogen status is reduced in cereal crops [52].

The shoots of maize are more responsive to salt stress than roots [53]. Salinity reduces the shoot growth by suppressing the initiation and expansion of leaves, and retards the internodes growth resulting from the reduction of the shoot growth [54]. Salt stress causes membrane leakage as a primary cellular response through displacing Ca^{2+} from the binding sites of the plasma membrane [55]. The integration of the plasma membrane and cell wall acidification process, which is partially dependent on adenosine triphosphate-driven outward pumping of protons across the intact plasma membrane in maize, is seriously affected by salinity stress [56]. The growth extension mainly depends on the apoplast's acidification, resulting in the enlargement of cells [57].

Chlorophyll is a raw material of photosynthesis, and salinity stress inflicted maize plants results in a notable reduction in leaf chlorophyll content [58-64] and carotenoid content [65, 66]. Salinity decreased maize seedlings' chlorophyll fluorescence ratio (Fv/Fm) [60]. Plants exposed to salinity stress higher than 10 dSm^{-1} severely declined the Fv/Fm of maize [67]. The photosynthesis of maize is decreased due to inhibition of growth and development of leaves and early abscission. At the same time, prolonged salt stress augmented ion toxicity, membrane disruption, and stomatal closure, which are responsible for severely reducing photosynthesis [68]. Salt stress harshly influenced the carbon fixation in maize [68]. Generally, the carbon fixation capacity of maize plants mostly depends on enzymes, stomatal conductance, photosynthetic pigments, and photosynthetic apparatus, which are severely reduced by salinity stress [44, 69]. Na^+ concentrations in the stems and leaves of maize genotypes increased under saline stress [50, 70-72]. A higher Cl^- concentration was recorded than Na^+ concentration in maize shoots [59]. On the other hand, the translocation of potassium (K) from root to shoot tissues in maize is disturbed by salinity, causing fewer K contents in the shoot than in the root [73]. Na^+ and Cl^- concentrations in maize varied due to genotype variations, experimental duration, growth stages, and fertility.

Salt stress conditions affect plants' physiology by changing plant cells' water and ionic balance, nitrogen and carbon dioxide assimilation rates, and protein biosynthesis mechanisms [21, 27, 74]. Reduced plant growth due to salt-stressed conditions depends upon the amount of salt in the soil, the type of specific salt, and salt-affected plant tissues [75]. Primarily, excess salt concentration species (Na^+ and Cl^-) damage plant root membranes, affecting the selectivity mechanism of the membrane, followed by an adverse effect on K balance, decrease in nitrogen assimilation enzyme activity (nitrate reductase), inhibition of photosystem II [76], and chlorophyll breakdown [26, 64, 77].

2.3 Reproductive Stage

Salinity significantly reduced the growth and productivity of crops throughout the globe [78-80]. Salinity stress considerably reduced the grain yield of maize by decreasing the number of grains and grain weight during the reproductive growth stage [81]. Reduced photosynthesis and photo-assimilates under saline stress are the major causes of poor grain formation, decreasing grains and grain weight [82], and poor biomass production [83]. Poor grain setting and filling at the reproductive stage owing to reduced translocation of assimilates from source to developing grains (sink) under salt stress ultimately reduced grain yield [84]. It has been accounted that salinity stress reduced the grain yield of maize by 22% when salinity increased to 20 dSm^{-1} [85], by 34% when soil

salinity increased from 3.8 to 7.4 dSm^{-1} [86] depending on the nature of variety, growing seasons, growth stages, etc.

3. Maize - Salt Stress Mechanisms

It has been judged earlier [87] that maize is moderately sensitive to salt stress. A crop species that maintains average growth and development in saline soils ranging the ECe of 3-6 dSm^{-1} is treated as a moderately tolerant crop [88]. Plants countenance saline stress in two phases: the osmotic stress phase and the specific ion toxicity phase [89]. Therefore, plant tolerance mechanisms are practically fragmented in those two phases. Proline and other compatible solutes contribute to establishing osmotic-stress tolerance in the plant by lowering tissue water potential [90]. On the other hand, stress tolerance mechanisms through the ionic phase comprise ion exclusion and tissue tolerance [75] and transportation of Na$^+$ ions from the shoot to the root via the phloem [91]. However, the use of each tolerance mechanism broadly varied by individual factors in salt-sensitive and salt-tolerant plants [75].

Maize plants develop various mechanisms to survive in saline soils. The principles mechanisms are: i) Ion homeostasis and compartmentalization (exclusion of toxic ions), ii) Biosynthesis of osmoprotectants and compatible solutes (activation of the antioxidant defense system), iii) Activation of enzymes and synthesis of antioxidant compounds, iv) Regulation of hormones (changes in hormonal balance), v) Apoplastic acidification, vi) Synthesis of polyamines, and vii) Generation of nitric oxide (NO) (Figure 1).
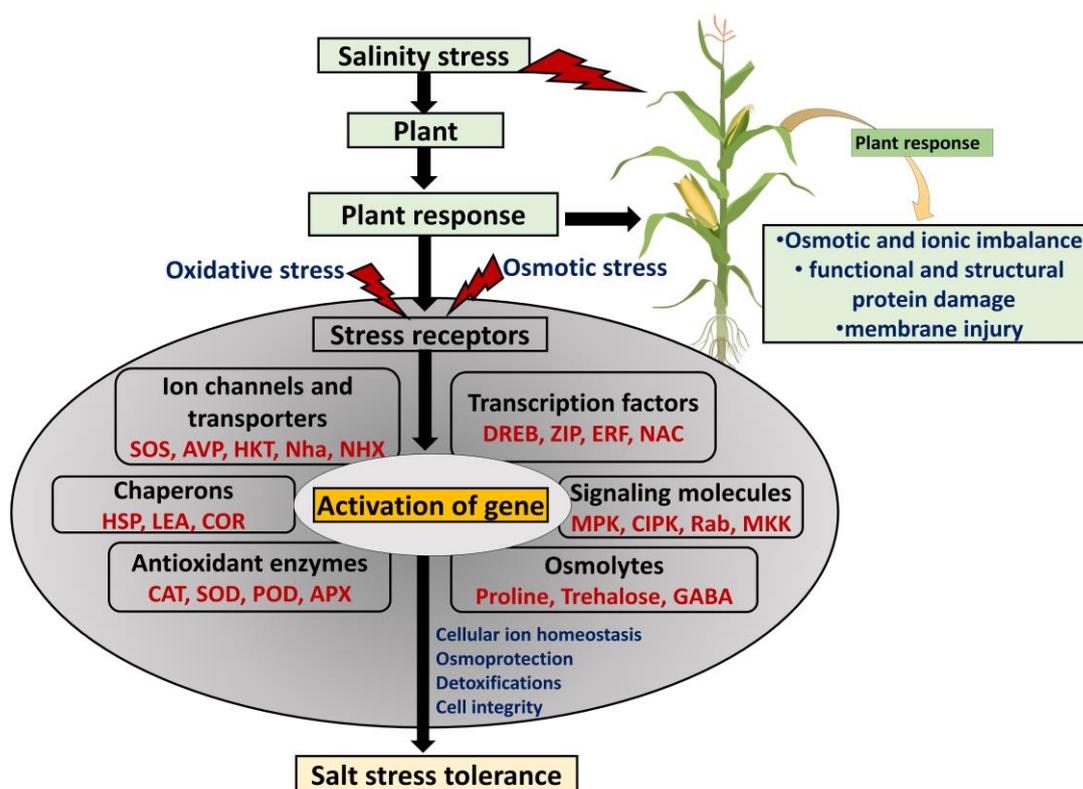

Figure 1 Mechanisms adopted by maize plants to survive in saline soils.

3.1 Ion Homeostasis and Compartmentalization

Excess accumulation of Na^+ is highly toxic to maize plants [92]. Therefore, excluding excessive Na^+ is an adaptive trait of plants to acquire salt resistance. Ion homeostasis through ion uptake and compartmentalization is an essential adaptive strategy for plants under salt stress [93-95]. Excess Na^+ is either transported to the vacuole through tonoplast Na^+/H^+ antiporters driven by the proton gradient or sequestered in older tissues, protecting the plant from salinity stress [96, 97]. Two types of H^+ pumps, viz., vacuolar-type H^+-ATPase (V-ATPase) and vacuolar pyrophosphatase (V-PPase), are present in the vacuolar membrane [98-100], and V-ATPase is more dominant H^+ pump present within the plant cell. Maize plants escape the cytosol from the toxic Na^+ in this way, and reduce the osmotic potential [101]. The salt tolerance of maize is connected with higher K^+, lower Na^+, and Cl^- fluxes [102], and is associated with a higher K^+/Na^+ ratio [103]. The salt-resistant maize plants excluded Na^+ more efficiently from leaf cell cytoplasm than the salt-sensitive maize plants [104]. Increasing K^+ uptake and preventing Na^+ entry by maintaining desirable K^+/Na^+ ratios in the cytosol are common adoption strategies of plants under salt stress [105]. Salt-tolerant maize genotypes have higher K^+/Na^+ ratios than sensitive ones [106].

3.2 Biosynthesis of Osmoprotectants and Compatible Solutes

Osmoregulation is a fundamental plant adaptation for reducing the impacts of salt stress, and it reduces the effect of salinity-induced osmotic stress by lowering osmotic potential due to the accumulation of some suitable solutes [26]. Compatible solutes (osmolytes) are a group of chemically diverse organic compounds that are uncharged, polar and soluble, and do not interfere with cellular metabolism, even at high concentrations. Proline, glycine betaine, soluble sugars, sugar alcohols, organic acids, and trehalose are the major compatible solutes, and the key osmolytes responsible for osmoregulation in maize under salt stress are proline and glycine betaine amid them. It has been reported that salt stress-induced maize plants accumulated more proline [73, 104, 107] and glycine betaine [108]. Salt-stressed plants produce more proline for osmotic adjustments and curtail saline toxicity [109, 110]. It provides tolerance towards stress, and serves as an organic nitrogen reserve during stress recovery. Salt-stressed plants also produce a sufficient amount of glycine betaine, which defends the plant cell from osmotic stress, improves salinity tolerance [76, 111], protects the photosynthetic pigments [112], and reduces the activity of reactive oxygen species (ROS) [109, 113]. It is evidenced that a strong positive correlation between increased proline and glycine betaine levels and stress tolerance index exists in plants under saline habitats. Salinity significantly reduced the total soluble sugar contents in maize leaves [107, 114] due to the inhibition of photosynthetic activity and increased partial utilization of carbohydrates into other metabolic pathways under salt stress. Higher accumulation of sugars and starch under salt stress [115] mitigates stress involving osmoprotection, carbon storage, and scavenging of ROS. The tolerant maize genotype accumulated more carbohydrates (122%) than the salt-sensitive genotype [104], indicating salt tolerance levels depend on the overproduction of carbohydrates.

3.3 Activation of Enzymes and Synthesis of Antioxidant Compounds

Plants under stress (abiotic and biotic stresses) conditions interrupt the electron transport chains (ETC) in chloroplasts and mitochondria, and molecular oxygen (O_2) acts as an electron acceptor under these conditions, leading to an increase in the accumulation of ROS. Moreover, plants' metabolic processes and enzymatic activities are changed due to salt-induced osmotic stress,

leading to the overproduction of ROS, which causes oxidative stress [116]. Overproduction of ROS like singlet oxygen ($^1O_2$), the hydroxyl radical (OH^-), the superoxide radical (O_2^-), and hydrogen peroxide (H_2O_2) are strongly oxidizing compounds (highly toxic) and damages proteins, lipids, carbohydrates, and deoxyribonucleic acid [117]. In chloroplasts, photosystems I and II and complex I, ubiquinone, and complex III of the ETC in mitochondria are essential sites for ROS formation [118]. For example, overproduction of H_2O_2 under salt stress collapses the leaf veins of maize due to leakage of adjacent cells [116]. Antioxidant metabolism, including antioxidant enzymes and nonenzymatic compounds, is critical in detoxifying ROS induced by salinity stress. Plants under salt stress show multigenic responses, including osmotic and ionic homeostasis and cell detoxification for antioxidant defense systems [119-121]. Salt tolerance of maize is associated with higher antioxidant activity (such as an enormous accumulation of polyphenols) under saline conditions [122]. Under saline conditions, higher antioxidant activity with higher polyphenol accumulation confirmed better leaf water content, leaf growth, membrane stability index, and plant growth in salt-tolerant maize [73]. Salinity tolerance in plants is directly linked with the activities of antioxidant enzymes like superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPX), ascorbate peroxidase (APX), and glutathione reductase (GR), and nonenzymatic antioxidant compounds [123, 124]. Enhanced enzyme activities are more pronounced in salt-tolerant maize plants than in salt-sensitive ones [125]. For example, CAT, GPX, and APX enzymes combined with SOD have superior H_2O_2 scavenging activity in the leaves and roots of salt-tolerant maize plants to salt-sensitive genotypes under salt stress [125].

3.4 Regulation of Hormones

Plant growth hormones influence the growth and development of plants [126]. The most essential phytohormones are auxins, gibberellins, cytokinins, ethylene, and abscisic acid, which help to promote plant growth. Salt-stressed maize plants synthesize endogenous growth hormones like abscisic acid (ABA) levels at the expense of indole acetic acid (auxins), which may escort stomatal closure for lessening water loss as a consequence of salinity-induced osmotic stress [127]. The root tips of maize get the gesture of impaired water availability under saline-induced osmotic effect and send a signal to shoots for regulating the whole-plant metabolism [128]. In this connection, salt-tolerant maize accumulates more ABA than salt-sensitive maize hybrid under salt stress [128, 129]. An increased concentration of ABA under salt stress enhanced leaf growth (reduced leaf sensitivity) of maize, possibly which could be allied to a growth-promoting function at the first phase of salt stress [130]. Salinity stress enhances osmotic stress and water deficit, increasing the endogenous ABA levels in the shoots and roots of maize [131], and this endogenous ABA in maize plants mitigates the inhibitory effect of salinity on photosynthesis, growth, and translocation of assimilates [131] and improves salt tolerance [132]. The accumulation of ABA in maize plants under salt stress increased the levels of K^+, Ca^{2+}, and compatible solutes such as proline, glycine betaine, total soluble sugars Na^+/K^+ and Na^+/Ca^{2+} ratios, which work against the uptake of Na^+ and Cl^-, and enhanced salt tolerance [133].

3.5 Apoplastic Acidification

Apoplastic acidification under salt stress is an essential indicator of salt tolerance. Cell-wall-loosening enzymes are activated due to lower apoplastic pH, which expands the cells [134]. Less

acidification reduces the seedling growth in maize during the first phase of salt stress owing to inefficient plasma membrane H^+ pumping by ATPase [135]. Reduced apoplastic pH maintained higher H^+-pumping in the salt-tolerant maize genotype by loosening the cell wall, which promoted more plant growth under salt stress than in the salt-sensitive genotype [47, 136]. In another study, it was reported that the growth of the salt-tolerant maize genotype dropped off throughout the first phase of salt stress despite sufficient cell wall acidification, indicating that other factors are responsible for limiting plant growth than apoplastic pH [137]. Therefore, apoplastic acidification under salt stress is not always an essential consideration for recovering the growth of maize plants [138].

3.6 Synthesis of Polyamines

In plants, polyamines (PA) are small, low molecular weight, ubiquitous, polycationic aliphatic molecules. Polyamines extensively recovered the growth and development of plants under stress [139, 140] and non-stress conditions [141, 142]. Plants under salt stress increased the endogenous PA levels. They played a significant task in abiotic stress tolerance, including salinity, owing to the positive correlation between increased polyamine levels and plant stress tolerance [143-146]. The PA catabolism regulates the intracellular polyamine level, and produces copper-binding diamine oxidases and FAD (flavin adenine dinucleotide) binding polyamine oxidases. It has been proved that these enzymes are involved in abiotic stress tolerance in plants [147, 148]. It has been noted the positive effects of PA through the maintenance of membrane integrity, regulation of gene expression for the synthesis of osmotically active solutes, reduction in ROS production, and inhibition of Na^+ and Cl^- ions accumulation in different plant organs [149-152]. The most common PA that are found within the plant system are diamine putrescine (PUT), triamine spermidine (SPD), and tetra-amine spermine (SPM) [153-156]. For example, SPM improves the growth and development of sorghum plants by increasing the activity of peroxidase and glutathione reductase enzymes with decreasing membrane lipid peroxidation levels under salt stress [157]. SPD increased the salt stress tolerance of cucumber seedlings by changing proteomic functions and metabolic pathways [158]. Overproduction of PUT in rice enhanced the salt tolerance [159]. Moreover, SPM and SPD are considered potent inducers of nitric oxide, another essential signaling molecule [160], and have been discussed in a separate title underneath. It has been reported that salt stress regulates PA biosynthesis and catabolism by acting as a cellular signal in hormonal pathways, thereby regulating ABA in response to stress [161].

3.7 Generation of Nitric Oxide

Nitric oxide (NO) is assumed to play a crucial role in salt stress tolerance in crop plants. NO is a small volatile gaseous molecule that contributes to various plant growth and developmental processes under stress and non-stress conditions, such as seed germination, root development, respiration, stomatal closure, flowering, cell death, and stress responses, as well as a stress signaling molecule [162-164]. It has been reported that NO protects against salinity stress in maize plants [165, 166]. NO triggers the activity of antioxidant enzymes (SOD, CAT, GPX, APX, and GR) in crop plants [165, 167]. NO mitigates the salt-induced oxidative damage in maize plants by enhancing the activities of antioxidant enzymes (SOD, POD, and CAT) and lowering MDA and H_2O_2 [166]. NO reacts with lipid radicals, thus preventing lipid oxidation, exerting a protective effect by scavenging

superoxide radicals and forming peroxynitrite that other cellular processes can neutralize. NO increases the salinity tolerance in maize plants due to enhanced antioxidant activities and modulation of the ROS detoxification system [168].

Plant salinity tolerance is also related to regulating plasma membrane (PM) H^+-ATPase and Na^+/K^+ ratio [163]. NO increases PM H^+-ATPase (H^+-PPase) activity [169], creating an H^+ gradient that stimulates the exchange of Na^+/H^+. An increment of Na^+/H^+ exchange may contribute to K^+ and Na^+ homeostasis, and increase the Na^+/K^+ ratio, leading to salt stress tolerance in maize inbred line seedlings [170].

4. Management Strategies

No doubt, salinity reduces crops' growth and productivity; hence, different methods are practiced to alleviate the salinity problem and increase the relative salt tolerance of crops. Various strategies are used to mitigate salt stress's negative impact on crop plants, like exogenous application of phytohormones, amino acids, sugars, osmolytes, and other plant growth regulators (Figure 2).
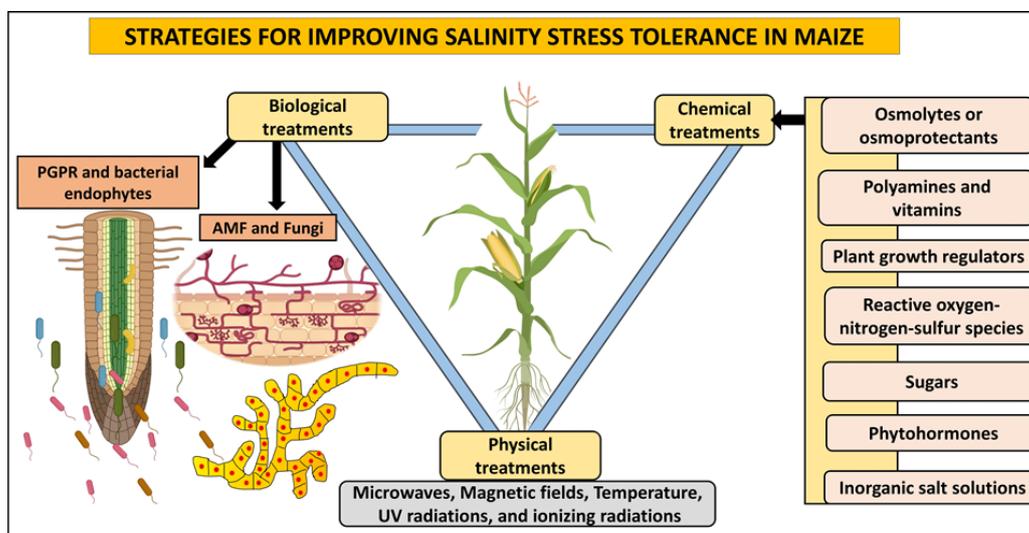

Figure 2 Different strategies for alleviating the effect of salt stress in maize.

4.1 Selection of Salt-Tolerant Genotypes

Introduction and selection of salt-tolerant maize genotypes in conjunction with suitable production technology are required to increase productivity in salt-affected regions. Maize genotypes have different levels of tolerance against salinity [43, 171, 172], and relative salt-tolerant genotypes that can enhance crop yield should be selected. Therefore, choosing tolerant genotypes would be an essential retrieval method to grow in saline-prone areas [173].

4.2 Seed Priming

Successful crop production depends on the optimum crop stands determined by the ideal level of seed germination. Salt stress extensively delays and reduces seed germination of maize because of osmotic stress induced by salinity on germinating seeds [26, 27, 174], and seed priming has the

potential role in overcoming these problems (Table 1). It has been reported in many studies that hydropriming of maize seed under saline conditions significantly increased germination rate [175], germination percentage, germination index, seedling vigor index, and seedling length [33]. Priming with sodium chloride, potassium chloride, and calcium chloride alleviates the adverse effects of salt stress and increases maize's germination and seedling growth traits [175-177]. Hormonal priming also alleviates the adverse effects of salt stress. It improves germination and seeding growth properties, as priming of maize seed with chloroethyl phosphonic acid augmented the biomass of seedlings under salt conditions [178], with 28-homobrassinolide increased seedling growth by enhancing the activities of antioxidative enzymes in addition to lowering lipid peroxidation and increasing protein concentration [179], with salicylic acid enhanced growth and development [180], with hydrogen peroxide improved seed germination percentage by increasing the activities of APX, CAT, and GPX [181], with ascorbic acid, thiamin, and pyridoxine improved growth or seed yield under [182]. Seed priming with 24-epibrassinolide (EBL) on maize grown with different levels of saline stress under semi-controlled conditions positively influenced the root length, root surface area, stem diameter, relative leaf water contents, total chlorophyll, photochemical activity of PSII (Fv/Fm), net rate of photosynthesis and transpiration, and nutrients (Zn, K) uptake in roots and shoots of maize, while it resulted in the lowest Na^+ and Na^+/K^+ ratio [183].

Table 1 Role of seed priming reclaims the salt tolerance.

Priming techniques	Priming agents	Improvement	References
Hydropriming	Water	Germination	[33]
		Germination and seedling growth characteristics	[175]
Hormonal priming	Ascorbic acid, thiamin, & pyridoxine	Growth, grain yield	[182]
	Salicylic acid	Growth and physiology (photosynthesis and carbohydrate metabolism)	[180]
	Ethylene	Biomass	[178]
	28-homobrassinolide	Protein content, antioxidative enzyme activities (decreased lipid peroxidation)	[179]
	Hydrogen peroxide	Germination percentage, activities of ascorbate peroxidase, catalase, and guaiacol peroxidase	[181]
Halopriming	NaCl	Emergence and germination rate, plant height, and yield;	[176]
		Shoot length, dry weight, leaf number and area, and chlorophyll content	[177]
Osmopriming	$CaCl_2$	Germination rate, number of cobs, shoot & root lengths, yield	[184]

Osmopriming (Organic)	*Moringa* leaf extracts	Crop growth & net assimilation rates, leaf area index, maintain more extended green leaf area.	[185]
Chemipriming	Phenylalanine	Germination, leaf area, root & shoot fresh & dry weights, lengths, chlorophylls and carotenoids	[186]

4.3 Organic Matter Management

An organic amendment has been proved as a practical approach to attenuate the salinity stress in soil. Modifications of soil through organic matter improve soil's physical and chemical properties. However, applying organic matter effectively combats salinity's adverse effect and increases salt-stressed maize's growth and yield. Using organic substances, such as solid waste, compost, vermicompost, manure, and cow dung, decreases soil salinity. It increases total nitrogen, available phosphorus, exchangeable potassium, calcium, and magnesium concentrations, and soil organic carbon and cation exchange capacity (CEC) by decreasing Na^+ concentration in maize crops.

Application of solid waste, vermicompost, and cow dung alleviates the adverse effects of soil salinity. It improves the shoot and root growth of maize plants by improving the physicochemical properties of soil and by reducing the electrical conductivity (EC) in soil [187]. Compost and vermicompost application in salt-stressed maize plants increased plant height and dry matter production by lowering soil pH and EC [188]. Manure application significantly released the salt-induced osmotic stress, decreased the electrolyte leakage in maize plants, and increased plant growth and grain yield [189]. Biochar is also an essential organic amendment of abiotic stresses, which enhances soil physicochemical properties such as soil structure, surface area, water holding capacity, CEC, and pH [190]. Salinity significantly decreased the growth of maize, whereas biochar mitigated the adverse effects of salt stress and enhanced the growth by lowering the uptake of xylem Na^+ concentration or maintaining nutrient balance within the plant [191]. The utilization of biochar has been demonstrated to enhance the growth and productivity of salt-stressed maize plants by augmenting K uptake while reducing Na uptake, as evidenced by studies [192-194]. Similar positive effects of biochar under salt-stressed-plants have been observed in other cereal crops such as wheat [195, 196] and rice [197, 198]. Compost manure and crop straw-derived biochar application in salt-stressed maize plants decreased saline toxicity by reducing the accumulation of Na^+ and Cl^- accumulation, increasing K concentration, CEC, water holding capacity, and pH, and improving maize growth and productivity [199]. Application of cow manure-made biochar significantly increased net water uptake efficiency (WUE), hydraulic conductivity, total N, P, exchangeable cations, CEC, total C, and pH, resulting in increased productivity of maize [200].

Additionally, using rice straw-derived biochar reduced the additional chemical fertilizers (NPK) rate by 25% in cowpeas under saline conditions [201]. Exogenous application of organic matter is an efficient and feasible way to mitigate saline toxicity and improve soil health and plant growth. Therefore, organic matter amendment could be an efficient approach for sustaining maize production in salt-affected soils.

4.4 Nutrients Management

Salinity stress reduces the growth and development of maize plants by reducing the uptake of essential plant nutrients such as N, K, Ca, Mg, Fe, and Zn [44, 59, 73, 202, 203]. Salt-stressed plants suffer nutrient deficiency by reducing their uptake due to over-competition of Na^+ with cationic ions (NH_4^+, K^+, Ca^{2+}, Mg^{2+}, Zn^{2+}, etc.) and Cl^- with anionic ions (NO_3^-, PO_4^{3-}, SO_4^-, Fe^{2-}, etc.) [204, 205]. Hence, more significant reductions of K^+, Ca^{2+}, and Mg^{2+} contents were recorded in leaves and roots of maize owing to combined stresses rather than with only the salt stress or only K^+, Ca^{2+}, and Mg^{2+} deficiency [44, 204]. Na^+ and Cl^- accumulation is increased in leaves and roots of maize under saline stress, while their accumulation is also aggravated due to K deficiency. Likewise, K^+/Na^+, Ca^{2+}/Na^+, and Mg^{2+}/Na^+ ratios are reduced rigorously in maize leaves and roots under saline and K stresses compared to their stress [44]. Therefore, applying essential nutrient elements in any form (through elemental/fertilizers) quickly rescued the adverse effects of salinity stress in maize plants.

The growth and productivity of maize are also affected by N deficiency due to the antagonistic effects of Cl^- and NO_3^- under salinity stress [204]. Therefore, nitrogen (N) application significantly ameliorated the adverse effects of salt stress and conspicuously increased the growth, yield, and N uptake in salt-stressed maize plants [206]. Application of N in salt-stressed maize plants increased the leaf area index, crop growth rate, net assimilation rate, and yield to a large extent [207]. In earlier studies, it has been acknowledged that the application of N extensively increased the antioxidant enzymes like such as CAT, GR, and glutathione-S-transferase activities in maize while decreasing the peroxide dismutase (POD) and SOD activities [54]. So, the N source is also an essential factor.

Potassium application enhanced the yield contributing characteristics and increased the yield of maize under saline conditions [208]. Similarly, K application in saline-affected maize plants significantly increased the grain yield by enhancing water uptake and turgor maintenance, mineral nutrition, leaf area index, and crop growth rate and reducing Na uptake through osmoregulation [209]. Na^+ concentration increased in saline soils, showing a higher value of Na^+/K^+ ratio. Conversely, K application exogenously decreased this ratio and alleviated the nasty effects of Na in maize [210, 211]. Recently, Hussain *et al*. [211] claimed that applying K sulfate and diammonium phosphate (DAP) as a mixture in saline soil increased the growth and productivity of maize. Foliar application of KCl and thidiazuron on maize plants remarkably increased growth by alleviating the adverse effects of saline stress [212]. They also concluded that thidiazuron more efficiently alleviated the adverse effects of salt stress than K fertilization due to considerable improvement of K, chlorophyll content, total carbohydrate, and total soluble sugar.

Among the micronutrients, boron (B) has a significant role in the plant cell wall and membrane constancy [212-214] and the growth and productivity of crops [215]. Applying B in salt-induced maize plants increased the membrane integrity of plants by increasing the concentration of K. It increased the growth by alleviating the negative effect of Na^+ and Cl^- [216].

Applying flue gas desulfurization gypsum (FGDG) reduces the deadly effects of Na^+ due to the swapping of Na^+ with Ca^{2+} at the cation exchange site. Consequently, it increases clay particle flocculation near the soil surface [217]. Adding furfural residue (FR) has been shown to increase soil organic carbon (SOC) content while reducing soil bulk density, particularly under saline conditions, attributed to its ability to lower soil pH [218]. The combined application of FGDG and FR in saline

soils recovered the soil properties by increasing SOC and mineral nutrients, decreasing soil pH and sodium content, and increasing maize [219].

Applying silicon (Si) increases the photosynthetic paraphernalia of salt-stressed maize plants by triggering the electron transport chain [220]. It has been proved that Si increased the salinity tolerance of the maize crop; the application of Si enhanced the salt tolerance of maize plants by reducing the oxidative and osmotic stress [221] by increasing biochemical and physiological activities like water-use efficiency, photosynthetic pigments, etc. [222]. Combined B and Si application helps enhance salinity-induced maize plants' growth and physiological functions. It alleviates the adverse effects of salt stress by increasing the concentration of total soluble sugars and proline [223]. It has been reported that the nutritional status of stress-stressed maize seedlings increased with the foliar application of iron [224]. Foliar application of H_2O_2 enhanced the salt tolerance of maize plants by increasing antioxidant enzymes like APX, GPX, SOD, and CAT [225].

4.5 Fresh Water Irrigation

Applying fresh water in saline habitats reduced salinity stress and increased the growth and yield of crops. Irrigation with fresh water at jointing, heading, and grain filling stages of maize increased the grain yield by 81.16% as compared to saline water irrigation of those stages, not only that two times saline water and one-time freshwater application increased yield by 35.39% [226]. It has been evidenced that alternating irrigation times of salt water and fresh water had a significant effect in lowering soil salinity and increasing grain yield of maize [227], irrigation of fresh water at the seedling stage promoted salt leaching and enhanced maize yield [228], freshwater irrigation at the heading stage recovered the earlier stress and improved the WUE and growth of maize [229]. Alternating fresh and saline water irrigation enhanced plant growth [230]. Applying fresh water during the sensitive stages and saline water during the non-sensitive stages of plant growth increased the irrigation utilization rate of saline water [231]. Alternate irrigation of fresh and saline water at 80:20 produced a similar yield of tomatoes with irrigation with fresh water alone [232]. Alternate irrigation of fresh water and saline water produced a higher yield of wheat and mustard than mixed irrigation at the same level of salt [233]. Freshwater can be substituted with saline water up to high values of EC (9 dSm^{-1}) without any loss in wheat and barley production where there is deficit irrigation [234]. An effective irrigation system and strategy control soil salinity and reduce soil's high saline toxicity. Alternate fresh and saline water irrigation (at seedling, jointing, and tasseling, and after tasseling) alleviates the salt stress and increases the yield of maize [235, 236].

The application of brackish water in salt-induced maize plants alleviated the stress effects. Brackish water irrigation in saline conditions increased the uptake of K while retarded the uptake of Na in some maize genotypes. Irrigation frequency affected soil salinity accumulation when using brackish water [237]. Generally, saline water irrigation alters the soil environment [238], affects the soil capillary action, and changes soil permeability and water retention [239], leading to accumulating salts in the soil and restricting crop growth [240, 241]. Applying three times irrigation with fresh and brackish water (80 mm of freshwater + 80 mm brackish water + 80 mm of salty water) increased the yield of winter wheat by reducing the soil salinity [242]. Applying high saline water with high frequency (one-day interval) enhanced the growth and yield of tomatoes [243].

Exogenous application of hydrogen-riched water (HRW) mitigated the effects of salt stress on the growth of maize roots. H$^+$-transporters are closely associated with transporting ions and small

molecules, essential for maintaining osmotic balance, ion homeostasis, and nutrition absorption. Application of HRW remarkably increased the activities of PM H^+-ATPase, tonoplast H^+-ATPase, and H^+-PPase, and increased the relative water content biomass, maintained ionic balance in maize seedlings, and finally increased salt tolerance [242].

4.6 Exogenous Application of Phytohormones

Phytohormones are chemical substances that play a significant role in plants' physiological and biochemical processes. Five classical phytohormones, viz., auxins, gibberellins, cytokinins, ethylene, and abscisic acid, significantly affect abiotic stress tolerance. Other well-known phytohormones are brassinosteroids, methyl jasmonates, salicylic acid, strigolactones, etc., which also alleviate environmental stresses. Applying phytohormones exogenously under salt stress conditions overcomes the adversative properties of salt stress and increases the growth and productivity of maize plants.

Indole-3-acetic acid (IAA), popularly known as auxin, significantly regulates plant growth. Salinity stress influences IAA homeostasis due to the alterations in IAA metabolism and distribution [244], and endogenous IAA level is decreased under salt stress [245, 246]. At the same time, the exogenous application of IAA alleviates the adverse effects of salt stress and enhances plant growth [247, 248]. However, foliar application of IAA increased the growth and yield of salt-stressed maize plants by improving the CAT and SOD activities [249]. It has also been reported that exogenous application of IAA enhanced the growth and yield of a salt-stressed maize plant by increasing the uptake of essential plant nutrients and decreasing the uptake of Na^+ remarkably [250]. Applying inorganic nutrients and IAA exogenously as pooled in maize plants grown in saline conditions increased P, Ca, and Mg while decreasing Na contents. Enhancement of plant growth by IAA and nutrient application is linked with an improved concentration of photosynthetic pigments, more K^+/Na^+ ratio, enhanced activities of antioxidant enzymes like CAT and SOD, and reduced membrane permeability under saline conditions. In another study, it has also been postulated that IAA enhanced the maize plant growth at the earlier stages to a variable extent by reducing the Na^+ and Cl^-, increasing K^+ and Ca^{2+} concentrations, and maintaining higher membrane permeability [73]. Likewise, exogenous IAA in wheat increased germination, growth, yield, and seed quality by alleviating the adverse effects of salt stress [251, 252].

Gibberellic acid (GA_3) generally involves improving the growth, yield, and quality of crops [126, 253], and salt stress reduces the endogenous level of GA_3 in crops, including maize [254]. It has been proved that salinity-induced oxidative stress and ionic toxicity usually inhibit plant growth by changing physiological and biochemical functions. At the same time, GA_3 overcame the harmful effects of NaCl-induced stress and enhanced physiological and biochemical traits macro and micro-nutrient concentration. Exogenous application of GA_3 on maize plants grown in NaCl-induced saline stress curtailed the adverse effects of Na^+ and Cl^- and enhanced the growth and nutritional status by increasing the concentration of proline that sustained membrane permeability and salt tolerance [255]. Foliar application of GA_3 in salt-induced maize plants enhanced plant growth by increasing the uptake of nutrients and decreasing Na^+ and Cl^- concentrations [256]. GA_3 is more efficient in tolerating the salinity of maize plants than salicylic acid (SA). Under the saline condition, GA_3 also ameliorated the saline toxicity in different crops and enhanced the seed germination of wheat [257-259], growth and yield of wheat grain [260, 261], rice [262], and tomato [263].

Cytokinin (Ck) is a vital phytohormone that plays a significant role in the growth and development of plants [264]. Generally, the application of Ck regulates the metabolism of the maize plant [265], and any alteration affecting the synthesis and homeostasis of Ck leads to the death of the plant tissue. Ck is reported to control plant adaptation to stress and increase plant salt tolerance [266-268]. However, exogenous application Ck is involved in numerous vital plant growth and development processes. Foliar application of Ck in maize plants considerably ameliorated the harmful effect of salt stress and increased growth, yield traits, and grain yield [248]. Exogenous application of Ck increases yield and quality (starch concentration) in rice cultivars under salt stress [269-271]. Ck interacts with auxins and ABA and increases the salt resistance in wheat plants [272]. Salama and Awadalla [273] stated earlier that kinetin is one of the cytokinins responsible for increasing plant growth in saline conditions. Kinetin application conquered the effects of salinity stress and increased the growth of wheat seedlings [274]. Kinetin enhances salt tolerance by modulating shoot chloride exclusion in maize [275]. Foliar spraying of Kinetin and IAA overcame the adversative effects of NaCl-induced stress in maize plants by increasing membrane permeability, K^+, and Ca^{2+} and reducing Na^+ concentrations [73].

Ethylene (ET) also plays a pivotal role in plant growth and metabolism as a phytohormone. Ethylene has been shown to enhance plant salt tolerance by promoting the homeostasis of Na^+/K^+, nutrients, and ROS [276]. Salinity stress induces ET production, which helps maintain the Na^+/K^+ homeostasis, resulting in enhanced salt tolerance [277]. In a recent study, it has been reported that ET triggers salinity tolerance in maize genotypes by modulating polyamine catabolism enzymes [278]. Foliar application of ET alleviates the adverse effects of salt stress in tomatoes and increases salt tolerance by improving chlorophyll content, stomatal conductance, and ion homeostasis [279]. Application of ET exogenously enhances salt tolerance in plants by increasing chlorophyll a/b, photosystem II function (Fv/Fm), redox state, and retention of K^+ in shoots and roots of arabidopsis [280]. Salinity stress inhibits seed germination through elevation of the H_2O_2, and exogenous ethylene treatment has been shown to regulate ROS homeostasis to induce the seed germination of arabidopsis [281]. They also concluded that ET with NO enhances seed germination by decreasing the H_2O_2 levels and modulation of ROS production induced by salinity stress.

Abscisic acid (ABA) is also a critical phytohormone that ameliorates stress-induced damage to crop plants. ABA facilitates signals to the plants to stay alive under salt stress [282]. Endogenous ABA level is increased due to plants being exposed to salt stress or water deficit conditions [283]. The concentration of ABA significantly increases in salt-resistant maize genotypes [284]. ABA weakened the harmful effect of NaCl and improved the tolerance of ionic stress in sorghum [285]. ABA amplifies xylem water potential and water uptake capacity in barley plants in the presence of salt stress [286].

Nonetheless, the exogenous application of ABA-induced rice salt tolerance [287]. Salt stress stimulates the synthesis of ABA in roots, which transports from root to shoot through xylem sap, and the concentration is correlated to the stomatal reactions. Exogenous application ABA reduces ethylene release and leaf abscission under salt stress in rice, probably by decreasing the accumulation of toxic Na^+ ions in leaves and roots [288]. Salt-induced ABA mediated the inhibition of leaf expansion and limited the accumulation of Na and Cl in the leaves of maize [289]. Soil salinity up-regulates the generic stress hormone like ABA that induces genes to alleviate salt stress in *Iris hexagona* [245].

Brassinosteroids (BRs) are a novel phytohormonal group of steroids distributed throughout the plant kingdom [290, 291]. The most critical BRs are brassinolide (BL), 24-epibrassinolide (24-EpiBL), 28-homobrassinolide (28-HomoBL), castasterone (CS), and 24-epicatasterone (24-EpiCS), which are commonly used for biotic stress tolerance of plants. BRs ameliorate plants under environmental stress, such as oxidative damage [292]. Under salt stress, the effects of BRs were mainly focused on plant growth and antioxidant systems [179, 293-295]. BRs are prominent in various physiological processes, like cell division and expansion, xylem differentiation, stem elongation, and root growth [292, 296]. BRs application enabled maize seedling growth to recover from the effects of salinity [297]. BRs boost seed germination, development, and the ability of maize seedlings to withstand salt stress by enhancing oxidative responses [298]. Exogenous application of BRs ameliorates the salt stress. It increases the yield in many crops by altering physiological activities like rice [299, 300], oilseed rape [301], berseem (*Trifolium alexandrinum* L.) [302], cowpea (*Vigna sinensis*) [303], and cucumber [304].

2-hydroxybenzoic acid is known as salicylic acid (SA) and is considered a plant phenolic phytohormone. It plays crucial regulatory functions to protect plants against biotic and abiotic stresses. It encourages plants against salinity by adjusting physiological and biochemical processes. NaCl-induced salinity stress reduced the growth, photosynthetic pigments, water status, electrolyte leakage, and antioxidant enzymes of maize, while exogenous SA improved those traits and increased salt tolerance [107]. SA increased the uptake of nutrients in maize plants under saline conditions by considerably reducing Na^+ and Cl^- accumulation [203]. Salinity stress decreased maize's dry weight and leaf area. At the same time, foliar application of SA alleviated the lethal effects of salinity and enhanced those traits by increasing lysine, arginine, glutamic acid, and serine [305]. SA application significantly increased photosynthetic pigments by preventing the degradation of the nucleus and chloroplast and overcame the toxicity generated by NaCl-stressed maize plants, which delays leaf senescence/abscission [306]. Khodary [180] postulated that the photosynthetic rate and carboxylating enzyme activities are increased in salt-induced maize plants with SA. Exogenous application of SA increased plant growth under saline conditions by increasing mineral nutrition and, decreasing oxidative stress in maize [203] and inducing hormonal status in wheat seedlings [307]. Many studies support that the exogenous application of SA increased the tolerance of maize to salinity and osmotic stress [308, 309].

Methyl jasmonate (MeJA) and its free-acid, jasmonic acid (JA), collectively referred to as jasmonates, are important lipid-based phytohormones that enhance the growth of plants under stress [245, 310, 311]. It has been reported that the JA level increases under salt stress, and salt-tolerant cultivars accumulate higher JA than salt-sensitive cultivars such as rice [312, 313], tomato [314], etc. No specific study was found regarding the exogenous application of JA on maize crops. However, application of JA exogenously alleviated the salinity stress in other cereal crops like rice seedlings by decreasing Na concentration and inducing ABA activity [313], enhanced the growth and photosynthesis of barley by reducing the inhibitory effect of high salt concentrations [315].

Strigolactones (SLs) are isolated from cotton root exudates and used as seed germination stimulants for plants in the Orobanchaceae family that parasitize plant roots (*Striga*, *Phelipanche*, and *Orobanche* spp.) [316]. The biosynthesis and signaling of SLs are regulated by various abiotic stress factors [317], including salinity stress [318, 319]. SLs interact with other phytohormones, especially auxin and ABA. SLs and H_2O_2 signaling alleviate the salt stress induced by arbuscular mycorrhizal fungus in *Sesbania cannabina* seedlings [320]. Arbuscular mycorrhizal (AM) colonization

alters the ABA catabolism, and higher ABA protects plants from the harmful effects of salt stress by encouraging the production of SLs via H_2O_2 signaling [321]. AM symbiosis boosts the strigolactone levels in plants, thereby alleviating salt stress in maize plants through enhanced stomatal conductance and photosystem II efficiency [322]. Applying stigmasterol in maize plants mitigated the adverse impacts of salt stress and enhanced growth and yield [323]. SLs are also involved in the interaction of plant roots with nitrogen-fixing bacteria (Rhizobium) and increased the nodulation of alfalfa inoculated with *Sinorhizobium meliloti* following SL (GR24) treatment [324].

Therefore, exogenous application of phytohormones helps to improve maize performance under salt stress, as manifested by increasing nutrient uptake, osmotic adjustment, and the antioxidant defense system.

4.7 Exogenous Application of Osmoprotectants

Compatible osmolytes mitigate the harmful effects of salt stress and improve plant growth. Proline is the main osmolyte produced by the hydrolysis of proteins in the plant under abiotic stress, reducing osmotic stress. However, proline is usually made and accumulated in plants under salt stress and plays a multifunctional role in regulating cytosolic acidity, maintaining protein and ROS, and aiding osmotic adjustments [325]. Applying proline led to elevated proline levels in plants experiencing salt stress, which correlated with enhanced salt tolerance [326]. Kaur and Asthir [327] mentioned the functions of proline as scavenging ROS, stabilizing DNA, proteins, and membranes, and reducing denaturation of NaCl-induced enzymes. It has been found in many studies [104, 328] that salt stress decreases the growth and yield of maize plants by reducing the total nutrient uptake and excess accumulation of Na^+ and Cl^- ions. Exogenous application of proline has been shown to increase nutrient uptake and reduce the adverse effects of salt stress in maize [328, 329]. Total nutrient uptake in maize plants decreases under saline stress, but the exogenous application of proline increases nutrient uptake and salt tolerance [330]. Exogenous proline also improves the salinity tolerance of maize by increasing the uptake of nutrients and decreasing Na accumulation in plants [331, 332].

Glycine betaine (GB) is a vital osmolyte curtailing abiotic stresses. It has been proved earlier that exogenous application of GB improved the growth, water status, net photosynthesis, and yield in salt-stressed maize plants by improving stomatal conductance and actual photosystem II efficiency [333]. They also noted that GB promoted plant growth under salinity by reducing Na and increasing K concentrations in shoots. The application of osmoprotectants exogenously improves the overall performance of maize through osmotic adjustment and antioxidant defense system under salt stress. Exogenous application of GB in plants under stressed environments plays a critical role in regulating enzyme activity, ROS homeostasis, etc., and improves stress tolerance [334-336].

Hydrogen peroxide (H_2O_2) application exogenously effectively curtailed salinity-induced stress by increasing the activities of CAT, GPX, APX, and SOD [225]. H_2O_2 pretreatment increased the salt resistance during subsequent exposure to salt-persuaded plants, and H_2O_2 metabolism is involved as a signal in the process of salt acclimation in maize plants [337]. El Sayed [46] mentioned another piece of information regarding hydrogel polymers: it improved maize plants' growth and morpho-physiological traits under salt stress by enhancing soil properties.

4.8 Exogenous Application of Polyamines

Exogenous application of polyamines enhanced the membrane integrity. It regulated the expression of genes for the synthesis of osmotically active solutes, as well as reduced ROS production and Na^+ and Cl^- ions accumulation in different organs of crops [151, 152, 338]. Exogenous application of polyamines alleviated the salt-induced reduction of photosynthetic efficiency [339]. Polyamines (SPM) application increased sorghum seedlings' growth and salt tolerance by increasing the activity of POX and GR enzymes and decreasing the level of membrane lipid peroxidation [157]. Exogenous SPD significantly enhanced enzymatic activities (SOD, POD, CAT and APX), soluble sugar, soluble protein, and free proline levels while reducing O_2 production rate, H_2O_2 and MDA accumulation, thereby aiding in maintaining osmotic balance and increased salt stress tolerance in oat seedlings [340]. They also urged that SPD contributes to higher expressions of proteins and defense mechanisms on antioxidant and detoxification and inhibits proteolysis, which might play essential roles in salt tolerance.

4.9 Exogenous Application of Nitric Oxide

Nitric oxide (NO) has a promoting effect on seed germination and plant growth under saline stress. Exogenous application of NO remarkably mitigates abiotic stress in crop plants [341-343]. Application of NO significantly improved plant growth under salinity stress by increasing the activities of antioxidant enzymes, for example, SOD, CAT, GPX, APX, and GR [344], and decreasing lipid peroxidation or MDA production [345]. Sodium nitroprusside (SNP) is well known as a donor of NO, and exogenous application of SNP on salt-induced *Lupinus luteus* seedlings heightened the seed germination and root growth by reducing the detrimental effect of the abiotic stress [346]. Foliar application of SNP increased the shoot dry weight of sweet corn under salinity stress [347].

4.10 Uses of Arbuscular Mycorrhizal Fungi

Arbuscular mycorrhizal fungi (AMF) improve stress tolerance and increase plant growth by mitigating abiotic stresses. AMF improved the photosynthesis and water use efficiencies in maize plants subjected to saline conditions [348]. AMF quickly penetrates the cortical cells of plant roots and forms arbuscular and vesicles. These unique structures in roots might contribute to the uptake of macro- and micro-nutrients from the soil and improve plant tolerance against stress. *F. mosseae*, an AM fungus, enhanced maize's resilience to salt by bolstering tissue density, expelling Na^+ from leaves, distributing Na^+ within plant organs, upholding K^+: Na^+ equilibrium, and safeguarding organelle structural integrity and functionality. [349]. Accumulation of soluble sugars in slat-stressed maize plants is increased by AMF colonization in the root, which improves salt tolerance [350]. This improvement is correlated with the nutrition of the host plant, improved K^+/Na^+ ratios, and superior osmotic adjustment. It has been reported earlier [351] that arbuscular mycorrhizal symbiosis regulates the expression of plant genes involved in proline biosynthesis, genes encoding aquaporins, and genes encoding late embryogenesis abundant proteins with chaperone activity. More than 30 different aquaporin genes are encoded in maize [352], and mycorrhizal plants maintain better water status in their tissues by regulating these genes. Although salt stress reduced the formation and colonization of AMF in maize roots [348], mycorrhizal plants are less affected by salt stress than non-mycorrhizal plants [351, 353-355].

4.11 Application of Plant Growth-Promoting Rhizobacteria

Soil microorganisms are used to lessen many abiotic stresses in crop plants [356]. Several microorganisms of different groups, like bacteria, fungi, and archaea, are available in soil [357, 358]. Among them, bacteria are extensively used for promoting plant growth under abiotic stresses, and these bacteria are known as plant growth-promoting rhizobacteria (PGPR). These bacteria (rhizospheric or endophytic) relieve abiotic stresses and enhance tolerance to host plants. The most critical bacterial genera are *Achromobacter*, *Azospirillum*, *Bacillus*, *Burkholderia*, *Enterobacter*, *Methylobacterium*, *Microbacterium*, *Paenibacillus*, *Pantoea*, *Pseudomonas*, *Rhizobium*, *Variovorax*, etc. [357, 358]. PGPR produces a key enzyme, 1-aminocyclopropane-1-carboxylate (ACC) deaminase, which mitigates the inhibitory effects of salt stress by lowering the ethylene concentration in maize plants and increasing production [359]. ACC deaminase containing PGPR eliminates the adverse effects of salt-induced ethylene in plants [360]. Inoculation of plants with PGPR strains, particularly *Pseudomonas* and *Enterobacter* spp., stimulated the growth and yield of maize expressively under salt stress [361]. PGPR (*Azospirillum*) inoculation enhanced salt resistance in maize plants by reducing the Na concentration, increasing the K^+/Na^+ ratio and calcium level in tissues, enhancing water flow and more dry matter production, and decreasing proline concentration [362] (Table 2). Maize seeds inoculation with PGPR detoxifies the salinity levels and increases the salt tolerance. PGPR inoculation in maize seeds improves plant growth by increasing proline levels and helps in osmotic adjustments under salt stress, which has been well documented. For example, inoculation of *Geobacillus* sp. increased the photosynthetic rate [363], *Pseudomonas* spp. Improved plant growth [325], *Arthrobacter pascens* decreased the Na accumulation. They increased plant growth [364], *Azotobacter chroococcum* improved nutrition [365], *Rhizobium* spp., *Rhizobium tropici* strain CIAT, *Azotobacter brasilense* strains Ab-V5 and Ab-V6 [366], and *A. faecalis* [367] enhanced the photosynthetic pigments and photosynthetic rate by the overproduction of proline in maize plants.

Table 2 Role of PGPR on salt tolerance of maize.

PGPR strains	Mechanisms	Improvement	References
Pseudomonas syringae, *P. chlororaphis*, *P. bathycetes, Enterobacter aerogenes, P. fluorescence*	ACC deaminase	Plant growth, RWC, chlorophyll content, and K^+/Na^+ ratio	[361]
		Growth, yield, and nutrition	[368]
P. aeruginosa	IAA production, ACC deaminase, phosphate solubilization, and biofilm formation	Water status, nutrition, and growth	[369]
Pseudomonas spp.	Osmotic regulation, EPS	Root and shoot growth	[367]
Pseudomonas putida biotype A, *P. fluorescens* biotype A	Osmotic regulation	Root-shoot length under gnotobiotic conditions	[370]

Azotobacter chroococcum strains C5 and C9.	Osmotic regulation	Exclusion of Na$^+$, uptake of K$^+$ in maize, K$^+$/Na$^+$ ratio, polyphenol, and chlorophyll contents	[365]
Azospirillum lipoferum strain Z4/1	Osmotic regulation	Markedly alter Na, K, & Ca selectivity; Decrease Na uptake, enhance K & Ca uptake; stimulate nitrate reductase and nitrogenase activity.	[362]
Bacillus megaterium	Osmotic regulation	Increase root hydraulic conductance that correlates with more plasma membrane-type two (PIP2) aquaporin in roots; More *ZmPIP1*;1 protein in leaves.	[371]
B. amyloliquefaciens	Soluble sugar content and antioxidant enzymes	Plant growth and photosynthetic rate	[372]
Rhizobium strain Thal-8 chickpea modulating	Osmotic regulation	Reduce electrolyte leakage and osmotic potential, increase proline, LRWC, and K and Ca uptake.	[325]

4.12 Adaption with Molecular Strategies

Molecular studies on salt tolerance in maize have revealed crucial insights. These include the identification of critical genes involved in salt tolerance mechanisms [373], the exploration of physiological, biochemical, and molecular responses in contrasting maize lines under salt stress [374], the use of genome-wide association studies to uncover the genetic basis for salt tolerance traits [375], and the classification of maize genotypes based on morphological characteristics to determine salt tolerance levels [376]. Research has identified essential genes like ZmPIF3, ZmHAK1, ZmNHX1, ZmSTG1, and Zm00001d053925 that play pivotal roles in enhancing salt tolerance in maize [375-379]. Luo et al. [380] used genome-wide association analysis to identify salt tolerance markers in maize. They predicted candidate genes and confirmed their roles with CRISPR/Cas9, advancing our understanding and offering avenues for genetic manipulation to enhance crop resilience to salinity stress. These genes involve various mechanisms, such as regulating stress responses, ion transport, osmotic balance, and photosystem activity under salt stress conditions. Maize utilizes defense mechanisms such as osmolyte production, activation of antioxidant enzymes, and regulation of ion transport to counteract salt stress [133]. Research endeavors to unravel salt tolerance mechanisms have resulted in the discovery of salt-tolerance QTL and the breeding of salt-tolerant maize varieties [381]. Additionally, studies have highlighted the importance of hormone signaling, Ca^{2+} signaling, and transcription factors in mediating salt stress responses in maize. The

findings underscore the significance of understanding the molecular basis of salt tolerance in maize for developing salt-resistant varieties and improving crop productivity in saline environments.

5. Conclusion

Salinity stress is a severe threat to agriculture, considerably reducing the growth, physiological functions, and yield of maize by negatively affecting different growth stages, such as seed germination and vegetative and reproductive stages. Salinity adversely affects photosynthetic apparatus, photosynthesis, respiration, transpiration, stomatal and hormonal regulation, water status, and enzymatic activities, which distress the growth performance of plants and consequently reduce yield. Plants cope with saline stress in various mechanisms like homeostasis of toxic ions, synthesis of compatible solutes, antioxidant compounds, and other substances (polyamines, NO), regulation of hormonal balance, apoplastic acidification, etc. It has been proved that different agronomic management practices can effectively eliminate/alleviate the phytotoxic effects of salt stress like the selection of salt-tolerant genotypes, priming of seeds and seedlings, the addition of organic matters, management of nutrients, application of freshwater, exogenous application of hormones, osmoprotectants, polyamines, and NO, and uses of arbuscular mycorrhizal fungi and PGPR. Plant scientists are focusing on developing a complete profile of genes, proteins, and metabolites responsible for different mechanisms of salinity tolerance in different crops. Recent molecular studies on salt tolerance in maize have identified essential genes, such as ZmPIF3, ZmHAK1, ZmNHX1, ZmSTG1, and Zm00001d053925, and utilized genome-wide association analysis and CRISPR/Cas9 technology to uncover genetic markers and mechanisms, offering the potential for enhancing crop resilience to salinity stress. However, there is a lack of information integration from genomic, transcriptomic, proteomic, and metabolomics studies. Therefore, a combined approach is essential for determining the key pathways or processes controlling salinity tolerance in maize/crops in the future. This chapter displays the tolerance mechanisms and mitigation strategies of maize under salinity stress that will be helpful for other maize improvement strategies.

Author Contributions

Conceptualization, Manuscript Development, writing—original draft preparation: Mohammad Sohidul Islam, Md. Rafiqul Islam, Md. Kamrul Hasan, ASM Golam Hafeez, Md. Kaium Chowdhury, Moaz Hosen Pramanik ; writing—review and editing, Muhammad Aamir Iqbal, Murat Erman, Celaleddin Barutcular, Ömer Konuşkan, Anamika Dubey, Ashwani Kumar, Ayman El Sabagh. All authors have read and agreed to the published version of the manuscript.

Competing Interests

The authors declare no conflicts of interest.

References

1. Khaliq A, Iqbal MA, Zafar M, Gulzar A. Appraising economic dimension of maize production under coherent fertilization in Azad Kashmir, Pakistan. Custos Agronegocio. 2019; 15: 243-253.

2. Majid MA, Islam MS, El Sabagh A, Hasan MK, Saddam MO, Barutcular C, et al. Influence of varying nitrogen levels on growth, yield and nitrogen use efficiency of hybrid maize (*Zea mays*). J Exp Biol Agril Sci. 2017; 5: 134-142.

3. Sannagoudar MS, Murthy KK. Growth and yield of maize (*Zea mays* L.) as influenced by planting geometry and nutrient management in maize based intercropping. Mysore J Agricl Sci. 2018; 52: 278-284.

4. Zia UU, Niazi AR, Ahmad Z, Alharby HF, Waraich EA, Abbasi A, et al. Dose optimization of silicon for boosting arbuscular mycorrhizal fungi colonization and cadmium stress mitigation in maize (*Zea mays* L.). Environ Sci Pollut Res. 2023; 30: 67071-67086.

5. Atta MI, Zehra SS, Ali H, Ali B, Abbas SN, Aimen S, et al. Assessing the effect of heavy metals on maize (*Zea mays* L.) growth and soil characteristics: Plants-implications for phytoremediation. PeerJ. 2023; 11: e16067.

6. International Plant Biotechnology Outreach (IPBO). Maize in Africa [Internet]. Ghent, Belgium: International Plant Biotechnology Outreach (IPBO); 2017. Available from: https://ipbo.sites.vib.be/sites/ipbo.sites.vib.be/files/2021-01/Maize%20in%20Africa.pdf.

7. Sabagh AE, Hossain A, Iqbal MA, Barutçular C, Islam MS, Çiğ F, et al. Maize adaptability to heat stress under changing climate. Plant stress physiology. London, UK: IntechOpen; 2020.

8. Food and Agriculture Organization (FAO). The state of food security and nutrition in the world [Internet]. Rome, Italy: Food and Agriculture Organization of the United Nations; 2019. Available from: https://www.fao.org/3/ca5162en/ca5162en.pdf.

9. Nuss ET, Tanumihardjo SA. Maize: A paramount staple crop in the context of global nutrition. Compr Rev Food Sci Food Saf. 2010; 9: 417-436.

10. Ranum P, Peña-Rosas JP, Garcia-Casal MN. Global maize production, utilization, and consumption. Ann N Y Acad Sci. 2014; 1312: 105-112.

11. Organization for Economic Cooperation and Development-Food and Agriculture Organization (OECD-FAO). OECD-FAO agricultural outlook [Internet]. Rome, Italy: FAO; 2018. Available from: https://www.oecd-ilibrary.org/agriculture-and-food/oecd-fao-agricultural-outlook-2020-2029_1112c23b-en.

12. Shiferaw B, Prasanna BM, Hellin J, Bänziger M. Crops that feed the world 6. Past successes and future challenges to the role played by maize in global food security. Food Secur. 2011; 3: 307-327.

13. Islam MS, Muhyidiyn I, Islam R, Hasan K, Hafeez AG, Hosen M, et al. Soybean and sustainable agriculture for food security. Soybean-recent advances in research and applications. London, UK: IntechOpen; 2022.

14. Hakim MA, Juraimi AS, Karim SR, Khan MS, Islam MS, Choudhury MK, et al. Effectiveness of herbicide to control rice weeds in diverse saline environments. Sustainability. 2021; 13: 2053.

15. Hameed M, Ahmad MS, Ashraf M, Öztürk M, Fatima S. Plant genetic resources of major and minor crops: Origin, sustainable use, and conservation. Crop production technologies for sustainable use and conservation. Palm Bay, FL: Apple Academic Press; 2019.

16. Intergovernmental Panel on Climate Change (IPCC). Summary for policymakers. Climate change 2013-The physical science basis: Working group I contribution to the fifth assessment report of the intergovernmental panel on climate change. Cambridge, UK: Cambridge University Press; 2014. Available from: https://www.cambridge.org/core/books/abs/climate-change-2013-the-physical-science-basis/summary-for-policymakers/356E277FD1FBC887845FB9E8CBC90CCD.

17. Intergovernmental Panel on Climate Change (IPCC). Summary for policymakers. Climate change 2007: Impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge, UK: Cambridge University Press; 2007.

18. Dodd GL, Donovan LA. Water potential and ionic effects on germination and seedling growth of two cold desert shrubs. Am J Bot. 1999; 86: 1146-1153.

19. Cakmak I. The role of potassium in alleviating detrimental effects of abiotic stresses in plants. J Plant Nutr Soil Sci. 2005; 168: 521-530.

20. Sosa L, Llanes A, Reinoso H, Reginato M, Luna V. Osmotic and specific ion effects on the germination of Prosopis strombulifera. Ann Bot. 2005; 96: 261-267.

21. Hassan N, Hasan MK, Shaddam MO, Islam MS, Barutçular C, El Sabagh A. Responses of maize varieties to salt stress in relation to germination and seedling growth. Int Lett Nat Sci. 2018; 69: 1-11.

22. Bojović B, Đelić G, Topuzović M, Stanković M. Effects of NaCl on seed germination in some species from families Brassicaceae and Solanaceae. Kragujevac J Sci. 2010; 32: 83-87.

23. Aliu S, Rusinovci I, Fetahu S, Gashi B, Simeonovska E, Rozman L. The effect of salt stress on the germination of maize (*Zea mays* L.) seeds and photosynthetic pigments. Acta Agric Slov. 2015; 105: 85-94.

24. Grewal HS, Norrish S, Cornish P. Subsoil salts affect root function, shoot growth and ionic balance of wheat plants. New directions for a diverse planet. Proceedings of the 4th International Crop Science Congress; 2004 September 26-October 1; Brisbane, Australia. Berlin, Germany: ResearchGate; 2004.

25. Gong DH, Wang GZ, Si WT, Zhou Y, Liu Z, Jia J. Effects of salt stress on photosynthetic pigments and activity of ribulose-1, 5-bisphosphate carboxylase/oxygenase in Kalidium Foliatum. Russ J Plant Physiol. 2018; 65: 98-103.

26. Hasegawa PM, Bressan RA, Zhu JK, Bohnert HJ. Plant cellular and molecular responses to high salinity. Annu Rev Plant Biol. 2000; 51: 463-499.

27. Khajeh-Hosseini M, Powell AA, Bingham IJ. The interaction between salinity stress and seed vigour during germination of soyabean seeds. Seed Sci Technol. 2003; 31: 715-725.

28. Khān MA, Weber DJ. Ecophysiology of high salinity tolerant plants. Amsterdam, Netherlands: Springer; 2008.

29. Allen JA. Intraspecific variation in the response of baldcypress (*Taxodium distichum*) seedlings to salinity. Ann Arbor, MI: Louisiana State University and Agricultural & Mechanical College; 1994.

30. Rumbaugh MD, Pendery BM, James DW. Variation in the salinity tolerance of strawberry clover (*Trifolium fragiferum* L.). Plant Soil. 1993; 153: 265-271.

31. Rasheed R. Salinity and extreme temperature effects on sprouting buds of sugarcane (*Saccharum officinarum* L.). Some histological and biochemical studies. Faisalabad Pakistan: University of Agriculture; 2009.

32. Murillo-Amador B, López-Aguilar R, Kaya C, Larrinaga-Mayoral J, Flores-Hernández A. Comparative effects of NaCl and polyethylene glycol on germination, emergence and seedling growth of cowpea. J Agron Crop Sci. 2002; 188: 235-247.

33. Janmohammadi M, Dezfuli PM, Sharifzadeh F. Seed invigoration techniques to improve germination and early growth of inbred line of maize under salinity and drought stress. Gen Appl Plant Physiol. 2008; 34: 215-226.

34. Khan MA, Ungar JA. Germination responses to salinity stress in *Atriplex triangularis*. Ohio J Sci. 1984; 84: 13.

35. Hasan MK, Islam MS, Islam MR, Ismaan HN, El-Sabagh A. Salinity tolerance of black gram cultivars during germination and early seedling growth. Cercet Agron Mold. 2018; 51: 51-68.

36. Farooq M, Basra SM, Rehman H, Mehmood T. Germination and early seedling growth as affected by pre-sowing ethanol seed treatments in fine rice. Int J Agric Biol. 2006; 8: 19-22.

37. Kamrul HM, Islam MS, Islam MR, Ismaan HN, El-Sabagh A. Germination and early seedling growth of mungbean (*Vigna radiata* L.) as influenced by salinity. Azarian J Agric. 2018; 5: 49-59.

38. Carpici EB, Çelik B, Bayram NG. Effects of salt stress on germination of some maize (*Zea mays* L.) cultivars. African J Biotechnol. 2009; 8: 4918-4922.

39. Djanaguiraman M, Senthil A, Ramadass R. Assessment of rice genotypes for salinity tolerance at germination and seedling stage. Madras Agric J. 2003; 90: 506-510.

40. Kaya M, Kaya G, Kaya MD, Atak M, Saglam S, Khawar KM, et al. Interaction between seed size and NaCl on germination and early seedling growth of some Turkish cultivars of chickpea (*Cicer arietinum* L.). J Zhejiang Univ Sci B. 2008; 9: 371-377.

41. Bybordi A. The influence of salt stress on seed germination, growth and yield of canola cultivars. Not Bot Horti Agrobot Cluj-Napoca. 2010; 38: 128-133.

42. Khodarahmpour Z, Ifar M, Motamedi M. Effects of NaCl salinity on maize (*Zea mays* L.) at germination and early seedling stage. Afr J Biotechnol. 2012; 11: 298-304.

43. Akram M, Ashraf MY, Ahmad R, Rafiq M, Ahmad I, Iqbal J. Allometry and yield components of maize (*Zea mays* L.) hybrids to various potassium levels under saline conditions. Arch Biol Sci. 2010; 62: 1053-1061.

44. Qu C, Liu C, Gong X, Li C, Hong M, Wang L, et al. Impairment of maize seedling photosynthesis caused by a combination of potassium deficiency and salt stress. Environ Exp Bot. 2012; 75: 134-141.

45. Pitann B, Kranz T, Mühling KH. The apoplastic pH and its significance in adaptation to salinity in maize (*Zea mays* L.): Comparison of fluorescence microscopy and pH-sensitive microelectrodes. Plant Sci. 2009; 176: 497-504.

46. El Sayed HE, El Sayed A. Influence of salinity stress on growth parameters, photosynthetic activity and cytological studies of *Zea mays*, L. plant using hydrogel polymer. Agric Biol J North Am. 2011; 2: 907-920.

47. Ahmed S, Iqbal M, Ahmad Z, Iqbal MA, Artyszak A, El-Sabagh A, et al. Foliar application of silicon-based nanoparticles improve the adaptability of maize (*Zea mays* L.) in cadmium contaminated soils. Environ Sci Pollut Res. 2023; 30: 41002-41013.

48. Konuşkan Ö, Gözübenli H, Atış İ, Atak M. Effects of salinity stress on emergence and seedling growth parameters of some maize genotypes (*Zea mays* L.). Turk J Agric Food Sci Technol. 2017; 5: 1668-1672.

49. Evlagon D, Ravina I, Neumann PM. Effects of salinity stress and calcium on hydraulic conductivity and growth in maize seedling roots. J Plant Nutr. 1992; 15: 795-803.

50. Niu G, Xu W, Rodriguez D, Sun Y. Growth and physiological responses of maize and sorghum genotypes to salt stress. ISRN Agron. 2012; 2012: 145072.

51. Ashrafuzzaman M, Khan MH, Shahidullah SM. Vegetative growth of maize (*Zea mays*) as affected by a range of salinity. Crop Res. 2002; 24: 286-291.
52. Munns R, James RA, Läuchli A. Approaches to increasing the salt tolerance of wheat and other cereals. J Exp Bot. 2006; 57: 1025-1043.
53. Munns R, Sharp RE. Involvement of abscisic acid in controlling plant growth in soil of low water potential. Funct Plant Biol. 1993; 20: 425-437.
54. Rios-Gonzalez K, Erdei L, Lips SH. The activity of antioxidant enzymes in maize and sunflower seedlings as affected by salinity and different nitrogen sources. Plant Sci. 2002; 162: 923-930.
55. Cramer GR, Epstein E, Lauchli A. Kinetics of root elongation of maize in response to short-term exposure to NaCl and elevated calcium concentration. J Exp Bot. 1988; 39: 1513-1522.
56. Spanswick RM. Electrogenic ion pumps. Annu Rev Plant Physiol. 1981; 32: 267-289.
57. Hager A. Role of the plasma membrane H^+-ATPase in auxin-induced elongation growth: Historical and new aspects. J Plant Res. 2003; 116: 483-505.
58. Demir Y, Kocacaliskan I. Effects of proline on maize embryos cultured in salt stress. Fresenius Environ Bull. 2008; 17: 536-542.
59. Turan MA, Elkarim AH, Taban N, Taban S. Effect of salt stress on growth, stomatal resistance, proline and chlorophyll concentrations on maize plant. Afr J Agric Res. 2009; 4: 893-897.
60. Deng CN, Zhang GX, Pan XL, Zhao KY. Chlorophyll fluorescence and gas exchange responses of maize seedlings to saline-alkaline stress. Bulg J Agric Sci. 2010; 16: 49-58.
61. Magnaye AM, Santos PJ. Responses of yellow corn (*Zea mays* L.) inbreds to salinity. Asia Life Sci. 2010; 20: 521-533.
62. Zahoor M, Khaliq R, Zafar ZU, Athar HR. Degree of salt tolerance in some newly developed maize (*Zea mays* L.) varieties. Iranian J Plant Physiol. 2011; 1: 223-232.
63. Molazem D, Azimi J. Morpho-physiological characterization in eight varieties of maize (*Zea mays* L.) under soil salinity. Polish J Environ Stud. 2015; 24: 2537-2542.
64. Zahra N, Mahmood S, Raza ZA. Salinity stress on various physiological and biochemical attributes of two distinct maize (*Zea mays* L.) genotypes. J Plant Nutr. 2018; 41: 1368-1380.
65. Tuna AL, Kaya C, Altunlu H, Ashraf M. Mitigation effects of non-enzymatic antioxidants in maize (*Zea mays* L.) plants under salinity stress. Aust J Crop Sci. 2013; 7: 1181-1188.
66. Methela NJ, Chowdhury AK, Islam T, Amiruzzaman M, Rohman MM. Loss of pigments and higher methylglyoxal contents in leaves of maize seedlings under salinity are associated with saline susceptibility. Biochem Mol Biol. 2017; 1: 39-43.
67. Akram M, Ashraf MY, Jamil M, Iqbal RM, Nafees M, Khan MA. Nitrogen application improves gas exchange characteristics and chlorophyll fluorescence in maize hybrids under salinity conditions. Russian J Plant Physiol. 2011; 58: 394-401.
68. Omoto E, Taniguchi M, Miyake H. Adaptation responses in C_4 photosynthesis of maize under salinity. J Plant Physiol. 2012; 169: 469-477.
69. Gong XL, Liu C, Zhou M, Luo LY, Wang L, Wang Y, et al. Oxidative damages of maize seedlings caused by combined stress of potassium deficiency and salt stress. Plant Soil. 2011; 340: 443-452.
70. Netondo GW, Onyango JC, Beck E. Sorghum and salinity: I. Response of growth, water relations, and ion accumulation to NaCl salinity. Crop Sci. 2004; 44: 797-805.
71. Goudarzi M, Pakniyat H. Comparison between salt tolerance of various cultivars of wheat and maize. J Appl Sci. 2008; 8: 2300-2305.

72. Carpici EB, Celik N, Bayram G, Asik BB. The effects of salt stress on the growth, biochemical parameter and mineral element content of some maize (*Zea mays* L.) cultivars. African J Biotechnol. 2010; 9: 6937-6942.

73. Kaya C, Tuna AL, Okant AM. Effect of foliar applied kinetin and indoleacetic acid on maize plants grown undersaline conditions. Turk J Agric For. 2010; 34: 529-538.

74. Shannon MC, Grieve CM. Tolerance of vegetable crops to salinity. Sci Hortic. 1998; 78: 5-38.

75. Munns R, Tester M. Mechanisms of salinity tolerance. Ann Rev Plant Biol. 2008; 59: 651-681.

76. Chattha MU, Khan MA, Khan I, Mahmood A, Chattha MB, Hassan MU, et al. Comparison of physio-biochemical and antioxidant enzymes in maize during early growth stage in response to salt stress. Pak J Bot. 2023; 55: 1991-1997.

77. Ball JT, Woodrow IE, Berry JA. A model predicting stomatal conductance and its contribution to the control of photosynthesis under different environmental conditions. In: Progress in photosynthesis research. Dordrecht: Springer Netherlands; 1987. pp. 221-224.

78. Hasan MK, El Sabagh A, Sikdar MSI, Alam MJ, Ratnasekera D, Barutcular C, et al. Comparative adaptable agronomic traits of blackgram and mungbean for saline lands. Plant Arch. 2017; 17: 589-593.

79. Hasan MK, Islam MS, Islam MR, Ismaan HN, Meena RS, Barutcular C, et al. Water relations and dry matter accumulation of black gram and mungbean as affected by salinity. Thai J Agril Sci. 2019; 52: 54-67.

80. Nahar K, Hasanuzzaman M. Germination, growth, nodulation and yield performance of three mungbean varieties under different levels of salinity stress. Green Farm. 2009; 2: 825-829.

81. Schubert S, Neubert A, Schierholt A, Sumer A, Zorb C. Development of salt resistant maize hybrids: The combination of physiological strategies using conventional breeding methods. Plant Sci. 2009; 177: 196-202.

82. Hiyane R, Hiyane S, Tang AC, Boyer JS. Sucrose feeding reverses shade-induced kernel losses in maize. Ann Bot. 2010; 106: 395-403.

83. Hu D, Li R, Dong S, Zhang J, Zhao B, Ren B, et al. Maize (*Zea mays* L.) responses to salt stress in terms of root anatomy, respiration and antioxidative enzyme activity. BMC Plant Biol. 2022; 22: 602. doi: 10.1186/s12870-022-03972-4.

84. Lohaus G, Hussmann M, Pennewiss K, Schneider H, Zhu JJ, Sattelmacher B. Solute balance of a maize (*Zea mays* L.) source leaf as affected by salt treatment with special emphasis on phloem retranslocation and ion leaching. J Exp Bot. 2000; 51: 1721-1732.

85. Sharif A, Rasul E, Nisar A, Sadiq M. Response of maize (*Zea mays* L.) genotypes to NaCl salinity induced at various growth stages of crop. Pak J Bio Sci. 1999; 2: 606-608.

86. Cucci G, Lacolla G, Boari F, Mastro MA, Cantore V. Effect of water salinity and irrigation regime on maize (*Zea mays* L.) cultivated on clay loam soil. Agricl Water Manage. 2019; 222: 118-124.

87. Zörb C, Schmitt S, Neeb A, Karl S, Linder M, Schubert S. The biochemical reaction of maize (*Zea mays* L.) to salt stress is characterized by a mitigation of symptoms and not by a specific adaptation. Plant Sci. 2004; 167: 91-100.

88. Hasanuzzaman M, Nahar K, Fujita M. Plant response to salt stress and role of exogenous protectants to mitigate salt-induced damages. In: Ecophysiology and responses of plants under salt stress. New York, NY: Springer; 2013. pp. 25-87.

89. Munns R. Physiological processes limiting plant growth in saline soil: Some dogmas and hypotheses. Plant Cell Environ. 1993; 16: 15-24.

90. Meloni DA, Oliva MA, Ruiz HA, Martinez CA. Contribution of proline and inorganic solutes to osmotic adjustment in cotton under salt stress. J Plant Nutr. 2001; 24: 599-612.

91. Tester M, Davenport R. Na$^+$ tolerance and Na$^+$ transport in higher plants. Ann Bot. 2003; 91: 503-507.

92. Fortmeier R, Schubert S. Salt tolerance of maize (*Zea mays* L.): The role of sodium exclusion. Plant Cell Environ. 1995; 18: 1041-1047.

93. Niu Xiaomu NX, Bressan RA, Hasegawa PM, Pardo JM. Ion homeostasis in NaCl stress environments. Plant Physiol. 1995; 109: 735-742.

94. Serrano R, Mulet JM, Rios G, Marquez JA, De Larrinoa IF, Leube MP, et al. A glimpse of the mechanisms of ion homeostasis during salt stress. J Exp Bot. 1999; 50: 1023-1036.

95. Hasegawa PM. Sodium (Na$^+$) homeostasis and salt tolerance of plants. Environ Exp Bot. 2013; 92: 19-31.

96. Reddy MP, Sanish S, Iyengar ERR. Photosynthetic studies and compartmentation of ions in different tissues of salicornia brachiata Roxb. under saline conditions. Photosynthetica. 1992; 26: 173-179.

97. Zhu JK. Regulation of ion homeostasis under salt stress. Curr Opin Plant Biol. 2003; 6: 441-445.

98. Dietz KJ, Tavakoli N, Kluge C, Mimura T, Sharma SS, Harris GC, et al. Significance of the V-type ATPase for the adaptation to stressful growth conditions and its regulation on the molecular and biochemical level. J Exp Bot. 2001; 52: 1969-1980.

99. Otoch MD, Sobreira AC, de Aragão ME, Orellano EG, Lima MD, de Melo DF. Salt modulation of vacuolar H$^+$-ATPase and H$^+$-Pyrophosphatase activities in *Vigna unguiculata*. J Plant Physiol. 2001; 158: 545-551.

100. Wang B, Luttge U, Ratajczak R. Effects of salt treatment and osmotic stress on V-ATPase and V-PPase in leaves of the halophyte *Suaeda salsa*. J Exp Bot. 2001; 52: 2355-2365.

101. Neubert AB, Zörb C, Schubert S. Expression of vacuolar Na$^+$/H$^+$ antiporters (ZmNHX) and Na$^+$ exclusion in roots of maize (*Zea mays* L.) genotypes with improved salt resistance. In: Plant nutrition for food security, human health and environmental protection. Beijing, China: Tsinghua University Press; 2005. pp. 544-545.

102. Hajibagheri MA, Yeo AR, Flowers TJ, Collins JC. Salinity resistance in Zea mays: Fluxes of potassium, sodium and chloride, cytoplasmic concentrations and microsomal membrane lipids. Plant Cell Environ. 1989; 12: 753-757.

103. Cerda A, Pardines J, Botelia MA, Martinez V. Effect of potassium on growth, water relations, and the inorganic and organic solute contents for two maize cultivars grown under saline conditions. J Plant Nutr. 1995; 18: 839-851.

104. Azevedo Neto AD, Prisco JT, Enéas-Filho J, Lacerda CF, Silva JV, Costa PH, et al. Effects of salt stress on plant growth, stomatal response and solute accumulation of different maize genotypes. Brazilian J Plant Physiol. 2004; 16: 31-38.

105. Wakeel A, Farooq M, Qadir M, Schubert S. Potassium substitution by sodium in plants. Critical Rev Plant Sci. 2011; 30: 401-413.

106. Akram M, Malik MA, Ashraf MY, Saleem MF, Hussain M. Competitive seedling growth and K$^+$/Na$^+$ ratio in different maize (*Zea mays* L.) Hybrids under salinity stress. Pak J Bot. 2007; 39: 2553-2563.

107. Agami RA. Alleviating the adverse effects of NaCl stress in maize seedlings by pretreating seeds with salicylic acid and 24-epibrassinolide. South African J Bot. 2013; 88: 171-177.

108. Mansour MMF, Salama KHA, Ali FZM, Abou Hadid AF. Cell and plant responses to NaCl in *Zea mays* cultivars differing in salt tolerance. Gen Appl Plant Physiol. 2005; 31: 29-41.

109. Saxena SC, Kaur H, Verma P, Petla BP, Andugula VR, Majee M. Osmoprotectants: Potential for crop improvement under adverse conditions. In: Plant acclimation to environmental stress. New York, NY: Springer; 2013. pp. 197-232.

110. Ben Ahmed C, Ben Rouina B, Sensoy S, Boukhriss M, Ben Abdullah F. Exogenous proline effects on photosynthetic performance and antioxidant defense system of young olive tree. J Agril Food Chem. 2010; 58: 4216-4222.

111. Makela P, Karkkainen J, Somersalo SJ. Effect of glycinebetaine on chloroplast ultrastructure, chlorophyll and protein content, and RuBPCO activities in tomato grown under drought or salinity. Biol Plant. 2000; 43: 471-475.

112. Chaum S, Kirdmanee C. Effect of glycinebetaine on proline, water use, and photosynthetic efficiencies, and growth of rice seedlings under salt stress. Turk J Agric For. 2010; 34: 517-527.

113. Ashraf M, Foolad MR. Roles of glycine betaine and proline in improving plant abiotic stress resistance. Environ Exp Bot. 2007; 59: 206-216.

114. Hassanein RA, Bassuony FM, Baraka DM, Khalil RR. Physiological effects of nicotinamide and ascorbic acid on Zea mays plant grown under salinity stress. I-Changes in growth, some relevant metabolic activities and oxidative defense systems. Res J Agric Biol Sci. 2009; 5: 72-81.

115. Parida AK, Das AB, Mohanty P. Investigations on the antioxidative defence responses to NaCl stress in a mangrove, Bruguiera parviflora: Differential regulations of isoforms of some antioxidative enzymes. Plant Growth Regul. 2004; 42: 213-226.

116. Menezes-Benavente L, Kernodle SP, Margis-Pinheiro M, Scandalios JG. Salt-induced antioxidant metabolism defenses in maize (*Zea mays* L.) seedlings. Redox Rep. 2004; 9: 29-36.

117. Groß F, Durner J, Gaupels F. Nitric oxide, antioxidants and prooxidants in plant defence responses. Front Plant Sci. 2013; 4: 419.

118. Gill SS, Tuteja N. Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. Plant Physiol Biochem. 2010; 48: 909-930.

119. Zhu JK. Plant salt tolerance. Trends Plant Sci. 2001; 6: 66-71.

120. Mittler R. Oxidative stress, antioxidants and stress tolerance. Trends Plant Sci. 2002; 7: 405-410.

121. Sairam RK, Tyagi A. Physiology and molecular biology of salinity stress tolerance in plants. Curr Sci. 2004; 86: 407-421.

122. Hichem H, Mounir D, Naceur EA. Differential responses of two maize (*Zea mays* L.) varieties to salt stress: Changes on polyphenols composition of foliage and oxidative damages. Ind Crops Prod. 2009; 30: 144-151.

123. Asada K. The water-water cycle in chloroplasts: Scavenging of active oxygens and dissipation of excess photons. Ann Rev Plant Biol. 1999; 50: 601-639.

124. Gupta KJ, Stoimenova M, Kaiser WM. In higher plants, only root mitochondria, but not leaf mitochondria reduce nitrite to NO, in vitro and in situ. J Exp Bot. 2005; 56: 2601-2609.

125. de Azevedo Neto AD, Prisco JT, Eneas J, de Abreu CEB, Gomes-Filho E. Effect of salt stress on antioxidative enzymes and lipid peroxidation in leaves and roots of salt-tolerant and salt sensitive maize varieties. Environ Exp Bot. 2006; 56: 87-94.

126. Islam MS, Hasan MK, Islam B, Renu NA, Hakim MA, Islam MR, et al. Responses of water and pigments status, dry matter partitioning, seed production, and traits of yield and quality to foliar application of GA$_3$ in mungbean (*Vigna radiata* L.). Front Agron. 2021; 2: 596850.

127. Younis M, El-Shahaby O, Nemat Alla MM, El-Bastawisy Z. Kinetin alleviates the influence of waterlogging and salinity on growth and affects the production of plant growth regulators in *Vigna sinensis* and *Zea mays*. Agronomie. 2003; 23: 277-285.

128. Schubert S. Advances in alleviating growth limitations of maize under salt stress. The proceedings of the international plant nutrition colloquium XVI. Davis, CA: Department of Plant Sciences, UC Davis; 2009.

129. Ali Q, Ahmad M, Kamran M, Ashraf S, Shabaan M, Babar BH, et al. Synergistic effects of rhizobacteria and salicylic acid on maize salt-stress tolerance. Plants. 2023; 12: 2519. doi: 10.3390/plants12132519.

130. De Costa W, Zorb C, Hartung W, Schubert S. Salt resistance is determined by osmotic adjustment and abscisic acid in newly developed maize hybrids in the first phase of salt stress. Physiol Plant. 2007; 131: 311-321.

131. Cramer GR, Quarrie SA. Abscisic acid is correlated with the leaf growth inhibition of four genotypes of maize differing in their response to salinity. Funct Plant Biol. 2002; 29: 111-115.

132. Hu D, Dong S, Zhang J, Zhao B, Ren B, Liu P. Endogenous hormones improve the salt tolerance of maize (*Zea mays* L.) by inducing root architecture and ion balance optimizations. J Agron Crop Sci. 2022; 208: 662-674.

133. Li J, Zhu Q, Jiao F, Yan Z, Zhang H, Zhang Y, et al. Research progress on the mechanism of salt tolerance in maize: A classic field that needs new efforts. Plants. 2023; 12: 2356.

134. Cosgrove DJ. Loosening of plant cell walls by expansins. Nature. 2000; 407: 321-326.

135. Zörb C, Stracke B, Tramnitz B, Denter D, Sümer A, Mühling KH, et al. Does H^+ pumping by plasmalemma ATPase limit leaf growth of maize (*Zea mays*) during the first phase of salt stress. J Plant Nutr Soil Sci. 2005; 168: 550-557.

136. Pitann B, Zörb C, Mühling KH. Comparative proteome analysis of maize (*Zea mays* L.) expansins under salinity. J Plant Nutr Soil Sci. 2009; 172: 75-77.

137. Pitann B, Schubert S, Mühling KH. Decline in leaf growth under salt stress is due to an inhibition of H^+ pumping activity and increase in apoplastic pH of maize leaves. J Plant Nutr Soil Sci. 2009; 172: 535-543.

138. Hatzig S, Hanstein S, Schubert S. Apoplast acidification is not a necessary determinant for the resistance of maize in the first phase of salt stress. J Plant Nutr Soil Sci. 2010; 173: 559-562.

139. Galston AW, Kaur-Sawhney R, Altabella T, Tiburcio AF. Plant polyamines in reproductive activity and response to abiotic stress. Bot Acta. 1997; 110: 197-207.

140. Gupta K, Dey A, Gupta B. Plant polyamines in abiotic stress responses. Acta Physiol Plant. 2013; 35: 2015-2036.

141. Knott JM, Romer P, Sumper M. Putative spermine synthases from *Thalassiosira pseudonana* and *Arabidopsis thaliana* synthesize thermospermine rather than spermine. FEBS Lett. 2007; 581: 3081-3086.

142. Panicot M, Minguet EG, Ferrando A, Alcázar R, Blázquez MA, Carbonell J, et al. A polyamine metabolon involving aminopropyl transferase complexes in Arabidopsis. Plant Cell. 2002; 14: 2539-2551.

143. Gupta K, Dey A, Gupta B. Polyamines and their role in plant osmotic stress tolerance. In: Climate change and plant abiotic stress tolerance. Weinheim, Germany: Wiley-VCH; 2013. pp. 1053-1072.

144. Yang J, Zhang J, Liu K, Wang Z, Liu L. Involvement of polyamines in the drought resistance of rice. J Exp Bot. 2007; 58: 1545-1555.

145. Groppa MD, Benavides MP. Polyamines and abiotic stress: Recent advances. Amino Acids. 2008; 34: 35-45.

146. Kovacs Z, Simon-Sarkadi L, Szucs A, Kocsy G. Differential effects of cold, osmotic stress and abscisic acid on polyamine accumulation in wheat. Amino Acids. 2010; 38: 623-631.

147. Takahashi T, Kakehi JI. Polyamines: Ubiquitous polycations with unique roles in growth and stress responses. Ann Bot. 2010; 105: 1-6.

148. Cona A, Rea G, Angelini R, Federico R, Tavladoraki P. Functions of amine oxidases in plant development and defence. Trends Plant Sci. 2006; 11: 80-88.

149. Tisi A, Angelini R, Cona A. Wound healing in plants: Cooperation of copper amine oxidase and flavin-containing polyamine oxidase. Plant Signal Behav. 2008; 3: 204-206.

150. Navakoudis E, Lütz C, Langebartels C, Lütz-Meindl U, Kotzabasis K. Ozone impact on the photosynthetic apparatus and the protective role of polyamines. Biochim Biophys Acta Gen Subj. 2003; 1621: 160-169.

151. Roy P, Niyogi K, Sen Gupta DN, Ghosh B. Spermidine treatment to rice seedlings recovers salinity stress-induced damage of plasma membrane and PM-bound H^+-ATPase in salt-tolerant and salt-sensitive rice cultivars. Plant Sci. 2005; 168: 583-591.

152. Shao J, Idrees F, Haroon M, Noushahi HA, Huang G, Hassan MU, et al. Versatile roles of polyamines in improving abiotic stress tolerance of plants. Front Plant Sci. 2022; 13: 1003155.

153. Alcázar R, Cuevas JC, Planas J, Zarza X, Bortolotti C, Carrasco P, et al. Integration of polyamines in the cold acclimation response. Plant Sci. 2011; 180: 31-38.

154. Kuznetsov VV, Shevyakova NI. Polyamines and stress tolerance of plants. Plant Stress. 2007; 1: 50-71.

155. Hussain SS, Ali M, Ahmad M, Siddique KH. Polyamines: Natural and engineered abiotic and biotic stress tolerance in plants. Biotechnol Adv. 2011; 29: 300-311.

156. Shu S, Guo SR, Yuan LY. A review: Polyamines and photosynthesis. In: Advances in photosynthesis-fundamental aspects. Rijeka, Croatia: InTech; 2012. pp. 439-464.

157. Chai YY, Jiang CD, Shi L, Shi TS, Gu WB. Effects of exogenous spermine on sweet sorghum during germination under salinity. Biol Plant. 2010; 54: 145-148.

158. Li B, He L, Guo S, Li J, Yang Y, Yan B, et al. Proteomics reveal cucumber Spd-responses under normal condition and salt stress. Plant Physiol Biochem. 2013; 67: 7-14.

159. Roy M, Wu R. Overexpression of s-adenosylmethionine decarboxylase gene in rice increases polyamine level and enhances sodium chloride-stress tolerance. Plant Sci. 2002; 163: 987-992.

160. Moschou PN, Paschalidis KA, Roubelakis-Angelakis KA. Plant polyamine catabolism: The state of the art. Plant Signal Behav. 2008; 3: 1061-1066.

161. Shevyakova NI, Musatenko LI, Stetsenko LA, Vedenicheva NP, Voitenko LP, Sytnik KM, et al. Effects of abscisic acid on the contents of polyamines and proline in common bean plants under salt stress. Russ J Plant Physiol. 2013; 60: 200-211.

162. Lamattina L, García-Mata C, Graziano M, Pagnussat G. Nitric oxide: The versatility of an extensive signal molecule. Annu Rev Plant Biol. 2003; 54: 109-136.

163. Crawford NM. Mechanisms for nitric oxide synthesis in plants. J Exp Bot. 2006; 57: 471-478.

164. Besson-Bard A, Pugin A, Wendehenne D. New insights into nitric oxide signaling in plants. Ann Rev Plant Biol. 2008; 59: 21-39.

165. Yildiztugay E, Ozfidan-Konakci C, Kucukoduk M. Exogenous nitric oxide (as sodium nitroprusside) ameliorates polyethylene glycol-induced osmotic stress in hydroponically grown maize roots. J Plant Growth Regul. 2014; 33: 683-696.

166. Kaya C, Ashraf M, Sönmez O, Tuna AL, Aydemir S. Exogenously applied nitric oxide confers tolerance to salinity-induced oxidative stress in two maize (*Zea mays* L.) cultivars differing in salinity tolerance. Turk J Agric For. 2015; 39: 909-919.

167. Mohamed AA, Khan EA, Misra AN. Mitigation effect of exogenous nitric oxide (NO) on some metabolic compounds of maize seedling grown under salt stress. J Phys Conf Ser. 2019; 1294: 052008.

168. Klein A, Hüsselmann L, Keyster M, Ludidi N. Exogenous nitric oxide limits salt-induced oxidative damage in maize by altering superoxide dismutase activity. South Afr J Bot. 2018; 115: 44-49.

169. Zhang Y, Wang L, Liu Y, Zhang Q, Wei Q, Zhang W. Nitric oxide enhances salt tolerance in maize seedlings through increasing activities of proton-pump and Na^+/H^+ antiport in the tonoplast. Planta. 2006; 224: 545-555.

170. Gao Y, Lu Y, Wu M, Liang E, Li Y, Zhang D, et al. Ability to remove Na^+ and retain K^+ correlates with salt tolerance in two maize inbred lines seedlings. Front Plant Sci. 2016; 7: 1716.

171. Khan AA, Rao SA, McNilly TM. Assessment of salinity tolerance based upon seedling root growth response functions in maize (*Zea mays* L.). Euphytica. 2003; 131: 81-89.

172. Giaveno CD, Ribeiro RV, Souza GM, de Oliveira RF. Screening of tropical maize for salt stress tolerance. Crop Breed Appl Biotechnol. 2007; 7: 304-313.

173. Ahsan RA, Mehdi SM, Rasheed MK, Tahir FA, Bhat B, Uallah R, et al. Evaluating the salinity tolerance of maize (*Zea mays* L.) genotype under brackish water application in Punjab-Pakistan. Life Sci J. 2013; 10: 913-919.

174. Farsiani A, Ghobadi ME. Effects of PEG and NaCl stress on two cultivars of corn (*Zea mays* L.) at germination and early seedling stages. World Acad Sci Eng Technol. 2009; 57: 382-385.

175. Ashraf M, Rauf H. Inducing salt tolerance in maize (*Zea mays* L.) through seed priming with chloride salts: Growth and ion transport at early growth stages. Acta Physiol Plant. 2001; 23: 407-414.

176. Bakht J, Shafi M, Jamal Y, Sher H. Response of maize (*Zea mays* L.) to seed priming with NaCl and salinity stress. Span J Agric Res. 2011; 9: 252-261.

177. Choudhary SK, Kumar V, Singhal RK, Bose B, Chauhan J, Alamri S, et al. Seed priming with $Mg(NO_3)_2$ and $ZnSO_4$ salts triggers the germination and growth attributes synergistically in wheat varieties. Agronomy. 2021; 11: 2110.

178. Carvalho RF, Piotto FA, Schmidt D, Peters LP, Monteiro CC, Azevedo RA. Seed priming with hormones does not alleviate induced oxidative stress in maize seedlings subjected to salt stress. Sci Agric. 2011; 68: 598-602.

179. Arora N, Bhardwaj R, Sharma P, Arora HK. 28-Homobrassinolide alleviates oxidative stress in salt treated maize (*Zea mays* L.) plants. Braz J Plant Physiol. 2008; 20: 153-157.

180. Khodary SEA. Effect of salicylic acid on the growth, photosynthesis and carbohydrate metabolism in salt-stressed maize plants. Int J Agric Biol. 2004; 6: 5-8.

181. Gondim FA, Gomes-Filho E, Lacerda CF, Prisco JT, Neto ADA, Marques EC. Pretreatment with H_2O_2 in maize seeds: Effects on germination and seedling acclimation to salt stress. Braz J Plant Physiol. 2010; 22: 103-112.

182. Ahmed-Hamad AM, Monsaly HM. Seed soaking presowing in vitamins versus the adverse effects of NaCl salinity on photosynthesis and some related activities of maize and sunflower plants. In: Photosynthesis: Mechanisms and effects. Dordrecht: Springer; 1998. pp. 2617-2620.

183. Ahmad A, Tola E, Alshahrani TS, Seleiman MF. Enhancement of morphological and physiological performance of *Zea mays* L. under saline stress using ZnO nanoparticles and 24-eibrassinolide seed priming. Agronomy. 2023; 13: 771. doi: 10.3390/agronomy13030771.

184. Gebreslassie GB, Qufa CA. Plant physiological stimulation by seeds salt priming in maize (*Zea mays*): Prospect for salt tolerance. Afr J Biotechnol. 2017; 16: 209-223.

185. Rehman H, Hassan I, Basra SMA, Afzal I, Farooq M, Wakeel A, et al. Seed priming improves early seedling vigor, growth and productivity of spring maize. J Integr Agric. 2015; 14: 1745-1754.

186. Zahra N, Raza ZA, Mahmood S. Effect of salinity stress on various growth and physiological attributes of two contrasting maize genotypes. Braz Arch Biol Technol. 2020; 63: e20200072.

187. Khatun M, Shuvo MAR, Salam MTB, Rahman SH. Effect of organic amendments on soil salinity and the growth of maize (*Zea mays* L.). Plant Sci Today. 2019; 6: 106-111.

188. Oo AN, Iwai CB, Saenjan P. Soil properties and maize growth in saline and non-saline soils using cassava industrial waste compost and vermicompost with or without earthworms. Land Degrad Dev. 2015; 26: 300-310.

189. Lashari MS, Ye Y, Ji H, Li L, Kibue GW, Lu H, et al. Biochar-manure compost in conjunction with pyroligneous solution alleviated salt stress and improved leaf bioactivity of maize in a saline soil from central China: A 2-year field experiment. J Sci Food Agric. 2015; 95: 1321-1327.

190. Bamminger C, Poll C, Sixt C, Högy P, Wüst D, Kandeler E, et al. Short-term response of soil microorganisms to biochar addition in a temperate agroecosystem under soil warming. Agric Ecosyst Environ. 2016; 233: 308-317.

191. Akhtar SS, Andersen MN, Naveed M, Zahir ZA, Liu F. Interactive effect of biochar and plant growth-promoting bacterial endophytes on ameliorating salinity stress in maize. Funct Plant Biol. 2015; 42: 770-781.

192. Lashari MS, Liu Y, Li L, Pan W, Fu J, Pan G, et al. Effects of amendment of biochar-manure compost in conjunction with pyroligneous solution on soil quality and wheat yield of a salt-stressed cropland from central China great plain. Field Crops Res. 2013; 144: 113-118.

193. Akhtar SS, Andersen MN, Liu F. Residual effects of biochar on improving growth, physiology and yield of wheat under salt stress. Agric Water Manage. 2015b; 158: 61-68.

194. Usman AR, Al-Wabel MI, Abdulaziz AH, Mahmoud WA, ElNaggar AH, Ahmad M, et al. Conocarpus biochar induces changes in soil nutrient availability and tomato growth under saline irrigation. Pedosphere. 2016; 26: 27-38.

195. Thomas SC, Frye S, Gale N, Garmon M, Launchbury R, Machado N, et al. Biochar mitigates negative effects of salt additions on two herbaceous plant species. J Environ Manage. 2013; 129: 62-68.

196. Drake JA, Cavagnaro TR, Cunningham SC, Jackson WR, Patti AF. Does biochar improve establishment of tree seedlings in saline sodic soils? Land Degrad Dev. 2016; 27: 52-59.

197. Sun J, He F, Shao H, Zhang Z, Xu G. Effects of biochar application on *Suaeda salsa* growth and saline soil properties. Environ Earth Sci. 2016; 75: 630.

198. Ait-El-Mokhtar M, Baslam M, Ben-Laouane R, Anli M, Boutasknit A, Mitsui T, et al. Alleviation of detrimental effects of salt stress on date palm (*Phoenix dactylifera* L.) by the application of arbuscular mycorrhizal fungi and/or compost. Front Sustain Food Syst. 2020; 4: 131.

199. Rita L, Vitti C. Use of organic amendments to reclaim saline and sodic soils: A review. Arid Land Res Manage. 2019; 33: 1-21.
200. Uzoma KC, Inoue M, Andry H, Fujimaki H, Zahoor A, Nishihara E. Effect of cow manure biochar on maize productivity under sandy soil condition. Soil Use Manage. 2011; 27: 205-212.
201. Osman ME, Mohsen AA, Nessim AA, El-Saka MS, Mohamed W. Evaluation of biochar as a soil amendment for alleviating the harmful effect of salinity on *Vigna unguiculata* (L.) Walp. Egypt J Bot. 2019; 59: 617-631.
202. Karimi G, Ghorbanli M, Heidari H, Khavari Nejad RA, Assareh MH. The effects of NaCl on growth, water relations, osmolytes and ion content in *Kochia prostrata*. Biol Plant. 2005; 49: 301-304.
203. Gunes A, Inal A, Alpaslam M, Erslan F, Bagsi EG, Cicek N. Salicylic acid induced changes on some physiological parameters symptomatic for oxidative stress and mineral nutrition in maize (*Zea mays* L.) grown under salinity. J Plant Physiol. 2007; 164: 728-736.
204. Shahzad M, Witzel K, Zorb C, Muhling KH. Growth-related changes in subcellular ion patterns in maize leaves (*Zea mays* L.) under salt stress. J Agron Crop Sci. 2012; 198: 46-56.
205. Islam MS, Akhter MM, El Sabagh A, Liu LY, Nguyen NT, Ueda A, et al. Comparative studies on growth and physiological responses to saline and alkaline stresses of foxtail millet (*Setaria italica* L.) and Proso millet (*Panicum miliaceum* L.). Aust J Crop Sci. 2011; 5: 1269-1277.
206. Gadalla AM, Hamdy A, Galal YG, Aziz HA, Mohamed MA. Evaluation of maize grown under salinity stress and N application strategies using stable nitrogen isotope. Proc Afr Crop Sci Conf. 2007; 8: 1553-1562.
207. Akram M, Ashraf MY, Waraich EA, Hussain M, Hussain N, Mallahi AR. Performance of autumn planted maize (*Zea mays* L.) hybrids at various nitrogen levels under salt affected soils. Soil Environ. 2010; 29: 23-32.
208. Maqsood T, Akhtar J, Farooq MR, Haq MA, Saqib ZA. Biochemical attributes of salt tolerant and salt sensitive maize cultivars to salinity and potassium nutrition. Pak J Agri Sci. 2008; 45: 1-5.
209. Akram M, Ashraf MY, Ahmad R, Waraich EA, Iqbal J, Mohsan M. Screening for salt tolerance in maize (*Zea mays* L.) hybrids at an early seedling stage. Pak J Bot. 2010; 42: 141-154.
210. El-Dissoky RA, Morsy EM, El-Shazly MA. Beneficial effect of potassium fertilization and yeast strains on maize plants grown on salt affected soil. J Soil Sci Agric Eng. 2013; 4: 827-842.
211. Hussain Z, Khattak RA, Fareed I, Irshad M, Mahmood Q. Interaction of phosphorus and potassium on maize (*Zea mays* L.) in saline-sodic soil. J Agric Sci. 2015; 7: 66-78.
212. El-Sharkawy HM, Shehata SA, Eisa S, Kishk ET, Khafaga HS, El-Naby ASA. Foliar application of thidiazuron, potassium chloride and boron with early cultivation date elevated growth and productivity of hybrid corn grown under adverse conditions. Int J Environ. 2017; 6: 31-41.
213. Bassil E, Hu H, Brown PH. Use of phenyl boronic acids to investigate boron function in plants. Possible role of boron in transvacuolar cytoplasmic strands and cell-to-wall adhesion. Plant Physiol. 2004; 136: 3383-3395.
214. Sezer S. Effect of boron fertilizer applications on the growth and B, N uptake of maize (*Zea mays* L.) under the different soils. J Food Agric Environ. 2014; 12: 1323-1327.
215. Islam MS, Hasan K, Sarkar NAA, Sabagh AE, Rashwan E, Barutçular C. Yield and yield contributing characters of mungbean as influenced by zinc and boron. Agric Adv. 2017; 6: 391-397.
216. Bastías EI, González-Moro MB, González-Murua C. Zea mays L. amylacea from the Lluta valley (Arica-Chile) tolerates salinity stress when high levels of boron are available. Plant Soil. 2004; 267: 73-84.

217. Mahmoodabadi M, Yazdanpanah N, Sinobas LR, Pazira E, Neshat A. Reclamation of calcareous saline sodic soil with different amendments (I): Redistribution of soluble cations within the soil profile. Agric Water Manage. 2013; 120: 30-38.

218. Wang L, Sun X, Li S, Zhang T, Zhang W, Zhai P. Application of organic amendments to a coastal saline soil in North China: Effects on soil physical and chemical properties and tree growth. PLoS One. 2014; 9: e89185.

219. Zhang J, Jiang X, Xue Y, Li Z, Yu B, Xu L, et al. Closing yield gaps through soil improvement for maize production in coastal saline soil. Agronomy. 2019; 9: 573.

220. Khan WU, Aziz T, Hussain I, Ramzani PM, Reichenauer TG. Silicon: A beneficial nutrient for maize crop to enhance photochemical efficiency of photosystem II under salt stress. Arch Agron Soil Sci. 2016; 63: 599-611.

221. Gattullo CE, Allegretta I, Medici L, Fijan R, Pii Y, Cesco S, et al. Silicon dynamics in the rhizosphere: Connections with iron mobilization. J Plant Nutr Soil Sci. 2016; 179: 409-417.

222. Khan WU, Aziz T, Maqsood MA, Farooq M, Abdullah Y, Ramzani PM, et al. Silicon nutrition mitigates salinity stress in maize by modulating ion accumulation, photosynthesis, and antioxidants. Photosynthetica. 2018; 56: 1047-1057.

223. Salim BBM. Effect of boron and silicon on alleviating salt stress in maize. Middle East J Agric Res. 2014; 3: 1196-1204.

224. Salama ZA, Shaaban MM, Abou El-Nour AEA. Effect of iron foliar application on increasing tolerance of maize seedlings to saline irrigation water. Egypt J Appl Sci. 1996; 11: 169-175.

225. Gondim FA, Gomes-Filho E, Costa JH, Alencar NLM, Prisco JT. Catalase plays a key role in salt stress acclimation induced by hydrogen peroxide pretreatment in maize. Plant Physiol Biochem. 2012; 56: 62-71.

226. Sang H, Guo W, Gao Y, Jiao X, Pan X. Effects of alternating fresh and saline water irrigation on soil salinity and chlorophyll fluorescence of summer maize. Water. 2020; 12: 3054.

227. Wang QM, Huo ZL, Zhang LD, Wang JH, Zhao Y. Impact of saline water irrigation on water use efficiency and soil salt accumulation for spring maize in arid regions of China. Agric Water Manage. 2016; 163: 125-138.

228. Zhang L, Yang P, Zheng W, Wang C, Zhang C, Niu M. Effects of drip irrigation models on chemical clogging under saline water use in Hetao District, China. Water. 2018; 10: 345.

229. Sun ZQ, Dong XQ, Wang XJ, Zheng DF, Dong L, Liu ZH. Effect of saline drip irrigation to soil water and salt distribution and cotton yield in northern Shandong plain. Agric Res Arid Areas. 2014; 32: 12-18.

230. Okhovatian-Ardakani AR, Mehrabanian M, Dehghani F, Akbarzadeh A. Salt tolerance evaluation and relative comparison in cuttings of different pomegranate cultivars. Plant Soil Environ. 2010; 56: 176-185.

231. Gawad GA, Arslan A, Gaihbe A, Kadouri F. The effects of saline irrigation water management and salt tolerant tomato varieties on sustainable production of tomato in Syria (1999-2002). Agric Water Manage. 2005; 78: 39-53.

232. Malash N, Flowers TJ, Ragab R. Effect of irrigation systems and water management practices using saline and non-saline water on tomato production. Agric Water Manage. 2005; 78: 25-38.

233. Minhas PS. Saline water management for irrigation in India. Agric Water Manage. 1996; 30: 1-24.

234. Hamdy A, Sardo V, Ghanem KAF. Saline water in supplemental irrigation of wheat and barley under rainfed agriculture. Agric Water Manage. 2005; 78: 122-127.

235. Zhu C, Naqvi S, Gomez-Galera S, Pelacho AM, Capell T, Christou P. Transgenic strategies for the nutritional enhancement of plants. Trends Plant Sci. 2007; 12: 548-555.

236. Huang M, Zhang Z, Zhu C, Zhai Y, Lu P. Effect of biochar on sweet corn and soil salinity under conjunctive irrigation with brackish water in coastal saline soil. Sci Hortic. 2019; 250: 405-413.

237. Tedeschi A, Menenti M. Simulation studies of long-term saline water use: Model validation and evaluation of schedules. Agric Water Manage. 2002; 54: 123-157.

238. Chen LJ, Li CS, Feng Q, Wei YP, Zheng H, Zhao Y, et al. Shifts in soil microbial metabolic activities and community structures along a salinity gradient of irrigation water in a typical arid region of China. Sci Total Environ. 2017; 598: 64-70.

239. He FH, Pan YH, Tan LL, Zhang ZH, Li P, Liu J, et al. Study of the water transportation characteristics of marsh saline soil in the Yellow River delta. Sci Total Environ. 2017; 574: 716-723.

240. Huang CH, Xue X, Wang T, Mascellis RD, Mele G, You QG, et al. Effects of saline water irrigation on soil properties in northwest China. Environ Earth Sci. 2011; 63: 701-708.

241. Ahmed CB, Magdich S, Rouina BB, Boukhris M, Abdullah FB. Saline water irrigation effects on soil salinity distribution and some physiological responses of field grown Chemlali olive. J Environ Manage. 2012; 113: 538-544.

242. Wang T, Xu Z, Pang G. Effects of irrigating with brackish water on soil moisture, soil salinity, and the agronomic response of winter wheat in the Yellow River delta. Sustainability. 2019; 11: 5801.

243. Rahil M, Hajjeh H, Qanadillo A. Effect of saline water application through different irrigation intervals on tomato yield and soil properties. Open J Soil Sci. 2013; 3: 143-147.

244. Schopfer P, Liszkay A, Bechtold M, Frahry G, Wagner A. Evidence that hydroxyl radicals mediate auxininduced extension growth. Planta. 2002; 214: 821-828.

245. Wang Y, Mopper S, Hasentein KH. Effects of salinity on endogenous ABA, IAA, JA, and SA in Iris hexagona. J Chem Ecol. 2001; 27: 327-342.

246. Sakhabutdinova AR, Fatkhutdinova DR, Bezrukova MV, Shakirova FM. Salicylic acid prevents the damaging action of stress factors on wheat plants. Bulg J Plant Physiol. 2003; 2003: 314-319.

247. Khan MA, Gul B, Weber DJ. Action of plant growth regulators and salinity on seed germination of Ceratoides lanata. Can J Bot. 2004; 82: 37-42.

248. Davani D, Nabipour M, Roshanfekr Dezfouli H. Effects of different concentrations of cytokinin and auxin hormones on yield and yield components of grain maize (*Zea mays* L.) in salinity conditions. Plant Prod. 2017; 40: 69-80.

249. Kaya C, Ashraf M, Dikilitas M, Tuna AL. Alleviation of salt stress-induced adverse effects on maize plants by exogenous application of indoleacetic acid (IAA) and inorganic nutrients-A field trial. Aust J Crop Sci. 2013; 7: 249-254.

250. Darra BL, Saxena SN. Role of IAA on the mineral composition of maize (*Zea mays*) crop under various osmotic stressed conditions. Plant Soil. 1973; 38: 657-661.

251. Akbari G, Sanavy SA, Yousefzadeh S. Effect of auxin and salt stress (NaCl) on seed germination of wheat cultivars (*Triticum aestivum* L.). Pak J Biol Sci. 2007; 10: 2557-2561.

252. Egamberdieva D. Alleviation of salt stress by plant growth regulators and IAA producing bacteria in wheat. Acta Physiol Plant. 2009; 31: 861-864.

253. Islam MS, Hasan MK, Islam MR, Chowdhury MK, Pramanik MH, Iqbal MA, et al. Water relations and yield characteristics of mungbean as influenced by foliar application of gibberellic acid (GA$_3$). Front Ecol Evol. 2023; 11: 1048768.

254. Elhakem AH. Salicylic acid ameliorates salinity tolerance in maize by regulation of phytohormones and osmolytes. Plant Soil Environ. 2020; 66: 533-541.

255. Tuna AL, Kaya C, Dikilitas M, Higgs D. The combined effects of gibberellic acid and salinity on some antioxidant enzyme activities, plant growth parameters and nutritional status in maize plants. Environ Exp Bot. 2008; 62: 1-9.

256. Rashad RT, Hussien RA. A comparison study on the effect of some growth regulators on the nutrients content of maize plant under salinity conditions. Ann Agric Sci. 2014; 59: 89-94.

257. Nayyar H, Walia DP, Kaistha BL. Performance of bread wheat (*Triticum aestivum* L.) seed primed with growth regulators and inorganic salts. Indian J Agric Sci. 1995; 65: 116-122.

258. Kumar B, Singh B. Effect of plant hormones on growth and yield of wheat irrigated with saline water. Ann Agric Res. 1996; 17: 209-212.

259. Afzal I, Basra SA, Iqbal A. The effects of seed soaking with plant growth regulators on seedling vigor of wheat under salinity stress. J Stress Physiol Biochem. 2005; 1: 6-14.

260. Parasher A, Varma SK. Effect of pre-sowing seed soaking in gibberellic acid on growth of wheat (*Triticum aestivum* L.) under different saline conditions. Indian J Biol Sci. 1988; 26: 473-475.

261. Iqbal M, Ashraf M. Gibberellic acid mediated induction of salt tolerance in wheat plants: Growth, ionic partitioning, photosynthesis, yield and hormonal homeostasis. Environ Exp Bot. 2010; 86: 76-85.

262. Prakash L, Prathapasenan G. NaCl-and gibberellic acid-induced changes in the content of auxin, the activity of cellulose and pectin lyase during leaf growth in rice (*Oryza sativa*). Ann Bot. 1990; 365: 251-257.

263. Maggio A, Barbieri G, Raimondi G, De Pascale S. Contrasting effects of GA$_3$ treatments on tomato plants exposed to increasing salinity. J Plant Growth Regul. 2010; 29: 63-72.

264. Lomin SN, Krivosheev DM, Steklov MY, Arkhipov DV, Osolodkin DI, Schmulling TR, et al. Plant membrane assays with cytokinin receptors underpin the unique role of free cytokinin bases as biologically active ligands. J Exp Bot. 2015; 66: 1851-1863.

265. Rijavec T, Jain M, Dermastia M, Chourey PS. Spatial and temporal profiles of cytokinin biosynthesis and accumulation in developing caryopses of maize. Ann Bot. 2011; 107: 1235-1245.

266. Iqbal M, Ashraf M, Jamil A. Seed enhancement with cytokinins: Changes in growth and grain yield in salt stressed wheat plants. Plant Growth Regul. 2006; 50: 29-39.

267. Ha S, Vankova R, Yamaguchi-Shinozaki K, Shinozaki K, Tran LS. Cytokinins: Metabolism and function in plant adaptation to environmental stresses. Trends Plant Sci. 2012; 17: 172-179.

268. Taiz L, Zeiger E, Møller IM, Murphy A. Plant physiology and development. 6th ed. New York, NY: Sinauer Associates; 2015.

269. Mathew J, Rayan KM. Influence of plant growth promoter in transplanted lowland rice. J Trop Agric. 1995; 33: 82-83.

270. Zahir ZA, Asghar HN, Arshad M. Cytokinin and its precursors for improving growth and yield of rice. Soil Biol Biochem. 2001; 33: 405-408.

271. Javid MG, Sorooshzadeh A, Sanavy SAMM, Allahdadi I, Moradi F. Effects of the exogenous application of auxin and cytokinin on carbohydrate accumulation in grains of rice under salt stress. Plant Growth Regul. 2011; 65: 305-313.

272. Iqbal M, Ashraf M, Jamil A, Ur-Rehman S. Does seed priming induce changes in the levels of some endogenous plant hormones in hexaploid wheat plants under salt stress? J Integr Plant Biol. 2006; 48: 181-189.

273. El Sabagh A, Çiğ F, Seydoşoğlu S, Battaglia ML, Javed T, Iqbal MA, et al. Salinity stress in maize: Effects of stress and recent developments of tolerance for improvement. Cereal Grains. London, UK: IntechOpen; 2021.

274. Naqvi SSM, Ansari R, Kuawada AN. Responses of salt stressed wheat seedlings to kinetin. Plant Sci Lett. 1982; 26: 279-283.

275. Chakrabarti N, Mukherji S. Alleviation of NaCl stress by pretreatment with phytohormones in Vigna radiata. Biol Plant. 2003; 46: 589-594.

276. Tao JJ, Chen HW, Ma B, Zhang WK, Chen SY, Zhang JS. The role of ethylene in plants under salinity stress. Front Plant Sci. 2015; 6: 1059.

277. Jiang C, Belfield EJ, Cao Y, Smith JA, Harberd NP. An Arabidopsis soil-salinity-tolerance mutation confers ethylene-mediated enhancement of sodium/potassium homeostasis. Plant Cell. 2013; 25: 3535-3552.

278. Freitas VS, de Souza Miranda R, Costa JH, de Oliveira DF, de Oliveira Paula S, de Castro Miguel E, et al. Ethylene triggers salinity tolerance in maize genotypes by modulating polyamine catabolism enzymes associated with H_2O_2 production. Environ Exp Bot. 2018; 145: 75-86.

279. Amjad M, Akhtar J, Anwar-ul-Haq M, Yang A, Akhtar SS, Jacobsen SE. Integrating role of ethylene and ABA in tomato plants adaptation to salt stress. Sci Hortic. 2014; 172: 109-116.

280. Yang L, Zu YG, Tang ZH. Ethylene improves Arabidopsis salt tolerance mainly via retaining K^+ in shoots and roots rather than decreasing tissue Na^+ content. Environ Exp Bot. 2013; 86: 60-69.

281. Lin Y, Yang L, Paul M, Zu Y, Tang Z. Ethylene promotes germination of Arabidopsis seed under salinity by decreasing reactive oxygen species: Evidence for the involvement of nitric oxide simulated by sodium nitroprusside. Plant Physiol Biochem. 2013; 73: 211-218.

282. Keskin BC, Yuksel B, Memon AR, Topal-Sarıkaya A. Abscisic acid regulated gene expression in bread wheat (*Triticum aestivum* L.). Aust J Crop Sci. 2010; 4: 617-625.

283. Zhang J, Jia W, Yang Y, Ismail AM. Role of ABA in integrating plant responses to drought and salt stresses. Field Crops Res. 2006; 97: 111-119.

284. Zörb C, Geilfus CM, Mühling KH, Ludwig-Müller J. The influence of salt stress on ABA and auxin concentrations in two maize cultivars differing in salt resistance. J Plant Physiol. 2013; 170: 220-224.

285. Amzallag GN, Lerner HR, Poljakoff-Mayber A. Exogenous ABA as a modulator of response of sorghum to high salinity. J Exp Bot. 1990; 41: 1389-1394.

286. Fricke W, Akhiyarova G, Veselov D, Kudoyarova G. Rapid and tissue-specific changes in ABA and in growth rate in response to salinity in barley leaves. J Exp Bot. 2004; 55: 1115-1123.

287. Sripinyowanich S, Klomsakul P, Boonburapong B, Bangyeekhun T, Asami T, Gud H, et al. Exogenous ABA induces salt tolerance in indica rice (*Oryza sativa* L.): The role of OsP5CS1 and OsP5CR gene expression during salt stress. Environ Exp Bot. 2013; 86: 94-105.

288. Gómez-Cadenas A, Arbona V, Jacas J, Primo-Millo E, Talon M. Abscisic acid reduces leaf abscission and increases salt tolerance in citrus plants. J Plant Growth Regul. 2002; 21: 234-240.

289. Cabot C, Sibole JV, Barcelo J, Poschenrieder C. Abscisic acid decreases leaf Na⁺ exclusion in salt-treated *Phaseolus vulgaris* L. J Plant Growth Regul. 2009; 28: 187-192.

290. Krishna P. Brassinosteroid-mediated stress responses. J Plant Growth Regul. 2003; 22: 289-297.

291. Montoya T, Nomura T, Yokota T, Farrar K, Harrison K, Jones T, et al. Patterns of dwarf expression and brassinosteroid accumulation in tomato reveal the importance of brassinosteroid synthesis during fruit development. Plant J. 2005; 42: 262-269.

292. Cao S, Xu Q, Cao Y, Qian K, An K, Zhu Y, et al. Loss of-function mutations in DET2 gene lead to an enhanced resistance to oxidative stress in Arabidopsis. Physiol Plant. 2005; 123: 57-66.

293. Ali B, Hayat S, Fariduddin Q, Ahmad A. 24-epibrassinolide protects against the stress generated by salinity and nickel in *Brassica juncea*. Chemosphere. 2008; 72: 1387-1392.

294. Ali Q, Athar HUR, Ashraf M. Modulation of growth, photosynthetic capacity and water relations in salt stressed wheat plants by exogenously applied 24-epibrassinolide. Plant Growth Regul. 2008; 56: 107-116.

295. Rady MM. Effect of 24-epibrassinolide on growth, yield, antioxidant system and cadmium content of bean (*Phaseolus vulgaris* L.) plants under salinity and cadmium stress. Sci Hortic. 2011; 129: 232-237.

296. Kartal G, Temelm A, Aricanm E, Gozukirmizim N. Effects of brassinosteroids on barley root growth, antioxidant system and cell division. Plant Growth Regul. 2009; 58: 261-267.

297. He RY, Wang GJ, Wang XS. Effect of brassinolide on growth and chilling resistance of maize seedlings. In: Brassinosteroids. Washington D.C.: American Chemical Society; 1991. pp. 220-223.

298. Wang B, Zhang J, Xia X, Zhang WH. Ameliorative effect of brassinosteroid and ethylene on germination of cucumber seeds in the presence of sodium chloride. Plant Growth Regul. 2011; 65: 407-413.

299. Sharma I, Ching E, Saini S, Bhardwaj R, Pati PK. Exogenous application of brassinosteroid offers tolerance to salinity by altering stress responses in rice variety Pusa basmati-1. Plant Physiol Biochem. 2013; 69: 17-26.

300. Das T, Shukla YM, Poonia TC, Meena M, Meena MD. Effects of brassinolide on physiological characteristics of rice (*Oryza sativa* L.) with different salinity levels. Ann Biol. 2013; 29: 228-231.

301. Efimova MV, Savchuk AL, Hasan JAK, Litvinovskaya RP, Khripach VA, Kholodova VP, et al. Physiological mechanisms of enhancing salt tolerance of oilseed rape plants with brassinosteroids. Russ J Plant Physiol. 2014; 61: 733-743.

302. Daur I, Tatar O. Effects of gypsum and brassinolide on soil properties, and berseem (*Trifolium alexandrinum* L.) growth, yield and chemical composition grown on saline soil. Legume Res. 2013; 36: 306-311.

303. EI-Mashad AA, Mohamed HI. Brassinolide alleviates salt stress and increases antioxidant activity of cowpea plants (*Vigna sinensis*). Protoplasma. 2012; 249: 625-635.

304. Lu XM, Yang W. Alleviation effects of brassinolide on cucumber seedlings under NaCl stress. Yingyong Shengtai Xuebao. 2013; 24: 1409-1414.

305. Hussein MM, Balbaa LK, Gaballah MS. Salicylic acid and salinity effects on growth of maize plants. Res J Agric Biol Sci. 2007; 3: 321-328.

306. Kulaeva ON, Burkanova EA, Fedina AB, Kokhlova VA, Bokebayeva GA, Vorbrodt HM, et al. Effect of brassinolide on protein synthesis and plant cell ultrastructure under stress conditions. In: Brassinosteroids. Washington D.C.: American Chemical Society; 1991. pp. 141-155.

307. Shakirova FM, Sakhabutdinova AR, Bezrukova MV, Fathudinova RA, Fathutdinova DR. Changes in hormonal status of wheat seedlings induced by salicylic acid and salinity. Plant Sci. 2003; 164: 317-322.

308. Tuna AL, Kaya C, Dikilttas M, Yokas I, Burun B, Altunlu H. Comparative effects of various salicylic acid derivatives on key growth parameters and some enzyme activities in salinity stressed maize (*Zea mays* L.) plants. Pak J Bot. 2007; 39: 787-798.

309. Ismail MA. Alleviation of salinity stress in white corn (*Zea mays* L.) plant by exogenous application of salicylic acid. Am J Life Sci. 2013; 1: 248-255.

310. Wasternack C, Hause B. Jasmonates and octadecanoids: Signals in plant stress responses and development. Prog Nucleic Acid Res Mol Biol. 2002; 72: 165-221.

311. Manzoor H, Bukhat S, Rasul S, Rehmani MI, Noreen S, Athar HU, et al. Methyl jasmonate alleviated the adverse effects of cadmium stress in pea (*Pisum sativum* L.): A nexus of photosystem II activity and dynamics of redox balance. Front Plant Sci. 2022; 13: 860664.

312. Shahzad AN, Pitann B, Ali H, Qayyum MF, Fatima A, Bakhat HF. Maize genotypes differing in salt resistance vary in jasmonic acid accumulation during the first phase of salt stress. J Agron Crop Sci. 2015; 201: 443-451.

313. Kang DJ, Seo YJ, Lee JD, Ishii R, Kim KU, Shin DH, et al. Jasmonic acid differentially affects growth, ion uptake and abscisic acid concentration in salt-tolerant and salt-sensitive rice cultivars. J Agron Crop Sci. 2005; 191: 273-282.

314. Pedranzani H, Racagni G, Alemano S, Miersch O, Ramirez I, Pena-Cortes H, et al. Salt tolerant tomato plants show increased levels of jasmonic acid. Plant Growth Regul. 2003; 41: 149-158.

315. Tsonev TD, Lazova GN, Stoinova ZG, Popova LP. A possible role for jasmonic acid in adaptation of barley seedlings to salinity stress. J Plant Growth Regul. 1998; 17: 153-159.

316. Xie XN, Yoneyama K, Yoneyama K. The strigolactone story. Ann Rev Phytopathol. 2010; 48: 93-117.

317. Ha CV, Leyva-Gonzalez MA, Osakabe Y, Tran UT, Nishiyama R, Watanabe Y, et al. Positive regulatory role of strigolactone in plant responses to drought and salt stress. Proc Natl Acad Sci. 2014; 111: 851-856.

318. Andreo-Jimenez B, Ruyter-Spira C, Bouwmeester HJ, Lopez-Raez JA. Ecological relevance of strigolactones in nutrient uptake and other abiotic stresses, and in plant-microbe interactions below-ground. Plant Soil. 2015; 394: 1-19.

319. Ma N, Hu C, Wan L, Hu Q, Xiong JL, Zhang CL. Strigolactones improve plant growth, photosynthesis, and alleviate oxidative stress under salinity in rapeseed (*Brassica napus* L.) by regulating gene expression. Front Plant Sci. 2017; 8: 1671.

320. Kong CC, Ren CG, Li RZ, Xie ZH, Wang JP. Hydrogen peroxide and strigolactones signaling are involved in alleviation of salt stress induced by arbuscular mycorrhizal fungus in *Sesbania cannabina* seedlings. J Plant Growth Regul. 2017; 36: 734-742.

321. Ren CG, Kong CC, Xie ZH. Role of abscisic acid in strigolactone induced salt stress tolerance in arbuscular mycorrhizal *Sesbania cannabina* seedlings. BMC Plant Biol. 2018; 18: 74.

322. Aroca R, Ruiz-Lozano JM, Zamarreño ÁM, Paz JA, García-Mina JM, Pozo MJ, et al. Arbuscular mycorrhizal symbiosis influences strigolactone production under salinity and alleviates salt stress in lettuce plants. J Plant Physiol. 2013; 170: 47-55.

323. Hashem HA, Bassuony FM, Hassanein RA, Baraka DM, Khalil RR. Stigmasterol seed treatment alleviates the drastic effect of NaCl and improves quality and yield in flax plants. Aust J Crop Sci. 2012; 5: 1858-1867.

324. De Cuyper C, Fromentin J, Yocgo RE, De Keyser A, Guillotin B, Kunert K, et al. From lateral root density to nodule number, the strigolactone analogue GR24 shapes the root architecture of Medicago truncatula. J Exp Bot. 2015; 66: 137-146.

325. Bano A, Fatima M. Salt tolerance in *Zea mays* L. following inoculation with rhizobium and pseudomonas. Biol Fertil Soils. 2009; 45: 405-413.

326. Okuma E, Murakami Y, Shimoishi Y, Tada M, Murata Y. Effects of exogenous application of proline and betaine on the growth of tobacco cultured cells under saline conditions. Soil Sci Plant Nutr. 2004; 50: 1301-1305.

327. Kaur G, Asthir B. Proline: A key player in plant abiotic stress tolerance. Biol Plant. 2015; 59: 609-619.

328. de Freitas PAF, de Souza Miranda R, Marques EC, Prisco JT, Gomes Filho E. Salt tolerance induced by exogenous proline in maize is related to low oxidative damage and favorable ionic homeostasis. J Plant Growth Regul. 2018; 37: 911-924.

329. Abd El-Samad HM, Shaddad MAK, Barakat N. The role of amino acids in improvement in salt tolerance of crop plants. J Stress Physiol Biochem. 2010; 6: 25-37.

330. Hamed AA, Wakeel SAMA. Physiological response of *Zea mays* exposed to salinity and to exogenous proline. Egypt J Bot. 1994; 34: 93-105.

331. Hasan MI, Kibria MG, Jahiruddin M, Murata Y, Hoque MA. Improvement of salt tolerance in maize by exogenous application of proline. J Environ Sci Nat Res. 2015; 8: 13-18.

332. Alam R, Das D, Islam M, Murata Y, Hoque M. Exogenous proline enhances nutrient uptake and confers tolerance to salt stress in maize (*Zea mays* L.). Prog Agric. 2017; 27: 409-417.

333. Yang X, Lu C. Photosynthesis is improved by exogenous glycinebetaine in salt-stressed maize plants. Physiol Plant. 2005; 124: 343-352.

334. Ahmad B, Zaid A, Sadiq Y, Bashir S, Wani SH. Role of selective exogenous elicitors in plant responses to abiotic stress tolerance. In: Plant abiotic stress tolerance. Cham: Springer; 2019. pp. 273-290.

335. Nawaz M, Wang Z. Abscisic acid and glycine betaine mediated tolerance mechanisms under drought stress and recovery in *Axonopus compressus*: A new insight. Sci Rep. 2020; 10: 6942.

336. Sabagh AE, Mbarki S, Hossain A, Iqbal MA, Islam MS, Raza A, et al. Potential role of plant growth regulators in administering crucial processes against abiotic stresses. Front Agron. 2021; 3: 648694.

337. de Azevedo Neto AD, Prisco JT, Enéas-Filho J, Medeiros JV, Gomes-Filho E. Hydrogen peroxide pre-treatment induces salt-stress acclimation in maize plants. J Plant Physiol. 2005; 162: 1114-1122.

338. Afzal I, Munir F, Ayub CM, Basra SMA, Hameed A, Nawaz A. Changes in antioxidant enzymes, germination capacity and vigour of tomato seeds in response of priming with polyamines. Seed Sci Technol. 2009; 37: 765-770.

339. Duan J, Li J, Guo S, Kang Y. Exogenous spermidine affects polyamine metabolism in salinity-stressed *Cucumis sativus* roots and enhances short-term salinity tolerance. J Plant Physiol. 2008; 165: 1620-1635.

340. Hai X, Mi J, Zhao B, Zhang B, Zhao Z, Liu J. Foliar application of spermidine reduced the negative effects of salt stress on oat seedlings. Front Plant Sci. 2022; 13: 846280. doi: 10.3389/fpls.2022.846280.

341. Kaya C, Ashraf M, Sonmez O, Polat T, Tuna AL. The combined effects of nitric oxide and thiourea on plant growth and mineral nutrition of salt-stressed plants of two maize cultivars with differential salt tolerance. J Plant Nutr. 2019; 42: 1-8.

342. Kaya C, Ashraf M. Nitric oxide is required for aminolevulinic acid-induced salt tolerance by lowering oxidative stress in maize (*Zea mays*). J Plant Growth Regul. 2021; 40: 617-627.

343. Saroj S, Dahire A, Dewangan M, Jain A. Assessment the effect of nitric oxide on yield parameters of wheat and maize under different levels of salt stress. Int J Curr Microbiol App Sci. 2018; 7: 1835-1842.

344. Klein AJ. Modulation of soybean and maize antioxidant activities by caffeic acid and nitric oxide under salt stress. Cape Town, South Africa: Department of Biotechnology, University of the Western Cape; 2012.

345. Duan P, Ding F, Wang F, Wang BS. Priming of seeds with nitric oxide donor sodium nitroprusside (SNP) alleviates the inhibition on wheat seed germination by salt stress. Zhi Wu Sheng Li Yu Fen Zi Sheng Wu Xue Xue Bao. 2007; 33: 244-250.

346. Çelik A, Eraslan F. Effects of exogenous nitric oxide on mineral nutrition and some physiological parameters of maize grown under salinity stress. Ziraat Fak Derg Suleyman Demirel Univ. 2015; 10: 55-64.

347. Manshoori F, Armin M, Marvi H. Role of sodium nitroprusside on mitigation of salt stress in sweet corn. Commun Fac Sci Univ Ank Ser C Biol. 2019; 28: 196-210.

348. Hashem A, Kumar A, Al-Dbass AM, Alqarawi AA, Al-Arjani ABF, Singh G, et al. Arbuscular mycorrhizal fungi and biochar improves drought tolerance in chickpea. Saudi J Biol Sci. 2019; 26: 614-624.

349. Kumar A, Sharma S, Mishra S, Dames JF. Arbuscular mycorrhizal inoculation improves growth and antioxidative response of *Jatropha curcas* (L.) under Na_2SO_4 salt stress. Plant Biosyst. 2013; 149: 260-269.

350. Kumar A, Sharma S, Mishra S. Evaluating effect of arbuscular mycorrhizal fungal consortia and azotobacter chroococcum in improving biomass yield of *Jatropha curcas*. Plant Biosyst. 2016; 150: 1056-1064.

351. Porcel R, Aroca R, Ruiz-Lozano JM. Salinity stress alleviation using arbuscular mycorrhizal fungi. A review. Agron Sustain Dev. 2012; 32: 181-200.

352. Chaumont F, Barrieu F, Wojcik E, Chrispeels MJ, Jung R. Aquaporins constitute a large and highly divergent protein family in maize. Plant Physiol. 2001; 125: 1206-1215.

353. Kumar A, Dames JF, Gupta A, Sharma S, Gilbert JA, Ahmad P. Current developments in arbuscular mycorrhizal fungi research and its role in salinity stress alleviation: A biotechnological perspective. Crit Rev Biotechnol. 2015; 35: 461-474.

354. Thind S, Chaudhary MS, Ditta A, Hussain I, Parveen A, Ullah N, et al. Impact of mycorrhizal fungi from different rhizospheric soils on fungal colonization, growth, and chlorophyll contents of Cenchrus ciliaris. Agronomy. 2022; 12: 2644.

355. Dubey A, Kumar A, Khan ML. Role of biostimulants for enhancing abiotic stress tolerance in Fabaceae plants. In: The plant family Fabaceae. Singapore: Springer; 2020. pp. 223-236.

356. Dubey A, Malla MA, Khan F, Chowdhary K, Yadav S, Kumar A, et al. Soil microbiome: A key player for conservation of soil health under changing climate. Biodivers Conserv. 2019; 28: 2405-2429.

357. Kumar A, Dubey A. Rhizosphere microbiome: Engineering bacterial competitiveness for enhancing crop production. J Adv Res. 2020; 24: 337-352.

358. Dubey A, Saiyam D, Kumar A, Hashem A, Abd_Allah EF, Khan ML. Bacterial root endophytes: Characterization of their competence and plant growth promotion in soybean (*Glycine max* (L.) Merr.) under drought stress. Int J Environ Res Public Health. 2021; 18: 931.

359. Muhammad Zafar-ul-Hye MZ, Farooq HM, Zahir ZA, Mubshar Hussain MH, Amjad Hussain AH. Application of ACC-deaminase containing rhizobacteria with fertilizer improves maize production under drought and salinity stress. Int J Agric Biol. 2014; 16: 591-596.

360. Nadeem SM, Hussain I, Naveed M, Asghar HN, Zahir ZA, Arshad M. Performance of plant growth promoting rhizobacteria containing ACC-deaminase activity for improving growth of maize under salt-stressed conditions. Pak J Agric Sci. 2006; 43: 114-121.

361. Nadeem SM, Zahir ZA, Naveed M, Arshad M. Rhizobacteria containing ACC-deaminase confer salt tolerance in maize grown on salt-affected fields. Can J Microbiol. 2009; 55: 1302-1309.

362. Hamdia MA, Shaddad MA, Doaa MM. Mechanisms of salt tolerance and interactive effects of *Azospirillum brasilense* inoculation on maize cultivars grown under salt stress conditions. Plant Growth Regul. 2004; 44: 165-174.

363. Abdelkader AF, Esawy MA. Case study of a biological control: *Geobacillus caldoxylosilyticus* (IRD) contributes to alleviate salt stress in maize (Zea mays L.) plants. Acta Physiol Plant. 2011; 33: 2289-2299.

364. Ullah S, Bano A. Isolation of plant-growth-promoting rhizobacteria from rhizospheric soil of halophytes and their impact on maize (*Zea mays* L.) under induced soil salinity. Can J Microbiol. 2015; 61: 307-313.

365. Rojas-Tapias D, Moreno-Galván A, Pardo-Díaz S, Obando M, Rivera D, Bonilla R. Effect of inoculation with plant growth promoting bacteria (PGPB) on amelioration of saline stress in maize (*Zea mays*). Appl Soil Ecol. 2012; 61: 264-372.

366. Fukami J, de la Osa C, Ollero FJ, Megías M, Hungria M. Co-inoculation of maize with *Azospirillum brasilense* and *Rhizobium tropici* as a strategy to mitigate salinity stress. Funct Plant Biol. 2017; 45: 328-339.

367. Naseem H, Bano A. Role of plant growth-promoting rhizobacteria and their exopolysaccharide in drought tolerance of maize. J Plant Interact. 2014; 9: 689-701.

368. Nadeem SM, Zahir ZA, Naveed M, Arshad M. Preliminary investigations on inducing salt tolerance in maize through inoculation with rhizobacteria containing ACC deaminase activity. Can J Microbiol. 2007; 53: 1141-1149.

369. Aslam F, Ali B. Halotolerant bacterial diversity associated with *Suaeda fruticosa* (L.) forssk. improved growth of maize under salinity stress. Agronomy. 2018; 8: 131.

370. Kausar R, Shahzad SM. Effect of ACC-deaminase containing rhizobacteria on growth promotion of maize under salinity stress. J Agric Soc Sci. 2006; 2: 216-218.

371. Marulanda A, Azcón R, Chaumont F, Ruiz-Lozano JM, Aroca R. Regulation of plasma membrane aquaporins by inoculation with a *Bacillus megaterium* strain in maize (*Zea mays* L.) plants under unstressed and salt-stressed conditions. Planta. 2010; 232: 533-543.

372. Chen L, Liu Y, Wu G, Veronican Njeri K, Shen Q, Zhang N, et al. Induced maize salt tolerance by rhizosphere inoculation of *Bacillus amyloliquefaciens* SQR9. Physiol Plant. 2016; 158: 34-44.

373. Luo X, Wang B, Gao S, Zhang F, Terzaghi W, Dai M. Genome-wide association study dissects the genetic bases of salt tolerance in maize seedlings. J Integr Plant Biol. 2019; 61: 658-674.

374. Hussain SS, Rasheed M, Ahmed ZI, Jilani G. Characterizing maize genotypes for salt tolerance using morphological and ionic traits at seedling stage. Int Letters Nat Sci. 2023; 86: 1-24.

375. Zhao Z, Zheng H, Wang M, Guo Y, Wang Y, Zheng C, et al. Reshifting Na$^+$ from shoots into long roots is associated with salt tolerance in two contrasting inbred maize (*Zea mays* L.) lines. Plants. 2023; 12: 1952. doi: 10.3390/plants12101952.

376. Li X, Wang X, Ma Q, Zhong Y, Zhang Y, Zhang P, et al. Integrated single-molecule real-time sequencing and RNA sequencing reveal the molecular mechanisms of salt tolerance in a novel synthesized polyploid genetic bridge between maize and its wild relatives. BMC Genomics. 2023; 24: 55. doi: 10.1186/s12864-023-09148-0.

377. Han ZP, Liu H, Zhao X, Zhang J, Guo S, Wang B, Zhao L, Jin Y, Guo, Y. A maize phytochrome-interacting factor ZmPIF3 improves salt stress tolerance in transgenic Arabidopsis seedlings. Res Square. 2023. doi: 10.21203/rs.3.rs-3012134/v1.

378. Mei X, Zhao Z, Bai Y, Yang Q, Gan Y, Wang W, et al. Salt Tolerant Gene 1 contributes to salt tolerance by maintaining photosystem II activity in maize. Plant Cell Environ. 2023; 46: 1833-1848.

379. Zhu Y, Ren Y, Liu J, Liang W, Zhang Y, Shen F, et al. New genes identified as modulating salt tolerance in maize seedlings using the combination of transcriptome analysis and BSA. Plants. 2023; 12: 1331. doi: 10.3390/plants12061331.

380. Luo M, Zhang Y, Li J, Zhang P, Chen K, Song W, et al. Molecular dissection of maize seedling salt tolerance using a genome-wide association analysis method. Plant Biotechnol J. 2021; 19: 1937-1951.

381. Cao Y, Zhou X, Song H, Zhang M, Jiang C. Advances in deciphering salt tolerance mechanism in maize. Crop J. 2023; 11: 1001-1010.