Salt Stress: Toxicity In Plant System- A review

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Abstract: This review basically describes the status of the salinity stress in the current scenario and their impact on plant system, Salinity leads to the accumulation of Na^+ and Cl^- in soil which consequently lowers the soil water potential as compared to the water potential of plant cells. This leads to reduced water uptake by plants and eventually causes severe stress in plant system and thus causes reduction in plant growth and poor yield.

Key words: Salinity; Reactive oxygen species; Proline; Antioxidant

Introduction:

Growing the world population in the coming decades would be require improved production of food, feed, fuel and raw materials from limited land area. The current world population of 7.8 billion is projected to increase by 11 billion over the next 12 years and other estimates suggest that 60% more cereals need to be produced to meet world requirement. Sustainably meeting such demand is a huge challenge, especially when compared to historical cereal yield trends which have been linear for nearly half a century with slopes equal. These days, the Farmers are going through the problems of soil, whether it is soil infertility or soil salt stress, this adversely affects their crops and the productivity of crops is declining drastically (Penella et al., 2017 and Machado et al., 2017). Crops can be different in different circumstances, including biotic and abiotic stresses, such as drought, salinity, and harsh temperatures (Rahneshan et al., 2018). Among the non-biological stresses, salinity is one of the most important limiting factors which affect the crop production in arid and semi-arid regions of the world, causing arable lands to substantially or partially lose their fertility and its annual damage to irrigated lands is worth 27.3 billion dollars (Qadir et al. 2014).

Soil salinity is a form of land degradation in which salts accumulate in the soil profile to an extent that plant growth or infra structures are negatively affected. A range of both field and laboratory procedures exist for measuring soil salinity. In the field, soil salinity is usually inferred from apparent electrical conductivity (EC a) using a range of devices, depending on the required depth of analysis, or size of the survey area. Salts are immensely soluble in ground and surface water. Salinity is the measure of the amount of salt present in soil and water. Salinity is broadly classified into primary and secondary. Primary salinity is the product of natural processes that deposit salts for an extended period on land and water like weathering, rain, and strong wind. Whereas, secondary salinity is the action of anthropogenic activity such as deforestation, clearing land, and excessive irrigation. Stress is one of the most challenging abiotic stresses for crops and is commonly associated with NaCl occurrence in plant habitats. All soils contain salts, and all irrigation water, whether from canals or underground pumping, including a very good quality, contain some dissolved salts. Therefore, salts are a common and necessary component of soil and many salts (Sodium, calcium and potassium) are essential for plants nutrients, but when the quantity of salt increases in the soil or water, it starts to affect the metabolism of plants, which causes the productivity of the plants to decline. Salt stress in plants causes various physiological and metabolic changes such as nutritional imbalance, inhibition of water uptake, seed germination, photosynthesis, and decrease in growth. It is important to tackle soil salt stress to nourish the world's growing population. Although, several mechanical and chemical methods have been devised by many workers to reclaim the salt-affected soils, they are either expensive or not readily feasible. Salinity stress is one of the most harmful abiotic stresses that distress agriculture by decreasing productivity all over the world (Singh et al., 2015). Therefore, to get a clutch with salinity is very important to achieve sustainable agriculture practices and to accomplish present and future food demand globally (Zorb et al., 2019). Climate change, environmental stresses, water shortage and reduction in soil fertility are the major constraints limiting the growth and productivity of crops and impose a threat to the future of food security for ever-increasing human population. The abiotic and biotic stresses have been reported to cause 50 and 30% losses, respectively, to agricultural product worldwide (Phour et al., 2020). The term soil salinity is used to describe the amount of salts within the soil such as NaCl, Na_2SO_4, $MgSO_4$, $MgCl_2$, $CaSO_4$, KCl, and Na_2CO_3 and the process of increasing their content is known as stalinization (Doganlar et al., 2010). High concentration of Na in the soil solution may depress and produce extreme ration of Na^+/Ca^+ or Na^+/K^+. Increases NaCl salt in particular, in the soil generates external osmotic potential that can prevent and decline the influx of water into the root. It is normally associated with NaCl occurrence in plant's environment. Plants are categorized into two categories glycophytes and halophytes based on their low and high tolerance toward NaCl, respectively, and glycophytes normally cannot tolerate over 100 mM NaCl. The severity of salt stress varies depending on plant growth, direction of growth, degree of plant tolerance, environmental factors and irrigation practices. Salt enters the roots with water and introduces the vascular part through vascular or apoplastic route. In the apoplastic pathway, salt with water enters the xylem through the intracellular region, whereas in the symplastic route, salt with water enters the roots through the epidermal plasma membrane and then travels cell to cell through plasmodesmata until discharging to the xylem (Shrivastava et al., 2014). In global agriculture, a significant proportion of cultivated land is affected by soil salinity. The problem has devastating effects on crops' growth, yield, and production. The adversities of salinity stress on crops become even worse in regions with low rainfall and high evaporation rate and where substandard irrigation practices are common. Soils enriched with salinity affect the growth, physiology, and production by triggering water deficit conditions, ionic toxicity, oxidative stress, and alteration in metabolic events (Majeed et al., 2020).

Negative effects of Salinity stress on plants:

Salinity is a major constraint for crop production, including by affecting almost all aspects of plant growth, such as germination, vegetative growth, and reproductive growth, it causes a 65% reduction in yield under moderate saline soils. Salt stress, despite various tolerance mechanisms adapted by different crops, decreases crop yield and leads to loss of arable land. Global food production is needed to increase by 38% and 57%in years 2025 and 2050, respectively to meet nutritional demand of a rapidly increasing world population (estimated to be 9.6 billion by 2050) (Nadeem et al., 2020). Salinity stress leads to loss of entire crop in susceptible crops or loss of economic parts up to 70% was reported in wheat, maize, barley and rice. Moreover, recent predictions pinpointed that climate change have severe unpleasant effects on soil salinity and also highlighted dramatic increase of salinity over few decades, which necessitates the renewal of existing technologies or to develop a novel technologies which are sustainable and ecofriendly (Nagaraju et al., 2020). Salinity decreases leaf water potential and turgor pressure and generates osmotic stress. Salinity enhances reactive oxygen species (ROS) content in the plant cell as a result of ion toxicity and disturbs ion homeostasis. Thus, it imbalances nutrient uptake, disintegrates membrane, and various ultra structure. Consequently, salinity leads to osmotic and ionic stress. Plants respond to salinity by modulating various morpho-physiological, anatomical, and biochemical traits by regulating ion homeostasis and compartmentalization, antioxidant machinery, and biosynthesis of osmoprotectants and phytohormones, i. e, auxins, abscisic acid, brassinosteroids, cytokinins, ethylene, gibberellins, salicylic acid, jasmonic acid, and polyamines. In this review, we have taken some parameters, to describe which way salinity stresses disturb to growth of plants.

Plant growth

Salinity stress shows a negative effect on the seed germination by changing the physiological activity of seed. It suppresses water potential, protein content, and reduced food reserve in germinating seeds of many plants, e.g., in broccoli and cauliflower (Wu et al., 2019). Salinity stress induced osmotic stress tolerance mechanism in plants. Salinity leads to build up of Na+ and Cl- in soil, consequently lowering the soil water potential as compared to water potential of plant cells. This leads to reduced water uptake by plants and eventually causes cellular dehydration. Also, some salts are toxic to plants when present in high concentration. The highly tolerant crops can withstand a salt concentration of the saturation extract up to 10 g/l. The moderately tolerant crops can withstand salt concentration up to 5 g/l. The limit of the sensitive group is about 2.5 g/l.

Photosynthesis

Salt stress causes decrease in plant growth and productivity by disrupting physiological processes, especially photosynthesis. The accumulation of intracellular sodium ions at salt stress changes the ratio of K : Na which seems to affect the bioenergetic processes of photosynthesis. There is increasing evidence that enhanced salinity changes photosynthetic parameters, osmotic and leaf water potential, transpiration rate, leaf temperature, and relative leaf water content. Salt also affects photosynthetic components such as enzymes, chlorophylls, and carotenoids.

Antioxidant defense machinery

During salinity stress, there is induction of ROS, which causes oxidative stress; therefore, plants facilitate antioxidant enzymatic and non-enzymatic machinery. In particular, the antioxidant enzymes which get increased are superoxide dismutase (SOD), catalase (CAT), peroxidase (POX) and ascorbate peroxidase

(APX), whereas non-enzymatic antioxidant which gets enhanced are glutathione (GSH), ascorbate (ASC) and its derivatives and photosynthetic accessory pigments like carotenoids (Mbarki et al., 2018).

Proline

Many studies show that salt stress triggers the induction of genes involved in proline biosynthesis, which leads to proline accumulation. Effects of salinity and variety were significant on membrane permeability and proline content. Salinity decreased relative water content and leaf water potential while increased membrane permeability and proline content. Results indicate that these parameters can be used as an appropriate measure to determine tolerance to salinity stress (Farkhondeh et al., 2012).

References

1) Doganlar, Z B., Demir, K., Basak, H and Gu, I. (**2010**) Effects of salt stress on pigment and total soluble protein contents of three different tomato cultivars, *African Journal of Agricultural Research*, vol. **5**, no. 15, pp: 2056-2065.
2) Farkhondeh, R., Nabizadeh, E and Jalilnezhad, N. **(2012)** Effect of salinity stress on proline content, membrane stability and water relations in two sugar beet cultivars, *International Journal of Agriculture Science*, Vol. 2, No. 5, pp: 385-392.
3) Mbarki, S., Sytar, O., Cerda, A., Zivcak, M., Rastogi, A., He, X., Zoghlami, A., Abdelly, C., Brestic, M., 2018. Strategies to mitigate the salt stress effects on photosynthetic apparatus and productivity of crop plants. In: Kumar, V., Wani, S.H., Suprasanna, P., Tran, L.-S.P. (Eds.), Salinity Responses and Tolerance in Plants, Vol 1: Targeting Sensory, Transport and Signaling Mechanisms. Springer International Publishing, Cham, pp. 85–136.
4) Machado, R M A and Serralheiro R P. (**2017**) Soil Salinity: Effect on Vegetable Crop Growth. Management Practices to Prevent and Mitigate Soil Salinization, *Horticulturae*, vol. **3**, no. 30, pp: 1-13.
5) Majeed, A and Siyyar, S. (2020) Salinity Stress Management in Field Crops: An Overview of the Agronomic Approaches. In: Hasanuzzaman M. (eds) Plant Ecophysiology and Adaptation under Climate Change: Mechanisms and Perspectives II. Springer, Singapore. https://doi.org/10.1007/978-981-15-2172-0_1
6) Nadeem, F., Azhar, M., Anwar-ul-Haq, M., Sabir, M., Samreen, T., ufail, A., Awan, H U M and Juan, W. (**2020**) Comparative Response of Two Rice (*Oryza sativa L.*) Cultivars to Applied Zinc and Manganese for Mitigation of Salt Stress, Journal of Soil Science and Plant Nutrition, vol. **20**, pp: 2059–2072.

7) Nagaraju, Y., Mahadevaswamy, R C., Gundappagol and Naik, N M. (2020) Response of Black Gram to Seed Biopriming with Facultative Halophilic Bacteria under Salinity, *International Journal of Environment and Climate Change*, vol. 10, no. 12, pp: 561-571.

8) Penella, C., Nebauer, S G., López-Galarza, S., Quiñones, A., Bautista, A S and Calatayud, A. (**2017**) Grafting pepper onto tolerant rootstocks: An environmental-friendly technique overcome water and salt stress, *Scientia Horticulturae*, vol. **226**, pp: 33–41.

9) Phour, M and Sindhu, S S. (2020) Amelioration of salinity stress and growth stimulation of mustard (Brassica juncea L.) by salt-tolerant Pseudomonas species, *Applied Soil Ecology*, vol.149, pp: 1-10.

10) Qadir, M., Quillerou, E., Nangia, V., Murtaza, G., Singh, M., Thomas, R J., Drechsel, P and Noble, A D. **(2014)** Economics of salt-induced land degradation and restoration. *Natural Resources Forum*, vol. 38, no. 4, pp: 282–295.

11) Rahneshan, Z., Nasibi, F and Moghadam, A A. (**2018**) Effects of salinity stress on some growth, physiological, biochemical parameters and nutrients in two pistachio (*Pistacia vera* L.) rootstocks, *Journal of Plant Interactions*, vol. **13**, no. 1, pp: 73-82.

12) Shrivastava, P and Kumar, R. (**2014**) Soil salinity: A serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation, *Saudi Journal of Biological Sciences*, vol. **22**, pp: 123–131.

13) Singh, D., Ram, P C., Singh, A., Singh, Y P., Sharma, P C and Srivastava, S. (**2015**) Alleviating adverse effect of soil salinity on biomass production and physiological changes in wheat (Triticum aestivum L.) through application of zinc fertilizer, *Research in Environmental and Life Sciences*, vol. **8**, no. 2, pp: 251-254.

14) Wu, L., Huo, W., Yao, D., Li, M., 2019. Effects of solid matrix priming (SMP) and salt stress on broccoli and cauliflower seed germination and early seedling growth. *Science Horticulture*, vol. 255, pp: 161–168.

15) Zörb, C., Geilfus, C M and Dietz, L J. (**2019**) Salinity and crop yield, *Plant Biology*, https://doi.org/10.1111/plb.12884.