Scientific Innovation Magazine
ISSN : 2584-1157

Influence of Salinity on Soil Physical Properties and Plant Growth

Gandikota Rupa Lalitha[1], Shiva Kumar Udayana[2], Lasyamayee Jena[3], *V. Siva Jyothi[2]

[1]Ph.D Research Scholar (Soil Science), Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore-641003, Tamil Nadu, India.

[2]Assistant Professor (SS&AC), College of Horticulture, Dr. Y.S.R. Horticultural University, Venkataramannagudem-534101, Andhra Pradesh, India.

[3]M.Sc (SS&AC), Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore-641003, Tamil Nadu, India.

[4]Assistant Professor (SS&AC), Agriculture College of Mahanadi, Acharya N.G Ranga Agriculture University, Mahanadi-518502, Andhra Pradesh, India.

*Corresponding author: **v.sivajyothi@angrau.ac.in**

Abstract

Soil salinity is a major environmental constraint to agricultural productivity and land sustainability, particularly in arid and semi-arid regions. The accumulation of soluble salts in the soil adversely affects its physical properties, leading to particle dispersion, loss of aggregate stability, reduced porosity, surface crusting, compaction, and restricted water infiltration. These structural alterations diminish the soils water-holding capacity and limit moisture availability to plant roots. Furthermore, salinity may influence the thermal properties of soil, compounding stress on plant physiological functions. Elevated salinity levels induce osmotic stress, reducing the ability of plants to absorb water, often resulting in apparent dehydration despite adequate soil moisture. High concentrations of ions such as sodium (Na^+) and chloride (Cl^-) interfere with

nutrient uptake and enzyme activity, contributing to nutritional imbalances and physiological dysfunctions. Critical plant processes including seed germination, root and shoot elongation, leaf development, photosynthesis, and overall biomass accumulation are significantly impaired under salinity stress. Plant responses vary depending on species, developmental stage, and the intensity and duration of exposure to salinity. Mitigating the effects of salinity requires an integrated, multidisciplinary approach encompassing agronomic, biotechnological, and engineering strategies. These include the application of soil amendments such as gypsum and organic matter, cultivation of salt-tolerant crop varieties, adoption of efficient irrigation practices, and biological interventions such as microbial inoculants and phytoremediation. Understanding the complex interactions among soil salinity, physical soil characteristics, and plant development is essential for formulating site-specific, sustainable management practices. An integrated approach to salinity management is vital for preserving soil health, ensuring food security, and maintaining long-term agricultural productivity in saline-prone areas.

1. Introduction

Salinity of soil is established to be one of the most important environmental issues affecting farmlands across the world. It is the condition of excess soluble salts in the soil that gives a negative impact on soil and poor plant productivity. Salinity may be natural such as weathering of parent rock substance and accumulation of salts by winds and waters in dry and semi-arid areas (Santhosh *et al*., 2025). Nevertheless, in most regions of the world, the salinity issue has been experiencing a higher level of escalation many times caused by the improper irrigation processes, inability of water drainage, and excessive groundwater pumping due to human activity. Around the world, salinity covers more than 800 million hectares of land such as saline salty soils as well as sodic soils. In India, alone, about 6.73 million hectors of land is degraded as a result of salinity and alkalinity which presents a major challenge to food security and viability of rural livelihoods (Sharma *et al*., 2021). The adverse effects of soil salinity are more dramatic in areas that have less fresh water supply and high evapotranspiration where salts have been found to be deposited in the root zone and as a result of which the plants do not grow well.

The physical characteristic of the soil is influenced by Salinity in the following ways. It destroys the soil structure, lowers aggregate stability and decreases porosity and permeability. The modifications impede the flow of water into the land and clogging of the ground, resulting in waterlogging and lack of adequate oxygen in the roots (Temesgen 2018). Moreover, the dispersion tendency of sodium ions of sodic soils causes the formation of crust and compaction which further limits the seedling emergence and root growth. Salinity subjects plants to osmotic stress and also to ionic stress. The abundance of salts in the soil solution reduces the water potential hence the plants find it hard to absorb the water. Besides, certain ions like Na^+ and Cl^- may turn toxic in case they accumulate in the tissues of plants and hinder all of the necessary processes like nutrient uptake, photosynthesis, and enzyme functioning (Okon *et al*., 2019). The salinity stress results in the impediment of growth, chlorosis of leaves, decrease in biomass and eventually decrease in the yield. Since the need of food is constantly increasing and arable lands are becoming more and more salinized, it is crucial to comprehend the processes that salinity influences soil characteristics and the condition of growing plants (Saddiq *et al*., 2021). It is the kind of understanding that is needed to come up with effective management strategies that will help reduce the effects of salinity and making the agricultural systems in salt affected regions to be sustainable.

2. Causes and Development of Soil Salinity

Soil salinity occurs when soluble salt concentrates in the soil profile. These soluble salt include chlorides, sulfates, and carbonates of sodium, calcium, and magnesium (Lalitha *et al*., 2022). The salts may be both natural in origin or may be due to man-made activities. Development of salinity depends on climatic factors, hydrological activity, soil type and land usage practices.

1. Natural (Primary) Salinization:

The natural processes where salinity is formed are during the weathering of the parent rocks which release soluble salts; and the deposition of marine salts delivered by the wind or previous sea beds. Due to low precipitation and high evaporation rates in arid and semi-arid lands (Chhabra et al., 2021), the salts are unable to be leached much and they end up accumulating in the root zone in the course of time. Saline ground water is also able to bring the dissolved salts to the surface through capillary rise particularly where the water tables are shallow.

2. Anthropogenic Salinization (Secondary):

Secondary salinization is greatly caused by human activities. The one that stands out the most is the wrong irrigating practices. Poor irrigation waters of high sodium content coupled with inadequate drainage will result in the buildup of salt in soils. In the case of no proper leaching, the soil is over-watered and there is a rise in water table and capillary salts circulation (Mohanavelu et al., 2021). The poor drainage systems in most instances do not clear excessive water leading to waterlogging and accumulation of salts.

3. Fertilizer and Industrial Effluents Society:

When used in excess or out of balance, chemical fertilizers may also lead to salinity on the soils, and this mostly happens along with the inadequacy of water supply. Likewise, when salty or alkaline industrial wastes are released into the farms and agricultural fields, the resulting salt loads are too high.

4. Deforestation and Destruction of vegetation cover:

The disturbance of water balance is observed when deep-rooted vegetation is cleared and forests or grasslands are transformed into croplands because it usually causes the levels of groundwater to increase (Wang et al., 2023). This may result into lower soil layer salts moving to the upper soil level and depositing at the surface.

5**. Climate Change and Rise of Sea level**:

The rise in sea-level due to the effect of climate may cause the intrusion of seawater into the freshwater aquifers and even the soils along the coast, thus causing salinization. Salt concentration on soils can be increased by the effect of climate change in increasing temperature and evapotranspiration rates. Salination of soil is a progressive process but also a complicated process. Knowledge of the underlying causes is essential to take appropriate and place-specific management measures to limit its negative effects on soil conditions and crops productivity.

3. Influence of Salinity on Soil Physical Properties

The physical characteristics of soil are also important in the healthiness of the soil, the water flows of soil and the growth of roots in the soil. High salinity greatly changes these characteristics, mostly impairing the physical qualities of the soil thus impairing its capacity to sustain growth of vegetation. This impacts to a significant extent on the nature of salts and its concentration, as well as the exchangeable sodium percentage in the soil.

3.1. Aggregate Stability and Soil Structure:

Salinity in particular sodicity (sodium content) has a detrimental effect on soil structure. The presence of the sodium ions breaks the inter-particle bonds causing dispersion of the clay and disintegration of soil aggregates (Rengasamy *et al*., 2018). This leads to loss of aggregate stability and predisposes the soil to crusting, compaction and erosion.

3.2. Porosity and bulk density:

The pores of the soil, particularly macro-pores are clogged by the dispersed clay particles, which decreases the total porosity and enhances the bulk density. Because of this, the flow of water and air in the soil is limited. This reduces availability of oxygen to roots and microbial communities, which influences plant health and biological activity of the soil negatively.

3.3. Infiltration Rate and Hydraulic Conductivity:

infiltration of soils tends to be low in soils that are salty and sodic. The hydraulic conductivity is also hindered by the particles that are distributed creating a dense accumulation of the particles at the surface or the soil profile (Osman *et al*., 2018). This stagnates the water, enhances surface runoff and decreases the rate of irrigation which aggravates water stress in plants.

3.4. Water holding Capacity and Moisture Availability:

Saline soils can have distorted water retention properties. Although saline soils may be able to retain more water based on greater microspores resulting with dispersion, a great part of the water is made unavailable to plants due to the osmotic effect. Having excess salts in the soil solution reduces the osmotic potential (Zainab *et al*., 2023); thus, even when the soil seems to be moist, plants find it hard to sustain water absorption.

3.5. Compaction and Surface Crusting:

The small particles get separated and become compacted during drying thus creating crusts on the surface that prevent germination of the seeds. Moreover, the destruction of soil clods and decrease in porosity results in compression that would inhibit further root access and water flow even more (Pauwels *et al*., 2023).

To conclude, the water relations, aeration and root growth are drastically compromised by the alteration of the soil physical characteristics caused by salinity. Such limitations do not only bring down the productivity of the plants but also makes the soils more prone to further degradation. The knowledge and control of such variations is very vital in the recovery of soil health in salt-prone areas.

4. Salt on Plant growth and development

Among the abiotic stresses that are super critical to the growth and development of plants is salinity, especially in the arid and semi-arid areas. Excess soluble salts in the root zone distort vital physiological and metabolic functions, which eventually lower crop yields. Salinity impairs the vegetation of the plants in a complex manner including osmotic pressure, ion oxidative, toxicity, and nutrient imbalance.

4.1. Osmotic Stress:

Osmotic stress is the immediate and the foremost impact of the salinity. Large amounts of salt in the soil solution reduce osmotic potential and hence roots are not able to absorb water in the soil effectively (Zhang *et al*., 2023). This in turn causes physiological drought to plants despite the moist soils. This causes low cell enlargement, abnormal development of the root and shoots and plant germination.

4.2. Ion Toxicity:

Of the various ions, accumulation of certain ions like sodium (Na^+) and chloride(Cl^-), in the tissues of plants, can be toxic. These ions disrupt major biochemical and enzymatic processes, break cell membranes and undermine photosynthetic process (Alharbi *et al*., 2022). The excessive levels of Na^+ have the potential to deny a patient the much needed nutrient such as potassium (K^+) and calcium (Ca^{2+}) leading to metabolic disturbances and structural damages.

4.3. Nutrient Imbalance:

Salinity influences the availability, uptake and transport of nutrients. Competitive inhibition or shifts in pH of the soil and ion exchange capacity may create nitrogen, phosphorus, potassium and calcium deficiencies in presence of excessive salts (Chhabra *et al*., 2021). This causes lack of plant vitality, chlorosis of leaves, necrosis of leaves which also leads to decrease in biomass.

4.4. Growth and Morphological modifications:

Salt stress incurs detrimental morphological changes in plants. These are: decrease of leaf area, increase of cuticles, decrease of internodes, decrease in root system and an increase of ratio in root to shoot. High salinity also slows down flowering as well as fruit set and seed development.

4.5. Yield Reduction and Photosynthesis:

Salinity also decreases the photosynthetic ability clear by decreasing the chlorophyll content, stomatal conductance and CO_2 assimilation. This has direct impact on the biosynthesis and translocation of carbohydrates thereby reducing the energy and productivity of the plants

(Hameed *et al*., 2021). Factors of prolonged exposure lead to great losses of yield in majority of crop species.

4.6. Species-Specific Responses:

The response of the plants to salinity strongly depends on species and genotype. Glycophytes (salt sensitive plants) are also more damaged compared to halophytes (salt tolerant species), which have developed different mechanisms, such as ion exclusion, salt compartmentation and osmotic adjustment (Mann *et al*., 2023).

5. Plant Responses and Plant Adaptations to Salinity

In saline conditions many physiological, biochemical and morphological responses attempt to survival and promoting growth are adaptive responses of plants. Such responses are species, genotype, growth stage specific and depend on the magnitude and the length of time of salinity (DosSantos *et al*., 2022). Salt-tolerating capacity is a poly-genetic trait which is a multifaceted process entailing various processes assisting the plants to evade, tolerate, or adjust to the negative environments.

5.1. Osmotic Adjustment:

Osmotic adjustment is one of the main changes of the plants in response to salinity; it is useful in terms of sustaining cell turgor and water uptake. Plants do so through the accumulation of compatible solutes (or osmoprotectants) e.g. proline, glycine betaine, sugars, and polyols. These molecules do not disarrange ordinary metabolic processes and assist in stabilization of proteins, and cellular structures at stress.

5.2. Ion homeostasis, Compartmentalization:

To avoid excess accumulation of toxic ions such as sodium (Na^+) and chloride (Cl^-) ion plants inhibit its intake into the roots or sequester them in the wall vacuole. Transport proteins like Na^+/H^+ antiporters ensure ion homeostasis and safeguard vital cell processes by this ion compartmentalization (Murtaza *et al*., 2024). The beneficial ions such as potassium (K^{2+}) and calcium (Ca^{2+}) are retained by the selective ion transport.

5.3. Antioxidant defensive mechanism:

Oxidative stress is a common feature of salinity which can enhance the synthesis of reactive oxygen species (ROS) to harm cellular membranes, proteins as well as DNA. To respond against this, the plants elevate the process of the enzyme named antioxidants, including superoxide dismutase (SOD), catalase (CAT), and peroxidases (POD) (Murtaza *et al*., 2024). ROS is mitigated by these enzymes that deactivate it and inhibit oxidative damage.

5.4**. Morphological Adaptations:**

Morphological changes that can be developed by plants in response to water shortage might include smaller leaf areas, thicker cuticles, deeper root systems and higher root-to-shoot ratios in order to reduce water loss and maximize water uptake (Hameed *et al*., 2021). It is found that some halophytes have special salt glands or bladders which expel surplus salts stored in the plant body.

5.5. Salt-Tolerant Varieties Halophytes:

Low-make hay and some wild plants have developed genetic penalties to deal with salinity. An example is the case of halophyte plants which do best in salty conditions since those are their natural conditions of existence (DosSantos *et al*., 2022). The current activities of crop breeding and genetic engineering aim at transferring the ability to tolerate salts in such species to major food crops.

6. Conclusion

Soil salinity is a critical threat to agriculture, especially in arid and semi-arid regions, driven by poor irrigation, erratic climate, and improper land use. Salinity alters soil structure, reduces porosity and infiltration, and disrupts water and air movement ultimately degrading soil health and limiting sustainable crop production. In plants, salinity causes osmotic stress and ion toxicity, impairing water uptake, nutrient absorption, enzyme activity, and photosynthesis. These disruptions lead to poor germination, stunted growth, leaf chlorosis, and reduced yields. Plant tolerance varies and involves mechanisms such as osmotic adjustment, selective ion uptake, antioxidant defense, and structural changes. Effective salinity management requires integrated approaches: improved irrigation and drainage, use of soil amendments (e.g., gypsum, biochar), salt-tolerant crop varieties, and microbial inoculants. Long-term control also involves regular salinity monitoring, farmer awareness, and sustainable land-use practices. Future research should focus on molecular mechanisms of salt tolerance and cost-effective, site-specific management tools. Combating soil salinity is essential for ensuring soil health, crop productivity, and food security.

7. References

1. Lalitha, G. R., Sekaran, N. C., Selvi, D., & Kalaiselvi, T. (2022) Development of Eco-friendly Technology for the Management of Dry Land Saline Soil. *International Journal of Plant & Soil Science*, 34(22): 25-36.
2. Salma Santhosh, S., Meena, S., Baskar, M., Karthikeyan, S., Vanniarajan, C., & Ramesh, T. (2025). Transformative strategies for saline soil restoration: Harnessing halotolerant

microorganisms and advanced technologies. *World Journal of Microbiology and Biotechnology*, *41*(5), 1-41.

3. Sharma, D. (2021). Reclamation and management of salt-affected soils for crop production with special emphasis on coastal region: trend and prospects. *Souvenir*, 11.
4. Temesgen, T. (2018). Review of Saline Water Irrigation Logging and Salt Affected Soil on Maize (Zea Mays L.) Yield and Managements. *International journal of food science and agriculture*, *2*(5), 95-107.
5. Okon, O. G. (2019). Effect of salinity on physiological processes in plants. *Microorganisms in saline environments: strategies and functions*, 237-262.
6. Saddiq, M. S., Iqbal, S., Hafeez, M. B., Ibrahim, A. M., Raza, A., Fatima, E. M., ... & Ciarmiello, L. F. (2021). Effect of salinity stress on physiological changes in winter and spring wheat. *Agronomy*, *11*(6), 1193.
7. Chhabra, R., & Chhabra, R. (2021). Nature and origin of salts, classification, area and distribution of salt-affected soils. *Salt-affected soils and marginal waters: Global perspectives and sustainable management*, 1-47.
8. Mann, A., Lata, C., Kumar, N., Kumar, A., Kumar, A., & Sheoran, P. (2023). Halophytes as new model plant species for salt tolerance strategies. *Frontiers in Plant Science*, *14*, 1137211.
9. Pauwels, R., Graefe, J., & Bitterlich, M. (2023). An arbuscular mycorrhizal fungus alters soil water retention and hydraulic conductivity in a soil texture specific way. *Mycorrhiza*, *33*(3), 165-179.
10. Zhang, D., Zhang, Y., Sun, L., Dai, J., & Dong, H. (2023). Mitigating salinity stress and improving cotton productivity with agronomic practices. *Agronomy*, *13*(10), 2486.

11. Alharbi, K., Al-Osaimi, A. A., & Alghamdi, B. A. (2022). Sodium chloride (NaCl)-induced physiological alteration and oxidative stress generation in Pisum sativum (L.): A toxicity assessment. *ACS omega*, *7*(24), 20819-20832.
12. Hameed, A., Ahmed, M. Z., Hussain, T., Aziz, I., Ahmad, N., Gul, B., & Nielsen, B. L. (2021). Effects of salinity stress on chloroplast structure and function. *Cells*, *10*(8), 2023.
13. Dos Santos, T. B., Ribas, A. F., de Souza, S. G. H., Budzinski, I. G. F., & Domingues, D. S. (2022). Physiological responses to drought, salinity, and heat stress in plants: a review. *Stresses*, *2*(1), 113-135.
14. Malakar, P., & Chattopadhyay, D. (2021). Adaptation of plants to salt stress: the role of the ion transporters. *Journal of Plant Biochemistry and Biotechnology*, *30*(4), 668-683.
15. Murtaza, G., Usman, M., Ahmed, Z., Hyder, S., Alwahibi, M. S., Rizwana, H., ... & Zeng, Y. (2024). Improving wheat physio-biochemical attributes in ciprofloxacin-polluted saline soil using nZVI-modified biochar. *Ecotoxicology and Environmental Safety*, *286*, 117202.
16. Mohanavelu, A., Naganna, S. R., & Al-Ansari, N. (2021). Irrigation induced salinity and sodicity hazards on soil and groundwater: An overview of its causes, impacts and mitigation strategies. Agriculture, 11(10), 983.
17. Wang, T., Wu, Z., Wang, P., Wu, T., Zhang, Y., Yin, J., ... & Yan, D. (2023). Plant-groundwater interactions in drylands: A review of current research and future perspectives. Agricultural and Forest Meteorology, 341, 109636.
18. Rengasamy, P. (2018). Irrigation water quality and soil structural stability: A perspective with some new insights. Agronomy, 8(5), 72.
19. Zainab, R., Hasnain, M., Ali, F., Dias, D. A., El-Keblawy, A., & Abideen, Z. (2023). Exploring the bioremediation capability of petroleum-contaminated soils for enhanced environmental sustainability and minimization of ecotoxicological concerns. Environmental Science and Pollution Research, 30(48), 104933-104957