REVIEW ARTICLE

AGRONOMIC VIEW OF SOIL SALINITY, ITS EFFECTS AND RECLAMATION - A Review

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ABSTRACT

Abiotic stress, particularly soil salinity, is currently to blame for a decline in the quality of world crop production and significant losses to global agricultural output. Plants are faced with enormous difficulties as a result of this stress, which has a detrimental effect on their productivity, growth, and development. In recent years, the amount of cultivated land with salinity and alkalinity issues has expanded. Agro-techniques for reclamations of saline soils such as leaching, drainage, using soil amendments, suitable choice of crops and varieties, etc. have been standardised over the years for its management due to the need to increase agricultural productivity as the global population grows exponentially. To improve crop output, it is necessary to increase agro techniques for managing and reducing soil salinity. The mechanism, traits, impacts, and reclamation of soil salinity for improved crop growth and development will all be covered in this paper.

Keywords: *Soil salinity, Effects, Mechanism, Reclamation.*

INTRODUCTION

One of the biggest global problems affecting the arid and semi-arid regions is soil salinity, which has a negative impact on agricultural production (El Hasini *et al.,* 2019). The surface soil covered with white salt efflorescence referred to as "saline," which means "salt like" (Jharia *et al.,* 2013). Due to brackish water irrigation and seawater intrusion into aquifers, the Mediterranean region is currently dealing with increased salt stress issues (Rana & Katerji, 2000). In 120 nations across a 954 million hectare (Mha) area, salt-affected soils cause a 7-8% production loss (Meena *et al.,* 2019). With more than 50% of the world's sodic soils comprised of salt-affected soils, Australia has the highest percentage (Shahid *et al.,* 2018). The deposit of oceanic salts transported by wind and rain are a significant contributor to salinity on the Australian continent (Munns & Tester, 2008). According to NAAS (2012), India is having 121 Mha of degraded land out of that 6.73 Mha is comprised of soil that has been damaged by salt. Worldwide, 3% of irrigated agricultural fields and 20% of all cultivated land are already affected by soil salinity (Srivastava and Kumar, 2015).

The salt content of the soil determines its salinity, and the process of raising the salt content is known as salinization. In comparison to healthy soils, saline soils will have a disproportionately high concentration of salt ions. Excessive salt attracts water and prevents it from being absorbed by plant roots, in addition to destroying the structure of the soil, because of this, plants may show signs of drought even in damp or soggy soil. Water that pools on the surface but doesn't penetrate could be another symptom of salt damage. When the water table is two to three metres below the soil's surface in drylands, salinity can develop. By means of capillary action, salts from the groundwater are brought to the soil's surface (Rajendar singh, 2015).

Saline soils

Saline soils are the soils, which is attributed with an elevated level of total salts, including nitrates of Na, Ca, and Mg as well as chloride, carbonate, and sulphate. Soil saturation paste of these soils at 25^{o}C have electrical conductivity (EC) > 4.0 dS/m, the pH is <8.2 and the exchangeable sodium percentage (ESP) is usually <15. Saline soils are in a flocculated state and hence are fairly permeable. Due to the osmotic effects of salts, the toxicity of soluble ions, and the lower availability of vital nutrients, these soils are under salinity stress (Rana *et al.,* 2016).

When the soil contains excess sodium salts and clay complex still contains exchangeable calcium, the soil is known as saline soils. The process of accumulation of salts leading to the formation of soils is known as salinization. (Sahai, 2001). Saline soils are found white crust of salt hence called white alkali/ brown alkali/ solon chalk. (Neem raj sunda, 2019).

Characteristics of saline soils:

The saline soils are recognized by the presence of white crusts of neutral salts on the surface, non-uniform crop stand (patchy), deep green, stunted plants and in some sensitive crops visible signs of salt injury such as tip burn of leaves and chlorosis. The main salts are sodium chlorides and sodium, calcium, and magnesium sulphates, with

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sodium making up more than 50% of the soluble cations. Neutral salts provide the soils their good permeability (Rao *et al.,* 2010).

Types of salinity

Primary salinity-naturally occurring salinity

Natural geological, hydrological, and pedological processes are responsible for the development of the majority of saline-sodic soils. Some of the parent materials of these soils include intermediate igneous rocks such as phenolytes, basic igneous rocks such as basalts, undifferentiated volcanic rocks, sandstones, alluvium and lagoonal deposits (Wanjogu *et al.,* 2001). According to Wanjogu *et al.* (2001), the majority of the arid and semi arid land receives less than 500 mm of rainfall per year, which when combined with a potential evapotranspiration of roughly 2000 mm per year results in salinization.

Secondary Salinity

Secondary salt-affected soils are those that have been salinized by human-caused factors, mainly as a consequence of improper methods of irrigation. If the irrigation system is not managed so that salts are leached from the soil profile, poor quality water will eventually cause salt to build up in the soil. According to Szabolcs (1992), 50% of all irrigation systems are damaged by salt. Dry land—non-irrigated landscapes, generally as a result of clearing vegetation and changes in land use.

- Deforestation is recognised as a main cause of salinization and alkalization of soils as a result of the impact of salt movement in both the upper and lower layers.
- Sea water intrusion—replacement of over-exploited groundwater in coastal aquifer systems by sea water.
- Point source— high salt concentrations in wastewater from intensive agriculture and industries.

Glycophytes

While excessive grazing, deforestation, irrigation, bad water quality, or intense agriculture are all causes of secondary salinity. Glycophytes are plants that are salt-sensitive. Glycophytes do not have systems for salt tolerance; rather, they have mechanisms for salt resistance. According to Yadav *et al.* (2011), glycophytes are able to adapt to a point by increasing the K^+/Na^+ ratio by active ion transport, which changes the ionic and electrochemical gradients to favour cytosolic activities. *Arabidopsis thaliana* is a model glycophyte that has allowed researchers to better understand salt resistance in glycophytes on a genetic, cellular, and whole plant level (Zhu, 2001). Salinity has an impact on both normal plant processes and seed germination in a growing plant (Malcolm *et al.,* 2003).

Halophytes

Halophytes are plants that can survive in environments with high levels of salt. One percent of plants are halophytes and can withstand salt concentrations of 300–1000 mM (Zhu, 2007). Some of the genes that glycophytes express under salt stress are constantly expressed in halophytes, and the two groups of plants have some genes in common (Radyukina *et al.,* 2007). Halophytes also have a mechanism for scavenging Reactive Oxygen Species and eliminating them (Parida and Das, 2005). Most halophytes respond to salinity by exclusion (Yadav *et al.,* 2011). The roots of mangroves exclude 99% of salts. The LEA protein, osmolyte biosynthesis enzymes, ion transporters, and regulatory molecules including protein kinases and phosphatases are all involved in halophyte gene expression (Aslam *et al.,* 2011).

Mechanisms of salinity in plants

Increased EC, poor soil structure, and reduced soil water potential are all effects of salinity in the soil. According to Munns and Tester (2008), there are two stages in the onset of salt stress in plants:

1. The osmotic phase and The ionic phase.

Osmotic phase begins shortly after salt builds up in the root zone. Because of the low soil water potential and the thick inner wall of the guard cells, the primary indicators of plants during the osmotic phase are stomata closure, a rise in leaf temperature, and hindered shoot elongation.

In contrast, the ionic phase begins after a few minutes to a few hours in various types of salt input, which involves salt accumulation in shoots over time and causes premature abscission and leaf senescence (Sirault *et al.,* 2009).

Effects of salinity on plants

Osmotic stress, one of the world's most severe stress factors caused by the presence of excessive salt concentrations in soil or water, has become particularly significant for many places with semiarid and arid climate zones. The consequences of salinity are also linked to the toxicity of specific ions, nutritional imbalance, or interactions of these factors, in addition to the physical (osmotic) effects of soluble particles restricting water intake by roots (Ashraf and Harris, 2004).

By eroding the fundamental soil structure, excessive pH and ESP degrade the soil and cause it to have poor physical properties. The root growth is impacted by poor soil physical characteristics. Plants' physiology and biochemistry are greatly impacted by salt, which has a negative impact on growth and yield. High levels of exogenous salt impair seed germination, result in a water shortage, and create an ion imbalance. Photosynthesis is the major process that is impacted in plants growing in saltwater conditions. According to Hu *et al*. (2017), salinity slows the growth of plants' reproductive organs. Numerous plants are stressed when electrolytic solutes build up in soil and water at high concentrations. Saline soils are found all across the world, as previously mentioned, but they are most common in semiarid and arid areas. The soluble minerals can build up in the root zone due to insufficient salt leaching and downward percolation there. The small amount of rainfall in hot, dry places is accompanied by high temperatures and low air humidity, which causes a lot of evaporation. Furthermore, these conditions are frequently linked to the existence of salt-bearing sediments and shallow, brackish groundwater in areas like river valleys, which causes the slow transformation of rich, fruitful soils into barren salty soils (Hillel & Vlek, 2005).

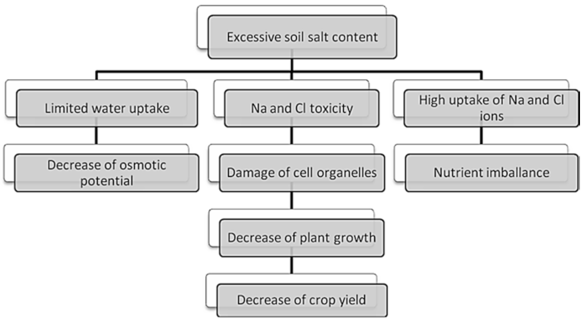

Figure: Overview of salt stress effects on plants (Evelin *et al*., 2009)

Reclamation and management of saline soils:

Salinity in soils can vary in type and intensity depending on the soil's texture, mineralogy, calcerousness, topography, hydrological conditions, and drainage patterns (Rao *et al.,* 2010). Therefore, reclamation and management of such soils must be site-specific and should involve a combination of methods are

1. Leaching of excess soluble salts
2. Lowering of water table by strengthening irrigation and drainage
3. Improved cultural management
4. Prevention of sea water intrusion in coastal areas
5. Selection of suitable crops and varieties
6. Using soil amendments.

Leaching and drainage:

Any long-term remedy for salinity in the root zone (0–20 cm) must include leaching and drainage. With finer soil texture, greater initial soil moisture content, more salinization, increased proportion of chlorides, poorer water quality, and shallower ground water, more water is needed for leaching (Rao *et al.,* 2010). The most efficient way for reclaiming salty soils is leaching them to remove soluble salts. This calls for adequate soil permeability and high-quality irrigation water. Leaching lessens the salt threat for plants, but it can also affect the soil's permeability and pH, which can lead to the decomposition of roots as the soil transitions from saline to sodic. Although providing appropriate drainage is the greatest long-term remedy to salinization, this technique is expensive. Hence, many irrigation plans, especially those in developing nations, lack sufficient drainage (Hamna *et al.,* 2019).

Drainage:

Agricultural drainage is essential to maintain the groundwater table, get rid of dissolved soluble salts from the soil profile, and remove extra water during heavy precipitation. Waterlogged salinity, however, continues to be a serious issue because of carelessness in many fertile regions of Australia, the Middle East, the United States, and Asia (Emadodin *et al*., 2012). One of the most crucial methods for removing salts from 1.5 m of depth was found to be sub-surface drainage (SSD). Saline soils can be recovered using two different kinds of SSD: (i) Horizontal sub-surface drainage, which utilises a network of drains made up of the main drain, lateral drains, and collectors to reach a root zone depth of 1.5–2.0 m (Nijland *et al.,* 2005) and (ii) vertical sub-surface drainage which is related to pumping of excess water by tube well (Bos, 2001).

Cultural management:

When organic manures such as green manures, crop residues, FYM, press mud, and other organic materials are added, water infiltration is improved, CO_2 is released during decomposition, and microbial activity, drainage, and nutrient delivery are all improved. Crop cultivation creates shade, lowers evaporation, and slows the ascent of salts. By transplanting seedlings that are mature (35–40 days old) with more plants per hill and closer spacing, one can increase crop survival and population density while also reducing salt intensity through shading. Leaching efficiency and salinity management are improved by controlled, routine irrigation with little water (Rao *et al.,* 2010).

Reclamation of Coastal Saline Soils:

Due to the variable salinity (dependent on rainfall) in coastal saline soils, effective crop planning, rainwater collection, dyke construction, deeper drains (up to 2.0 m), and organic manuring increase productivity. For the purpose of restoring coastal saline soils and sustaining crop production in them, several technologies have been standardised and improved. It has been successful using *Rabi* cropping on mono-cropped coastal saline soils, salt-tolerant rice cultivars, rainfall harvesting in dugout farm ponds, integrated rice-fish culture, and effective nutrient management have practised (Sharma and Chaudhari, 2012). In the nation's coastal regions, a novel "Doruvu" technology has gained popularity. The method is skimming shallow depth fresh water floating on the saltwater and storing it in conical holes that have been scooped out and are known locally as "Doruvus." These regions appear to offer potential for multi-storeyed integrated agroforestry systems that include livestock, diverse arable crops, fish or prawn culture, poultry, plantation crops and more (Kumar and Sharma, 2020).

Selection of suitable crops and varieties:

However, the site must be considered when choosing tolerant crops because soil texture, climate, and management all affect salinity tolerance levels. Plants should not be grown if they are either too sensitive or just partially tolerant to the degree of salinity present. Pulses, carrots, onions, lemons, grapes, plums, peaches, and apples are some examples of very sensitive crops. While maize, millets, cabbage, cauliflower, broad beans, cowpeas, and radish are medium sensitive. Spinach, sugarcane, rapeseed, mustard, rice (direct planting), and wheat are examples of crops that are medium-tolerant. Barley, rice (transplanted), cotton, sugar beetroot, safflower, karnal grass and date palm are examples of crops that are highly tolerant. Cluster beans/cotton/wheat/barley and pearl millet/sorghum-barley/wheat/mustard are suggested cropping systems for saline soils in arid and semi-arid areas (Rana *et al.*,2016).

Using soil amendments:

For the rehabilitation of saline alkali soils, soil additives like gypsum ($CaSO_4$), calcium chloride dehydrate ($CaCl_2 2H_2O$), and sulfuric acid (H_2SO_4) have been utilised. The exchangeable Na^+ is typically replaced with Ca^{++} in these modifications. The displaced sodium must be leached out of the plant rooting zone for amendments to work. Due to water availability issues and/or poor site drainage, this is not always practical. However, even without leaching, adding gypsum to the soil will lessen crusting on the surface and enhance moisture retention (Mark Majerus, 1996).

CONCLUSION

Problems with salinity can arise naturally or as a result of human activity in all climatic situations. Soil salinity undermines the resource base by decreasing soil quality and can occur due to natural causes or from misuse and mismanagement. By lowering the water table by improving irrigation and drainage, improving cultural management, preventing sea water intrusion in coastal areas, choosing suitable crops and varieties, and using soil amendments, there is possible to reduce the salinity in soil and ultimately improve the resource base.

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