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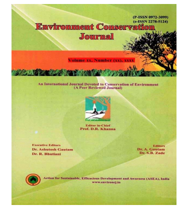

A review on impact of salt stress in soil health and its suitable control measure

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ABSTRACT

Soil salinity is associated with the accumulation of soluble salts in higher concentration deteriorating soil health associated with unfavourable environment for plant growth. It is mostly confined to those regions where there is high temperature and low precipitation, mostly in arid and semi-arid regions. Major factors responsible for soil salinity can be categorised into primary and secondary factor affecting at the spatial and temporal scale. Higher concentration of soluble salts in soil increase the osmotic potential disrupting the movement of water from root to leaf. So, soil salinity is primarily associated with the water stress condition in plants which is a direct impact to plants. Indirectly it interferes with the nutrients absorption which is one of the most important factors for proper plant growth. Plants poses different mechanisms to avoid salt stress condition in soil but maximum of it are an active processes were additional energy must have to spend for it that can impact proper growth and production. The ions primarily responsible for both the soil and plant stress under soil salinity are Na^+ and Cl^- which concentration increases with certain primary and secondary soil salinization factors. So, primary aim to control the impact of soil salinity is to reduce the activity/concentration of both Na^+ and Cl^- from the soil. So, use of the essential nutrients (K^+ and SO_4^{-2}) that has an antagonistic relationship with the salts is a new approach. Due to similar charge and physico chemical properties of K^+ and SO_4^{-2} with toxic ions Na^+ and Cl^- respectively, there lies an antagonistic relationship. Furthermore, SO_4^{-2} of its less toxicity to plants and improve soil pH condition especially in arid and semi-arid region, the combination of K^+ and SO_4^{-2} salt is a good combination to ameliorate the Na^+ and Cl^- toxicity under saline soil.

Introduction

Soil salinization is an important land degradation process that has a significant impact on agriculture restricting crop growth and its production. It refers to the amount of water soluble salts present in soil solution (Rahman *et al.*, 2022). The water soluble salts responsible for soil salinity belongs to neutral salts including calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), chloride (Cl^-) and sulphate (SO_4^{-2}) (Guo *et al.,* 2017). Since neutral salts are involve in soil salinization process, the pH of the soil is always <8.5 but Electrical conductivity (EC) higher than 4 dS m^{-1}. Soil salinization is associated with the accumulation of these soluble salts in higher concentration to the soil making unfavourable environment for crop growth. The soluble salts responsible for soil salinity belongs to essential nutrients except with Na^+ a beneficial nutrient, however with higher concentration of these salts in soil their lies certain negative effect to both soil and plant. Therefore, the problems developed due to soil salinity are primarily related with the salts of Na^+ and Cl^- in soil

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(Li *et al.,* 2019; Rahman *et al.*, 2022; Bhardwaj *et al.*, 2020). Soil salinity level varies from place to place which predominantly depend upon the climatic condition of a region and is mostly confined to those regions where there is high temperature and low rainfall mostly under arid and semi-arid region (Akça *et al.,* 2020). Another important factor for soil salinization turns to be the elevation level of land where lower elevated land has chances of concentrating more level of soluble salts as in coastal region (Celleri *et al.*, 2022). In near future it is expected to affect the world food production more strongly and extensively with increasing distribution of soil salinization. When the salinity level in soil increases more than 60 mM, it is evident that the Na^+ level also increases. Increasing soil salinity has a significant effect on soil properties especially soil structural stability, affecting soil infiltration and permeability and ultimately affecting soil water movement which will impact directly or indirectly to plant growth. But, directly soil salinity will affect the absorption of water by plant roots, impart toxicity and finally retard growth. So, soil salinity is always related with the water stress developed in the vicinity of roots in soil (Arif *et al.,* 2020; Ma *et al.*, 2022).

The absorption of water from soil by plant depends on the potential gradients generated from soil-plant, plant-leaves and leaves-atmosphere. For proper water absorption there must be a decreasing trend of water potential from soil to leaf of a plant. The lowest water potential on leaf surface is achieved due to evapotranspiration processes taking place on the leaf surface where water content is the lowest. This lower water content and potential on plant leaf results in the movement of water from soil to roots through stem and finally to leaf, which maintained a continuum (Goyal *et al.,* 2021). However with higher concentration of soluble salts in soil, the osmotic potential increases reducing the soil water potential of root rhizosphere that breaks the continuum of water potential from root to leaf. An extra energy has to apply by the plant to absorb water against the concentration gradients which results in lower growth of the plant and productivity. Excess amount of soluble salts in the vicinity of the root zone under saline condition will hamper the water absorption by plants resulting in water stress condition (Hussain *et al.,* 2019). The impact of soil salinity can be categorized into direct and indirect effect (Chen *et al.,* 2019). The direct effect includes reduction of water absorption by plant due to disruption of water potential continuum with excess amount of dissolved salts in the soil. Another is the ion toxicity to plant with higher concentration of dissolve salts which is harmful for the proper functioning of a plant. Cl^- toxicity can developed in saline soil and will lead to show certain visual symptoms like leaf burning, dry leaf tissue, stunted growth and in severe cases death of the plant. Indirectly it interferes with the nutrients absorption which is one of the most important factors for proper plant growth. There are certain antagonisms between essential nutrients and the harmful ions during soil salinity (Zörb *et al.,* 2019). With the increase concentration of dissolved salts (mostly Na^+ and Cl^-), Na^+, especially compete (antagonistic effect) with NH_4^+ and K^+; Cl^- with NO_3^- which drastically affect plant growth (Javed *et al.,* 2022). Indirectly soil salinity affects soil structure making soil more dispersed. During the ion exchange process in soil higher concentration of Na^+ ions will replace cations like Ca^{2+} and Mg^{2+} from the clay lattice which actually maintained the soil aggregate stability. Furthermore because of low charge density and higher hydrated ionic radii of Na^+, it will disperse the soil primary particles (sand, silt and clay) making structurally unstable (Choudhary and Kharche, 2018). Thus aggregation of soil particles is drastically affected making soil more dispersed. The dispersed particles (especially silt and clay) on the other hand will block all the pores of soil affecting soil permeability. The infiltration rates of soil drops drastically resulting in water stagnation and higher rate of erosion during rainy season. In dry spell the dispersed soil becomes hard enough and cracks are form which will severely affect the seed germination and root growth.

Plants have different mechanisms to mitigate salt stress and most of it are an active processes were additional energy must spend for it. Some of the important mechanisms include enzyme production in the root cell membrane, removal of excess salts through plant leaves and filtration in the membrane bound organelle vacuoles. The above mechanism to withstand soil salinity requires additional amount of energy that can impact proper growth of the plant

(Zhao *et al.,* 2020). So, now it is high time to find out a strategy to cope up the soil salinity problem. Different strategies to withstand the effect of dissolve salts in saline soil causing water stress and ion toxicity is to reduce the concentration of salts in soil and absorption through roots. If the toxic salts attached in the clay lattice can be removed or the toxic ions in the soil can be replace by some other essential nutrients which doesn't have toxicity effects to both soil and plants, can be another strategies to reduce the effect of salt stress. It has been reported that their lies an antagonisms between the ions (Na^+ and Cl^-) of dissolved salts with some of the essential nutrients/ions (Ca^+, Mg^+ and K^+) (Naz *et al.*, 2021; Wakeel 2013). This antagonistic relationship can be used as a remedial measure to control soil salinity problem. Out of all K^+ because of it luxury consumption properties it is widely used to control the salinity stress in soil and plants.

Major causes of soil salinization

Salts are not an alien to the soil. It is available on the earth crust in the form of primary minerals since our earth is formed. After all most of the salts presences in soil are essential nutrients, its optimum availability to soil is vital for proper plant growth. The only problem in soil salinization is excess deposition of soluble salts to the soil. Any factors that deposit or increase the concentration of salts in soil are responsible for salinization. Different causes of soil salinity can be grouped into four factors (Fig. 1) viz. Geological, climatic, hydraulic and anthropogenic factors depending on how the salts accumulation takes place. However, major factors can be categorised into primary and secondary factor affecting at the spatial and temporal scale (Seydehmet *et al.,* 2018). Different natural phenomenon that determined the salinization process belongs to primary factors (Rafik *et al.*, 2022). So, geological, climatic, hydrological and topographical factors belong to the primary salinization. Whereas different anthropogenic activities like Faulty agricultural practices, canal irrigation, irrigation with saline water, shallow water table, tube well irrigation, industrial waste water and deforestation comes under secondary salinization. Geological factors include volcanic eruption, parent materials, its transportation and deposition. Most of the rocks formed after cooling and consolidation of molten magma are primarily polymineralic and different mineral salts are present in it. After disintegration and decomposition of the rocks and mineral constituents the salts present in it will transfer to soil. The weathered parent materials containing salts will be transported by different agents (wind, water, gravity, snow etc.) and distributed to different places which alter the properties of soil. So, naturally salts are present in every type of soil which concentration depends on the mineral constituents of the parent rocks/materials. However the problem of soil salinity lies with the climatic condition of the region. Although salinization takes place in all climatic regions but generally it confined to the region where there is high temperature and low rainfall. Under this condition evaporation loss of soil water will triggered, resulting more salt to be concentrated on the surface soil. Furthermore, with scarcity of rainfall water movements are restricted making water to stagnant in a particular places and after evaporation more salts will concentrate in the soil. So, naturally saline soils are widespread in the coastal region, arid and semi-arid region of the world. Topography also influences soil salinization directly with the depth of groundwater and indirectly with lateral and vertical infiltration of sea water to the aquifers (Celleri *et al.,* 2022). Topographic condition and saline shallow water table are also the most effective factors responsible for soil salinity built up (Akça *et al.,* 2020). When ground water gets shallower there is an up flow of water containing higher concentration of salts through capillarity to the plant root zone and surface soil. Water logging and soil salinity decreases with increase in elevation along topographical gradients. It is also predicted that the impact of global warming could increase sea level resulting with increase in vertical and lateral infiltration of sea water to aquifers that could enhance soil salinity problem. So, in the low lying region higher concentration of soluble salts coupled with high evaporation rate leads to accelerate soil salinization making more vulnerable to salt stress.

Secondary factor of soil salinization primarily includes land use change, deforestation, climate change and irrigation (Wang *et al.,* 2020; Yang *et al.,* 2019; Bernzen *et al.,* 2019; Moharana *et al.,* 2019). Land use change primarily to increase the agricultural holdings for feeding the growing population globally is one of the major factors for soil salinization. It has been reported that an extensive and rapid change of ecosystem takes place over the last 50 years, which has not took place in any other time (Hobbs *et al.,* 2009). These changes are mainly related with the land use change for the increasing population globally. Clearing forest for agriculture practices leads to soil health deterioration which ultimately reduces the crop production constantly if not maintained properly. Land use change altered the potential characteristic of the area making more vulnerable to the present climate change. So, understanding the information of land use change is also essential to assess the effect of climate change and environmental impact due to human intervention (Borrelli *et al.,* 2020). In arid and semi-arid region, soil salinity is mostly due to the capillary rise of water from groundwater leading to the upward movement of soluble salts along with water making high concentration of salts in the surface soil. Any land use changes that affect or reduced the hydrological cycle will leads to increase the level of water table accelerating the salinization problem. It can be seen that the salinity problem due to land use change is mostly due to overexploitation of land for agriculture practices (Table 1). So, with increase in agriculture holding more exploitation of natural resources also increases making more vulnerable to soil salinity. And most of the secondary factors relating to soil salinization are due to intensive agricultural practices.

Another important secondary factor for soil salinization includes the present climate change which is a big concern for soil health sustainability and food security. The most important concern for soil health due to climate change is severe exhaustion of soil organic carbon (SOC). By 2050 the content of SOC in soil is predicted to reduce by 14% to 23% (Haj-Amor *et al.,* 2020). For agriculture sustainability and soil health an optimum amount of SOC is essential. And, as far as climate change is concern soil is an important sink for carbon (C) which has an impact on global warming (Rawat *et al.,* 2022). So, the climate change especially with temperature and erratic rainfall will greatly affect soil salinization problem in the near future. Since soil salinization is all about the deposition of salts in the surface soil due to excess evaporation of water containing solutes. So, increase in atmospheric temperature with low rainfall due to global warming, there is likely to increase the salinization problem in near future. It is projected in coastal region to reach the salinity levels more than 4 dSm^{-1} in 2050 (Haj-Amor and Bouri, 2019). Another study using HYDRUS-1D and the global circulation model (MIROC5) shows that the electrical conductivity of the cultivation region of northeast Thailand is predicted to increase up to the average value of 3.31 dSm^{-1} in the year 2081 to 2100 (Yoshida *et al.,* 2021). Different researchers has also predicted to increase the soil salinity level globally which is directly or indirectly related with the climate change/global warming. So, now it is time to get ready for the consequences for our action with some strategies to mitigate the soil salinization problem especially in agriculture sector. Because "everything else can wait, but not agriculture" a remarked by Jawaharlal Nehru (Swaminathan, 1972).

For an intensive agriculture and crop diversification water is a vital component. Large distribution of rainfed agriculture (52 percent of country's net sown area) in India results in need for area expansion under irrigation to increase food security (Bal *et al.,* 2022). However, water requirement for domestic use, industrial requirement and agricultural need increases but the supply of fresh water globally decreases with time (Flörke *et al.,* 2018). There are certain reasons affecting fresh water availability, but among all one of it is the present global climate change (Flörke *et al.,* 2018). So, the progressive requirement of water for different sectors leads to reused and recycled of the available water (Ghernaout, 2018; Phogat *et al.,* 2020). In agriculture with rapid increase in human population, demand for diverse food items increases substantially. Water is one of the most important inputs which are vital for crop production. But the availability of good quality water for irrigation purpose decreases substantially particularly in those regions of arid and semiarid. So, to meet the need of irrigation water, recycling and reused of water is a quiet a common practices. In many part of the globe used of field drainage water has already been started despite of higher concentration of salts present in it (Abou El Hassan and Allam, 2017). The salts concentration increases with every recycled and reused of water if not treated properly. But to meet the water requirement of today's intensive agriculture, farmers did not concerned about the salt present in the irrigation water and subsequently accelerated soil salinity. Increasing shortage of irrigation water with increasing demand for food production in agriculture makes the farmers use more and more ground water (Pulido-Bosch *et al.,* 2018). Therefore, used of poor quality ground water for irrigation in the surface soil also substantially increase the salt concentration accelerating soil salinity problem.

Impact of soil salinity on plant

Salt is associated with the rocks and its minerals constituents during earth formation. The primary salt mineral present in earth crust is rock salt or halite. During the process of soil formation i.e. the disintegration and decomposition of rocks and minerals, salts are transferred to the soil. So, naturally salts are important constituents of soil and its present in soil is important as salts are nutrient to both plant and animal (Herbert *et al.,* 2015). The only concern is the quantity of salts within a threshold value. If the quantity of salts exceeds a threshold value, only then it will be harmful to the plants. The accumulation of excess salts in soil which eventually affect the crop growth and even death of the plant is due to the abiotic stress developed in soil which is referred to as salt stress (Abdelraheem *et al.,* 2019). Salt stress is one of the limiting factors for crop production especially in arid, semi-arid region and coastal. In salt stress condition the process of osmosis can reverse and water will come out from the plant to soil due to higher concentration of dissolved salts in soil. In this situation plant will loses water and suffer stress with stunted growth. The pathway of water from soil through plant to the atmosphere or the soil-plant-atmospheric continuum (SPAC) will be greatly affected by salt stress condition (Minhas *et al.,* 2020). The potential gradients developed from root through shoot to the shoot will disrupt. The water potential in the soil will dropped resulting in reverse flow of water from plant to soil. So, the impact of salt stress is quiet related with the draught stress, since in both the cases water is the limiting factor for proper growth of the plant (Forni *et al.,* 2017). The main impact of salt stress can be grouped into three broad topic i.e. germination effect, physiological effect and ionic effect (Farooq *et al.,* 2017; Jangra *et al.,* 2022). Seed germination is an emergence of radicles through the seed coat which is a very important stage in a plant life cycle. For a proper germination and early seedling growth a sufficient supply of water in soil is essential for appropriate imbibition of the seed coat for radicle to emerge. During this early establishment stage of plant they are very sensitive to the salt stress either because of osmotic effect reducing water absorption or ionically through the toxic effect of ions causing imbalance in nutrient uptake. Different other reason for salt stress on germination can be suppressed protein content, reduce phosphatase activity, increased soluble sugar, starch, absicic acid and reducing gibberellic acid.

Photosynthesis is one of the most important processes where green plant transformed light energy to chemical energy. It provides 90% of the plant dry matter. However this process is highly sensitive to salt stress with its effect on opening and closing of stomata (stomatal conductance), destruction of chlorophyll pigments and damage of photosystems (PS) reaction in plant (Mahlooji *et al.,* 2018). The extent of stress by salts on photosynthesis depends on the types of salt stress, its concentration, duration of stress, plant species and its age (Ma *et al.,* 2020). The effect of soil salinity on plant photosynthesis is primarily related with the reduction of PSII activities than stomatal reduction (Najar *et al.,* 2019). Under salinity stress condition, relative water content (RWC) of plant decreases with concomitant dropped of leaf water potential (LWP). Accumulations of toxic ions like Cl^- and primarily Na^+ in plant leaves affects cell turgidity which ultimately leads to the closing of stomata (to prevent cell plasmolysis) reducing CO_2 uptake and photosynthetic process. Cl^- toxicity in glycophytes leads to chlorosis and necrosis of leaves which reduces the plant growth. Visual symptoms start from the leaf edges which precede the inner leaf and finally leaf abscission takes place. Cl^- toxicity developed due to soil salinity is not only a thread to food security but it also affects the aesthetic values of ornamental plants leading to decrease its marketable values. The toxicity effect of chloride is more severe than sulphate in saline soil (Irakoze *et al.,* 2022). It has been reported that half the concentration of chloride toxicity is equal to full concentration of sulphate.

Different salts affect crop growth differently (Javed *et al.,* 2022). Even though stress developed due to soil salinity is always associated with the excess amount of NaCl in the soil. Different other salts are also present in salt stress soil of which salts of Na^+, Cl^-, SO_4^{-2}, CO_3^-, HCO_3^-, and BO_3^- are common. It has been reported by different researchers that salinity problem caused by Cl^- and SO_4^{-2} are not similar (Yu *et al.,* 2018; Ahmadi and Souri, 2018; Reich *et al.,* 2017). On different studies conducted on rice, wheat, maize and French beans shows less detrimental effect of SO_4^{-2} salts compared with Cl^- salts on growth and yield. Under solution of same concentration (Isoosmotic concentration), Cl^- salinity is much more toxic than SO_4^{-2} salinity affecting photosynthesis of peanut and causes severe leaf chlorosis reducing its growth. Sweet pepper plant growth is also significantly affected by the presence of Cl^- when compare with SO_4^{-2} salinity reducing its fruit quality and marketable value of pepper (Navarro et al., 2002). The toxicity effect of SO_4^{-2} salinization on sorghum species is comparable or even more than Cl^- toxicity which increases with increase in its concentration due to suppression of K and Mg in the shoot. In a hydroponic culture technique under barley crop SO_4^{-2} salinity is more detrimental than Cl^- under different cultivar used in the study (Datta *et al.,* 1994). Different salts (NaCl, Na_2SO_4 and Na_2CO_3) in soil affect fresh dry matter and water content of the pea plant differently. The toxicity effect of different salts affect pea plant is in the order Na_2CO_3> NaCl> Na_2SO_4 (Abd El-Samad and Shaddad, 1996). In another study the stresses developed by neutral salts (NaCl and Na_2SO_4) and alkali salts (Na_2CO_3 and $NaHCO_3$) on barley crop differ. More severity is under alkali salts than the neutral salts. However when the salinity of a medium increases more than 60 mM, Na^+ concentration also increases slowly in saline stress but sharply under alkali stress soil (Yang *et al.,* 2009). Osmotic stress and ionic toxicity are the general problem in both saline stress and alkali stress soil, in addition to this high pH is associated with alkaline stress leading to soil structure deterioration. In many cities, globally lawn occupies maximum area of garden, backyard, park, even terraces. So, the popularity of turf grass is increasing day after day. For growing turf grass, timely irrigation is a must and understanding the salt effect on turf grass is also crucial to maintain the aesthetic and ornamental benefits. On above that turf grass possess many inevitable functional benefits such as it control soil erosion, maintain ecological balance, reclaim polluted environment, improve soil quality, reduces air and noise pollution. Different salts of CO_3^-, Cl^- and SO_4^{-2} on leaves of turf grass affect different level of injuries (leaf firing). Leaf firing injuries in turf grass is mainly due to high pH caused by CO_3^- salts and Cl^- is primarily involved in reducing the growth than Na^+ in irrigation water (Gao and Chen, 2012).

Mitigation of soil salinity

Different causes of soil salinization has already discussed in the previous sections. All of it has direct or indirect relationships with the climate (temperature and rainfall) of the region. With continuous increase in global population the effect of man-made climate change or global warming are also predicted to increase and worsen in decades to come. There is evidence that climate change will affect the intensity and frequency of rainfall and will also increase the temperature (Guntukula, 2020; Kogo *et al.,* 2021). So, scarcity of rainfall and high temperature due to climate change can increase the soil salinity problem in the near future if we do not control it. Different strategies are there to manage/reduce the effect of soil salinity to plants and it mainly includes three methods, namely eradication, conversion and control of the excess salts present in soil (Shahid *et al.,* 2018; Hayat *et al*. 2020; Hafez *et al.,* 2021). Eradication includes those practices that remove the salts from the soil through drainage or flushing whereas conversion is all about the chemical amendments used to reduce the caustic effect of salts. The reduction of evaporation lost from the soil and growing of salt tolerant crop variety are the important control method. Another method under this category can be use of any essential nutrients that has an antagonistic relationship with the salts present in soil. Due to similar physico chemical properties of Potassium (K) with sodium (Na), calcium (Ca) and magnesium (Mg), there lies an antagonistic relationship (Daoud *et al.,* 2020; Yan *et al.,* 2020). So, the widely used essential element to reduce the effect of salts is K (Table 2). Salts is not an alien to the earth, it is an important constituents of soil

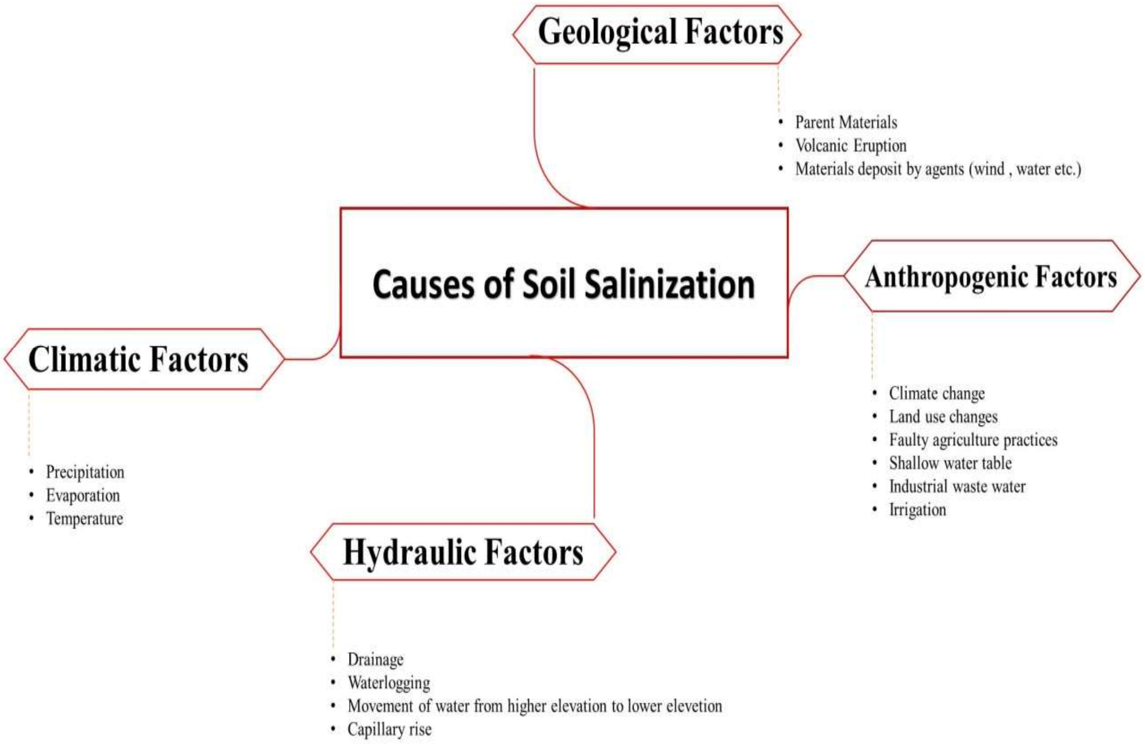

Figure 1: Different factors affecting soil salinization.

Table 1: Impact of different land use changes on soil salinity in different parts of the globe

SN	Land use change		Impact	References
	From	**To**		
1	Rice	Shrimp farming	Increased soil salinity	Ali (2006)
2	Bare land, fallow land	Intensive agriculture	Irrigation related salinization problem increases	Zewdu *et al.,* 2016
3	Grassland	Crop land	Soil salinization increases	Yu *et al.,* 2018
4	Active paddy land	Abandoned paddy land	Soil salinization increases	Gopalakrishnan and Kumar, 2021
5	Rice farming	Salt water shrimps farming	Soil salinization increases	Islam *et al.,* 2019
6	Date Palm	Bare land	Soil salinization increases	Turk and Aljughaiman, 2020
7	Unirrigated farmland; Grassland	Irrigated farmland; Farmland	Soil salinization increases	Wang and Li, 2013
8	Perennial pasture	Annual pasture	More runoff and salt load in the catchment area	Tuteja *et al.,* 2003

Table 2: Salinity control measure of crops grown under different medium by using K_2SO_4

SN	Crop	Medium	Treatment	Best	Reference
1.	Wheat (*Triticum aestivum*)	Sand culture	150 mM NaCl	200 mM	Kausar and Gull (2014)
2.	Lettuce (*Lactuca sativa*)	Nutrient film technique (NFT)	40mM NaCl	10 mM	Tzortzakis (2009).
3.	Tomato (*Lycopersicon esculentum*), cucumber (*Cucumis sativus*) and pepper (*Capsicum annum*)	Sand culture	60 mM NaCl and pH 8.5	3 mM	Kaya *et al.,* 2002
4.	Bean (*Phaseolus vulgaris*)	Control condition of temperature and light	20 mM of NaCl	1000 and 2000 $mg^{-1}kg$	Erdinç *et al.,* 2018
5.	Mustard (*Brassica juncea*)	Hydrophonic	150 mM of NaCl	6 mM	Yousuf *et al.,* 2015
6.	Rice (*Oryza sativa*)	Hydrophonic	12-24 mM L^{-1}	1.2 mM L^{-1}	Munir *et al.,* 2019
7.	Olive (*Olea europaea*)	Medium-textured soil	0, 50, 100 and 150 mM of NaCl	100 mM of K	Chartzoulakis *et al.,* 2006
8.	Sugarcane (*Saccharum officinarum*)	Hydroponic	100 mM L^{-1} of NaCl	3 mM L^{-1}	Ashraf *et al.,* 2010

derived from the weathering of different primary salt minerals. Presence of salts in an optimum condition is vital for plant growth as all of it (Ca, Mg, Na, Cl) are either essential or beneficial nutrients. Soil salinization is all about higher concentration of dissolve salts in soil near to the root zone which incite osmotic stress and ions toxicity to the plant. The extent of toxicity differs from salts to salts and also from plant to plant (Zhang *et al.,* 2018). Optimum ratios of different ions are essential in plant cells for the proper functioning and yield development. So, the antagonistic relation of K with other ions can be used as a strategy to maintain the ionic level in the plant cell that will reduce the toxicity of salts to plants. K is an essential elements required by the plant which primarily involve in water movement and stomatal functioning. Plants can absorb K in an amount far exceed from the requirement when readily available in the soil, and is called as luxury consumption of K (Jungers *et al.,* 2019). Luxury consumption of K does not influence toxicity and crop yield. Its availability in turn will reduce the ionic imbalance/toxicity impart by dissolved salts in saline soil. The antagonistic effect of K with different ions in saline soil can reduce the uptake and toxicity of ions such as Na, Ca and Mg.

Different researchers have worked under different crops to see the effect of K for reducing the salinity stress for better productivity (Table 2). A study conducted by Kausar and Gull (2014) on wheat crop initiate salt stress in sand culture at a concentration of 150 mM. Under this salinity stress different concentrations of KSO_4 (50, 100, 150, 200 mM) were applied to see its ameliorating nature on growth and yield of the crop. It has been observed that the application of 200 mM of KSO_4 proved to be the best for ameliorating the saline stress. There is also evidence from the finding of Tzortzakis (2009) in lettuce grown with the nutrient film technique (NFT) under greenhouse conditions that inclusion of K_2SO_4 reversed the negative impact of salinity on plant growth. Another worked done by Kaya et al., 2002 under different vegetable crops (tomato, cucumber and pepper) shows the effect of salts concentration (60 mM of NaCl) and pH (8.5) of the medium affecting chlorophyll content, plant growth, water absorption and membrane permeability. The adverse effect on plant is primarily due to the high salinity condition than that of high pH. But inclusion of K in the form of K_2SO_4 improved the plant health and maintained the proper ratio of the ions inside the plant. K_2SO_4 application under constant exposer of plant (beans) with 20 mM of NaCl shows positive results on nutritional element content, root and shoot dry matter content (Erdinç *et al.,* 2018). A study conducted by Taha *et al.* (2020) comparing different methods of K application for controlling salinity stress under soybean (*Glycine max*) shows the exogenous application of K_2SO_4 were more effective than seed soaking (SS) and foliar spray (FS) at improving the yield, seed quality and physio-biochemical attributes of soybean. Under saline condition maintaining higher concentration of K in any medium for plant growth serve as an effective measure for regulating the growth and productivity of mustard crop (Yousuf *et al.,* 2015). In saline-sodic stress condition, higher concentration of Na^+ results in lower uptake of K^+ in plants. Application of higher doses of K^+ results in maintaining/improving K^+:Na^+ in plant tissue enhancing rice (*Oryza sativa*) growth by improving the concentration of enzymes, physiological activities and biochemical properties (Munir *et al.,* 2019). Yield increments of wheat (*Triticum aestivum*) with the inclusion of K^+ along with phosphorus (P) in saline-sodic soils of Pakistan were observed. Application of K and P together at the rate of 150 kg K_2O ha^{-1} and 120 kg P_2O_5 ha^{-1} increased the yield of wheat by improving the nutrients dynamic of soil (Hussain et al., 2016). An experiment conducted in salt affected soils of Egypt under rice-wheat cropping system shows that inclusion of K in the form of Mono potassium phosphate along with compost treatment increases the grain and straw yield of both rice and wheat. A study conducted on a tree species of olive in medium textured soil of subtropical region of Greece shows a significant correlation of salinity with the concentration of Na^+ and Cl^- in the leaves and fruits. But with increase in K^+ concentration salinity stress decreases, which shows a negative correlation (Chartzoulakis *et al.,* 2006). A hydroponic experiment conducted to see the effect of salt stress under different genotypes of sugarcane shows enhancement of Na^+ concentration in plant tissue and significantly reduced the root and shoot growth (Ashraf *et al.,* 2010). It has been showed that application of K^+ alone or combination with silicon (Si) significantly prevent the uptake and transport of Na^+ in plant and can improve its yield even under salt stress condition. Activities of different antioxidant enzymes decreases under salt stress condition nevertheless inclusion of K^+ along with zinc significantly increase the enzymes activities. Furthermore, significant decrement of oxidative stress and increment of root, shoot and spike of wheat crop were reported with increase in concentration K^+ (Jan *et al.,* 2017).

Conclusion

Soil salinization has a significant impact on the physio-biochemical aspects, growth and yield of crops/plants, which ultimately affect the future food security. Most of the factors responsible for soil salinization directly or indirectly related with the climate. So, chances of increasing the salinity problem in the near future is expected with increasing global climate change. The continual increase of global population has a direct relation with the present global climate change. Certain unwanted activities taking so far (deforestation, landuse change, overexploitation of underground water, etc) that increased the soil salinization process is directly or indirectly related with the growing population. Complete halt of the growing population globally is not possible as so with the soil salinity problem. So, developing management practices that can reduce the salinity effect is vital for an agricultural sustainability. However finding the practice that suits the problem most is also a great concern since some management practices has certain negative effect to both soil and water. So, use of the essential nutrients (K^+ and SO_4^{-2}) that has an antagonistic relationship with the salts (especially Na^+ and Cl^-) present in soil is a new approach. Due to similar charge and physico chemical properties of K^+ and SO_4^{-2} respectively with toxic ions Na^+ and Cl^- of saline soil, there lies an antagonistic relationship. Furthermore, SO_4^{-2} of its less toxicity to plants and improve soil pH condition especially in arid and semi-arid region, the combination of K^+ and SO_4^{-2} salt is a good combination to ameliorate the Na^+ and Cl^- toxicity under saline soil for sustaining both soil and plant production.

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Conflict of interest

The authors declare that they have no conflict of interest.

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