# Influences of salinity on plant productivity

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**Accepted 16th December, 2021**

An attempt has been made to review the influences of salinity on plant productivity. The study established that salinity affects almost every aspect of plant life including germination, vegetative growth and development, reproduction, and primary production, hence impacts negatively on food security by decreasing water availability, increasing the concentration of ions and diminishing soil microbes, water permeability as well as soil aeration. Although, some plants, mainly the mangroves have some salt regulatory mechanisms in their systems, there is the need to control and effectively manage salinity using appropriate techniques which includes increased drainage, planting of salt tolerant crops and restoring balance via chemical amendments to enable us reclaim the already degraded lands, identify potential salinity issues by monitoring and proffering environmental education to all and sundry.

**Key words:** Salt stress, plant growth, salt regulation, management options.

## INTRODUCTION

Salinity is the saltiness of dissolved salt contents of water body (Aslem et al., 2011). It refers to the presence of salts in the land surface in the soil or rocks or dissolved in water in rivers or ground water. Different plants have varying tolerance levels to salinity. The problem of salinity is typified by an excess of inorganic salts and it is common in arid and semi-arid land where it was naturally formed under the prevailing climatic conditions and due to higher rates of evapotranspiration as well as lack of leaching. Salinity is seen as an environmental menace because it is a threat to plant life and agriculture worldwide (Shannon and Grieve, 2014).

Salinity had been reported to limit plant growth, development and productivity, hence considered a threat factor to food security (Yadav et al., 2011; Neymann, 2014). Although salinity can develop naturally in soils and waters, where human intervention has disturbed natural system, soil salinity also occurs naturally on sea salt marshes or areas in soil composition (primary salinization). Secondary salinization occurs when soils that once had a low concentration of salts becomes saltier because of irrigation and poor drainage (Zhu, 2001). Tertiary salinity occurs when water is reapplied to crops or horticulture over many cycles, either directly or by allowing it to filter into the groundwater before pumping it out for reapplication. Salts in soil can result in the deterioration of soil structure and decreased capacity to hold water or aerate hence affecting plant nutrition. Farmers are supposed to use fresh water to irrigate fields and farms in arid and semiarid areas but because of the high demand for freshwater in many other sectors, growers now use water with higher salt content including drainage water, treated wastewater and ground water hence salinity of soils has increased in recent times (Yadav et al., 2011). Sodicity is a secondary result of salinity in clay soils, where leaching through either natural or human induced processes have washed soluble salts into the subsoil resulting in a decreased allocation of fresh water to agriculture (Grattan and Grieve, 2000).

Salinity is a major abiotic stress factor limiting growth and productivity of many plants including rice, millet, maize, soya bean and cowpea in many areas of the world due to increasing use of poor quality of water for irrigation and soil salinization (Zhu, 2001; Agbogidi, 2021). It also affects pastures and trees by interfering with nitrogen uptake, reducing growth and stopping plant reproduction. Plant species vary in how well they tolerate salt affected soils. Salt tolerance in plants varies and it can act as drought on plants preventing roots from performing their osmotic activities where water and nutrient move from a region of a lower concentration to an area of higher concentration. High salt level interferes with the germination of new seeds and also affects seedling growth and development of many plants species. As soil salinity level increases the stress of germination and increases seedlings. Perennial plants such as alfafa and red clover can handle salinity stress better than annual plants like wheat (Badr and Shafei, 2002). In many cases, salinity can have toxic effects on plants because of the high concentration of certain salts in the soil. Salinity has been shown to result in nutrient immobilization where nutrients will be present but not in available states (Epstein, 2001).

Salinity, viewed as an excess of salts in plants, soil and or water is often underestimated in agriculture but it can build up with time and manifest noticeable effects (Parida and Das, 2005). It affects almost every aspect of plants growth including germination, vegetative growth and reproductive development as well as yields hence food security. High salt concentrations impose osmotic stress, limit water uptake from soil, encourages sodium accumulation in cells which could lead to death of cells and increase senescence because excess salt results in dehydration in the plant sap and tissues (Neymann, 2014). Depending on the type of concentration of the salt present, there may be toxicity issues and suppression of uptake of particular nutrients through ionic competition and wilting and leaf burn or dryness of leaves are common symptoms of plants which are traceable to sodium and or chlorine toxicity. Salinity affects soil structure and inhibits plant metabolism (Yadav et al., 2011).Three major types of tolerance known are; minimum, maximum and optimum ranges of tolerance. Some organisms have narrow range of tolerance (steno-range) while others have wide range of tolerance (euro-range). Salt tolerance of various plants is shown in Table 1.

**Types of salinity**

Four major types of salinity include:

1. Dry land salinity: This is a natural process for soils. This is a deliberate act by plants to prevent water from entering the soil profile thereby making the ground water to be saline**.**
2. Irrigation salinity is the rise in saline groundwater and the build-up of salt in the soil surface in irrigated areas. It is made worse when water used to irrigate comes from salty sources.
3. Urban salinity: It is a combination of excess water and salt in the environment. It causes damage to many natural and built assets including buildings, commentaries, bridges, pipelines and parks.
4. Industrial salinity: When the source is from industrial sectors like mines from groundwater, seepage and from rainwater coming in contact with mine workings or spoil.

## EFFECTS OF SALINITY ON PLANTS

Halophytes are salt tolerant plants. Halophytes grow in soils or waters of high salinity. They come in contact with saline water through their roots or by salt spray such as saline semi deserts, mangrove, swamps, marshes and sloughs as well as seashores. Notable examples are *Spartina alterniflora, Salicornia, Atriplexhalimus and A. nummularia*. They are polyphyletic; some of them are highly specialized to remove salts from their system but majority of them accumulate ions to lower cell osmotic potential (Zhu, 2001; Nikalje et al., 2019).

Glycophytes cannot tolerate salts and they are highly susceptible to high salinity. They are plant species that are not tolerant to salinity but can maintain low sodium levels in their aboveground tissues but are killed by 100-200 Mm of NaCl. They grow in non-saline soils and water bodies (Mohammad et al., 2016).

High salinity is destructive to plts.

**Table 1.** Salt tolerance of various plants.

| Salt tolerance EC (ds/m) | Field crops | Forages | Vegetable | Trees, shrubs |
|---|---|---|---|---|
| Very high, 20 | | Altai wildrye grass, lemons grass | | |
| High, 16 | Kocher, sugar beets | Altai wildlife, tall wheat grass, Russian wild rice, slender wheat grass | | Siberian salt trees, sea buckthorn, silver buffalo berry |
| 8 | 6-row barley, safflower, sunflower 2-row barley fall age, winter wheat, spring wheat | Birds foot, trefoil, sweat clover Alfalfa brome grass | Garden beets, asparagus spinach | Hawthorn, Russian olive, American elm, Siberian elm, Villous lilac, laurels leaf, willows |
| Moderate | Oats, yellow mustard Meadow fescue, flax, canola | Crested wheat grass, reed canary grass | Tomatoes, broccoli, cabbage | Spreading juniper, poplar, ponderosa pine, apple, mountain ash |
| 4 | Corn | | Sweet corn, potatoes | Common lilac, Siberian crab apple, Manitoba maple, Viburnum |
| Low | peas field, beans | Dover white, alsike dover, red clover | Carrots, onions, strawberries, peas, beans | Colorado blue spruce, rose, douglas fir, balsam fir, cottonwood aspen, birch, raspberry |
| 0 | | | | Black walnut, dogwood, little leaved linden, Winged Euonymus, spiraea, larch |

Source: Zhu (2001); Parida and Das (2005); Yadav et al. (2011).

Salinity is a wide-spread issue on the globe that impairs crop production even at very low levels. They are toxic to the plant body resulting in an inhibition of many physiological and chemical processes including nutrient uptake and assimilation and consequently reduce plant growth. At high concentrations, salts can also change the way water mixes and lead to the formation of salty pockets near the bottom of lakes, creating biological dead zones (Yadav et al., 2011). Soils can be saline due to geohistorical processes or they can be manmade. The formation is determined by the water and salt balance which is likened to oceans and seas; where more salts come in than go out. The incoming water from the land brings salt that remain because there is no outlet and the evaporating water does not contain salts. Salinity tolerance refers to the ability of an organism to withstand an extreme variation in environmental condition in terms of salinity. Plants mitigate negative fitness differently based on their general innate defense strategies and mechanisms and this plays an integral part in the survival of the organism. Tolerance traits play a major role in plant defense, development, survival, productivity and food insecurity. Nutrient disturbance under salinity reduce plant growth by affecting the availability, transport and partitioning of nutrients. While salinity can reduce the availability of some nutrients, it makes others more readily available (Aslem et al., 2011). Soil salinity is a serious environmental issue and it impacts plant growth, development, yield, productivity and hence food security.

Salinity affects crops production, pastures and trees by interring with nitrogen cycles, reducing growth and impeding plant reproduction. Some ions especially chloride are toxic to plants and as the concentration of these ions increases, the plant is poisoned and dies. High salinity results in high osmotic potential of the soil solution as such, the plant has to use more energy to absorb water. Under extreme cases, plants may be unable to absorb water hence wilting may set in even when the surrounding soil is saturated. Salinity affects almost all aspects of plant development including germination, vegetative growth and reproductive development. Soil salinity imposes ion toxicity, osmotic stress, nutrient deficiency and oxidative stress on plants thus, limits water uptake from the soil hence considered a serious environmental stress because it affects general metabolism and biomass production (Manoj, 2016)

Salinity has also been reported to negatively affect germination as shown in Figure 1.

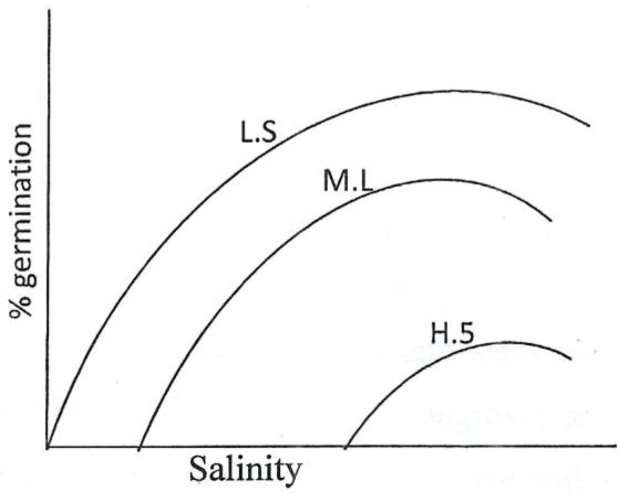


**Figure 1.** Influences of salinity on seed germination of crop plants.

## Effects of salinity on photosynthesis and food production

Water is a raw` material for photosynthesis. Increased salinity can reduce food production. At low salinity, stomatal conductance is unchanged but becomes reduced at high salinity. Mshembula et al. (2012) maintained that salinity is a great threat to agricultural crop productions. In some areas like North Atlantic near Greenland, cooled high salinity surface waters could become so dense to sink to great depths. Such changes in water cycle could significantly impact ocean circulation and the climate to which we live. High salinity is detrimental to agriculture, infrastructure and the environment. Irrigation and dry land salinity can cause a reduction in the productivity of agricultural lands and degrade the natural environments leading to a changed land use and other environmental and social impacts. Salinity has a huge effect on what species can exist in aquatic environments. The amount of salts in the water has many impacts on fish and other invertebrates including plant species. Agbogidi (2011) noted that as salinity increases, the species richness and growth of freshwater and marine biota is reduced. Agbogidi (2011) also posited that salinity is increasing at a very high rate because of anthropogenic activities of man and other abiotic factors thereby affecting the physical and biotic components of both aquatic and terrestrial environments. For example, the amount of dissolved oxygen is reduced, leading to biodiversity loss, affecting the ecosystem as a whole. Water with high salinity is heavier and denser and will definitely sink underneath less saline and warmer water. This can affect the movements of ocean currents as well as marine life forms which need to regulate its intake of salt water. Salinity has also been reported to negatively affect primary productions in marshes (Agbogidi, 2011). Changing salinity is a master factor in the distribution of both marine and estuarine habitats. Increased salinity can considerably affect aquatic organisms especially the cyanophyceae and the zooplankton. Salinity is also likely to influence the evolutionary transition to marine life. It is logical to reason that if primary productivity is directly affected by salinity in aquatic habitats, aquatic systems considered as natural endowments with great treasures and fortunes would be negatively affected thereby leading to loss biodiversity and food insecurity (Agbogidi, 2019; Emyne and Hoekstra, 2014).

## Effects of salinity on mangroves

Salinity has been shown to affect mangroves in the following ways: Delay root initiation in mangroves, reduction in final seedling establishment and rates, decreases in growth of plants, inhibition of biomass accumulation and stem elongation, decrease in leaf number and area, and reduction in nitrogen accumulation. Mangroves are generally found where salinity ranges from 0-90 ppt. Red mangroves are abundant where soil salinity ranges from 60 to

65ppt but black and white mangroves have been encountered in soil with salinities greater than 90 ppt (Parida and Das, 2005). In restricted bays and flats, water salinities often range over 40ppt and for most plant species, these conditions inhibit growth and productivity. Salt stress can induce ion toxicities such as membrane disorganization, production of reactive oxygen species and disturbances of nutrient balance (Parida and Das, 2005). Increased salinity causes reduced nitrogen accumulation in some species but inhibit the uptake of potassium which could result in apparatus destruction thereby limiting primary productivity and also decreases water quality, degrade wetlands, endanger wetland species and decrease wetland diversity (Grattan and Grieve, 2000; Agbogidi and Arinze, 2014).

**Salinity and seed germination**

Salinity can affect seed germination drastically by creating osmotic potential which prevents water uptake, or by toxic effects of ions on embryo viability. Agbogidi (2011) observed the shoot growth was significantly reduced by salinity due to the inhibitory effect of salt on cell division and enlargement in the growing plantt. Soil salinity interferes with biological uptake of nutrients and water thus, disturbing necessary physiological functions required for growth and development of plants hence salinization is a substantial contributor to land degradation and consequently a major threat to soil health and food security. Salinity also has drastic effects on the ecosystem. It affects farms, decrease plant growth, and water quality resulting in low crop yields and degraded stock water supplies. Excess salt affects overall soil health (physical, biological and chemical), reduce productivity, killing plants and leaving bare soil that is prone to erosion (Khaijah-Hosseini et al., 2014). Lower plants including fungi, algae, bryophytes and pteridophytes are affected by salinity thereby acting as toxins which are deleterious. Excess salinity can cause crop failure in plants such as sugar cane and maize (Kong, 2014).

**Salinity and plant aging**

Yadav et al. (2014) reported enhanced senescence in plants grown in high salinity when compared to those grown in low or no salinity. This implies that salinity increases plant aging. There is an alteration in the soil water balance which when not well addressed could result in dehydration and concentration of salts in the plant sap and tissues, nutrient-imbalance, products, yields and stomatal closure; all these contribute to enhance aging (Aslem et al., 2011). Salinity also has drastic effects on the ecosystem. It affects farms, decrease plant growth, and water quality resulting in low crop yields and degraded stock water supplies. Excess salt affects overall soil health, reduce productivity, kill plants and leave bare soil that is prone to erosion (Agbogidi, 2020).

## SALTS REGULATION IN MANGROVES

Mangroves are trees, shrubs, succulents, herbs, ferns, grasses, forbs and plants which grow in the tropics and subtropics, along the coastlines and are usually adapted to anoxic and saline condition of the marshy environments (Agbogidi and Arinze, 2014). Mangroves are obligate halophytes; salts are necessary for their growth. They cannot survive in fresh water environments permanently because salt water is a physiological requirement. Across the globe, halophytes are found in two distinct kinds of environments; intertidal zones and inland saline soils. The mangrove ecosystem is characterized by presence of breathing roots called pneumatophores, prop roots, ever green leaves, ability to exclude or excrete salt, viviparous germination, presence of organic and inorganic nutrients, shallow shores, presence of organic materials in the soil, high salinity as well as high tidal range among others (Tomlinson, 2003). Mangroves are faced with high salinity by the coastal environment but still survive. They have the ability to tolerate sodium chloride (NaCl) through various mechanisms. Notable examples are *Rhizophora* sp., *Avicenna* sp., *Laguncularia* sp. Salts cause stress to mangroves and they do not need it to survive. Salinity can cause osmotic stress and reduce the availability of water resulting in stomatal closure and reduced supply of carbondioxide. In the same vein, during long term saline conditions, mangroves maneuver ways to cope with high salinity. Mangroves need anatomical and morphological adaptations such as salt glands, salt bladders (for selective exclusion or accumulation of ions), development of succulence (dilution of ion concentration), cellular sequestration and a high concentration in the vacuoles causes it to take up more water and swell up. These mechanisms termed physiological responses and survival mechanisms include:

1. Salt exclusion: The red mangrove is an excellent salt excluder separating fresh water using a non-metabolic ultra-filtration system.
2. Salt secretion mostly in the black and white mangroves (Epstein, 2001).
3. Leaf fall/ leaf shedding: Salt is expelled from the mother plant when the leaves fall.
4. Accumulation of compatible solutes. This serves not only to increase cellular osmolarity to counter osmotic stress but also to avoid increases in ionic strength of cytoplasm.
5. Reduction in transpiration rate and surfaces by using stems, flowers as against leaves (Zakharin and Panichkin, 2009).
6. Active growth and increase in succulence of cells. Succulence is a mechanism to store water in tissues, which include curled leaves, fine hair, waxy cuticles, high stomatal density, reflective leaves and salt excretion from their plant organs.
7. Mangroves are well equipped with cross-tolerance mechanism and are well prepared before stress imposition. Similarly, pretreatment or priming with salinity or other stress in early developmental stage of halophytes improves their salt tolerance at later stage indicating that halophytes might have stress memory that helps them to respond better to stress conditions.
8. Effective metabolism and photosynthesis as well as the tightly knit interactions between ion homeostasis, cell signaling, cell differentiation and growth call for intensive cooperation.
9. Others include the development of various physiological and biochemical mechanisms in order to survive in soil with high salt concentrations. These mechanisms include some of the following:

a. Ion homeostasis and compartmentalization;
b. Ion transport and uptake;
c. Biosynthesis of osmo-protectants and compatible solutes;
d. Activation of antioxidant enzyme and synthesis of antioxidant compounds;
e. Synthesis of polyamines
f. Generation of nitric oxide (NO)
g. Hormone modulation
h. Some of their seeds can germinate in the presence of high salinity.
i. Some species can accumulate NaCl or synthesize osmotically compatible solutions including proline, glycine, and betaine in their shoots to increase their ability to absorb water.

**Mechanisms evolved by glycoplants to manage salinity**

Glycoplants have also evolved several types of mechanism such as osmotic tolerance (ability of the plants to tolerate initial drought aspect of salt stress and to maintain the following: A stomatal conductance and leaf expansion; b, tissue tolerance (an increase of survival of old tissues as well as helping in compartmentalization of $Na^+$ and $Cl^-$ at cellular and intracellular level to avoid toxic levels of substances within the cytoplasm and accumulation of compatiblesolutes within the Cytoplasm; c, $K^+$ accumulation and d, Na+ exclusion from leaf blades (Mohammad et al., 2016).

**Soil salinity management**

Soil salinity management relates to managing the problem of the soil and reclaiming salinized agricultural land. The major aim is to control soil degradation by salinization and reclaim already saline or salty soils. Soil reclamation includes soil improvement, rehabilitation, remediation, recuperation or amelioration. The primary method of controlling soil salinity is to permit 10 to 20% of the irrigation water to leach the soil, draw and discharged through an appropriate drainage system. The drainage water is usually 5 to 10 times higher than that of the irrigation water and it is released or discharged out through an outlet which may pose environment problems to downstream areas. Other management measures include:

1. Identification of potential salinity issues through environment monitoring and regular crop monitoring of sap level using Nu-test(R).
2. Testing the soils and water will provide an

indication of their salinity and can often help in identifying the type of salts present. It also helps to identify potential issues for them to be addressed before a problem arises.

3. Salinity is the result of biophysical changes to our landscape. To manage it efficiently, we must half or reverse some of the changes including:

a. Protection and management of native vegetation as well as prevention of further loss.
b. Efficient and effective water usage. For instance, water taken from a river for irrigation can increase the salinity downstream and the quantity of salt in the landscape.
c. Afforestation will help reduce the influx of salt movement to water bodies. Salt interception schemes can also be effective. In the same vein, physically stopping the ground water table from rising and/or preventing salt from entering rivers via pumps, and
d. Environment education to all and sundry.

## CONCLUSION

This paper had established that salinity has serious significant effects on plant productivity and yields, hence, efforts should be made to control and manage salinity effects on plants and its environment in order to enhance plant productivity and food security.

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