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Impact of saline water on growth, yield, quality, nutrient uptake in various crops: A review

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Abstract
This article as a review, gives concise information on effects of saline irrigation water on various growth and yield attributes of various crops and their nutrient uptake rate by influencing the nutrient status in soil system. One of the major problems confronting irrigated agriculture nowadays throughout the world is the decreasing availability of fresh water. Nowadays, the competition for fresh water in the development of urbanization, industry and agriculture caused the decline of fresh water for irrigation. The progressive decrease of fresh water resources is leading towards the inevitable use of saline water for irrigation purpose. Any degradation in the quality of soil can significantly produce many undesirable changes in the environment and also reduces the overall crop yield. Adoption of suitable and possible handy options available to curb effect of saline water under cultivation of various crops is highly necessary to enhance the productivity by sustaining the environment.

Keywords: Saline water, growth, yield, nutrient, quality, soil properties, EC

Introduction

Saline water is used to irrigate croplands in different parts of the world, especially in arid and semi-arid regions, which occupy 41% of the global land surface (UNDP 1997) [41], with poor water quantity and quality. In addition, irrational human activities, such as poor agricultural management, flood irrigation and so on, also aggravate salinization, due to ineffective control of the accumulation of salts in soil. Therefore, salinity increases in extensive portions of irrigated lands, which become degraded by salinization (Ghassemi *et al.* 1995) [17]. The negative impact of saline irrigation water can be mitigated by implementing appropriate management of saline water and soil, which requires a better understanding of how growth, yield, nutrient uptake and soil properties are affected by the irrigation system, water management strategies, irrigation frequency, etc., and when to use saline water to irrigate arid croplands. The aim of this review was to study the effects of saline water irrigation on various crops. As a result of irrigation with alkali-saline groundwater and poor agricultural management, the phenomena of soil salinization have increased significantly in recent decades (Ma and Wei 2003) [24]. Khodapanah *et al.* (2009) [22] stated that excess salt increases the osmotic pressure of the soil solution that can result in a physiological drought condition. Even though the field appears to have plenty of moisture, the plants wilt, because of insufficient water is being absorbed by the roots to replace the water lost from transpiration. Irrigation water quality has been found to affect the soil chemical and physical properties including infiltration. For the moderate and high EC-SAR water treatments, sodium concentration was significantly higher and the calcium and magnesium levels were significantly lower in the surface layer of soil compared with the sub soil (Ayers and Westcot, 1994) [6]. Zartman *et al.* investigated the variation of physical and chemical properties of sandy and calcareous soil under saline water irrigation. They reported that four years of irrigation led to dramatic increase in conductivity, soluble sodium, calcium, magnesium, and sodium adsorption ratio of the soil solution. The results also implied an evident decrease in hydraulic conductivity of the soil, but soil bulk density and moisture characteristic curve did not change considerably. Variations of the physical and hydraulic properties of the soil will inevitably cause variations of salt and water movement in the soil. The primary effect of high EC water on crop productivity is the inability of the plant to compete with ions in the soil solution for water termed as physiological drought (Bauder *et al.*, 2006; Tatawat and Singh Chandel, 2008; John Alexander and Mahalimgam, 2011) [8, 40, 20]. As a result, deficit irrigation and saline water irrigation have been used more prevalently in agriculture to overcome drought and sustain crop yields (Oron *et al.*, 1999) [28]. Salt stress in arid and semi-arid regions is one of the major stresses that can severely limit plant growth and productivity (Sharma and Rao, 1998) [35].

Effect of saline irrigation water on Growth attributes

Ali *et al.* (2006) [2] revealed that a low level of salinity with electrical conductivity (EC) of 5 to 6 dSm-1 can cause significant reduction in plant height of susceptible rice lines. Fraga *et al.* (2010) [15] investigated the effect of different levels of salinity of irrigation water of 0.3, 0.75, 1.5, 3.0 and 4.5 dSm-1 on plant attributes and found that the irrigation water salinity between 1.5 and 3.0 dSm-1 caused a quadratic reduction of the plant height ($p < 0.01$) of plants. Bustan *et al.* (2004) [10] determined the effects of saline water irrigation on potato production in an arid environment with special focus on the interactions with weather conditions revealed that tuber yield was most sensitive to combined salt and heat stress when heat waves occurred at 40–60 days after emergence. The combined stress apparently leads to the collapse of mechanisms for avoiding salt accumulation in young expanding leaves, resulting in failure of vegetative growth recovery and a consequent reduction in the leaf area index and canopy functioning. The effects of drip irrigation with saline water on waxy maize (Kang *et al.*, 2010) [21] revealed that as salinity of irrigation water increased, seedling biomass decreased, and the plant height, fresh and dry weight of waxy maize in the thinning time decreased by 2% for every 1 dS m^{-1} increase in salinity of irrigated water. Irrigation water use efficiency (IWUE) increased with the increase in salinity of irrigation water when salinity was <10.9 dS m^{-1}. Precipitation during the growing period significantly lightened the negative impacts of irrigation-water salinity on the growth. Sifola and Postiglione (2002) [37] found that carbon assimilation rate, stomatal conductance and water use efficiency of the saline treatments were lower than the fully irrigated plants at 0.54 dS m^{-1}. Salinity decreased plant dry matter and height at harvest. Irrigation by saline water of EC 10 and 13 dSm-1 significantly ($p = 0.05$) suppressed most growth attributes of wheat compared to irrigation by fresh water of salinity 0.385 dSm-1. LAI at 49 and 90 DAS decreased significantly as salinity of irrigation water increased except for 4 dSm−1 in which the LAI increased significantly compared to the other treatments. Mojid *et al.* (2013) Cicek and Cakirlar (2002) [11, 12] observed that with increasing salt stress from -0.3 and -0.5 MPa caused a decrease in shoot dry weight. Azevedo Neto *et al.* (2004) [7] revealed that salinity (25 mol L-1 per day NaCl salt for 15 days) reduced the dry biomass of maize root and shoot. Billah *et al*. (2017) [9] conducted an experiment with different levels of salinity 0, 8, 12, 16 dSm-1 in rice and determined that reduction percent of shoot weight was the lowest in 8 dSm-1 (65.33%) of salinity and was the highest in 16 dSm-1 (97.90%). Aref, F (2013) [5] reported that the primitive growth stages of rice, *i.e.,* tillering and panicle initiation showed more sensitivity to salinity than final growth stages (panicle emergence and ripening). Therefore, the researcher concluded that, irrigation with saline water at the early growth stages has more negative effect than on yield and its components.

Effect of saline irrigation water on yield and yield attributes

Singh *et al*. (2009) [38] studied the effect of saline water irrigation with double line source line sprinkler on wheat and concluded that increasing the quantities of water applied with saline/alkali waters using sprinklers can enhance productivity of wheat. the rate of decline in yields of wheat was less with sprinklers (2.7%) when compared with the conventional flood irrigation (3.9%) method per unit increase in salinity. Rad *et al*. (2012) [31] found that application of four levels of saline irrigation water (2, 4, 6 and 8 dSm-1 respectively) at four growth stages (tillering, panicle initiation, panicle emergence and ripening) significantly decreased length of filled panicle, number of filled grains per filled panicle, number of spikelets per filled panicle and total number of spikelets per panicle of rice. Ming chen *et al*. (2009) [26] studied the effect of saline water irrigation to oleic sunflower through drip system in silt soils and found that yield decrease with the increase of salinity of irrigation water.. The yield decreased by 1.8% for every 1 dS m^{-1} increase in salinity level of irrigation water. Feizi *et al.* (2010) [14] higher levels of water salinity the yield components such as seed yield (26%), biomass yield (dry weight) (71.1%), number of plant per hectare (63.6%), 1000-seed weight (52.3%), plant height (62.4%), number of capitula per plant (60.4%) and capitula weight per plant (60.4%) were significantly decreased. Although, irrigation with high amount of salt in water (11.2 dS m^{-1}) during the entire growth period reduced the yield, irrigating with water salinity of 3.4 dS m^{-1}, until plant emergence and then applying high irrigation water salinity levels significantly increased the yield components. Leaching application caused a significant increase in the yield and yield components. Jha *et al*. (2012) [19] found that water quality had pronounced effect on physical and hydrological properties of soil and affected the yield of wheat crop. Imposition of treatment of gypsum (3.03 kg m^{-3}) and FYM (3.13 kg m^{-3}) has improved water use efficiency of wheat crop. Application of gypsum based on 100% neutralization of RSC value of irrigation water resulted in significant improvement of crop yield and water use efficiency of crops. Yuan *et al.* (2018) [42] found that the maize yield decreased over 25% and the water use efficiency also gradually declined when irrigated with water containing 6 gL-1 and 9 gL-1 salinity levels. It was observed that higher salinity level of irrigation water and long duration of saline water irrigation resulted in more salt accumulation and decline in yield. Aref and Rad (2012) [4] noticed that reduction in spikelets per panicle in saline water treatments was upto 26% when compared to fresh water treatment.

Effect of saline water irrigation on composition, uptake of nutrients and quality

Increase in salinity level increased the levels of Ca, Na and Cl in the plants and decreased the levels of K, N and maize yield (Akhtar *et al*., 2003) [1]. Prasad *et al.* (2006) [30] studied the effect of varying levels of inorganic ameliorants pyrite (P) @ 0, 5, 10 and 15 g and organic ameliorants molasses (M) @ 0, 5, 10 and 15g on various parameters of green gram with saline water irrigation and found that with the increase in saline water levels @ 50 me L^{-1} significant decrease in the protein, N, P, K and S contents in grain and straw of green gram. Whereas, the applied inorganic and organic chemical ameliorants @ 15 g pot^{-1} achieved better uptake by plant, which may be ascribed to its role in improving soil physical properties. De Pascale *et al*. (2003) [13] reported that the Na and Cl concentrations increased in salinized plants where as nitrogen content, K Ca and Mg concentrations decreased upon salinization. Pervaize *et al.* (2002) [29] observed that with an increase in salinity, the K content was decreased where as Na concentration increased. Irshad *et al.* (2004) [18] showed that saline irrigation water has a tremendous impact on the yield potential of crops. When the crop is irrigated with saline water, the roots contained the highest Na content; Ca and Mg were higher in the leaf, whereas K and Cl were highest in the stalk. Salinity reduces the growth of plant through osmotic effects, reduces the ability of plants to take up water and this causes reduction in growth. Na+ and Cl- are the principal ions in majority of salt affected soils, which mainly affect plants growth. The roots of rice plants readily absorb Na+ which are distributed in all plant organs to pose ion damage, osmotic stress and imbalance nutrition (Siringam *et al*., 2011) [39]. Almodares and Sharif (2007) [3] in Iran revealed that salinity of water has an adverse effect on sugar beet and sweet sorghum biomass. The effect of irrigation water quality was not significant for sugar characteristics such as brix, pol and purity. However, responses of cultivars on the above parameters were significant and sugar beet cultivars had higher brix, pol and purity and lower invert sugar and starch than sweet sorghum cultivars. Maqsood *et al*. (2008) [25] reported that a decrease in protein and fiber content accumulation in maize grain is associated with salt stress. High external Na+ concentration interferes with nitrogen absorption resulting in low protein concentration in the grains. The obtained results show that salinity not only reduces plant growth and yield but also causes a nutritional imbalance and deteriorates grain quality.

Effect of saline water irrigation on soil physical and chemical properties of soil

Shainberg *et al.* (2002) [34] also reported that irrigation with saline water may introduce sodium into the exchange complex of soils. Exchangeable sodium deteriorates soil structure and permeability. Further the agriculture-induced salinity and sodicity not only influences the chemical and physical characteristics of soils but also greatly affects soil microbial and biochemical properties (Rietz and Haynes, 2003) [33]. Irrigation with saline water increased soil salinity and alkalinity (ESP) and decreased growth of plants and yield (Sharma and Dubey, 1988; Rajesh and Bajwa, 1997) [36, 32]. Lal *et al*. (1998) [23] studied the quality of ground water and its impact on soil properties. The results revealed that the ground water parameters like Na, Mg, Ca, etc. were dominated followed by carbonates and bicarbonates. The EC of soil was significantly and positively correlated with EC of irrigation water. Murray and Grant (2007) [27] reported that salinity has direct effect on soil structure due to high concentration of sodium. If the soil is irrigated with saline water, the cation exchange capacity of soil becomes concentrated with sodium creating a sodic soil.

Conclusion and Recommendations

The increasing demand for water in the world, especially in the arid and semi-arid regions, has forced growers to use saline water. However, long-term use of saline water accumulates salts in soil and results in unsustainable irrigation practice leading to the necessity of land drainage and land leaching. Disturbed ionic homeostasis due to salinity caused a marked reduction in growth and yield components of crops accompanied with low nutrient contents in shoot, root and grain and pose risks to soil health. Likewise the quality parameters including grain protein, fat and fiber contents were also decreased in response to salinity caused by irrigation water

The use of poor quality irrigation water without proper amendments should be discouraged as it can increase soil salinity. With the use of saline waters for irrigation, there is need to undertake appropriate management practices to prevent the development of excessive soil salinization for crop production. Management need not necessarily attempt to control salinity at the lowest possible level, but rather to keep it within limits commensurate with sustained productivity.

Management practices for the control of salinity include: selection of crops or tolerant varieties that will produce satisfactory yields under the resulting conditions of salinity, land-preparation and planting methods explored aid in the control of salinity, irrigation procedures that maintain a relatively high soil-moisture regime and that periodically leach accumulated salts from the soil and maintenance of water conveyance and drainage systems and use of organic manures, green manures and amendments. The crop type, the water quality and the soil properties determine, to a large degree, the management practices required to optimize production.

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