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SOIL SCIENCES

ROLE OF LEACHING FRACTION TO MITIGATE ADVERSE EFFECTS OF SALINE WATER ON SOIL PROPERTIES

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ABSTRACT

The general response of plants to soil and water salinity depends upon climate, soil characteristics, topography and management strategies. Water, even may be saline, is becoming more precious natural resource. Hence, there should be more crops and jobs per drop while conserving the quality of present terrestrial and ground water. Saline water has been used for production of fodder and forages in many countries. Managing soil and water salinity under prevailing conditions of Pakistan is very important subject. Use of brackish water increased the salt concentration of soil. Resultantly, the growth of plants and yield becomes at threat. The salt stress is translated into decrease in growth rate and resultantly, biomass production decreases significantly. This reduction is gradual, depending upon increase in salt concentration in the root medium, while each species has a critical threshold value where it will start showing negative response. Leaching fractions may help keeping concentration of salts low when irrigation water is saline. Current experiment was conducted at College of Agriculture, University of Sargodha during the year 2018. The objective of study was to check the role of leaching fractions of mitigate adverse effect of saline water on soil properties. In this experiment saline water of 03 types (canal, EC = 2 and 3 dSm^{-1}) were used as such and with leaching fraction of 0, 10 and 20%. Randomized complete block design was used to make layout of experiment with three replications. Sorghum was used as test crop. Pre and post-harvest soil analysis was carried out for different physical and chemical characteristics i.e. pH, EC and SAR, organic matter, phosphorus and potassium. Results of the experiment indicated that leaching fraction technique proved successful to mitigate the negative effects of saline water irrigation on soil properties (pH, EC, SAR, organic matter content, concentration of phosphorus and potassium).

KEYWORDS: Canal and brackish water; soil properties; sorghum; leaching fraction; Pakistan.

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INTRODUCTION

Saline water is one of the key factor that limits crop growth and yield because most of the water available for irrigation is unfit for irrigating crops due to the presence of excessive concentration of salts (Fuller *et al.,* 2012).The use of saline water for prolong time for irrigating crops increase the EC of the soil (Kim *et al.,* 2016). Saline water irrigation has negative impacts on soil water- plant-relationship, sometime limiting the physiological activities of the plants and eventually the production of crops (Plaut *et al.,* 2013). There is a need to minimize the salts toxicity and improvement in soil properties by using the cost effective approaches soil (Shaaban *et al.,* 2013).

Pakistan is situated in arid and semi-arid area where low soil fertility high salt accumulation in soil and lack of good quality water for crop production are key problem. Careful use of marginal lands and water restrained resource is a critical technique for sustainable crop production. The main role of saline water on crop production is salinity measured as EC of soil that evaluates the amount of salts or dissolved ions, charged debris in water. Salinity measurement is the major criteria for classification of water. Water is one of the most common and most important substance on earth's surface. Deficiency of good quality water is major problem of all arid climatic regions of the world (Minhas *et al.,* 2007). In Pakistan, water shortage is noticeable stress which has adverse impact on the yield of various plants. So, improving the wise use of available resources of irrigation water is excellent way to enhance the water use efficiency in low rainfall areas (Pawlowski *et al.,* 2009). The shortage of fresh water resource limits the crop production.

The salinity of the soil is the main factor limiting the productivity of arable crops. It is estimated that 5-10% of arable land, which covers 75 to 100 million hectares internationally is affected by this natural threat

(Munns, 2005). In sodic soils, high pH, unavailability of micronutrients, disturbs structure and porosity of the soil is resulted by Na/salt accumulation. Most plants are sensitive to salts at all stages of development from seed germination to vegetative growth and reproduction. In the world, soil salinity and/or sodicity represents extra risk to sustainable agriculture. Keeping in view with a report by (FAO, 2000) that globally 8×10^{8} ha lands are affected either with sodicity (4.34×10^{8} ha) or salinity (3.97×10^{8} ha), each of which constitute about 6% of the total area in the world. The soil affected by salt is not new nor is it sudden effect of salts. However, its seriousness is increasing due to poor soil management strategies. It is revealed that extreme temperature and insufficient rainfall promotes salinization. According to a survey that 6.68 mha soils out of the all (79.61 mha) are affected by salt (Khan, 1998) and about 23.68 million-hectare lands are cultivated (GOP, 2014). In Pakistan, salt-affected soils are found on vast arable land significant extents, so application of gypsum is pre requisite to reclaim these soils (Ghafoor *et al.,* 2012). Because of higher ranges of SAR, EC and RSC pumped ground water negatively affects the crop production and soil properties (Murtaza *et al.,* 2009). While, proper management strategies could be helpful in the restoration of such deteriorated soils (Qadir *et al.,* 2001).

Soils that contain excessive concentration of soluble salts and sodicity have higher values of pH, SAR, ESP, and EC. However, salt effected soil is usually poor in potassium (K) phosphorus (P) and nitrogen (N). Because of enhanced pH due to salinity, availability of micronutrients is also adversely impaired (Lakhdar *et al.* 2009).

Improving the physical, chemical and biological properties of soils affected by salts can be restored through the use of gypsum and / or EJM as a treatment for the sustainable use of soil and crop productivity, thereby promoting growth and growth. (Ghafoor *et al.,* 2004). It may be the best way to maintain soil productivity, fertility and salt tolerance in addition to organic fertilizer (Das *et al.,* 2013). The treatment of saline soil using marinated factors such as gypsum, farm yard manure, green manure, organic modification and urban solid waste, is the subject of fruitful research and can be applied throughout the world, with great benefits like lower in cost easy to implement and effective (Hanay *et al.,* 2004). There is evidence that soil amended with organic fertilizers reduce the toxic effects of salinity in different plant species (Idrees *et al.,* 2004 and Abu-El-Majd *et al.,* 2008).

Brackish water irrigation effects on soil enzyme activity, soil carbon dioxide flux and organic matter decomposition (Iqbal, 2015). Effect of salinity was studied on catalase, invertase, B-glucosidase, cellulose and polyphenol oxidase enzymes under drip irrigation condition.The results depicted that in contrast with fresh water irrigation the activities of invertase, B-glucosidase and cellulose declined by 31.7% - 32.4%, 29.7% - 31.6% and 20.8% - 24.3% whereas soil polyphenol oxidase activity was increased. The microbial biomass and microbial quotient decreased, whereas microbial metabolic quotient increased with increasing levels of salinity. Soil carbon dioxide fluxes were in order of CK (0.31 g L^{-1}) > (3.0 g L^{-1}) > (5.0 g L^{-1}). The decomposition rate of organic matter in plastic film mulched soils was significantly higher than that in the non-plastic film mulched soils. It was concluded that brackish water adversely affects the activities of soil enzymes due to which soil microbial biomass, soil carbon dioxide flux and organic matter decomposition were decreased.

Leaching is a natural environment concern when it contributes to ground water contamination. As water from rain, flooding, or other sources seeps into the ground, it can dissolve chemicals and carry them into water. The leaching fraction (LF) is defined as the ratio of the quantity of water draining past the root zone to that infiltrated into the soil's surface. Leaching Requirement (LR) is defined to be the amount of water applied to flush out of the root zone excess salts that are present in the soil and which are detrimental to crop production. In agriculture, leaching is the loss of water-soluble plant nutrients from the soil, due to rain and irrigation. Leaching may also refer to the practice of applying a small amount of excess irrigation where the water has a high salt content to avoid salts from building up in the soil (Ghafoor *et al*., 2004). Keeping in the view above discussion current study was planned to check the role of leaching fractions to mitigate adverse effect of saline water on soil properties.

MATERIALS AND METHODS

The research was done to examine the leaching fraction; an efficient soil management strategy for the use of brackish water on sorghum plants (*Sorghum bicolor*) under field condition during summer 2018. The experimental site was carried out at College of Agriculture, University of Sargodha sited 32.08° North range and 72.67° East longitude. Its elevation is above the sea level i.e. 193 meters.This study was performed in (RCBD) design with 9 treatments that were replicated four times. The plot size was 3.5m × 3.5m having row to row spacing of 75 cm and plant to plant distance of 25 cm. The treatments of the experiments were as under:

T_1 = Irrigation of canal water (control)

T_2 = Irrigation of water of EC 2.0 dS m^{-1}

T_3 = Irrigation of water of EC 3.0 dS m^{-1}
T_4 = Irrigation of canal water (control) with 10% Leaching fraction
T_5 = Irrigation of water of EC 2.0 dS m^{-1} with 10% Leaching fraction
T_6 = Irrigation of water of EC 3.0 dS m^{-1} with 10% Leaching fraction
T_7 = Irrigation of canal water (Control) with 20% Leaching fraction
T_8 = Irrigation of water of EC 2.0 dS m^{-1} with 20% Leaching fraction
T_9 = Irrigation of water of EC 3.0 dS m^{-1} with 20% Leaching fraction

Before sowing the sorghum experimental field was prepared by 2-3 cultivation with tractor-installed cultivar. Sorghum cultivar "Hegari" was sown @ 40 kg $acre^{-1}$. To keep plant to plant distance 25 cm, thinning was done after germination. The hoeing was done two times in the whole growing season to reduce weed-crop competition. The first irrigation was applied after 10 days of germination while other irrigations were applied to the crop according to water requirements of the crops. Fertilizers like SOP, SSP and Urea were the N, P, and K sources used in the experiment.These fertilizers were applied @ 80, 60, 60 kg ha^{-1} for N, P and K respectively. At maturity, the crop was harvested, and different parameters were noted. Before sowing and after harvesting the crop, soil analysis was carried out. The soil samples were collected from the depth of 0-15 cm with the help of soil auger. From every plot, soil sample was collected. The analysis was made according to the methods as described in Handbook 60 of U.S Laboratory Staff (1969). Soil samples, dried in oven, were used for all determinations. The soil characteristics, before cultivation are indicated here:

Table 1. Analysis of experimental soil

Characteristic	Unit	Value
pH_s	-	8.1
EC_e	dSm^{-1}	0.89
SAR	-	3.62
Soil Textural Class	-	Clay loam

RESULTS AND DISCUSSION

Effect of brackish water on pH_s of soil

Soil pH affects many chemical processes in the soil. The plant nutrients availability is greatly affected by soil pH because it controls the chemical form of various types of nutrients. The use of saline water affected the soil pH significantly. The maximum value (8.4) of soil pH was measured (Fig.1) under T_3 (water of EC 3.0 dSm^{-1} with 0% leaching fraction). However, the lowest (7.6) pH of soil was obtained where irrigation with canal water was applied with 20% leaching fraction (T_7). According to Hossain *et al.* (2015) irrigation with saline water enhanced the salt concentration in soil and also increased the soil pH. According to Luedelinga *et al.* (2005) the soil pH increases with increase in salinity. However, by using leaching fraction technique, it can reduce excessive salts from root zone of plants and improved soil physical properties (Sarwar, 2005).

Effect of brackish water on EC_e of soil

Data regarding EC of soil exhibited (Fig. 2) that by the use of saline water EC of soil respond positively. The highest soil EC (3.4 dSm^{-1}) was measured under T_3 (water of EC 3.0 dsm^{-1} with 0% leaching fraction). The lowest EC (1.3 dSm^{-1}) of soil was obtained where canal water was applied with 20% leaching fraction (T_7). The work of the previous researcher also supported these results that continuous irrigation with saline water enhanced the soil pH, EC and SAR of soil due to accumulation of salts in the soil. Similar, results were reported by Zein *et al.* (2003) who stated that soil chemical properties such as soil pH, EC, SAR, Na and Cl increased significantly due to salinity. This is very simple to understand that addition of salts in the form of brackish water irrigation will lead to salt build up in soil. The same phenomenon has been claimed by Sarwar *et al.* (2003).

Effect of brackish water on SAR of soil

Soil SAR was significantly affected by the use of saline water with and without leaching fraction. Among all the treatments, the T_3 (water of EC 3.0 dS m^{-1} with 0% leaching fraction) produced the highest SAR (15.46) of soil (Fig. 3). The treatment T_7 (canal water with 20% leaching fraction) recorded the lowest SAR (5.21) of soil. According to Fard *et al.* (2007) irrigation with saline water increases the SAR of soil and leaching efficiency was helpful to decrease the water salinity that reduced the SAR of soil. Sodium adsorption ratio (SAR) is yard stick used to measure the sodicity of a soil. Sodicity is the accumulation of sodium ion in excessive quantities, which hinder plant growth directly or through the impairment of physical soil conditions. A clear decrease in soil SAR was recorded in different pot and field experiments by Sarwar (2005) due to leaching of salts.

Effect of brackish water on organic matter of soil

Organic matter is very important to provide nutrients. It also binds soil particles into aggregates and improves the water holding capacity of soil. Organic matter (%) of soil was significantly affected by use of canal and saline water with or without leaching fraction. Data regarding organic matter (%) of soil is presented in Fig. 4 which revealed that maximum organic matter in soil was obtained from the plots which were under the canal water irrigation followed by the plots irrigated with the water of EC 2.0 dS m^{-1} and EC 3.0 dS m^{-1}. Similar effect of leaching fraction was observed within treatments. Organic matter in soil of the plots having 20% leaching fraction was noted to be higher than those having 10 and 0% leaching fraction. The treatment T_7 demonstrated dominance over all the other treatments because of canal water with 20% leaching fraction. As the EC of irrigation water increased and the leaching fraction decreased organic matter in soil was reduced. The maximum organic matter (0.88%) in soil was obtained from the plots which were under the canal water irrigation + 20% leaching fraction. The minimum organic matter in soil (0.64%) was observed in the plots of treatment T_3 which were irrigated with the water of EC 3.0 dSm^{-1} with 0% leaching fraction. These results are supported by the findings of Malik *et al.* (2015) who reported that by the use of saline water organic matter (%) in soil reduced significantly. Organic matter is regarded as the ultimate source of nutrients and microbial activity in the soil. It is the deciding factor in soil structure, water holding capacity, infiltration rate, aeration and porosity of the soil. Thus, if only one soil parameter of productivity is to be considered that may be organic matter. During many studies, it was noted that leaching of salts may lead to build of soil organic matter (Sarwar, 2005).

Effect of brackish water on phosphorus content of soil

Data Fig. 12 revealed that irrigation with canal and saline water had a significant impact on the phosphorous contents of soil. The maximum phosphorus content (7.93 mg kg^{-1}) in the soil was obtained from the plots which were under the canal water irrigation + 20% leaching fraction (T_7). The minimum phosphorus content (6.7 mg kg^{-1}) was observed in the plots of treatment T3 which were irrigated with the water of EC 3.0 dS m^{-1} with 0% leaching fraction. The results of Hossain *et al.* (2015) supported these findings who described that that nitrogen, phosphorous and potassium contents of soil decreases with increase salinity level of soil.

Effect of brackish water on potassium content of soil

The availability of potassium in the soil is very essential for plant growth. The higher salinity greatly reduced the availability of potassium in the soil. Potassium contents of soil were affected significantly with the application of canal and saline water. The maximum potassium content of the soil (3.5 meq/L^{-1}) was obtained from the plots which were under the canal water + 20% leaching fraction (T_7). The minimum potassium content (2.81 meq/L^{-1}) was observed in treatment T_3 which were irrigated with the water of EC 3.0 dS m^{-1} with 0% leaching fraction. Ashraf and Ali (2008) stated that due to irrigation with saline water the potassium contents in soil decreased and thus supported these findings.

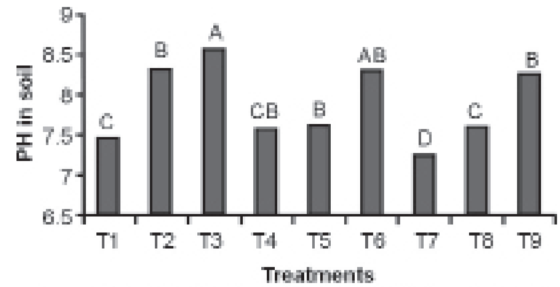

Fig. 1. Impact of canal and saline water with and without leaching fraction on pH of soil

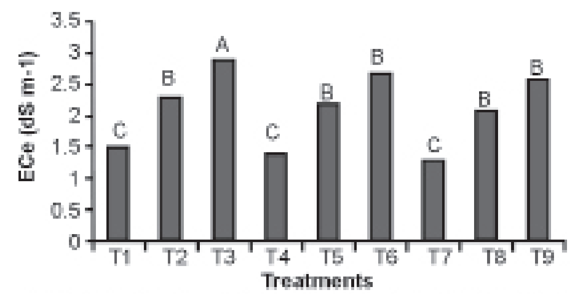

Fig. 2. Impact of canal and saline water with and without leaching fraction on ECe (dS m^{-1}) of soil

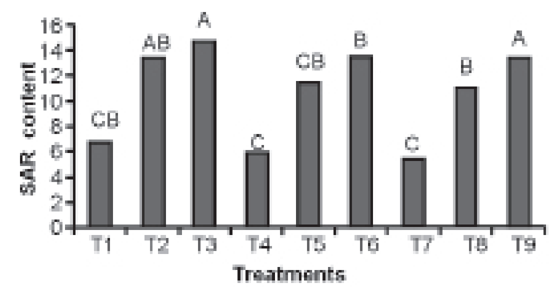

Fig. 3. Impact of canal and saline water with and without leaching fraction on SAR (meq/L) of soil

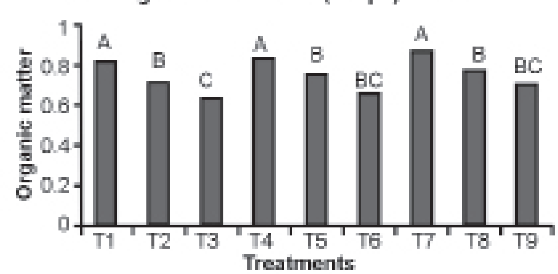

Fig. 4. Impact of canal and saline water with and without leaching fraction on organic matter

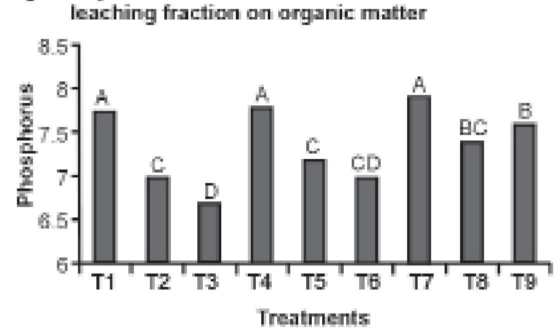

Fig. 5. Impact of canal and saline water with and without leaching fraction on P (meq/L) of soil

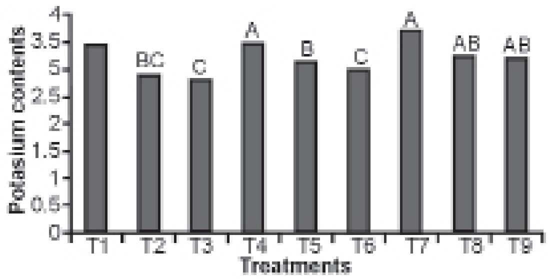

Fig. 6. Impact of canal and saline water with and without leaching fraction on K (meq/L) of soil

CONCLUSION

The results of the experiment revealed that management technique of leaching fraction proved effective in reducing the detrimental effects of saline water. The results of the study demonstrated that application of saline water with leaching fraction at various rates mitigated the deleterious effects of saline water on the growth of sorghum by improving the properties of soil as well as improving the content of nutrients in sorghum plants. Among all the treatments, T_7 (canal water + 20% leaching fraction) performed the best which produced the highest values of nutrients content in sorghum plants as well as improved the properties of soil like pH, EC, and SAR. However, the treatment T_3 (water of EC 3.0 dSm^{-1}) increased soil electrical conductivity, pH and SAR concentration.

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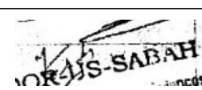
2	Ghulam Sarwar	Supervisor	
3	Muhammad Aftab	Assisted in sample collection as well as in data analysis	
4.	Mukkram Ali Tahir	Co-supervisor	
5.	Noor-us-Sabah	Co-supervisor	
6	Ayesha Zafar	Helped in laboratory analysis