Research Article

Systematic use of Saline Water with Leaching Fraction for Improving Soil Health under Arid Conditions

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Abstract | Water scarcity is major constraint toward achieving sustainable agriculture in developing countries like Pakistan. Shortage of good quality water compels the farmers to use brackish water. Use of saline water along with leaching fraction could be useful by keeping low concentration of salts in the root surrounding area. This study assessed the role of leaching in alleviating the negative effect of saline water on soil characteristics. Results of the studies indicated that 6.57% reduction in soil pH (7.6), 46.06% reduction in EC (1.3 dS m^{-1}), and 46.41% reduction in SAR (5.3) while 17.34%, 5.4% and 5.66% increase in soil organic matter, soil available phosphorus (P) and potassium (K) content respectively were obtained using canal water with 20% leaching fraction (T_7). It was found that under scenario of good quality water scarcity, systematic use of saline water with 20 % leaching fraction could be successfully used for betterment of impaired soil chemical properties (EC, pH, SAR). Our results showed that the leaching fraction was found to be effective to alleviate the negative effects of saline water on the soil properties. However, verification of this work at different agro-ecological zones and for other field crops will be required for future implementation.

Received | March 24, 2021; **Accepted** | June 30, 2021; **Published** | August 29, 2021
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Citation | Hamza, A., M.A. Tahir, N. Us-Sabah, G. Sarwar and M. Luqman. 2021. Systematic use of saline water with leaching fraction for improving soil health under arid conditions. *Sarhad Journal of Agriculture,* 37(4): 1222-1229.
DOI | https://dx.doi.org/10.17582/journal.sja/2021/37.4.1222.1229
Keywords | Systematic use, Leaching fraction, Saline water, Soil properties, Sorghum

Introduction

Water is most significant for the growth of the plant and abundantly present in the growing plant. Water is also a vital resource of a country and a restrictive aspect for sustainable agricultural production. Limited water supply is the key factor that harms cultivated crops (Shahid *et al*., 2012; Hussain *et al*., 2020). In dry climatic areas, shortage of water is considered the most limiting growth factor due to low rainfall (Anwar *et al*., 2011). The growing population of the world and continuously lessening in water resources has a damaging impression on food security (Alam *et al*., 2009; Hussain *et al*., 2019). There is not enough good quality water for crops in low rainfall areas, that's why wastewater can be irrigated (Minhas *et al*., 2007; Kaledhonkar *et al*., 2019; Kaledhonkar *et al*., 2020).

Pakistan primarily falls under an arid and semiarid region of the world, where frequent edaphic factors including salinity of soils, low soil organic matter and fertility as well, available poor quality of underground water and drought that limits crop yields and production. Even though the adverse change in rainfall because of climatic changes may increment water assets in a few territories; this expansion can't be contrasted with expanded future requests for freshwater assets or resources (Fuller *et al*., 2012). The powerful water quality rule on crop production is the water salt-

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iness risk as estimated by EC of soil that evaluates the number of salts that dissolved ions or particles, charged particles in a sample of water. Proper use of available irrigation water is the best technique in low rainwater areas (Pawlowski *et al*., 2009; Elhindi *et al*., 2020).

Soil salinity is the main determinant for crops affecting 5-10 % of arable land worldwide, according to estimates, between 75 and 100 M ha (Szabolcs, 1994; Munns, 2002). An excess of Na in soil with optimal pH called coastal salinity (Munns *et al*., 2002). An excess of Na in the soil with a higher pH called sodicity (Ragab *et al*., 2008). In sodic soils, because high pH accessibility of micronutrients and destabilizes the structure and porosity of the soil, which causes water extraction (Munns and Tester, 2008). Although salinity is common hurdle in agricultural productivity around the world (Abdelsattar *et al*., 2020) and a wealth of knowledge is cited to understand about genes which participate in tolerance for salinity, and there are very few efforts made to improve salinity tolerance (Flowers, 2004), except for barley (Iqbal, 2015), or soybean (Carter *et al*., 2005).

The soil affected by salt is not new, but its seriousness is growing due to poor soil management techniques (Khan, 1998), unveil that high temperatures and low rainfall promote the movement of the increase in salt from the soil solution, which causes salinization. According to the survey (GOP, 2010) that 6,677 M ha soil out of the total (79.61 M ha) are affected by salt (Khan, 1998) and 23.04 M ha are cultivated land. Around 56 percent of Pakistan's salt-infected soil is salt-sodic and needs an external calcium source (Mirbahar and Sipraw, 2000; Ghafoor *et al*., 2012). The higher SAR and EC levels in pumped soil water in Pakistan negatively affected crop production and soil quality (Murtaza *et al*., 2009). In contrast, this water is used efficiently and produced for irrigation by decent soil management technologies in the first stage of rehabilitation. Leaching fraction is the amount of water applied additionally to the crop delta of water (Qadir *et al*., 2001; Manzoor *et al*., 2019).

Soil with high Na^+ content has higher values of pH, SAR, ESP, and EC_e. Higher pH of saline environment affect the availability of micronutrients like iron, zinc, manganese and copper (Lakhdar *et al*., 2009). The high Na^+ and Cl^- concentration affects cells and plant development (Munns and Termaat, 1986). The higher soil salt level degrades the soil's physical and chemical properties (Wong *et al*., 2009). Subject to the surface and the screen, organic matter is lost significantly in corroding due to the low content and higher organic matter in the soil (Nelson and Oades, 1998). Total N and organic C have been reduced by increased sodium-rich irrigation, showed by Chandar *et al*. (1994). Frankenberg and Bingham (1982) found that the activity of the soil enzyme decreased due to high EC value as salinity interrupts C, N, P and S cycles.

The present study aimed to examine the impact on soil properties with saline water of the leaching fraction.

Materials and Methods

Experimental site and treatments

This experiment was conducted at research area of College of Agriculture, University of Sargodha. The city of Sargodha is placed in the arid to semi-arid climate zone. It is situated at 193 m above sea level. The maximum summer temperature is 50°C (122°F) till late spring while in winter temperature is low as the point of solidification. The warmer season lies between April to October and the cooler season from November to March. The Annual shower is around 400 mm and the monsoon season is in July and August. For experiment nine treatments with four replications were applied using RCBD. Treatments include: T_1 = Continuous irrigation with canal water, T_2 = Continuous irrigation with water of EC 2.0 dSm^{-1} (the amount of 71.305 g NaCl salt was used to prepare 100 liter water having EC = 2.0 dSm^{-1} using ground water as source), T_3 = Continuous irrigation with water of EC 3.0 dS m^{-1}, T_4 = Continuous irrigation with canal water with 10% leaching fraction, T_5 = Continuous irrigation with water of EC 2.0 dS m^{-1} with 10% leaching fraction, T_6 = Continuous irrigation with water EC 3.0 dSm^{-1} with 10% leaching fraction, T_7 = Continuous irrigation with canal water with 20% leaching fraction, T_8 = Continuous irrigation with water of EC 2.0 dSm^{-1} with 20% leaching fraction and T_9 = Continuous irrigation with water EC 3.0 dSm^{-1} with 20% leaching fraction.

Crop husbandry

Sowing of sorghum seeds: Before sowing, preparation of seed bed was performed. Sorghum cultivar JS-263 was used as a test crop. Distance between rows was 75 cm and between plants was 25 cm while seed rate was 40 kg per acre. Performance of various agronomic practices was done depending upon crop need.

Fertilizer application: Inorganic fertilizer including N, P, K were applied @ 100-50-50 kg ha^{-1}, respectively as urea, diammonium phosphate (DAP) and potassium sulphate. Application of complete dose of P and K was done at sowing while application of urea was done in three splits (at sowing, 30 and 60 days after treatment completion). For fertilizer application, 2 bags of DAP with 1 bag of urea per hectare was used. Whole incorporation of DAP was done at sowing while ½ bag urea was applied at planting, and another ½ bag of urea was applied at the first irrigation.

Harvesting: Crop harvesting was done at maturity and collection of plant samples was done and analyzed for desired parameters. Pre and post-harvest soil analysis were carried out for different physical and chemical characteristics. Soil sampling was done from all the plots and analysis was performed for EC, pH, SAR calculation. Soil pH was determined using pH meter. EC meter (Jenway Model-4070) was used for determination of EC_e. Following formula was used for the determination of SAR after determining Na by flame photometer and Ca + Mg by titration methods;

$$SAR = Na^{+} / (Ca^{2+} + Mg^{2+}/2)^{1/2}$$

All the ions were expressed in me L^{-1}

Statistical analysis

Statistical analysis of collected data and calculation of ANOVA was done by using statistix 8.1. Comparison of means was done using Tukey's (HSD) test (Steel *et al*., 1997).(Table 1 and 2).

Results and Discussion

Saline water effect on soil pH

Soil pH affects many chemical processes in the soil. The plant nutrients availability greatly influenced by soil pH because it controls the chemical form of various types of nutrients. The use of saline water affected the soil pH significantly. Data in Figure 1 indicated that the maximum value (8.4) of soil pH was measured under T_3 which was followed by T_2 and T_6 that produced 8.2 and 8.1 pH of soil respectively. The 7.9, 7.8 and 7.9 pH of the soil was recorded with T_5, T_8 and T_9 respectively. However, the lowest (7.6) pH of the soil was obtained having canal water with a 20 % leaching fraction (T_7) indicating 6.57% reduction in pH over original pH value. Hossain *et al*. (2015) revealed the application of saline water higher the salt content in soil and also increased the soil pH. According to Luedelin *et al*. (2005) the soil pH increases with an increase in salinity, however, by using the leaching fraction technique it can be reduced significantly. Manzoor *et al*. (2019) and Sarwar *et al*. (2003) also concluded similar outcomes.

Table 1: *Soil characteristics used in experiments.*

Characteristics	Unit	Value
Saturation percentage	%	29.0
pH_s	-	8.1
EC_e	dS m^{-1}	0.89
CO_3	me L^{-1}	3.60
HCO_3	me L^{-1}	6.30
Cl	me L^{-1}	4.10
SO_4	me L^{-1}	3.80
Ca + Mg	me L^{-1}	4.50
Na	me L^{-1}	10.8
SAR	-	3.62
Textural Class	-	Sandy Clay Loam
Organic matter	%	0.75
Available P	mg kg^{-1}	7.4
Water soluble potassium	me L^{-1}	3.53

Table 2: *Analysis of canal water used in experiment.*

Characteristics	Unit	Value
EC	dS m^{-1}	0.21
Total soluble salts (TSS)	$mmol_c L^{-1}$	7.20
Carbonates (CO_3^{2-})	$mmol_c L^{-1}$	Nil
Bicarbonates (HCO_3^{-})	$mmol_c L^{-1}$	1.30
Chlorides (Cl^{-1})	$mmol_c L^{-1}$	0.70
Sulphates (SO_4^{2-})	$mmol_c L^{-1}$	0.10
Calcium + magnesium (Ca^{2+}+Mg^{2+})	$mmol_c L^{-1}$	2.0
Sodium (Na^{+})	$mmol_c L^{-1}$	0.10
Sodium adsorption ratio (SAR)	$(mmolL^{-1})^{1/2}$	0.10
Residual sodium carbonates (RSC)	$mmol_c L^{-1}$	Nil

Saline water effect on soil EC (dS m^{-1})

EC of soil affects the crop productivity as it correlates with different soil characteristic like soil organic carbon, soil texture, salinity and cation exchange capacity. Data regarding EC of soil presented which exhibited that by the use of saline water EC of soil respond significantly. Data in Figure 2 showed that the highest (3.4 dS m^{-1}) soil EC was measured under T_3. The EC

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of soil for treatments T_2, T_5, T_6, T_8 and T_9 were 2.3, 2.4, 2.3, 2.1 and 2.3 dS m^{-1} respectively (Figure 2). Whereas the lowest EC (1.3 dSm^{-1}) of soil was obtained in (T_7) reflecting 46.06% reduction in soil EC over original value. The increased EC value is due to buildup of salt as a result of application of salty water. The work of the previous researcher also reported that continuous irrigation with saline water enhanced the soil pH, EC and SAR of soil due to the accumulation of salts in the soil. Related results were described 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. Manzoor *et al*. (2019) and Sarwar *et al*. (2003) also concluded parallel findings.

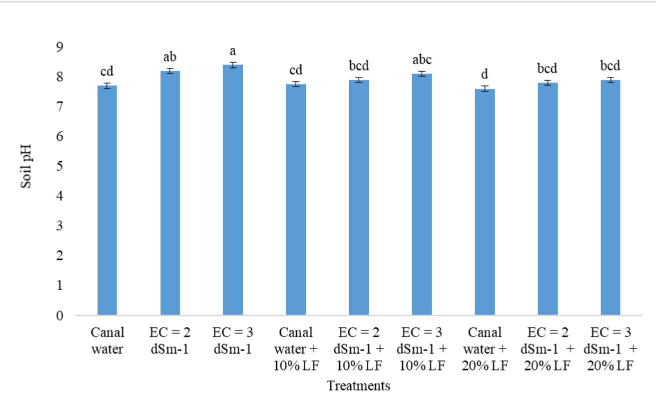

Figure 1: *Systematic use of saline water with leaching fraction for improving pH of soil.*

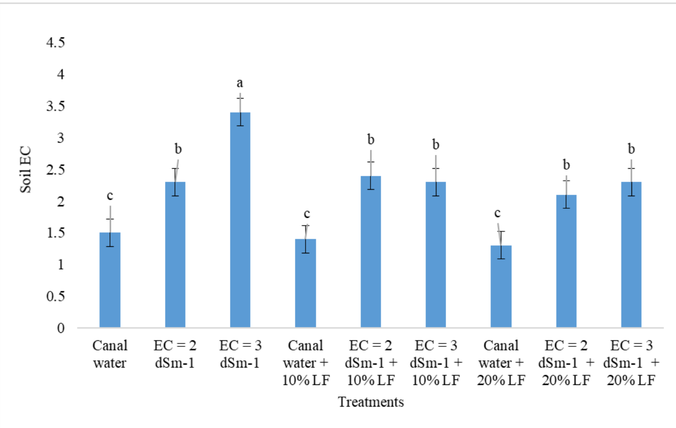

Figure 2: *Systematic use of saline water with leaching fraction for improving EC (dS m^{-1}) of soil.*

Saline water effect on soil SAR

The SAR of soil used to determine the sodium affected soil that is helpful to determine the management practices. Soil SAR was significantly affected by the use of saline water alone and along leaching fraction. Among all the treatments, the T_3 was produced the highest SAR (15.46) of soil which was followed by T_6 and T_9. The 13.61, 13.82 and 12.39 of soil SAR were obtained under the treatments of T_2, T_5 and T_8 respectively. The treatment T_7 recorded the lowest SAR (5.21) of soil which was reflecting 46.41% reduction in soil SAR over original value. According to Fard *et al*. (2007) showed that irrigation with saline water increase the SAR of soil and leaching efficiency was helpful to decrease the water salinity that reduces the SAR of soil. Manzoor *et al*. (2019) and Sarwar *et al*. (2003) also concluded parallel findings (Figure 3).

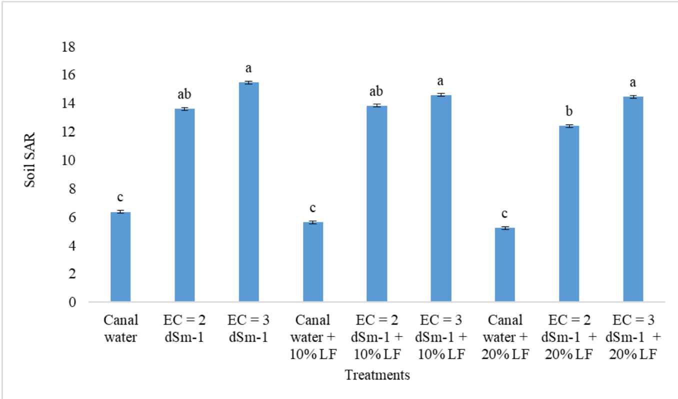

Figure 3: *Systematic use of saline water with leaching fraction for improving SAR of soil.*

Saline water effect on Sodium (meq L^{-1}) content of soil

Sodium (Na) presence in the soil solution stunted the plant growth mainly due to a decrease in the water uptake ability of the plant. Data revealed that the impact of canal and saline water alone and along with leaching fraction was found significant. The maximum concentration of sodium (17.85 meq L^{-1}) in soil was observed for T_3. The 16.65 and 16.03 meq $L^{-1}$of sodium concentration in soil was recorded for T_6 and T_9 respectively. These treatments (T_3, T_6 and T_9) were proved significant with each other. The values of sodium concentration in the soil for T_2, T_5 and T_8 were 16.34, 16.54 and 14.65 meq L^{-1}respectively. The T_7 (canal water with 20percent leaching fraction) recorded the lowest sodium concentration (7.50 meq L^{-1}) in soil. However, the 7.97 and 8.55 values of sodium concentration in the soil for T_4 (canal water with 10percent leaching fraction) and T_1 (canal water with 0percent leaching fraction) were obtained. Similar findings were reported by Manzoor *et al*. (2019), Sarwar *et al*. (2003) and Fard *et al*. (2007) who stated that salty water usage increase the sodium concentration in soil however, and suitable leaching fraction along with saline irrigation water can be used to control the sodium in the soils. Irrigation with saline water enhanced the soil sodium contents in the soil (Figure 4).

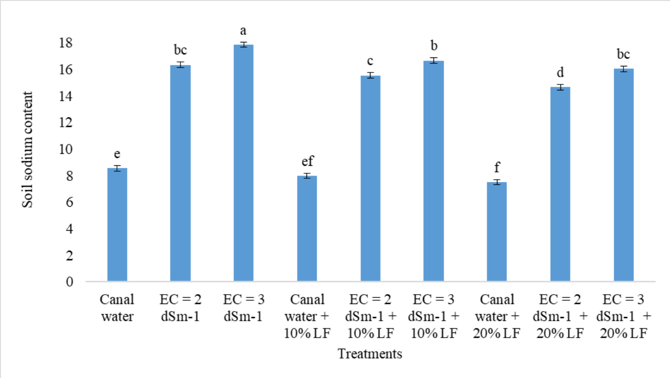

Figure 4: *Systematic use of saline water with leaching fraction for improving sodium (meq L^{-1}) of soil.*

Saline water effect on soil organic matter (%)

To improve the soil structure, water holding capacity and supply of nutrients, organic matter is very important. The use of canal and saline water with or without leaching fraction significantly affected organic matter (percent) soil. Figure 5 shown that organic matter (percent) data in soil were found to be the highest recorded organic matter (0.88 percent) in soil by T_7 indicating 17.34% increase in soil organic matter over original value (Figure 5). T_7 performed better among all treatments. Treatments T_4 and T_1 produced 0.85 and 0.83 percent organic matter. While T_3, T_6 and T_9 produced the lowest organic matter in the soil (0.64 percent) (Figure 5). These three therapies (T_3, T_6 and T_9) have, however, been demonstrated to be significant. These results related to the findings of Malik *et al.* (2015) who reported negative relation between salty water application and organic matter (percent) in soil. Manzoor *et al.* (2019) and Sarwar *et al.* (2003) also concluded parallel findings.

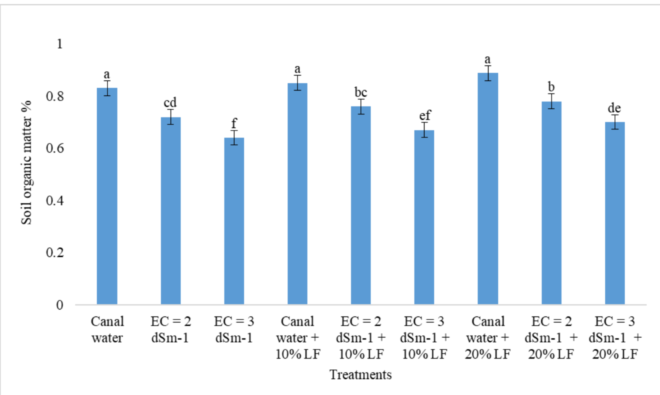

Figure 5: *Systematic use of saline water with leaching fraction for improving organic matter (%) of Soil.*

Saline water effect on soil phosphorus (mg kg^{-1})

The function of phosphorus (P) in the soil is very essential. Insufficient phosphorus content in the soil affects root growth. Data showed a significant impact on the phosphorous content of the soil when watering from the canal and saltwater. The data shown in Figure 6 reflected that the application of canal water with or without the leaching fraction performed well than water having EC = 2 and 3 dS m^{-1} water. The maximum phosphorus content (7.8 mg kg^{-1}) in soil was obtained under T_7 indicating 5.4% increase in soil available P content over original value, followed by T_4 and T_1 with the same soil phosphorus value (7.70 mg kg^{-1}) (Figure 6). However, the lowest phosphorous contents (6.80 mg kg^{-1}) in soil was obtained with T_3 which was followed by T_6 that produced 7.00 mg kg^{-1} phosphorous contents in soil. The results of Hossain *et al.* (2015) are in line with our findings who described that the nitrogen, phosphorous and potassium contents of the soil decrease with an increase salinity level of the soil. Manzoor *et al.* (2019) and Sarwar *et al.* (2003) also concluded parallel findings.

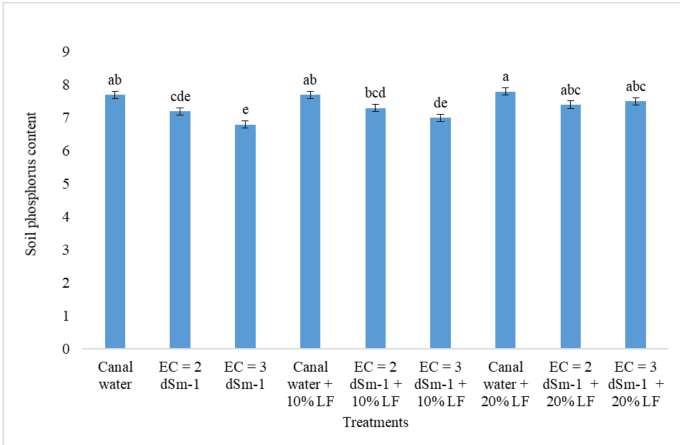

Figure 6: *Systematic use of saline water with leaching fraction for improving phosphorous (mg kg^{-1}) of soil.*

Saline water effect on soil potassium (meL^{-1})

The availability of potassium (K) in the soil is very essential for plant growth. The increased salinity significantly decreased potassium availability in the soil. The application of canal and saline water has affected the potassium content of the soil significantly. Figure 7 illustrated the data on soil potassium content showing maximum potassium (3.73 me L^{-1}) soil content with T_7 indicating 5.66% increase in soil available P content over original value, followed by T_4 and T_1 soil potassium content of 3.51 and 3 me L^{-1}, respectively in soils. However, a statistically significant interaction between T_4 and T_1 was found. Among all the treatments, canal water with or without leaching fraction showed superiority. The values of potassium contents in the soil for T_2, T_5 and T_8 were 2.92, 3.17 and 3.29 me L^{-1} respectively. Whereas, minimum phosphorous contents (2.81 me L^{-1}) in soil was recorded with T_3

which was followed by T_6 that produced 3.03 meL^{-1} K contents in soil (Figure 7). Ashraf and Ali (2008) stated that due to irrigation with saline water the potassium contents in soil decreased. Manzoor et al. (2019) and Sarwar et al. (2003) also concluded parallel findings.

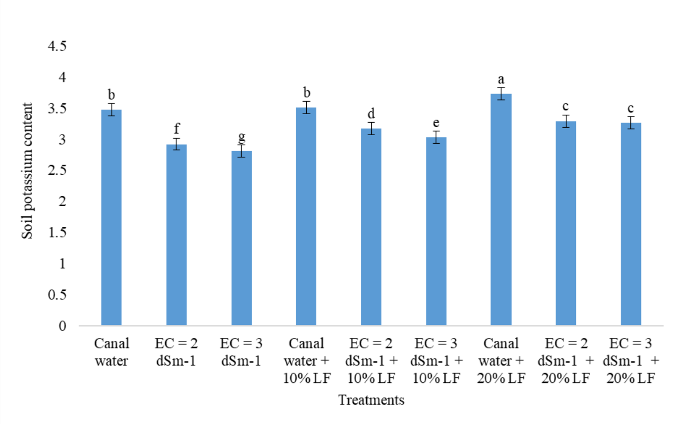

Figure 7: *Systematic use of saline water with leaching fraction for improving potassium content (me L^{-1}) of soil.*

Conclusions and Recommendations

The research showed that the leaching fraction performed better in terms of improving the impaired chemical properties of soil. Use of canal water with 20 % leaching fraction proved superior among all treatments and the soil characteristics such as pH, EC and SAR were significantly improved with numerically 6.57 %, 46.07 % and 46.41 % reductions respectively while 17.34 %, 5.4 % and 5.66 % increase in soil organic matter, soil available phosphorus (P) and potassium (K) content respectively. Thus, under scarce resources of good quality water, saline water can be safely used along with leaching fraction.

Novelty Statement

Systematic use of saline water along with leaching fraction can be used successfully for growing fodder crops.

Author's Contribution

Ameer Hamza: Designed and conducted the research.
Mukkram Ali Tahir: Supervised the research.
Noor-us-Sabah: Co-Supervised.
Ghulam Sarwar: Technically assisted at every step.
Muhammad Luqman: Statistical analysis.

Conflict of interest
The authors have declared no conflict of interest.

References

Abdelsattar M.M., M.A. Ahmed, M.N. Hussein, Abd El-Ati and A.M. Saleem. 2020. Impacts of saline water stress on livestock production: A review. SVU-Int. J. Agric. Sci. 2(1): 1-12. https://doi.org/10.21608/svuijas.2020.67635

Alam, M.M., E.S. Mace, E.J. Van Oosterom, A. Cruickshank, C.H. Hunt, G.L. Hammer and D.R. Jordan. 2014. QTL analysis in multiple sorghum populations facilitates the dissection of the genetic and physiological control of tillering. Theor. Appl. Genet. 127: 2254-2266. https://doi.org/10.1007/s00122-014-2377-9

Anwar, S., M. Shafi, J. Bakht, M.T. Jan and Y. Hayat. 2011. The response of barley genotypes to salinity stress as alleviated by seed priming. Pak. J. Bot. 43: 2687-2691.

Ashraf, M. and Q. Ali. 2008. Relative membrane permeability and activities of some antioxidant enzymes as the key determinants of salt tolerance in canola (*Brassica na*pus L.). Environ. Exp. Bot. 63: 266–273. https://doi.org/10.1016/j.envexpbot.2007.11.008

Carter, C.T., C.M. Griev and J.A. Poss. 2005. Salinity effects on emergence, survival, and ion accumulation of Limonium perezii. J. Plant Nutr. 28: 1243–1257. https://doi.org/10.1081/PLN-200063293

Chander, K., S. Goyal and K.K. Kapoor. 1994. Effect of sodic water irrigation and farmyard manure application on soil microbial biomass and microbial activity. Appl. Soil Ecol. 1: 139-144. https://doi.org/10.1016/0929-1393(94)90033-7

Elhindi, K.M., A. Fahed, A.M. Algahtania and M.A. Alotaibia. 2020. Effect of irrigation with saline magnetized water and different soil amendments on growth and flower production of *Calendula officinalis* L. plants. Saudi J. Biol. Sci. 27(11): 3072-3078. https://doi.org/10.1016/j.sjbs.2020.09.015

Fard, B.M., M. Heidpour, A. Aghakhani and M. Feizi. 2007. Effect of irrigation water salinity and leaching on soil chemical properties in an arid region. Int. J. Agric. Biol. 9(3): 446-469.

Flowers, T.J. 2004. Improving crop salt tolerance. J. Exp. Bot. 55: 307-319. https://doi.org/10.1093/

jxb/erh003

Frankenberger, W.T. and F.T. Bingham. 1982. Influence of salinity on soil enzyme activities. Soil Sci. Soc. Am. J. 46: 1173–1177. https://doi.org/10.2136/sssaj1982.03615995004600060011x

Fuller, M.P., J.H. Hamza, H.Z. Rihan and M. Al-Issawi. 2012. Germination of primed seed under NaCl stress in wheat. Int. Sch. Res. Network Bot. 12: 1-5. https://doi.org/10.5402/2012/167804

Ghafoor, A., G. Murtaza, M.Z. Rehman, Saifullah and M. Sabir. 2012. Reclamation and salt leaching efficiency of treatments for tile-drained saline-sodic soil using marginal quality water for irrigating rice and wheat crops. Land Degrad. Develop. 23: 1-9. https://doi.org/10.1002/ldr.1033

GOP. 2010. Agricultural Statistics of Pakistan 2009-2010. Govt. of Pakistan, pp: 108–115. Ministry of Food, Agriculture and Livestock. Food, Agriculture Livestock Division, Islamabad, Pakistan.

Hossain, N., M. Muhibbullah, K.M.B. Ali and M.H. Molla. 2015. Relationship between Soil Salinity and Physico-chemical Properties of Paddy Field Soils of Jhilwanja Union, Cox's Bazar, Bangladesh. J. Agric. Sci. 7(10): 10-17. https://doi.org/10.5539/jas.v7n10p166

Hussain, M.I., A. Muscolo, M. Farooq and W. Ahmad. 2019. Sustainable use and management of non-conventional water resources for rehabilitation of marginal lands in arid and semiarid environments. Agric. Water Manage. 221: 462-476. https://doi.org/10.1016/j.agwat.2019.04.014

Hussain, M.I., M. Farooq, A. Muscolo and A. Rehman. 2020. Crop diversification and saline water irrigation as potential strategies to save freshwater resources and reclamation of marginal soils-a review. Environ. Sci. Pollut. Res. 27: 28695-28729. https://doi.org/10.1007/s11356-020-09111-6

Kaledbonkar, M.J., B.L. Meena and P.C. Sharma. 2019. Reclamation and Nutrient Management for Salt-affected Soils. lndian J. Fert. 15 (5): 566-575.

Kaledhonkar, M.J., A.K. Singh, R. Singh and B.L. Meena. 2020. Management of saline water irrigation in water stress arid regions. technological advances in enhancing productivity of salt affected soils, 69-82. Editors: P. Masilamani, K. Arulmozhiselvan and P. Balasubramaniam Today & Tomorrow's Printers and Publishers, New Delhi 110002 (India).

Iqbal, M.A. 2015. Overviewing forage shortage for dairy animals and suitability of forage sorghum for ensiling. Glob. Vet. 14(2): 173-177.

Khan, G.S. 1998. Soil Salinity/Sodicity Status in Pakistan, pp: 59. Soil Survey of Pakistan, Lahore.

Lakhdar, A., M. Rabhi, T. Ghnaya, F. Montemurro, N. Jedidi and C. Abdelly. 2009. Effectiveness of compost use in salt-affected soil. J. Hazard Mater. 171: 29-37. https://doi.org/10.1016/j.jhazmat.2009.05.132

Luedelinga, E., M. Nagieba, F. Wichernb, M. Brandtc, M. Deurerd and A. Buerkerta. 2005. Drainage, salt leaching and physicochemical properties of irrigated man-made terrace soils in a mountain oasis of northern Oman. Geoderma. 125: 273-285. https://doi.org/10.1016/j.geoderma.2004.09.003

Malik, M.A., S.M. Nadeem, M. Ibrahim, and S. Hussain. 2015. Effective use of brackish water for improving soil properties and chickpea (*Cicer arietinum* L.) growth through organic amendments. Soil Environ. 34(1): 65-74.

Manzoor, M.Z., G. Sarwar, M.A. Tahir, N.U. Sabah, A. Zafar and S. Muhammad. 2019. Leaching fraction: An effective tool to mitigate ill effects of brackish water. Pak. J. Agric. Res. 32(3): 549-554. https://doi.org/10.17582/journal.pjar/2019/32.3.549.554

Manzoor, M.Z., G. Sarwar, M. Aftab, M.A. Tahir, N.U, Sabah and A. Zafar. 2019. Role of leaching fraction to mitigate adverse effects of saline water on soil properties. J. Agric. Res. 57(4): 275-280.

Minhas, P.S, S.K. Dubey and D.R. Sharma. 2007. Comparative effects of blending, intera/inter-seasonal cyclic uses of alkali and good quality waters on soil properties and yields of paddy and wheat. Agric. Water Manage. 87:83–90. https://doi.org/10.1016/j.agwat.2006.06.003

Mirbahar, M.B. and A.M. Sipraw. 2000. On-Farm tile drainage with farmers participant, experience and future strategies. Proceeding National Seminar on Drainage in Pakistan, August 16-18, 2000 held at MUET, Jamshoro, pp: 1-14.

Munns, R. and A. Termaat. 1986. Whole plant responses to salinity. Aust. J. Plant Physiol. 3: 143-160. https://doi.org/10.1071/PP9860143

Munns, R. and M. Tester. 2008. Mechanisms of salinity tolerance. Annu. Rev. Plant Biol. 59: 651-681. https://doi.org/10.1146/annurev.arplant.59.032607.092911

Munns, R. 2002. Comparative physiology of salt and water stress. Plant, Cell Environ. 25(2): 239-250. https://doi.org/10.1046/j.0016-8025.2001.00808.x

Murtaza, G., A. Ghafoor, G. Owens, M. Qadir and U.Z. Kahlon. 2009. Environmental and economic benefits of saline-sodic soil reclamation using low-quality water and soil amendments in conjunction with a rice-wheat cropping system. J. Agron. Crop Sci. 195: 124-136. https://doi.org/10.1111/j.1439-037X.2008.00350.x

Nelson, P.N. and J.M. Oades. 1998. Organic matter, sodicity and soil structure. In: Sumner ME, Naidu R (eds) Sodic soils: distribution, properties, management and environmental consequences. Oxford University Press, New York.

Pawlowski, A., J.L. Guzman, F. Rodriguez, M. Berenguel, J. Sanchez and S. Dormido. 2009. Simulation of greenhouse climate monitoring and control with wireless sensor network and event-based control. J. Sensors. 9: 232-252. https://doi.org/10.3390/s90100232

Qadir, M., A. Ghafoor and G. Murtaza. 2001. Use of saline-sodic water through phytoremediation of calcareous saline-sodic soils. Agric. Water Manage. 50: 197-210. https://doi.org/10.1016/S0378-3774(01)00101-9

Ragab A.A.M., F.A. Hellal and M.A. El-Hady. 2008. Water Salinity Impacts on Some Soil Properties and Nutrients Uptakeby Wheat Plants in Sandy and Calcareous Soil. Aust. J. Basic Appl. Sci. 2(2):225-233.

Sarwar, G., N. Hussain, F. Mujeeb, M. Abid and A. Hassan. 2003. Correlation of brackish water and chemical properties of silty clay loam soil. Pak. J. Soil Sci. 22 (1): 65-73.

Shahid, M.A., R.M. Balal, M.A. Pervez, T. Abbas, M.A. Aqeel, A. Riaz and N.S. Mattson. 2015. Exogenous 24-epibrassinolide elevates the salt tolerance potential of pea (*Pisum sativum* L.) by improving osmotic adjustment capacity and leaf water relations. J. Plant Nutr., 38(7): 1050-1072.

Steel, R.G., J.H. Torrie and D.A. Dickey. 1997. Principles and Procedures of Statistics: A Biological Approach. 3rd ed. McGraw-Hill, Inc. Book Co. NY, pp. 352-358.

Szabolcs, I. 1994. Soils and salinisation. In Handbook of Plant and Crop Stress. Ed. M Pessarakali. pp. 3-11. Marcel Dekker, New York.

U.S. Salinity Laboratory Staff. 1969. Diagnosis and improvement of saline and alkaline soils. USDA and book-60 USDA. The US. Govt. Printing Office, Washington DC, USA.

Wong, V.N.L, R.C. Dalal and R.S.B. Greene. 2009. Carbon dynamics of sodic and saline soils following gypsum and organic material additions: laboratory incubation. Appl. Soil Ecol. 41: 29-40. https://doi.org/10.1016/j.apsoil.2008.08.006

Zein, F.I., S.A.A. El-Wahab, M.A. El-Abaseri and A.T.A. Moustafa. 2003. Evaluation of some wheat varieties to salt tolerance. Egypt. J. Soil Sci. 43(3): 319-327.