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RESEARCH PAPER

Variations in nutrient concentrations of maize as affected by different levels of brackish water under normal soil conditions

Imran Shehzad[1], Ghulam Sarwar[1]*, Muhammad Zeeshan Manzoor[1], Fakhar Mujeeb[2], Ayesha Zafar[1] and Faheem Khadija[3]

[1]Department of Soil & Environmental Sciences, College of Agriculture, University of Sargodha, Sargodha, Pakistan
[2]Soil Bacteriology Section, Ayub Agricultural Research Institute (AARI), Faisalabad, Pakistan
[3]Citrus Research Institute, Sargodha, Pakistan

*Corresponding author: Ghulam Sarwar (ghulam.sarwar@uos.edu.pk)

Key Message: Use of brackish water is always injurious for soil and plant health affecting nutrients concentration in maize. In this study, use of canal water proved to be fruitful in mitigating the ill effects of saline water on the nutrients concentration in maize.

ABSTRACT: Decline in agriculture production due to salinity is one of the key problems in many areas around the globe including Pakistan. Cyclic use is a strategy where saline and good quality water is used in a cyclic manner for leaching down the salts accumulated during irrigation of saline water. In this manner, salt accumulation does not rise beyond tolerance limit of the crop. The experiment consisted of four treatments that were replicated four times and randomized complete block design (RCBD) was used to make layout. Treatments were; T1 = continuous irrigation with canal water, T2 = continuous irrigation with water of EC 2.0 dS m^{-1}, T3 = continuous irrigation with water of EC 3.0 dS m^{-1} and T4 = continuous irrigation with water of EC 4.0 dS m^{-1}. Maize was sown as a test crop. Pre- and post-harvest soil analyses were carried out for different physical and chemical characteristics. The results of plant analysis for nitrogen, phosphorous, potassium, calcium, magnesium and sodium percentage in maize plant showed that irrigation with canal water significantly enhanced the concentration of these nutrients in maize plants except sodium which was produced maximum under irrigation with water of EC = 4 dS m^{-1}. The irrigation water having EC = 2 and 3 dS m^{-1} produced less values of these nutrients in maize as compared to canal water but significantly higher than that of irrigation water (EC = 4 dS m^{-1}). It was concluded that use of brackish water affected the concentration of all nutrients negatively.

Keywords: Brackish and canal water, Irrigation, Maize, Electrical conductivity

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INTRODUCTION

Maize (*Zea mays* L.) is cross-pollinated specie and monoecious crop of Asia, and now a days it is considered as the backbone of poultry feed industry. It is very nutritious fodder and is the largest resource of livestock feed in all over Pakistan. Maize can be grown for fodder purpose with extensive climatic range. It is harvested after 8-10 weeks of sowing (Rashid & Iqbal, 2012). Maize is moderately salt sensitive crop (Maas & Hoffman, 1977). Maize also has significant role for the production of value-added foods like jellies, glucose, flakes, and custard in many industries. Now a days, corn (maize) is also used in the production of varnishes, ammunition, paints shortening compounds, soaps and many other products. Maize fodder contains 51.69% neutral detergent fiber, 40.18% crude fiber, 28.797% cellulose, 22.98% acid detergent fiber, 10.35% crude protein, and 9.09% moisture whereas maize seed grains contain 71.97% starch, 4.85% oil, 9.74% protein, and 9.44% crude fiber (Ali et al., 2014). Weed pervasion, excessive or sometimes no uses of fertilizers are among the main reasons due to which yield and growth of maize is affected (Khan et al., 2013).

At present global agriculture faces many problems, such as need of 70% more food production to feed 2.3 billion additional people by 2050, while fighting against hunger and poverty, more efficiently consuming rare natural resources and adapting to drastic changes of climate (Food and Agriculture Organization [FAO], 2009). Because of various abiotic stresses, low productivity in most cases is recorded. It has been expected that more than 50% of yield is decreased because of abiotic stresses and the salt stress is one of them (Rodriguez et al., 2005). Around the globe, salt stress is the foremost concern for agriculture because it affects almost all functions of the plant. Greater than 6% of the land in world and a third of the arable lands are severely under salt stress (FAO, 2008). Irrigated land comprising of a total 18.63 million ha in Pakistan is the backbone of country's agriculture (Government of Pakistan [GOP], 2019), while 6.68 million ha of this irrigated land is damaged by salts (Zahra et al., 2015). Therefore, an appropriate reclamation remedy is direly needed (Qadir et al., 2000). Accumulation of toxic salts in cultivated areas always retards the growth of plants and productivity (Khan & Panda, 2008). The development of soil salinity is due to two main causes, one is the direct tide during the rainy season, and the second is the upward movement of saline groundwater during the dry season (Haque, 2006).

Salinity affects every plant at any growth and development stage but germination rate, seedling growth, and percentage of germination are affected in different ways according to plant species (Gul and Weber, 1999). High concentrations of salts affect seed germination and mobility of water causing ion to be disrupted, leading to osmotic stress and ion toxicity. The salinity causes osmatic stress which are due to decrease of soil water potential (Khan & Panda, 2008). Due to salinity stress, photosynthetic capacity of plants is affected that leads to a decrease in biomass production. Reduction in the pigment contents of the leaves is due to rise in levels of salts that increase the level of Na^+ and Cl^- while decrease the level of K^+ and Ca^{2+} contents (Mansour et al., 2005). Due to installation of private wells, soil surface salinity is growing day by day. Unfortunately, 70-75% of the groundwater pumped for irrigation is not of the usable standard due to the high electrical conductivity (EC), sodium adsorption ratio (SAR), and residual sodium carbonate (RSC) values that result in poor crop productivity. Using unfit water poses problems of salt buildup in the rhizosphere. The increase of salinity in the root zone can be detrimental to the crop growth (Patel & Pandey, 2009).

The management of salt affected soils involves a combination of agricultural practices such as water quality, chemical modification, and local conditions including climate, economic, and cultural practices as well as environment conditions and the existing agricultural system. Previously, a lot of research scientists compiled effective tools to alter and use of several modifications to improve the properties of saline soils, which may be either physical or chemical (Hanay et al., 2004). The significance of use of organic matter in this regard has been recognized due to its effect on the upgrading and altering the properties of saline soil for the growth of the crop, as well as role as a source of nutrients. Several organic modifications, such as compost and manure, have been examined for their effectiveness in the recovery of saline soils (Wahid, 1998). Therefore, this research study was designed to examine the negative effect of brackish water on nutrient concentration of maize plants under field conditions.

MATERIALS AND METHODS

This study was performed in randomized complete block design (RCBD) with 4 treatments that were replicated 4 times during summer season, 2018. The plot size was 3.5m × 3.5m having row to row spacing of 75 cm and plant to plant distance of 25 cm. Climatic data of the experimental site was also noted for the whole research duration (Fig. 1). The treatments of the experiments were as under:

T1 = Continuous irrigation with canal water (control) having EC = 0.23 dS m^{-1}
T2 = Continuous irrigation with water of EC 2.0 dS m^{-1}
T3 = Continuous irrigation with water of EC 3.0 dS m^{-1}
T4 = Continuous irrigation with water of EC 4.0 dS m^{-1}

Soil analysis

Soil samples were taken before sowing and after harvesting of the crop and soil analysis was done (Table 1). The soil samples were collected at the depth of 0-15 cm with the help of soil auger. Analytical methods of Handbook 60 of USDA (United States Salinity Laboratory Staff, 1969), or otherwise mentioned, were used for different determinations.

Digestion of plant samples for the determination of Na, K, Ca, Mg, N and P contents

Plant samples (0.5 g) were transferred into digestion vessel. A volume of 10 ml of diacid mixture (HNO_3: $HClO_4$ = 2:1) was taken into the vessel and kept for overnight. Samples were digested next day on hot plate at 250 ºC till material became transparent. After it, samples were filtered with Whatman filter paper No. 40 and all the samples were stored in plastic bottles. Na and K from digested plant samples were determined through flame photometer, while Ca and Mg were determined using atomic absorption spectrophotometer and P was determined using colorimetric method with spectrophotometer.

Sowing of maize seeds

The bed for sowing of maize seeds was prepared through cultivation of field for 2-3 times with tractor-mounted cultivar. Maize variety "Sargodha 2002" was sown on March 15, 2018 using 37 kg ha^{-1} seed rate. For weeds free crop, twice hoeing practice was done to avoid competition between weeds and crop. Before irrigation, water of required range, as mentioned in the treatment plan, was prepared and then applied accordingly.

Fertilizer application

Inorganic fertilizers {(urea, DAP (diammonium phosphate) and SOP (sulphate of potash)} were applied @ 190-150-100 kg ha^{-1} N, P, K, respectively.

Harvesting and plant analysis

At maturity (77 days after sowing), the crop was harvested on June 01, 2018. The dried plant samples were ground to 40 mesh.

Statistical analysis

The collected data were analyzed statistically by using statistics 8.1 analysis of variance (ANOVA) technique and significant differences of treatments means were compared using Tukey's (HSD) test at 5% probability level (Steel et al., 1997).

Table 1 Original analysis of experimental soil before cultivation

Parameters	**Unit**	**Value**
pH_s (soil reaction)	-	8.3
EC_e (electrical conductivity)	dSm^{-1} (deci Siemen/meter)	0.73
Carbonates	meq L^{-1} (milli equivalent/liter)	1.5
Bicarbonates	meq L^{-1} (milli equivalent/liter)	3.12
Chloride	meq L^{-1} (milli equivalent/liter)	2.95
Sulfate	meq L^{-1} (milli equivalent/liter)	1.47
Calcium + Magnesium	meq L^{-1} (milli equivalent/liter)	2.92
Sodium	meq L^{-1} (milli equivalent/liter)	3.65
SAR (sodium adsorption ratio)	-	3.02
Soil textural class	-	Clay loam

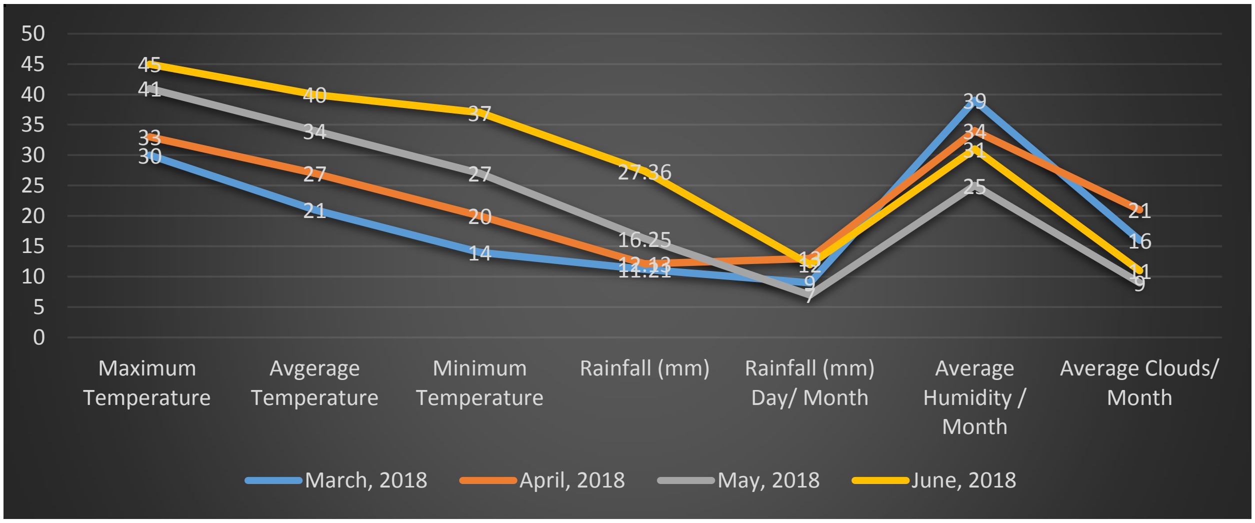

Fig. 1 Climatic data of the experimental site

RESULTS AND DISCUSSION

Nitrogen (%) in maize plants

Nitrogen plays an important role in physiological and organic chemistry processes in plants. Nitrogen is an element of the many vital organic compounds starting from nucleic acids to proteins. It's a constituent of the chlorophyll molecule that plays a very important role in plant chemical process. Data indicated that using brackish water affected nitrogen (%) of maize significantly. It was also obvious from the data that differences among various treatments were significant when seen in terms of statistics. The highest nitrogen (0.88%) of maize was gained in the treatment grown with canal water (Fig. 2). This treatment (canal water) proved superior to all other treatments. In the same way nitrogen of 0.72 and 0.64% was noted with water of EC = 2 dSm^{-1} and water of EC = 3 dSm^{-1} (T_2 and T_3) respectively. However, both these treatments T_2 and T_3 were significant in terms of statistics. Application of irrigation water having EC = 4 dS m^{-1} (T_4) produced nitrogen of 0.59% in maize plant. The work of the previous researcher like Hu & Schmidhalter (1997); Banziger et al. (2002) examined that by increasing salinity levels, the N, P, and Mg^{2+} in plants improved significantly. According to Hu & Schmidhalter (2005), under drought and salinity, the nitrogen and phosphorous concentration in plants enhanced significantly. Findings of Murtaza (2019) were also in the same directions, who applied canal and saline water to grow sorghum crop. Similarly, results of Manzoor (2019) were also almost similar, who conducted a field experiment to grow sorghum crop applying canal and saline water.

Phosphorous (%) in maize plants

Phosphorus is required for many processes including the storage and transfer of energy, photosynthesis, the regulation of some enzymes, and the transport of carbohydrates. The effect of brackish water on phosphorous (%) in maize plant was significant. However, among all the treatments the highest phosphorous (%) in maize plant (0.16%) was recorded in the treatment grown with canal water (Fig. 3). It was also obvious from the data that differences among various treatments were significant when seen through the yardstick of statistics. The Fig. 3 also indicated that irrigation with saline water of EC = 2 dSm^{-1} and water of EC = 3 dS m^{-1} (T_2 and T_3) decreased phosphorous (%) in maize plants 0.14 and 0.12% respectively. The irrigation with water of EC = 4 dS m^{-1} (T_4) recorded lowest phosphorous (0.11%) in maize plants. The results showed that all the treatments proved statistically significant with each other in terms of phosphorous (%) in maize plants. Results of Naheed et al. (2008) also agreed to the present findings and which revealed that varying concentration of salts in soil like control, 20 mmol/kg, 40 mmol/kg and 60 mmol/kg reduced the content of phosphorus in rice. The outcomes of Liebersbach et al. (2004) and Sawwan et al. (2000) were also in line with our findings. Findings of Murtaza (2019) were also in the same directions who applied canal and saline water to grow sorghum crop. Similarly, results of Manzoor (2019) were also in the same direction who conducted a field experiment to grow sorghum crop applying canal and saline water.

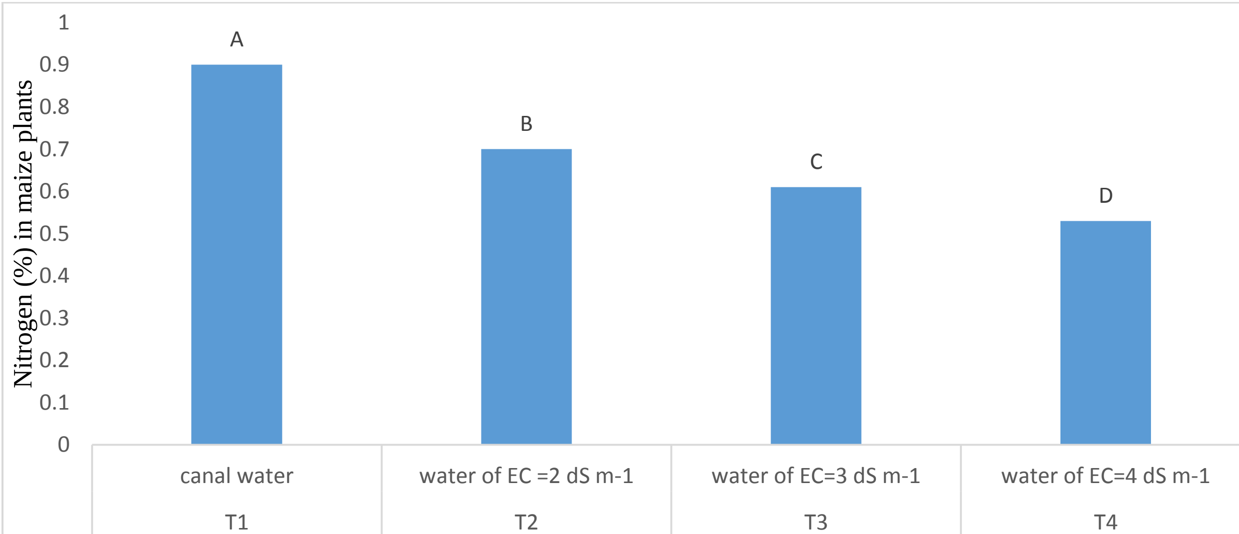

Fig. 2 Effect of canal and saline water on nitrogen (%) of maize plants

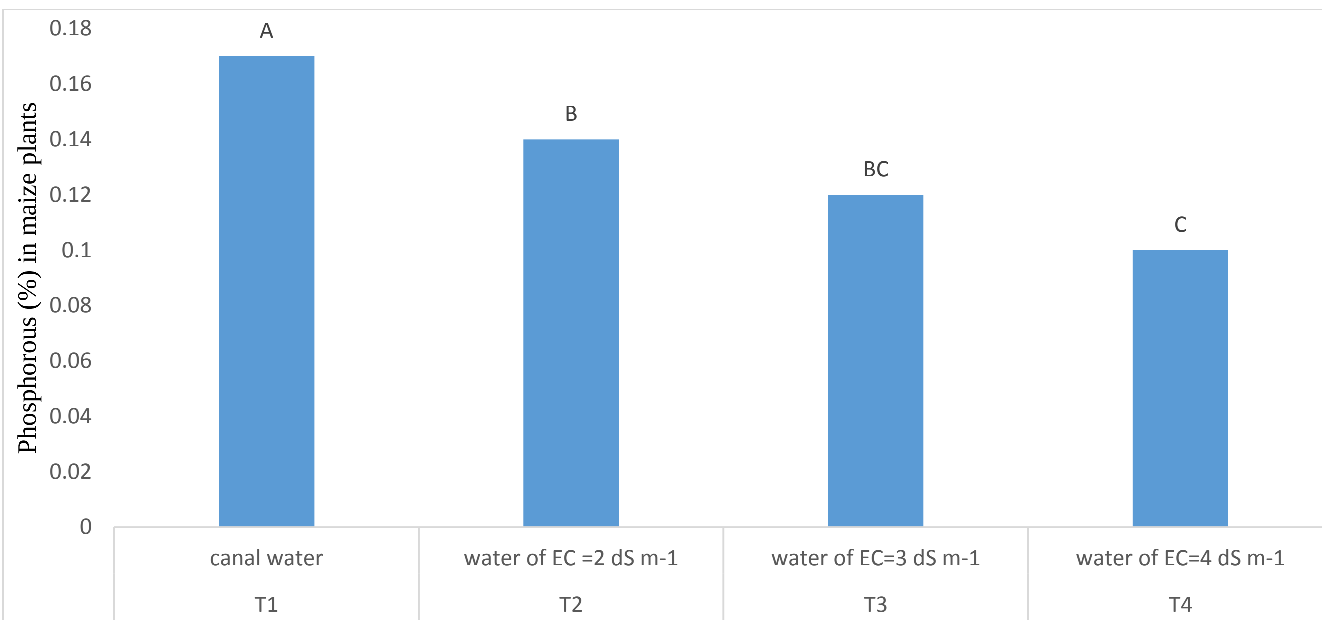

Fig. 3 Effect of canal and saline water on phosphorous (%) of maize plants

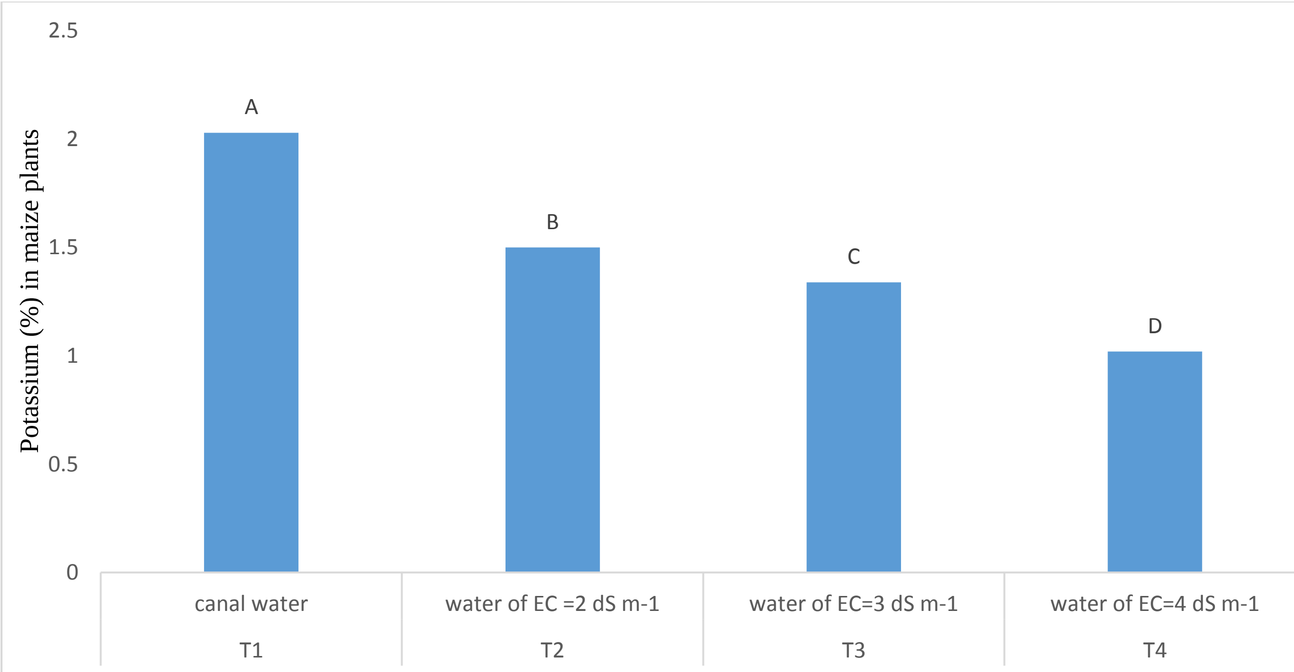

Fig. 4 Effect of canal and saline water on potassium (%) of maize plants

Potassium (%) in maize plants

Potassium is an important factor in protein synthesis, glycolytic enzymes, and photosynthesis. Potassium (%) in maize plant was considerably affected by use of brackish water. Data regarding potassium (%) in maize plant was presented in Fig. 4, which showed that irrigation with canal water (T_1) caused maximum potassium (2.02%) in maize plant. Among all the treatments, canal water showed superiority over all others treatments. It was also obvious from the data that differences among various treatments were significant when seen through the yardstick of statistics. The irrigation with water of EC = 2 and EC = 3 dS m^{-1} (T_2 and T_3) concentrated 1.60 and 1.37% potassium in maize plants respectively. However, T2 and T3 were significant statistically. The minimum potassium (1.13%) in maize plant was obtained with water of EC = 4 dS m^{-1} (T_4). According to Naheed et al. (2008), a significant reduction in the leaf and root K^+ was observed by increasing salinity levels from 20 to 30 mmol/kg of NaCl and maximum value was recorded where no treatment was applied. These outcomes are further justified by Leidi et al. (1991), who claimed that NaCl significantly affected the mineral nutrients in wheat plants and a significant reduction in K^+ concentration was also noted than no salt stress. Findings of Murtaza (2019) were also alike, who applied canal and saline water to grow sorghum crop. Similar were the results of Manzoor (2019), who conducted a field experiment to grow sorghum crop applying canal and saline water.

Calcium (%) in maize plants

Calcium is responsible for holding together the cell walls of plants. When calcium is deficient, new tissue such as root tips, young leaves, and shoot tips often exhibit distorted growth. Data showed concentration for calcium (%) in maize plants which revealed that impact of canal and brackish water on calcium (%) in maize plant was significant. It was also obvious from the data that differences among various treatments were significant when seen through the yardstick of statistics (Fig. 5). The highest calcium (0.16%) in maize plant was obtained where maize was grown with canal water (T_1). The other treatments, irrigation with water of EC = 2 dS m^{-1} and water of EC = 3 dS m^{-1}(T_2 and T_3) were proved non-significant. The treatments T_2 and T_3 (water of EC = 2 dS m^{-1} and water of EC = 3 dS m^{-1}) showed calcium in maize plant of 0.14 and 0.12% respectively. However, among all the treatments, lowest calcium (0.09%) in maize plant was measured with irrigation of water having EC = 4 dS m^{-1}. Our findings are supported by Essa (2002) who revealed that the contents of Ca, K, Mg were lowered in soybean plant by applying water having salts for irrigation. Naheed et al. (2008) also demonstrated a decrease in root and leaf K^+ and Ca^{2+} with enhancing NaCl concentration. Findings of Murtaza (2019) were also in the same directions who applied canal and saline water to grow sorghum crop. Similarly, results of Manzoor (2019) were also similar, who conducted a field experiment to grow sorghum crop applying canal and saline water.

Magnesium (%) in maize plants

Magnesium is an indispensable mineral for plant growth, it plays a major role in the production of chlorophyll, on which photosynthesis depends. Data depicted (Fig. 6) that applying of canal and brackish water had a considerable impact on the magnesium (%) in plants of maize. Application of canal water was better than irrigation with water of EC = 2, 3 and 4 dS m^{-1}(T_2, T_3 and T_4). It was also obvious from the data that differences among various treatments were significant. The maximum magnesium (0.08%) in maize plant was measured where the maize plants were grown with canal water (T_1). Irrigation with water of EC = 2 dS m^{-1} and water of EC = 3 dS m^{-1}(T_2 and T_3) decreased (0.07 and 0.06%) magnesium in maize plants respectively. However, all the treatments were found significant with each other. Water having value of EC = 4 dS m^{-1} (T_4) recorded minimum magnesium (0.05%) in maize plants as compared to all other treatments. According to Essa, (2002), the different levels of EC (0.5, 2.5 4.5, 6.5 and 8.5 dS m^{-1}) decreased the concentration of calcium, potassium and magnesium in soybean leaves as compared to control. A research study was performed by Hu & Schmidhalter (1997) who claimed that the concentration of magnesium in the leaves of wheat crop was decreased due to salinity. Findings of Murtaza (2019) were also in the same directions who applied canal and saline water to grow sorghum crop. Similarly, results of Manzoor (2019) were almost the same who conducted a field experiment to grow sorghum crop applying canal and saline water.

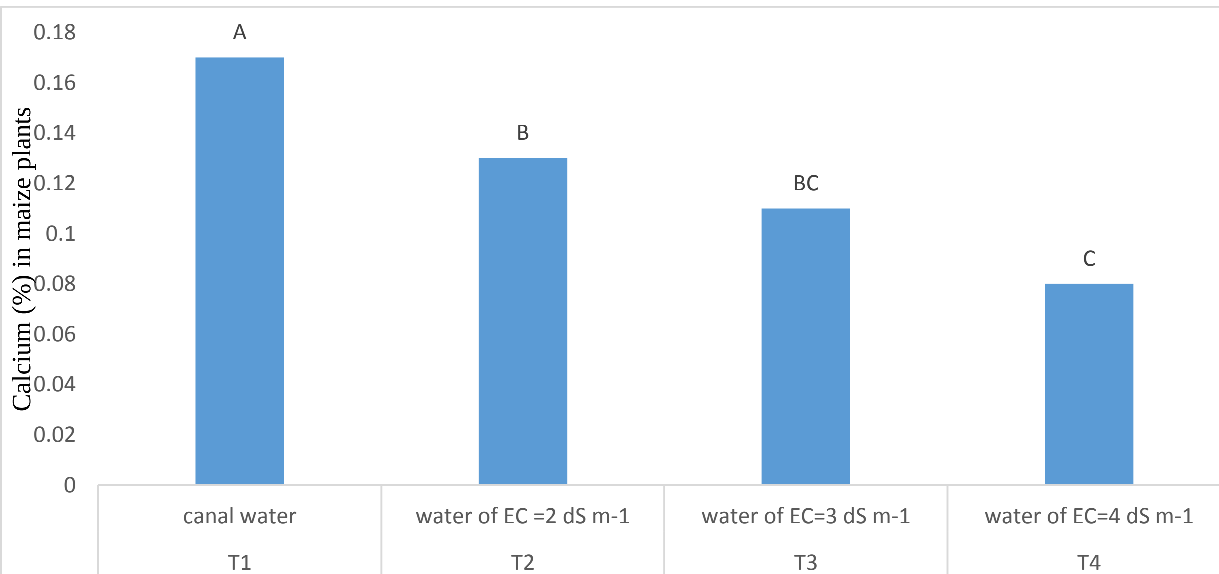

Fig. 5 Effect of canal and saline water on calcium (%) of maize plants

Sodium (%) in maize plants

Sodium is usually required by plants in a minute amount and not be considered as essential element. Sodium in plants plays a vital role in many processes of plant growth and development, but specifically in metabolism and chlorophyll. Maize plants responded significantly to application of canal and brackish water in term of sodium (%) in maize plant. Among all the treatments, irrigation with canal water (T_1) found better as compared to others. It was also obvious from the data that differences among various treatments were significant. The sodium (%) in maize plant was increased with rise in EC of water used for irrigating maize. The highest sodium (0.94%) in maize plant was observed with water of EC = 4 dS m^{-1} (4.23). The irrigation with water of EC = 3 and EC = 2 dS m^{-1} (T_3 and T_2) recorded 0.74 and 0.48% sodium in maize plants respectively. However, T_3 and T_2 were significant statistically. These both treatments were statistically significant with each other. The minimum sodium (0.19%) in maize plant was obtained where irrigation with canal water was applied (Fig. 7). Similar outcomes were found by Essa, (2002) that salinity stress prompted sodium accumulation in leaves of soybean. According to Naheed et al. (2008) applying varying levels of salty water markedly raise sodium as well as chloride concentrations in rice plants over control. Findings of Murtaza (2019) were also alike, who applied canal and saline water to grow sorghum crop. Similarly, results of Manzoor (2019) were also aligned to present study, who conducted a field experiment to grow sorghum crop applying canal and saline water.

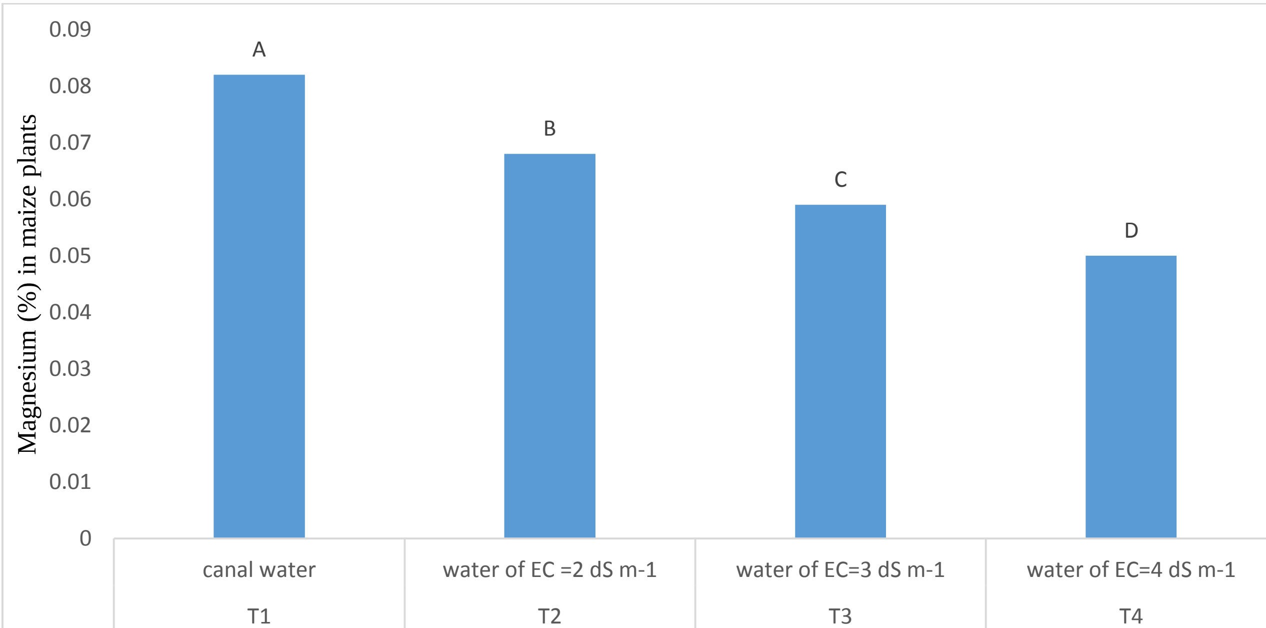

Fig. 6 Effect of canal and saline water on magnesium (%) of maize plants

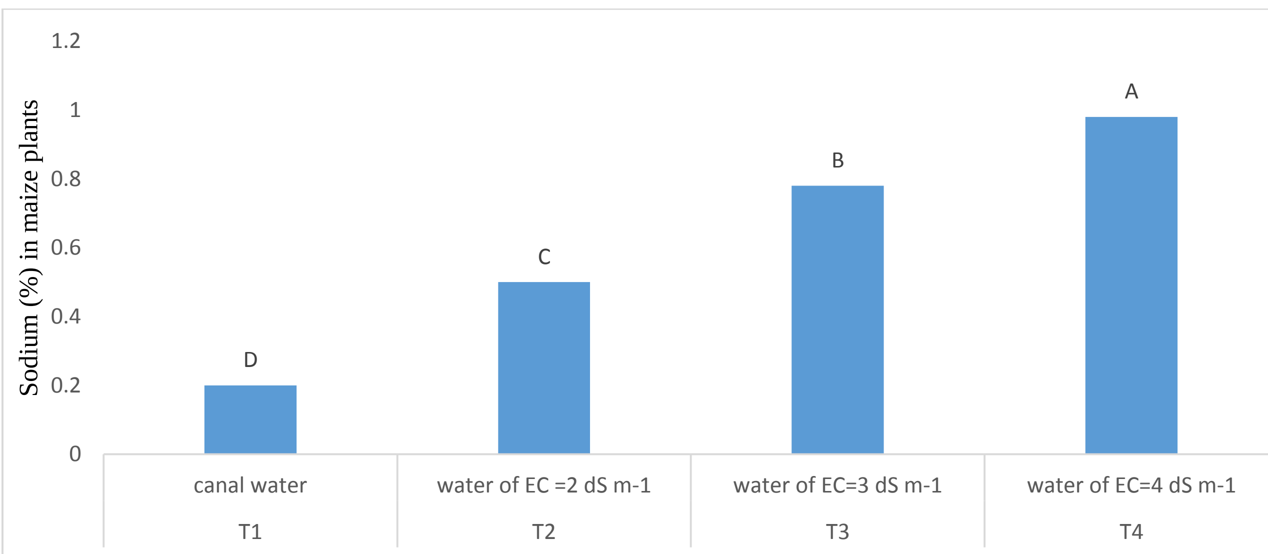

Fig. 7 Effect of canal and saline water on sodium (%) of maize plants

CONCLUSION

It is concluded that canal and brackish water impart significant impact on nutrients concentration in maize. Among all the treatments, the use of canal water was proved to be the best to obtain the highest nutrients (nitrogen, phosphorus, potassium, calcium and magnesium) concentration in maize plants. The increase in the value of EC of irrigation water from 2 to 4 dS m^{-1} reduced the nutrients concentration and enhanced the concentration of sodium in maize plants. Maize biomass yield was also affected significantly with the use of saline water as irrigation source, but yield and all other related yield parameters have been published in a separate paper.

Author Contribution Statement: Imran Shehzad conducted and carried out this research study. Ghulam Sarwar planned, designed and supervised this research study and he is the program leader and provided the research facilities. Muhammad Zeeshan Manzoor helped in conducting the research project and wrote the manuscript. Fakhar Mujeeb contributed in the plant analysis of the parameters prescribed in the manuscript. Ayesha Zafar helped in conducting the research project and wrote the manuscript being Research Associate of this project. Faheem Khadija contributed in data analysis, description and edited the manuscript. All the authors read and approved the manuscript to be published in Journal of Pure and Applied Agriculture.

Conflict of Interest: The authors declare that they have no conflict of interest.

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