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RESEARCH PAPER

Efficiency of farm yard manure to mitigate drastic saline water impacts on nutrients uptake by sorghum (*Sorghum bicolor*)

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Key Message: This study provides a clear image of the enhanced nutrient uptake by sorghum plants by the use of FYM under saline irrigation system.

Abstract: The continuous use of saline water results in salt buildup in soil leading to reduced crop yield as well as soil resource deterioration. However, adding organic matter in either form may help in lowering salts in the rhizosphere. A trial was conducted to examine the efficacy of farm yard manure (FYM) in modifying the salinity and enhancing the uptake of nutrients by sorghum. In this experiment irrigation, water of 3 different types (canal water and saline water of electrical conductivity values 2 and 3 dS m^{-1}) was applied and coupled with FYM @ 5 and 10 Mg ha^{-1}. The experiment was comprised of 9 treatments; T_1= Canal Water, T_2 = water of EC 2 dS m^{-1}, T_3 = water of EC 3 dS m^{-1}, $T_4 = T_1$ + FYM @ 5 Mg ha^{-1}, $T_5 = T_2$ + FYM @ 5 Mg ha^{-1}, $T_6 = T_3$ + FYM @ 5 Mg ha^{-1} , $T_7 = T_1$ + FYM @ 10 Mg ha^{-1} , $T_8 = T_2$ + FYM @ 10 Mg ha^{-1} and $T_9 = T_3$ + FYM @ 10 Mg ha^{-1}. The experiment was laid according to RCBD with four replications. Sorghum cultivar "Hegari" was grown as a test crop. Pre and post-harvest soil analysis was carried out for various soil characteristics. Results indicated that among all the treatments, T_7 (T_1 + FYM @ 10 Mg ha^{-1}) performed best in enhancing N, P, K, Ca and Mg uptake while lowering the uptake of Na by sorghum. However, the treatment T_3 (water of EC 3.0 dS m^{-1}) lowered N, P, K, Ca and Mg uptake while enhancing sodium content in sorghum plants. © 2020 Department of Agricultural Sciences, AIOU

Keywords: FYM, Nitrogen, Phosphorus, Potassium, Saline water, Sorghum

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Introduction

Sorghum is 5^{th} most significant grain crop and second cheapest source of energy and nutritional needs following pearl millet (*Pennisetum glaucum*). As it is C4 grass with more ability to process photosynthesis and tolerate different abiotic and biotic stresses. Therefore, it is moderately salt tolerant and well suited to arid and semi-arid regions where salinity is a major concern (Chowdary et al., 2016). Sorghum is not only a source of food and feed, but also a source of raw materials for the production of alcohol, fiber and biofuels. It is grown as a staple food in India and Africa (Mehmood et al., 2008). Sorghum is grown on an area of 0.34 m ha in Pakistan. There is an upward and downward trend from 1991-2011 in sorghum cropped areas. The area under sorghum crop was 490 thousand hectares in 1990 which declined in 1991 and then grew rapidly at the end of 1992 while it was 457 thousand hectares in 2011. Similarly, the production of sorghum had an upward and downward trend from 1990-2011 which declined in 1991 and then grew swiftly in 1992. The production of sorghum was 195 thousand tons during the year 1990 while it was 303 thousand tons in the year 2011. Resultantly, area under sorghum crop has not increased as compared to the sorghum production. The decrease in area might be due to unfavorable climatic conditions and economics. The annual production of sorghum in the world is 60 million tons whereas in Pakistan is 0.21 million tons with an average yield of 620 kg/hectare (Habib et al., 2013).

Among all abiotic disorders, salinity is the major growth limiting factor (Giaveno & Ferro, 2003). Pakistan is located in a semi-arid region having 6.67 million hectares of area damaged by salinity which constitute about $1/3^{rd}$ of cultivable area. Additionally, out of 6.67 million hectares, 3.7 and 2.90 million hectares is saline and sodic/saline-sodic in nature (Khan et al., 2010). The photosynthetic process, formation of proteins and the uptake of essential nutrients is affected by the presence of salinity resulting in reduced production of crops (Khan & Panda, 2008). Hence, the adoption of suitable managing practices is required in order to minimize harmful impacts of salts (Qadir & Schubert, 2002). The application of brackish water results in an increase in soil EC (Kim et al., 2016). The water of saline nature has negative impacts on soil water plant relationship, sometimes limiting physiological activities of the plants and eventually the production of crops (Plaut et al., 2013).

The dynamic decrease in resources of fresh water is driving toward unavoidable utilization of saline water for irrigating crops (Ali et al., 2019). There is a dire need to adopt suitable management practices for the use of saline water irrigation systems and to avoid the buildup of salts in soil for sustainable crop production. The increase in demand for resources of fresh water has compelled farmers to use poor quality water for irrigation purposes. Irrigating crops with poor quality water for the whole growing season limits the productivity of crops, even the tolerant crops do not produce satisfactory yield (Chowdary et al., 2016). Salinity of irrigation water is one of the crucial factors that restricts the yield of crops because most of the water available for irrigation is unfit for irrigation due to the presence of excessive concentration of salts (Fuller et al., 2012). Salinity is leading to degradation of natural soil resources which affect the agricultural production (Ren et al., 2019). The elevated salinity is a major cause of reduction in yield for economically important crops (Ivushkin et al., 2019). Hence, excessive soluble salts and exchangeable sodium are major salt related issues in soils (Paz et al., 2019). Soil salinity is a global problem (Chen et al., 2019). Hence, the prevention of salinity is a key for better crop productivity in arid and semi-arid regions (Wang et al., 2019).

The crop growth is severely affected due to imbalance of nutrients, oxidative stress, osmotic effect and water deficit (Kim et al., 2016). The growth of most crop plants is lowered by the presence of salts in soil (Zorb et al., 2019). Irrigation with water of saline nature may result in salt accumulation in the rhizosphere resulting in reduced yield and uptake of plant nutrients (Ahmed et al., 2007). The increase in demand for resources of good quality water has compelled the farmers to use saline irrigation while irrigating crops with this kind of water for extended durations limits the productivity even that of tolerant varieties (Narjary et al., 2019). However, mixing good and poor-quality water is being practiced to keep the irrigation water salinity below threshold level (Oster, 1994). The most valuable method for lowering salts is leaching of excessive sodium away from the roots (Ghafoor et al., 2001). Similarly, adding organic matter like FYM and solid municipal waste is also an effective approach for ameliorating soils affected by salts and excessive sodium on exchange complex (Pang et al., 2010). Organic matter like FYM not only enhances the nutrient availability but also the soil fertility status resulting in increased fodder productivity (Ahmad et al., 2007). Organic matter such as FYM, poultry manure, compost and residues of crops enhances the availability of nitrogen in soil leading to improved fertility of the soil as well as the production of fodder and grains. The recycling of nutrients from organic matter like FYM and compost has been given more attention for assuring sustainable use of land. The importance of organic matter in improving soil properties and fertility status is well documented by many scientists (Mahajan et al., 2008).

The use of saline irrigation causes an increase in soil electrical conductivity (Kim et al., 2016). Saline water application for longer durations may cause the problem of increased root zone salinity leading to reduced yield and deterioration of natural soil resources (Ahmed et al., 2007). Hence, it is necessary to lessen destructive salinity impacts by adopting appropriate strategies of management (Qadir & Schubert, 2002). It is necessary to understand the salinity distribution as well as its composition for better management of soil (Wang et al., 2020). The incorporation of crop residues and organic materials like FYM is being recommended and utilized from many years due to increase in the cost of inorganic fertilizers. The addition of such materials not only enhances the availability of nutrients but also plays a dynamic role in enhancing soil fertility resulting in improved production of crops (Ahmad et al., 2007). The use of organic matter like FYM not only enhances the nutrient availability but also plays a vital role in improving the fertility status of the soil resulting in increased production of fodder. The addition of organic matter such as FYM, poultry manure, compost and residues of crops enhances the availability of nitrogen in soil leading to improved fertility of the soil as well as the production of fodder and grains (Ahmad et al., 2007). The use of fermented manure enhances the growth characteristics of sorghum (Abusuwar, 2019). Organic matter is of countless importance for soil carbon and nitrogen in varying ecosystems which can increase the nutrition of plants (Marzi et al., 2020).

The use of organic matter has gained much importance due to the increase in cost of synthetic fertilizers. In Pakistan, the most commonly available source of organic matter is farmyard manure (Iqbal et al., 2008). Higher yield of maize fodder can be obtained by amending soil with chicken and cattle manure along with ash of wood (Bekeko, 2014). The application of organic matter improves biological and physico-chemical characteristics of soils affected by salts, resulting in an improvement in growth through accelerating the leaching of toxic salts and cation exchange (Clark et al., 2007). The decay of manures results in increased levels of CO_2 in the soil and release of H^+ ions which promotes the dissolution of $CaCO_3$ liberating calcium for the exchange of sodium (Ghafoor et al., 2001). Hence, the application of organic matter is essential for sustainable use of land and productivity of the crops (Hu et al., 2011). It may be the most appropriate way to improve and maintain the soil productivity, fertility status and salt tolerance in addition to organic fertilizer (Das et al., 2013). The objective of the research study was to evaluate the effect of irrigation management technique (use of organic matter in the form of FYM) on the nutrient content of sorghum when continuously irrigated with saline water under local conditions.

Materials and Methods

Experimental location

This experimental trial was conducted at research area of College of Agriculture, University of Sargodha, Pakistan sited 32.08 ^{o} North latitude and 72.67 ^{o} East longitude to examine the importance of FYM to mitigate drastic saline water impacts on nutrients uptake by *Sorghum bicolor*. For this purpose, normal field was selected and analyzed for different properties (Table 1).

Experimental set up

This study was performed in (RCBD) design with 9 treatments that were replicated four times. The plot size was 3.5 m × 3.5 m in which 75 cm and 25 cm is row-row and plant-plant distance. The treatments of the experiments were: T_1 = Canal water; T_2 = Water of EC 2.0 dS m^{-1}; T_3 = Water of EC 3.0 dS m^{-1}; T_4 = T_1 + FYM @ 5 Mg ha^{-1}; T_5 = T_2 + FYM @ 5 Mg ha^{-1}; T_6 = T_3 + FYM @ 5 Mg ha^{-1}; T_7 = T_1 + FYM @ 10 Mg ha^{-1}; T_8 = T_2 + FYM @ 10 Mg ha^{-1}; T_9 = T_3 + FYM @ 10 Mg ha^{-1}. Seed beds were prepared according to layout. Farm yard manure (FYM) was used as a source of organic matter and was also analyzed for the content of organic matter (FYM = 45.0 % organic matter). FYM was applied to the respective treatment plots after seed bed preparation. After 15 days of FYM incorporation in the soil, sorghum cultivar "Hegari" was sown @ 40 kg $acre^{-1}$. The hoeing was done 2 times to reduce weed-crop competition. First irrigation to the crop was given after 10 days of germination while other irrigations were applied to the crop according to water requirements of the crop. Fertilizers like SOP, SSP and Urea were the N, P, K sources used in the experiment. At maturity harvesting was done and plant samples were analyzed for various nutrients concentrations.

Plant analysis

The analysis was made according to the methods written in Hand Book 60 (U.S. Salinity Laboratory Staff, 1969) or otherwise mentioned.

Total nitrogen

Dried and powdered plant material (1.0 g) was digested using 40 ml of H_2SO_4 and 8 g of digestion mixture (K2 SO_4: Fe SO_4: Cu SO_4 = 10: 1: 0.5) for each sample. When the solution became transparent and yellowish green, it was allowed to cool and transferred to 100 ml volumetric flask and made up to the mark. The solution was filtered and stored in plastic bottles for further analysis. Ten ml of the aliquot was taken from the above prepared solution for distillation. Nitrogen evolved as ammonia was collected in receiver containing boric acid (4 %) solution and mixed indicator (bromocresol green and methyl red) and titrated against 0.1 N H_2SO_4 (method of sulphuric acid digestion) (Hu & Barker, 1999) and distillation with micro Kjeldahl's apparatus (Jackson, 1962).

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

Plant samples of 0.5 g were transferred into digestion vessel. 10 ml of diacid mixture (HNO_3: $HClO_4$= 2:1) were added into the vessel and kept for a single day. In this way, digestion of plant samples was completed (Method 54 a).

Sodium, potassium, calcium, magnesium and phosphorous determination

Na and K from digested plant samples were determined by flame photometer (Method 57 & 58 a). Atomic absorption spectrophotometer was used for determining Ca and Mg from digested plant samples (Method 55 a & 56). Total phosphorus in plant samples was determined by using the extracts of wet digestion and spectrophotometer (Method 61).

Data analysis

All data was statistically analyzed by statistix 8.1 ANOVA technique by comparing the significance of treatments through Tukey's (HSD) test at 5% probability level (Steel et al., 1997).

Table 1 Analysis of experimental soil

Characteristic	Unit	Value
pH_s	-	7.8
EC_e	dS m^{-1}	1.33
SAR	-	5.44
Soil textural class	-	Clay loam

Results

Nitrogen (%) in sorghum plants

Nitrogen is needed by plants to complete their life cycle. It is the integral component of chlorophyll molecules therefore it plays a key role in photosynthesis. Fig. 1 showed that the maximum nitrogen content (0.64%) was recorded in T_7 (T_1+ FYM @ 10 Mg ha^{-1}) followed the treatment where canal water was used along with 5 Mg ha^{-1} FYM (T_4) and treatment T_8 (T_2 + FYM @ 10 Mg ha^{-1}) that produced 0.60 and 0.57% content of nitrogen in sorghum plants, respectively. However, the treatment T_4, T_7 and T_8 were statistically non-significant with each other. The nitrogen content of 0.56, 0.53 and 0.52% was noted in the treatment T_1 (canal water), T_9 (T_3 + FYM @ 10 Mg ha^{-1}) and T_5 (T_2 + FYM @ 5 Mg ha^{-1}) respectively. However, T_1, T_9 and T_5 were statistically non- significant. The minimum nitrogen content (0.46%) was found in treatment where water of EC 3.0 dS m^{-1} was applied for irrigation (T_3) which was followed T_2 (water of EC 2.0 dS m^{-1}) and T_6 (T_3 + FYM @ 5 Mg ha^{-1}) that produced 0.49% content of nitrogen (Fig. 1).

Phosphorous (%) in sorghum plants

Phosphorus plays a key role as it is involved in the processes of respiration, photosynthesis and energy storage in plants. Phosphorus is required by plants as it is the component of genetic material (DNA). Fig. 2 showed that maximum phosphorus content (0.22%) was recorded in T_7 (T_1 + FYM @ 10 Mg ha^{-1}) followed by treatment where canal water was used along with 5 Mg ha^{-1} FYM (T_4) and treatment T_8 (T_2 + FYM @ 10 Mg ha^{-1} that produced 0.20% content of phosphorus in sorghum plants. However, T_4, T_7 and T_8 were non-significant statistically. The phosphorus content of 0.19, 0.18 and 0.17% was recorded in T_1 (canal water), T_9 (T_3 + FYM @ 10 Mg ha^{-1}) and T_5 (T_2+ FYM @ 5 Mg ha^{-1}) respectively. The lowest phosphorus (0.11%) was found in treatment where water having EC value 3.0 dS m^{-1} was used for irrigation (T_3) followed T_2 (water of EC 2.0 dS m^{-1}) and T_6 (T_3 + FYM @ 5 Mg ha^{-1}) that both produced 0.13% content of phosphorus (Fig. 2). The treatments T_3, T_2 and T_6 were non-significant when compared with each other.

Potassium (%) in sorghum plants

Potassium is important for plants as it controls the closing and opening of stomata as well as water uptake by plants. The highest potassium content (2.24%) was produced in T_7 (T_1+ FYM @ 10 Mg ha^{-1}) followed by T_4 (T_1 + FYM @ 5 Mg ha^{-1}) and T_1 (canal water) that produced 2.19 and 2.07% content of potassium, respectively (Fig. 3). Similarly, the potassium content of 2.03, 1.83 and 1.78% was noted in T_8 (T_2 + FYM @ 10 Mg ha^{-1}), T_5 (T_2 + FYM @ 5 Mg ha^{-1}) and T_2 (water of EC 2.0 dS m^{-1}) respectively. However, T_5 and T_2 were statistically non-significant. The lowest potassium content (1.36%) was noted in T_3 (water of EC 3.0 dS m^{-1}) followed by T_6 (T_3 + FYM @ 5 Mg ha^{-1}) and T_9 (T_3+ FYM @ 10 Mg ha^{-1}) that produced 1.56 and 1.66% content of potassium, respectively (Fig. 3). However, T_3, T_6 and T_9 were shown significant with each other in terms of statistics.

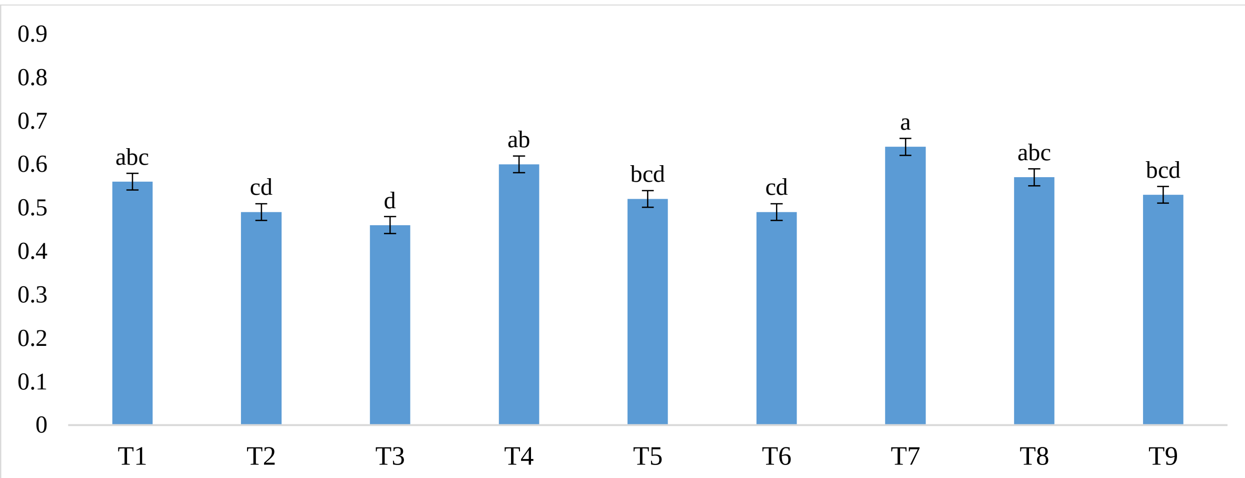

Fig. 1 Impact of canal and saline water with and without FYM on nitrogen (%) in sorghum plants

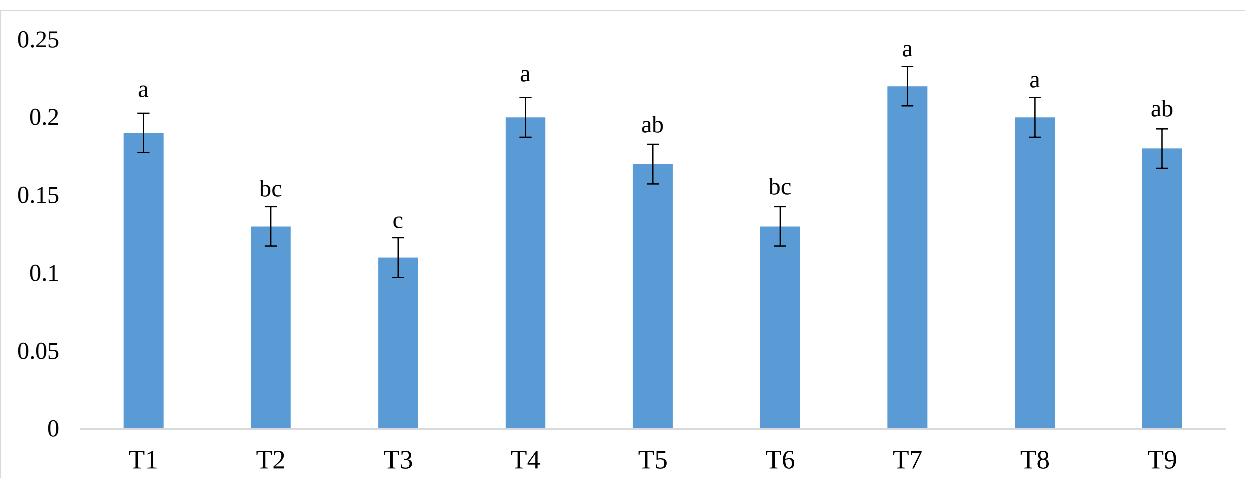

Fig. 2 Impact of canal and saline water with and without FYM on phosphorous (%) in sorghum plants

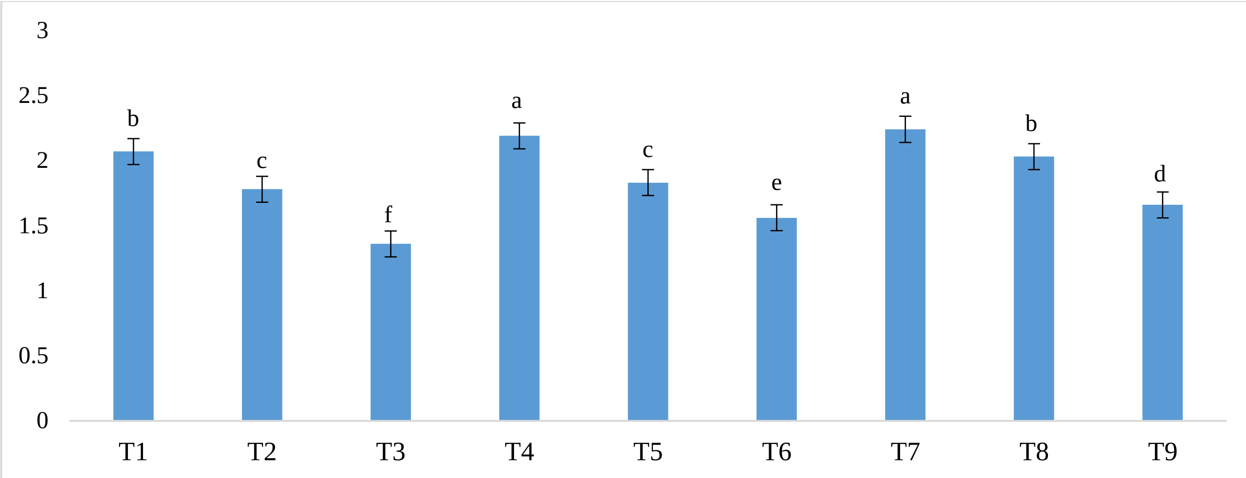

Fig. 3 Impact of canal and saline water with and without FYM on potassium (%) in sorghum plants

Calcium (%) in sorghum plants

Calcium is required by plants in minute quantities as it is essential for the integrity of cell wall. The highest calcium content (0.32%) was found in T_7 (T_1 + FYM @ 10 Mg ha^{-1}) followed by T_4 (T_1 + FYM @ 5 Mg ha^{-1}) and T_1 (canal water) that produced 0.30 and 0.29% content of calcium in sorghum plants, respectively (Fig. 4). Similarly, the calcium content of 0.27, 0.24 and 0.23% was noted in T_8 (T_2 + FYM @ 10 Mg ha^{-1}), T_5 (T_2 + FYM 5 Mg ha^{-1}) and T_2 (water of EC 2.0 dS m^{-1}), respectively. However, T_2 and T_8 were statistically significant. The minimum calcium content (0.18%) was found in T_3 where water having EC 3.0 dS m^{-1} was applied which was followed by T_6 (T_3 + FYM 5 Mg ha^{-1}) and T_9 (T_3 + FYM 10 Mg ha^{-1}) that produced 0.19 and 0.21% content of calcium, respectively (Fig. 4). However, T_3, and T_9 were shown significant with each other in terms of statistics.

Magnesium (%) in sorghum plants

Magnesium is a macronutrient required by plants to complete their growth stages as it is needed for the proper functioning of many enzymes. It also serves as a central atom in the molecules of chlorophyll. Fig. 5 showed that maximum content of magnesium (0.099%) was found in T_7 (T_1+ FYM @ 10 Mg ha^{-1}) followed by T_4 (T_1 + FYM 5 Mg ha^{-1}) and T_8 (T_2 + FYM 10 Mg ha^{-1}) that were recorded 0.093 and 0.088%, respectively.T_7, T_4 and T_8 were statistically. The magnesium contents of 0.086, 0.082 and 0.081% were recorded in T_1 (canal water), T_5 (T_2 + FYM 5 Mg ha^{-1}) and T_9 (T_3 + FYM 10 Mg ha^{-1}) respectively. The lowest magnesium (0.071%) was found in T_3 (water of EC 3.0 dS m^{-1}) followed by T_6 (T_3 + FYM @ 5 Mg ha^{-1}) and T_2 (water of EC 2.0 dS m^{-1}) that were recorded 0.075 and 0.077%, respectively (Fig. 5). However, T_6 and T_2 were non-significant with each other in terms of statistics.

Sodium (%) in sorghum plants

Sodium is required by plants in minute quantities to maintain their growth and to promote metabolism. However, the excessive concentration of sodium in soil deteriorates soil properties resulting in restricted development and growth of plants. Fig. 6 showed that sodium (%) in sorghum plants was affected significantly by applying canal and saline water with and without FYM. The highest concentration of sodium in sorghum plants (0.37%) was found in T_3 (water of EC 3 dS m^{-1}) followed by the treatment T_6 (T_3 + FYM @ 5 Mg ha^{-1}) and T_2 (water of EC 2.0 dS m^{-1}) that were noted 0.35 and 0.34% respectively. The content of sodium in sorghum plants in other treatments such as T_9 (T_3 + FYM @ 10 Mg ha^{-1}), T_5 (T_2+ FYM @ 5 Mg ha^{-1}) and T_8 (T_2 + FYM @ 10 Mg ha^{-1}) were recorded 0.33, 0.32 and 0.30% respectively. The minimum content of sodium in sorghum plants (0.25%) was found in T_7 (T_1 + FYM @ 10 Mg ha^{-1} followed by T_4 (T_1 + FYM 5 Mg ha^{-1}) and T_1 (canal water) that were recorded 0.27 and 0.28%, respectively (Fig. 6).

Discussion

The concentration of various elements in the tissues of plants refers to chemical composition. Plants need a variety of chemical elements to live and to complete their growth cycle. Use of poor-quality water poses harmful effects to soil health which ultimately affects plant growth. The decline in soil quality results in poor nutrient uptake by crops. The salinity in soil caused by the use of poor-quality water restricts the uptake of plant nutrients. High content of salts in soils of Pakistan as induced by aridity is limiting the nutrient uptake by plants. The presence of salinity lowers the potential of water resulting in poor nutrient uptake. However, use of FYM in this regard is the best strategy to lower the elevated level of salts in soil, hence, alleviating the salinity and enhancing nutrient uptake.

Our findings are favored by Abou El-Magd et al. (2008) that adding FYM enhanced the nitrogen content of sweet fennel leaves and minimized the drastic effects of salinity. Alam et al. (2016) also revealed that organic matter additions gave tolerance to rice plants by improving the nitrogen content and mitigating the salinity. Sharif et al. (2014) found an increase in the uptake of nitrogen as well as increased content of nitrogen in leaves of sorghum by manuring of soil. Similarly, Manzoor et al. (2019) observed an increase in nitrogen uptake by the use of canal water and reduction in nitrogen uptake by the use of saline water. The low availability of phosphorus severely affects plants (Abbaszadeh-Dahaji et al., 2019). Lakhdar et al. (2008) stated that organic waste addition enhanced the phosphorus content in *Hordeum maritimum* shoots. These conclusions are also favored by Sharif et al. (2014) who stated that applying composted organic materials enhanced the uptake of phosphorus as well as growth of sorghum plants grown in a salinity environment.

Similar results were reported by Bano and Fatima (2009) who stated that the presence of salinity reduces the potassium content in plants. Similarly, Lakhdar et al. (2008) observed that adding organic materials in soil enhances the potassium content of plants even grown in a salinity environment. Likewise, Rani et al. (2020) found that the integrated use of organic manures along with recommended fertilizers increased the potassium content in wheat crop. Al-Harbi (1995) noted reduction in calcium content of cucumber and tomatoes by enhancing the salinity level of soil. Kaya et al. (2001) stated that the calcium, phosphorus and nitrogen uptake was inhibited by NaCl availability. The outcomes of this research are favored by Naeini et al. (2005) that enhancing water salinity lowered magnesium uptake in pomegranate cultivars. These findings are also reinforced by the outcomes of Walker and Bernal (2008) who described that applying compost under the conditions of salinity enhanced the content of magnesium in the shoots of sugar beet. These findings are favored by the outcomes of Walker and Bernal (2008) that the content of sodium in shoots of sugar beet was considerably lowered by applying compost under salinity conditions. Al-Harbi (1995) found an increase in the buildup of sodium in cucumber and tomato plants by enhancing the salinity level of soil. Shehzad et al. (2019) found that enhancing the salinity of irrigation water increased the sodium content in sorghum. Choudhary et al. (2004) found that using saline water for irrigation purposes caused an increase in the content of sodium in the juice of sugarcane. Benazzouk et al. (2019) observed a decrease in sodium accumulation in leaves of tomato by the use of vermicompost.

The results of the study revealed that nutrient content in plants decreased by increase in water salinity. However, the use of FYM under the saline irrigation system improved the nutrient content in plants and lowered the content of sodium in sorghum plants. Our findings are supported by Al-Harbi (1995) who observed increased accumulation of sodium in cucumber and tomato plants by enhancing the salinity level of soil. Similarly, Choudhary et al. (2004) found that using saline water for irrigation purposes caused an increase in the content of sodium in the juice of sugarcane. Kaya et al. (2001) that the calcium, phosphorus and nitrogen uptake was inhibited by NaCl availability. Alam et al. (2016) reported that adding FYM enhanced nutrient uptake particularly of nitrogen in rice plants. Similarly, Lakhdar et al. (2008) observed that adding organic materials in soil enhances the potassium, magnesium, calcium, phosphorus and nitrogen content of plants even grown in a salinity environment.

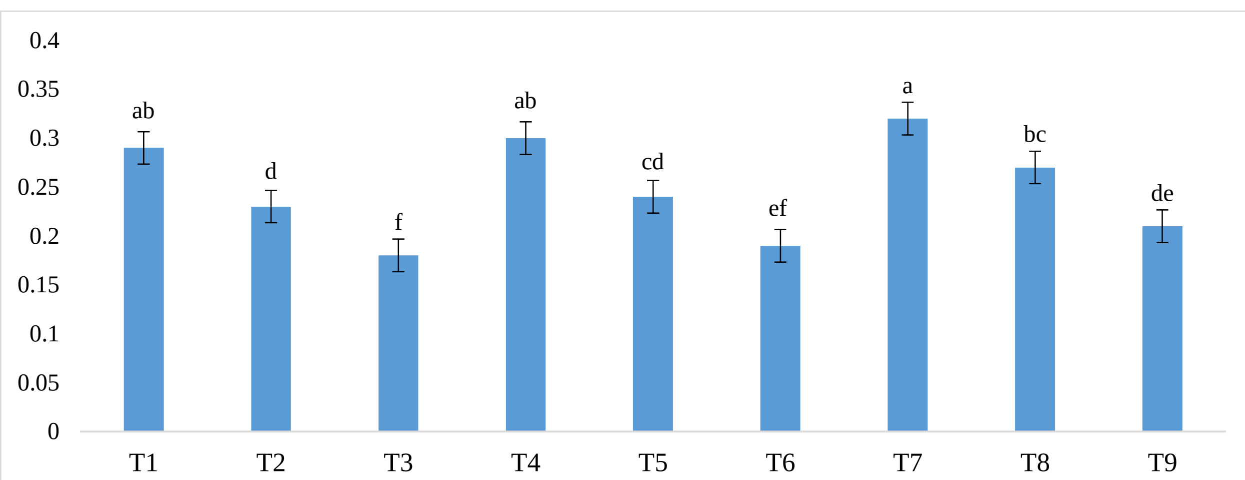

Fig. 4 Impact of canal and saline water with and without FYM on calcium (%) in sorghum plants

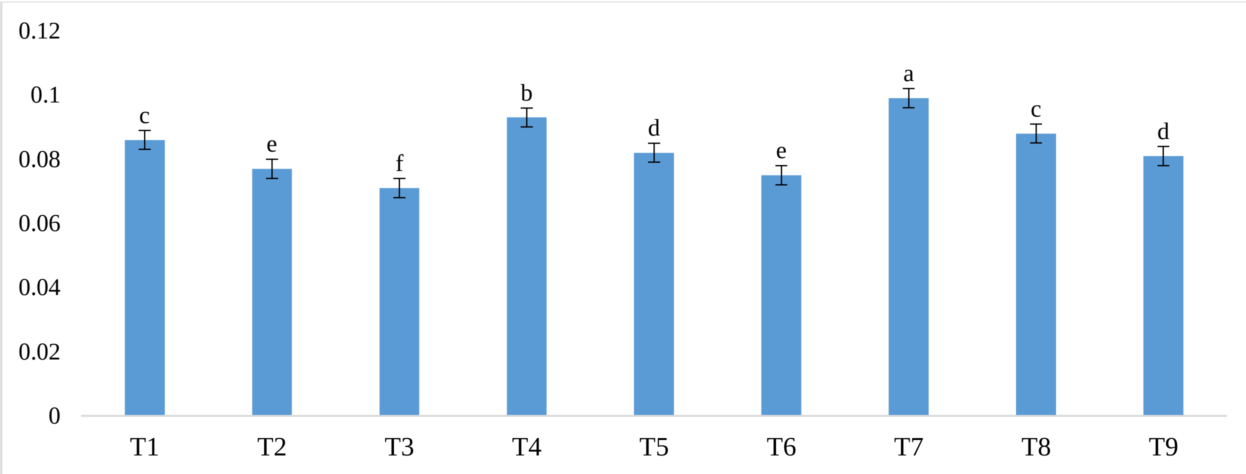

Fig. 5 Impact of canal and saline water with and without FYM on magnesium (%) in sorghum plants

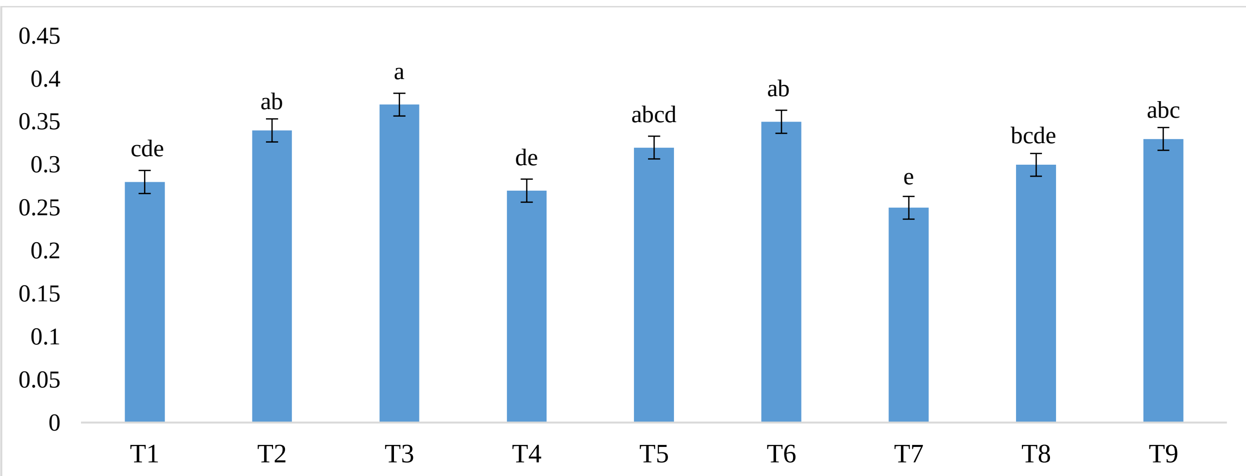

Fig. 6 Impact of canal and saline water with and without FYM on sodium (%) in sorghum plants

Conclusion

The results of the experiment showed that adding FYM proved effective treatment in minimizing detrimental effects of saline water. The results of study demonstrated that application of FYM mitigated deleterious saline water impacts on growth of sorghum by improving the content of nutrients in sorghum plants. Among all the treatments, T_7 (T_1 + FYM @ 10 Mg ha^{-1}) performed the best which enhanced nitrogen, phosphorus, potassium, calcium and magnesium content in sorghum plants. However, T_3 (water of EC 3.0 dS m^{-1}) increased sodium content in sorghum plants with a net reduction in nitrogen, phosphorus, potassium, calcium and magnesium concentration.

Author Contribution Statement: Ghulam Murtaza conducted and carried out this research study. Ghulam Sarwar planned, designed and supervised this research study. Muhammad Zeeshan Manzoor helped in conducting the research project. Ayesha Zafar edited the manuscript. All the authors read and approved the manuscript to be published.

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

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