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Influence of Sowing Methods and Mulching on Soil Salt Dynamics and Performance of Fodder Sorghum Irrigated with Saline Water

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Abstract

The present study was undertaken to study the influence of sowing methods and mulching on soil salt dynamics and performance of fodder sorghum when irrigated with saline water. Application of saline water (4 irrigations with water of EC 6.0 dS m^{-1}), gradually increased the soil salinity in soil profile. The soil salinity increased by 1.27 times over normal irrigation water in 0-60 cm soil depth. Among the sowing methods, ridge and furrow sowing with alternate furrow irrigation recorded lowest salinity development in surface 0-15 and 15-30 cm soil layers. The salinity was 36.4 and 49.1 per cent higher under two-row raise beds as compared to ridge and furrow in upper 0-15 and 15-30 cm soil layers, respectively. Mulching with crop residue maintained lower levels of salinity over bare soil. Mulched soil had 24.8 per cent higher moisture content in 0-60 cm soil profile than un-mulched treatment. Irrigation with saline water significantly reduced the fodder yield of sorghum by 10.6 per cent as compared to irrigation with normal water. Sowing of fodder sorghum on two-row raised beds recorded significantly the highest fodder yield over flat bed and ridge and furrow sowing which was 8.2 per cent higher over flatbed sowing.

Key words: Fodder sorghum, Mulch, Sowing methods, Soil moisture, Soil salinity

Introduction

Soil salinity is one of the main constraints for successful agriculture production, particularly when irrigation is an essential for agriculture production (Ahloowalia *et al.*, 2004) in arid and semiarid regions. The inadequate rainfall during the crop growth period with higher evaporative demand also increases the salt accumulation in soil. Increasing fresh water demand for ever growing population and other sectors of economy would also reduce the availability of water for agriculture. Therefore, water scarcity and the predicted impact of climate change will necessitate the use of alternate available water resources in agriculture, such as saline water, to narrow the gap between demand and supply of freshwater. The irrigation demand of crops could be met using the poor-quality water (saline and sodic) in crop production with suitable soil and water management modification to prevent the crop from stress. Different agronomic strategies are being adopted for alleviating the adverse effects of salinity. The irrigation with saline water requires a suitable agronomic manipulation so as to retain the salts below the root zone and same to be prevented from upward flow through capillaries (Dong, 2012a). The use of saline water without appropriate management can result in the accumulation of salts in the root zone with associated negative impacts on crop productivity. Agronomic practice like raised bed sowing is gaining importance in row crops for managing salt movement in the soil and also due to water savings of 25-30% (Sayre, 2007). Mulching on soil surface with different materials can reduce the water evaporation from soil surface by acting as physical barrier and increase the available stored soil water for plant use with reduction in salt build-up in the soil (Dong, 2012b). Suitable land configuration like ridge and furrows and raised bed sowing also found to save 20-30% irrigation water, increase water use efficiency and leach the salt from furrows.

In recent years, deficiency of feed and fodder for livestock is identified as one of the major constraints in achieving desired level of their productivity, particularly in summer season. Sorghum [*Sorghum bicolor* (L.) Moench], widely grown owing to its ability to grow under varying soil and agro-climatic situations, is an important fodder crop for cattle. During summer, it is a main source of green fodder for the animals when no other fodder crop is grown. Salinity can cause ion toxicity, osmotic stress, mineral deficiencies which adversely affect photosynthetic, physiological and biochemical processes limiting crop yield and production to various levels across species (Krishnamurthy *et al.*, 2007; Hamid *et al.*, 2008). Growing of sorghum under problem soil or water may affect its quality and productivity which in turn may affects the animal health. So, this study has been undertaken to assess the best agronomic practice which can moderate the effect of salinity on production and quality of sorghum.

Materials and Methods

Experimental details

Present field study was carried out in the lysimeter facilities at the Central Soil Salinity Research Institute Karnal, Haryana to study the effect of saline water irrigation on salt and moisture dynamics in soil and fodder sorghum performance under different sowing methods and mulch. The initial EC_2 (soil:water ratio of 1:2) and pH_2 (soil:water ratio of 1:2) of the experimental soil were 0.32 dS m^{-1} and 7.53, respectively. The experiment consisted of two salinity levels (normal irrigation water of 0.6 dS m^{-1} and saline water of 6 dS m^{-1}), three methods of sowing (flat bed, two-row raised bed and ridge and furrow with alternate furrow irrigation) and two mulch levels (without mulch and straw mulch @ 5 Mg ha^{-1}). The experiment was laid out in factorial randomized block design with three replications. The sorghum "Hybrid Mayur" was sown on 08th May 2015 and harvested for green fodder at 65 days after sowing (DAS). The two-row raised beds were prepared freshly with 30 cm wide raised bed and 15 cm furrow, two rows sorghum were sown on both shoulders bed keeping row to row distance of 20 cm. Under ridge and furrow method, ridge and furrow were prepared keeping center to center distance of 30 cm between furrows or ridges and the crop was sown in furrows. Under flat bed, crop was sown at 30 cm row spacing. The crop was fertilized with 100 and 40 kg ha^{-1} of N and P_2O_5, respectively. Full dose of P_2O_5 (single super phosphate) and one third of N were applied at the time of sowing. The remaining N was applied in two equal splits as top dressings after first and third irrigation. For normal irrigation water, water from tube well of experimental farm was used. For the saline water, the normal water was mixed with water of 15 dS m^{-1} EC in suitable proportion to make EC level of 6 dS m^{-1}. The quality of irrigation water used is presented in the table 1. Irrigation to crop was given at predetermined IW/CPE ratio of 1.2 with 6 cm depth of irrigation water at each irrigation. Under two-row raised bed and ridge and furrow plots, 6.0 cm depth of water was given based on irrigation area available in furrows. In the ridge and furrow system, one of two neighboring furrows was alternately irrigated during consecutive irrigations.

Soil study

Periodical soil samples, before and 48 h after each irrigation, were taken at 15 cm interval up to 60 cm soil profile depth to study the salinity and moisture changes. From two-row raised bed, soil samples were taken from center of the raised bed and from furrows separately. In ridge and furrow method, soil samples were collected form irrigated furrows. Electrical conductivity of soil: water (1:2) solution was measured from the soil samples taken from different soil layers (0-15, 15-30, 30-45 and 45-60 cm) before and after each irrigation. Moisture content in the soil samples taken

Table 1. Quality of irrigation water used

Treatment	EC	pH	CO_3 (meq L^{-1})	HCO_3 (meq L^{-1})	Ca+Mg (meq L^{-1})	RSC (meq L^{-1})	Na (meq L^{-1})	SAR
Normal	0.66	7.55	–	5.0	5.6	–	0.96	0.57
Saline	6.0	7.40	–	4.4	23.8	–	36.4	10.6

periodically from different depths was determined gravimetrically by drying in the hot air oven at 105 °C till the constant weight.

Crop study

Observations on growth parameters (plant height,SPAD readings, dry matter accumulation, number of leaves/plant and Leaf/stem ratio) and green fodder yield were recorded at harvest stage i.e. 65 DAS. Nutrient concentration (N, K and Na) in fodder sorghum leaves were determined using standard methods. Data obtained were analyzed statistically by using standard analysis of variance (Gomez and Gomez, 1984).

Results and Discussion

Soil salt dynamics

The soil salinity estimated up to 60 cm soil profile depth before and after every irrigation under different treatments is depicted in Fig. 1. The levels of salinity increased gradually with the application of saline irrigation water. This consistent increase after every irrigation resulted in gradual buildup

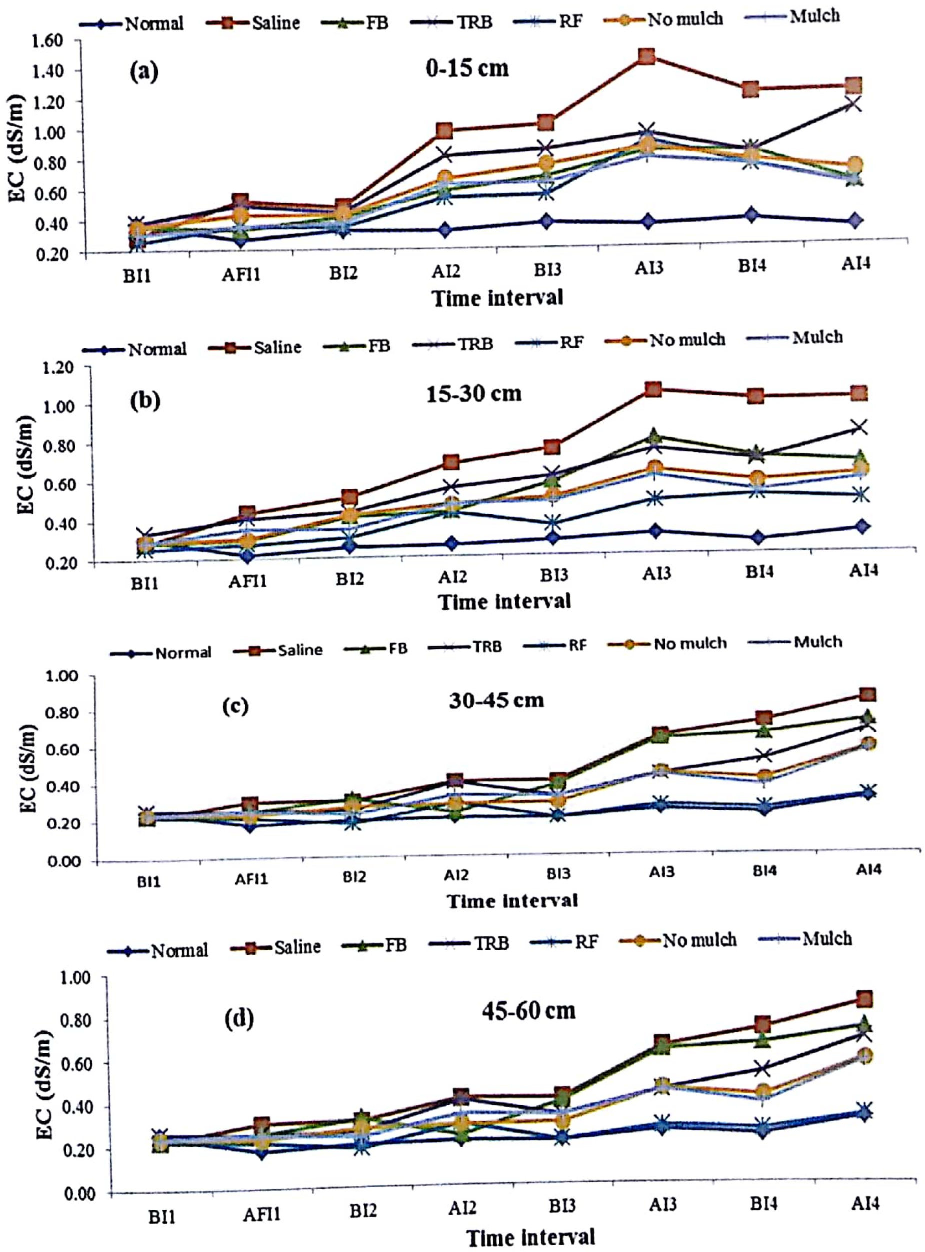

Fig. 1 Dynamics of soil salinity under normal and saline water irrigation, sowing methods and mulch in 0-15 (a), 15-30 (b), 30-45 (c) and 45-60 (d) cm soil layers before (B) and after (AF) each irrigation (I). FB: flat-bed; TRB: two-row raised bed; RF: ridge and furrow

of soil salinity, being more persistent in upper soil profile. The application of 4 irrigations of 6 dS m^{-1} increased the soil salinity from 0.34 to 0.90 dS m^{-1} which was 165.3 per cent higher over normal water irrigation in the top 15 cm soil profile. The similar increase in 15-30, 30-45 and 45-60 cm soil depth were noticed as 158.6, 111.9 and 73.0 per cent, respectively compared to normal irrigation water.

Notable variation in development of soil salinity was observed among the various methods of sowing (Fig. 1). The mean soil salinity after 4 irrigations were maximum on top of the two- row raised bed sowing in the surface 0-15 and 15-30 cm soil layers followed by flat bed and the least under ridge and furrow method of sowing. The salinity was 36.4 and 49.1 per cent higher under two-row raise beds compared to ridge and furrow sowing in upper 0-15 and 15-30 cm soil layers. For two-row raised beds, the application of irrigation water in furrows resulted in movement of salts from furrows to beds, thereby led to increased salinity on center of raised beds. Increased salt accumulation on top of the beds has been reported by Choudhary *et al.* (2008) because of the upward movement of salts through capillary rise. Though below 30 cm soil layer (30-45 and 45-60 cm), the trends of salinity build up in soil was reversed as flatbed> two-row raised beds>ridge and furrow.

Further ridge and furrows with alternate furrow irrigation recorded lowest soil salinity build up across all the irrigations in 0-60 cm soil layer compared to two-row raised beds and flatbed sowing (Fig. 1). Under ridge and furrow sowing, the irrigation was applied only in alternate furrow in consecutive irrigations and only 40 per cent of water was received compared to flat-bed sowing. This reduced the total quantity of water application and thereby lower salt accumulation in the soil through irrigation. Similarly, the accumulation of salts in furrows of two-row raised beds also observed lower throughout the soil profile compared to top of the raised beds which were 16.5, 18.7, 24.9 and 48.4 per cent lower then raised beds (Fig. 2). Application of water in the furrows allows salts to leach down from the furrows (Bakker *et al.*, 2010) and also movement of salts on beds/ridges which might lower the salinity under furrows.

The effect of mulching with paddy crop residue @ 5.0 Mg ha^{-1} on soil salt accumulation was more prominent in upper soil layers (0-15 and 15-30 cm) (Fig. 1). Mulching the soil surface with paddy crop residues recorded lower levels of salinity on top 0-30 cm soil compared to bare soil. Crop residues on the soil surface restricts the loss of water through evaporation, thus lesser upward movement of leached salts from lower layers, could have moderated salt redistribution in soil (Deng *et al.*, 2003; Qiao *et al.*, 2006). The effect of mulching on salt accumulation in lower soil profile (30-60 cm) was not prominent. Huang *et al.* (2001) also reported a reduced salt content in the top 30 cm soil and smaller reductions in salt content in the 30-60 cm soil depth than in those of the overlying layers when soil was mulched with wheat straw.

Soil moisture dynamics

Gravimatric soil moisture content under different treatments in 0-60 cm soil layers is depicted in Fig. 3. There was no substantial variation in moisture per cent was seen between saline and normal irrigation water treatments throughout the soil profile (0-60 cm). Among the sowing methods, the flat bed had considerably higher moisture content in the top 0-15 cm soil layer followed by two-row raised bed and ridge and furrow. However the difference in moisture content was not prominent below 30 cm soil layer. The ridge and furrow sowing recorded relatively lower moisture content before and after each irrigation followed by two row raised beds and flat bed sowing. This might be due to application of lower quantity of water under ridge and furrow and two row raised beds compared to flat bed.

Muching with crop residues showed higher moisture content in soil profile before and after each irrigation which was considerably higher in to 30 cm soil profile (Fig. 3). Mulched soil had 50.7, 32.0, 21.3 and 6.9 per cent higher moisture content in 0-15, 15-30, 30-45 and 45-60 cm soil depth, respectivley than un-mulched plots. Crop residues placed on the soil surface shade the soil, serve as a water vapor barrier against evaporation

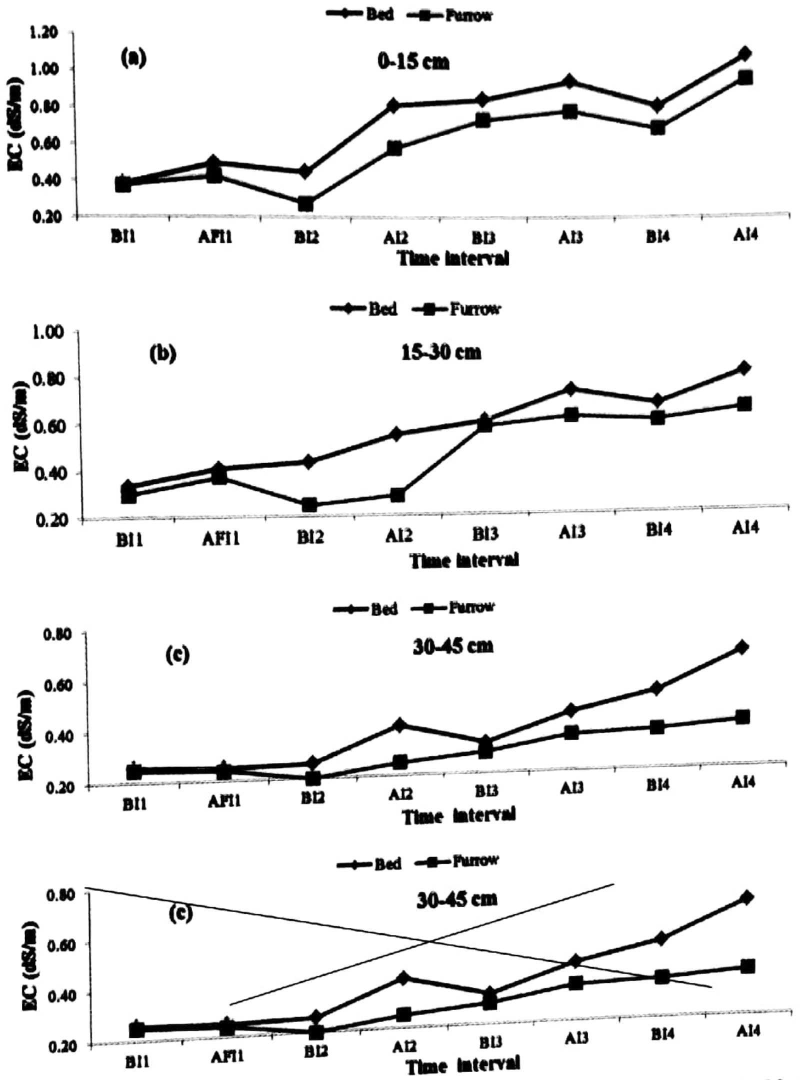

Fig. 2 Dynamics of soil salinity under bed and furrow of tow- row raised bed in 0-15 (a), 15-30 (b), 30-45 (c) and 45-60 (d) cm soil layers before (B) and after (AF) each irrigation (I). FB: flatbed; TRB: two row raised bed; RF: ridge and furrow

losses, slow surface runoff and increase infiltration (Ji and Unger, 2001; Mulumba and Lal, 2008) thereby reduced loss water from soil and increased moiture retention as compared to bare soil.

Growth of fodder sorghum

Irrigation with saline water adversely affected the growth parameters of fodder sorghum at harvest stage (Table 2). Though, there was no significant reduction in plant height of fodder sorghum was noticed at harvest stage. However, SPAD readings, dry matter accumulation/plant (DMA/plant), no. of leaves/plant and leaf/stem ratio at harvest of fodder sorghum were significantly reduced under saline water irrigation as compared to normal water. This might be due to inhibitory effect of salts on the different physiological processes such as water absorption from soil, water translocation, cell division, cell enlargement and differentiation, photosynthesis respiration and the balance of endogenous hormones (Parlak *et al.*, 2008; Hassanein *et al.*, 2010) which in turn reduced the growth of sorghum.

The plant height, SPAD values and number of leaves/plant not differ significantly under methods of sowing. DMA and leaf/stem ratio were significantly higher in two-rows raised bed sowing as compared to flat bed and ridges and furrow. The latter two treatments were remained statistically similar. Mulching with crop residues had higher values of all the growth parameters of fodder sorghum though significant increase over no mulch treatments was recorded only in case of no. of leaves/plant at harvest. The retention of

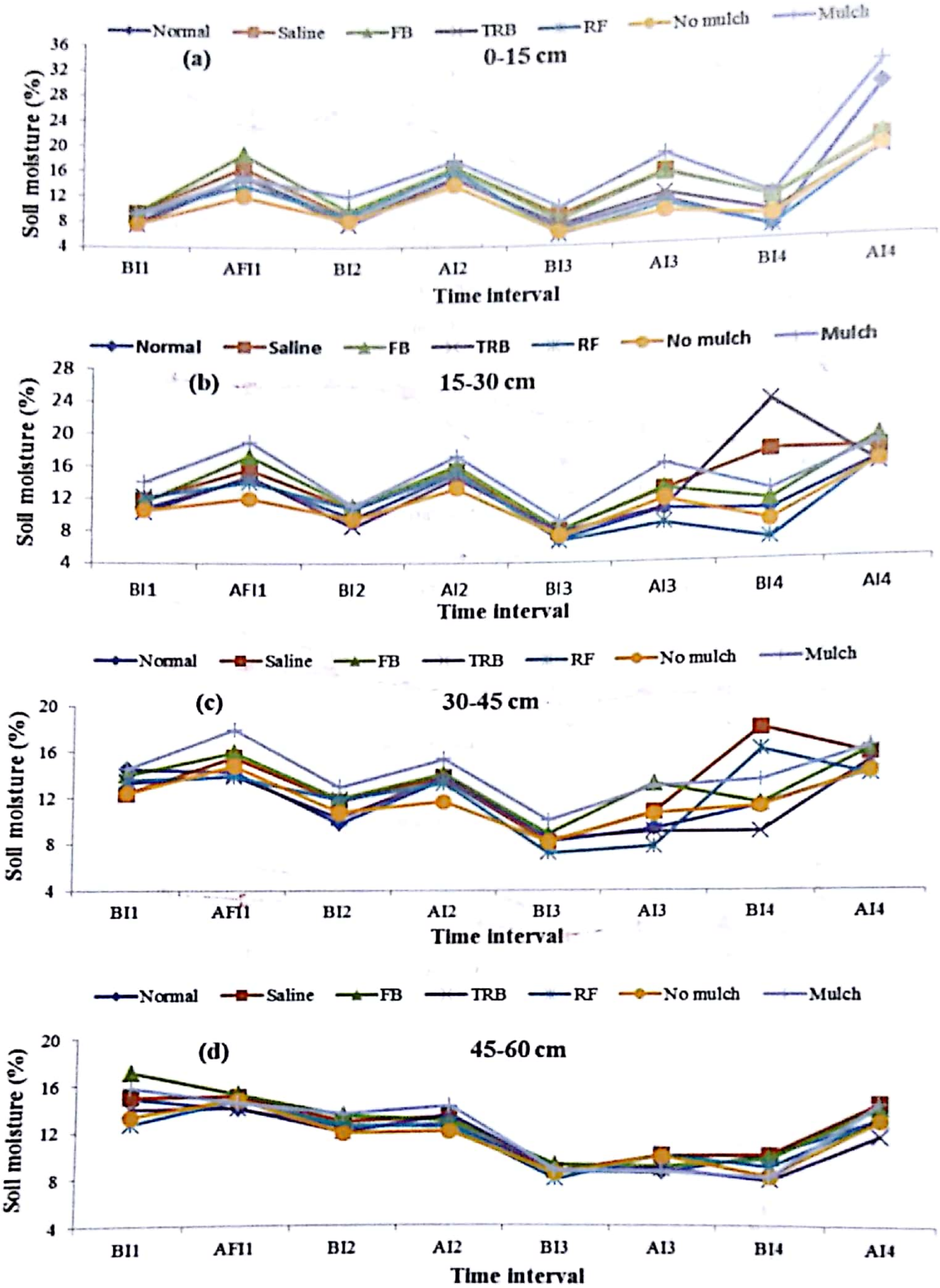

Fig. 3 Dynamics of soil moisture under different treatments of salinity, sowing methods and mulch in 0-15 (a), 15-30 (b), 30-45 (c) and 45-60 (d) cm soil layers before (B) and after (AF) each irrigation (I). FB: flatbed; TRB: two-row raised bed; RF: ridge and furrow

soil moisture for longer time, moderation of soil temperature and reduction in soil salinity under mulched soil might attributed in better growth of sorghum.

The green fodder yield of sorghum varied significantly due to levels of salinity, sowing methods and mulching (Table 2). Green fodder yield reduced significantly under irrigation with saline water which was registered as 8.9 per cent lower than irrigation with normal salinity (0.6 dS/m EC) water. The decrement in fodder yield by increasing salt concentration attributed mainly to the harmful effect of salinity on growth (Table 2) and physiological parameters of sorghum (Data not shown). Therefore, reduction in growth,

Table 2. Effect of salinity, sowing methods and mulch on growth and yield of fodder sorghum

Treatment	Plant height (cm)	SPAD readings	DMA (g/plant)	No. of leaves/ plant	Leaf/stem ratio	Green fodder yield (Mg ha^{-1})
Salinity (EC dS m^{-1})						
0.6	273.7	53.3	8.4	8.9	7.1	59.6
6	264.5	48.8	6.7	8.2	6.0	53.3
SEm±	5.8	1.2	0.2	0.2	0.2	1.6
LSD (p≤0.05)	NS	3.4	0.5	0.6	0.4	4.7
Sowing methods						
Flat bed	264.0	49.1	6.9	8.5	6.2	56.3
Two row raised bed	275.5	52.9	8.9	8.7	7.6	60.9
Ridge and furrow	267.8	51.1	6.8	8.6	7.1	52.2
SEm±	7.1	1.4	0.2	0.2	0.2	2.0
LSD (p≤0.05)	NS	NS	0.6	NS	0.6	5.7
Mulching						
No mulch	262.5	50.3	7.3	7.9	6.4	56.3
Straw mulch @ 5 Mg ha^{-1}	275.7	51.8	7.7	9.3	6.7	56.6
SEm±	5.8	1.2	0.2	0.2	0.2	1.6
LSD (p=0.05)	NS	NS	NS	0.6	NS	NS

NS: Non-significant

Table 3. Effect of salinity, sowing methods and mulch on nutrient content in fodder sorghum

Treatment	N (%)			K (%)			Na (mg kg^{-1})		
	20DAS	40 DAS	60 DAS	20DAS	40 DAS	60 DAS	20DAS	40 DAS	60 DAS
Salinity (EC dS m^{-1})									
0.6	2.78	2.39	1.81	2.22	1.52	1.24	235	357	173
6.0	2.67	2.20	1.61	2.13	1.40	1.05	293	465	226
SEm±	0.05	0.05	0.03	0.04	0.03	0.02	5	9	4
LSD (p≤0.05)	NS	0.13	0.10	NS	0.08	0.06	16	26	12
Sowing methods									
Flat bed	2.73	2.26	1.65	2.14	1.40	0.97	288	483	215
Two row raised bed	2.74	2.37	1.77	2.16	1.51	1.18	222	343	190
Ridge and furrow	2.71	2.26	1.71	2.22	1.48	1.29	283	408	193
SEm±	0.07	0.06	0.04	0.05	0.04	0.03	6	11	5
LSD (p≤0.05)	NS	NS	NS	NS	NS	0.08	19	32	15
Mulching									
No mulch	2.69	2.26	1.62	2.11	1.42	0.99	298	468	213
Straw mulch @ 5 Mg ha^{-1}	2.77	2.33	1.80	2.24	1.51	1.30	230	353	185
SEm±	0.05	0.05	0.03	0.04	0.03	0.02	5	9	4
LSD (p≤0.05)	NS	0.13	0.10	0.12	0.08	0.06	16	26	12

nutrient absorption (Table 3), results in drought stress, ion toxicity and mineral deficiency leading to reduced growth and biomass productivity.

Among the methods of sowing, fodder sorghum grown on two rows raised beds recorded significantly highest green fodder yield which was at par with flat bed and significantly higher over ridge and furrow sowing. However, later two treatments also remained statistically at par with each other. Under two row raised beds, the movement of salts took place towards center of beds and furrow and side of beds remained less affected (Devkota *et al.*, 2015) and conserve more moisture, congenial for better growth and productivity of crop. The reduction in fodder yield under ridge and furrow sowing was mainly due to reduction in water applied through alternate furrow irrigation. However, this gave statistically similar yield as obtained under flat bed with substantial water saving and lower salt accumulation. Though, there was numerical increase in green fodder yield with mulching than no mulch but the difference between two remained non-significant.

Nutrients content

Variations in nutrient content (N, K and Na) of fodder sorghum at various crop stages as affected by salinity, sowing and mulching are shown in Table 3. The N and K contents showed a decreasing trend with the advancing crop growth from 20 to 60 DAS. While Na content increased with advancement in crop growth from 20 to 40 DAS, but its content decreased at further stage of crop i.e. 60 DAS. The N and K content in fodder sorghum significantly reduced under saline water irrigation than normal water at 40 and 60 DAS of crop. While, Na content significantly increased with salinity at 20, 40 and 60 DAS of crop. Increase in Na^+ contents due to addition of saline water, decreases the K^+ contents in plant leaves, attributed to the effect of competition between Na^+ and K^+ ions on the absorptive sites of the plant roots (Esmaili *et al.*, 2008; Patel *et al.*, 2010).

The contents of N and K did not vary significantly under different methods of sowing except K content at 60 DAS which was significantly higher in ridge and furrow planted sorghum. The increase in K content of sorghum leaves under ridge and furrow might be due to lesser competition exerts by Na in uptake of K as this method received lower quantity of irrigation water and thereby lower accumulation of Na took place. The Na content in fodder sorghum was significantly higher under flat-bed sowing than two-rows raised beds sowing at 20, 40 and 60 DAS stages of crop. The addition of more quantity of salts through irrigation under flat-bed sowing might result in corresponding increase in Na uptake by crop.

Mulching with crop residues significantly increased the N and K content in fodder sorghum at various growth stages of crop as compared to without mulching. The improvement in total uptake of nutrients under residue applied treatments ascribed to favorable moisture condition in the soil maintained for relatively longer period. Thus, the favorable moisture condition led to higher translocation and assimilation of nutrients to plant leaves (Sharma *et al.*, 2010; Paliwal *et al.*, 2011). Contrary to this, reverse was observed with Na content where significant reduction in Na content, which significantly reduced under mulching at all the growth stages of fodder sorghum.

Conclusions

The results of present study revealed that quantity of irrigation water and agronomic manipulation through sowing methods and mulching had influenced the accumulation and distribution of soil salinity and crop performance. Sowing of fodder sorghum on two-row raised bed resulted in highest fodder yield with 40% saving of irrigation water. The soil salinity buildup was minimum under ridge and furrow sowing with alternate furrow irrigation with at par fodder yield as of flat-bed sowing. Mulching with crop residue reduced the salt accumulation in crop root zone and increased the crop yield. However, this was a micro plot study and for final recommendation needs test in larger plots.

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References

Ahloowalia BS, Meluzynski M and Nichterlein K (2004) Global impact of mutation derived varieties. *Euphytica* **135:** 187-204.

Bakker DM, Hamilton GJ, Hetherington R and Spann C (2010) Salinity dynamics and the potential for improvement of water logged and saline land in a Mediterranean climate using permanent raised beds. *Soil and Tillage Research* **110(1):** 8-24.

Choudhary MR, Munir A and Mahmood S (2008) Field soil salinity distribution under furrow-bed and furrow-ridge during wheat production in irrigated environment. *Pakistan Journal of Water Resources* **12(2):** 33-40.

Deng L, Chen M, Liu Z, Shen Q, Wang H and Wang J (2003) Effects of different ground covers on soil physical properties and crop growth on saline-alkaline soil. *Chinese Journal of Soil Science* **34(2):** 93–97.

Devkota M, Gupta RK, Martius C, Lamer JPA, Devkota KP, Sayre KD and Vlek PLG (2015) Soil salinity management on raised beds with different furrow irrigation modes in salt-affected lands. *Agricultural Water Management* **152:** 243-250.

Dong H (2012a) Combating salinity stress effects on cotton with agronomic practices. *African Journal of Agricultural Research* **7(34):** 4708-4715.

Dong H (2012b) Underlying mechanisms and related techniques of stand establishment of cotton on coastal saline-alkali soil. *Chinese Journal of Applied Ecology* **23(2):** 566-572.

Esmaili E, Kapourchal SA, Malakouti MJ and Homaee M (2008) Interactive effect of salinity and two nitrogen fertilizers on growth and composition of sorghum. *Plant Soil and Environment* **54(12):** 537-546.

Gomez KA and Gomez AA (1984) *Procedures for Agricultural Research*. John Willley and Sons, NewYork.

Hamid M, Ashraf MY, Rehman KU and Arshad M (2008) Influence of salicylic acid seed priming on growth and some biochemical attributes on wheat growth under saline conditions. *Pakisthan Jounal of Botany* **40(1):** 361-367.

Hassanein MS, Ahmed AG and. Zaki NM (2010) Growth and productivity of some sorghum cultivars under saline soil condition. *Journal of Applied Sciences Research* **6(11):** 1603-1611.

Huang Q, Yin Z and Tian C (2001) Effect of two different straw mulching methods on soil solute salt concentration. *Arid Land Geography* **24:** 52-56.

Ji S and Unger PW (2001) Soil water accumulation under different precipitation, potential evaporation and straw mulch conditions. *Soil Science Society of America Journal* **65:** 442-448.

Krishnamurthy L, Serraj R, Hash CT, Dakheel AJ and Reddy BVS (2007) Screening sorghum genotypes for salinity tolerant biomass production. *Euphytica* **156:** 15-24.

Mulumba LN and Lal R (2008) Mulching effects on selected soil physical properties. *Soil and Tillage Research* **98:** 106-111.

Paliwal DK, Kushwaha HS and Thakur HS (2011) Performance of soybean (*Glycine max*)-wheat (*Triticum aestivum*) cropping system under land configuration, mulching and nutrient management. *Indian Journal of Agronomy* **56(4):** 334-339.

Parlak M and Parlak AO (2006) The effect of different irrigation water salinities on silage sorghum (*Sorghum bicolor* (L.) Moench) yield and soil salinity. *Tarým Bilimleri Dergisi* **12(1)**: 8-13.

Patel PR, Kajal SS, Patel VR, Patel VJ and Khristi SM (2010) Impact of salt stress on nutrient uptake and growth of cowpea. *Brazilian Journal of Plant Physiology* **22(1):** 43-48.

Qiao H, Liu X, Li W, Huang W, Li C and Li Z (2006) Effect of deep straw mulching on soil water and salt movement and wheat growth. *Chinese Journal of Soil Science* **37(5):** 885-889.

Sayre K (2007) Conservation agriculture for irrigated agriculture in Asia. In: Lal R, Suleimenov M, Stewart BA, Hansen DO and Doraiswamy P (eds) *Climate Change and Terrestrial Carbon Sequestration in Central Asia*. Taylor and Francis, The Netherlands, pp 211-242.

Sharma AR, Singh R, Dhyani SK and Dube RK (2010) Effect of live mulching with annual legumes on performance of maize (*Zea mays*) and residual effect on following wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **55(3):** 177-184.

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