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EFFECT OF CUT-SOILER PSSD ON GROWTH, FODDER YIELD AND QUALITY OF PEARL MILLET CROP USING SALINE IRRIGATION WATER

NEHA[1,2], GAJENDER YADAV[1]*, R. K. YADAV[1], ASHWANI KUMAR[1], A. K. RAI[1] AND JUNYA ONISHI[3]**

[1]ICAR–Central Soil Salinity Research Institute, Karnal-132001 (Haryana), India
[2]CCS Haryana Agricultural University, Hisar-125004 (Haryana), India
[3]Japan International Research Center for Agricultural Sciences (JIRCAS), Ohwasi, Tshukuba, Ibaraki, 305-8686, Japan
*(e-mail : gajender.icar@gmail.com; **RK.Yadav@icar.gov.in)*
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SUMMARY

Soil salinity influences the performance of plants and determines their establishment and distribution. Salinity is regarded as one of the major limiting factors to crop production in arid and semi-arid regions worldwide with more than 6% total land area. Low precipitation, irrigation with saline water, a rising water table, and poor irrigation practices generally cause salinity stress. A double spilt plot lysimeter study was conducted with two replications at ICAR-CSSRI, research farm, Karnal to evaluate Cut-soiler simulated Preferential Shallow Sub surface Drainage (PSSD) effectiveness in salt removal and subsequent effect on growth, yield and forage quality of pearl millet. The study comprised of Cut-soiler PSSD as main plot treatment with two soil types i.e. saline sandy loam and heavy texture soil (sub-plot) and three irrigation water (sub-sub plot) salinity levels (4, 8, 12 dS/m). The Cut-soiler PSSD reduced soil salinity by 49.19 %. The plant height, number of leaves and effective tillers, plant density, green fodder yield, dry matter yield and crude protein content increased significantly under Cut-soiler. Cut-soiler constructed PSSD salt removal resulted in better plant growth and biological, green fodder and dry matter yields. The increment in biological yield was 12.64 %. However, subsequent increase in irrigation water salinity from 4.0 to 8.0 and further to 12 dS/m decreased biological yield by 12.72, 12.20 and 11.41 t/ha, respectively and also caused significant variation on fodder quality parameters. Hence, Cut-soiler PSSD proved beneficial to mitigate adverse effect of salt stress by significantly improving growth and fodder yield and quality traits in pearl millet crop.

Key words : Salinity stress, cut-soiler PSSD, fodder quality, pearl millet [*Pennisetum glaucum* (L.)]

Environmental conditions, such as rainfall, soil salinity, and solar radiation influence the performance of plants and determine their establishment and distribution (Liu *et al.,* 2019). Soil salinity is regarded as one of the major limiting factors to crop production worldwide. More than 6% of the world's total land area (Munns and Tester, 2008) and approximately 20% of the arable land is affected by salinity (Negrao *et al.,* 2017). Crop yields decline considerably when EC_e value of the soil solution exceeds over 4 dS/m. Therefore, crop cultivation in such conditions is not practically economical at all without amending the soil salinity. Soil salinization is a common land degradation problem in arid and semi-arid regions of India, affecting productivity and socio-economic status of poor and marginal farmers. In irrigated lands, seepage from canals, excess irrigation, drainage congestion and irrigation with marginal quality saline and sodic waters induce salinization (Ambast *et al.,* 2006) and aggravate secondary salt enrichment in soil profiles. This salt enrichment affects water and nutrient transformations and reduces crop productivity. As such initial osmotic stress followed by ion toxicities is the main limitation to plant growth in saline soils. It is estimated that India loses annually 16.84 million tonnes of farm production valued at Rs. 230.2 billion due to salt affected soils (Sharma *et al.,* 2015). Besides soil salinity, poor quality water use for irrigation varies from 32-84% in different states and adversely affect crop production (Minhas, 1996).

Pearl millet (*Pennisetum glaucum* L.) is a predominant millet, forage and stover crop for arid and semi-arid regions of India (Yadav *et al*., 2011). Due to its high nutritional value and adaptation to marginal conditions, pearl millet is an important source of food and feed for humans and livestock in dry rainfed areas (Arya *et al*., 2015). Pearl millet are being evolved and there is need to standardise the optimum dose of nitrogen for better forage yield and quality (Shekara *et al.,* 2019). The continuous supply of balanced nutritive forage is essential to the milch animal for enhancing milk productivity (Meena *et al.,* 2012). The adverse effects of salinity on plants include reduced nutrient uptake including K^+, nutrient imbalance, ion toxicity because of high Na^+ and Cl^- concentrations, oxidative stress and osmotic stress (Shrivastava and Kumar, 2015). Plants grown under saline conditions are stressed and are characterized by increased levels of free proline and carbohydrate content in different tissues as a response to osmotic adjustment (Heuer and Nadler, 1998). Hernandez *et al.,* (2000) reported that salinity induced by increasing salinity from 0 to 100 m mol/L NaCl caused reduction in the plant growth, particularly shoot growth in pearl millet. Salinity in the crop root zone has a major influence on plant growth and yield, if appropriate management practices are not followed to maintain root zone salinity (Minhas and Gupta, 1993). The reclamation of the saline soils often requires higher drainage intensity for quick leaching of salts from the soil profiles. Strategies worked out for successful crop production on saline soils after drainage include initial leaching management (minimizing water requirement for leaching by synchronizing with monsoon rains, etc.), proper selection of crops/cultivars, irrigation (method, controlled frequency for enhancing water-table contribution, canal water use during the initial stages including pre sowing for conjunctive use with drainage waters).

Cut-soiler (a tractor-mounted farm implement) constructed residue filled PSSD, made at 40-60 cm depth, is a novel technique. It is supposed to drain out excess water and simultaneously salts to manage root zone salinity and thus improve crop growth, production and quality of produce. In this study, Cut-soiler PSSD operation was simulated in semi controlled lysimeters with the objectives of evaluation of its effectiveness in salt removal and its subsequent effect on growth, yield and forage quality of pearl millet.

MATERIALS AND METHODS

Experimental details

To evaluate the efficacy of Cut-soiler PSSD (preferential shallow sub-surface drainage) in improving the performance of pearl millet under salinity stress, an experiment was conducted in *kharif* seasons of 2019 and 2020 at ICAR-CSSRI semi controlled lysimeter facility. The Cut-soiler PSSD simulated drains were constructed manually for the critical evaluation of changes in soil salinity. The study comprised of 12 treatment combinations in double split plot design with two replications. The plot size was 4 m^2 (in 2m x 2m x 3m L*W*H) with row to row distance of 30 cm and plant to plant 15 cm. Cut-soiler PSSD was applied in 12 plots as main plot treatments along with control (without Cut-soiler) in another 12 plots. The two soil types in sub plots *i.e.* saline sandy loam and heavy texture soil; collected from selected representative sites as sub plot treatment *i.e.* 6 plots of each type of soil in both Cut-soiler and control. Three saline water irrigation treatments *viz.,* 4, 8 and 12 dS/m were applied in sub-sub plots and irrigations scheduled as per crop water requirement.

Observation recorded

The soil salinity (EC_e) and reaction (pH_s) under different treatments were measured as per the method prescribed by Richards (1954). Crop performance was monitored in terms of growth traits and three plants

TABLE 1
Mean monthly meteorological parameters during 2019-2020

Month	Year- 2019				Year- 2020			
	Temperature (°C)		RH (%)	Rainfall (mm)	Temperature (°C)		RH (%)	Rainfall (mm)
	Tmax.	Tmin.			Tmax.	Tmin.		
July	147.4	108.7	225	80.2	140.1	84.3	169.2	38
Aug	126.2	104.4	315.6	178.4	144.9	94	213.1	81.5
Sept	167.5	130.6	392.5	90.6	180.3	134.5	326.1	286.2
Oct	129.4	97.5	284.8	10.2	132.8	106.7	325.9	212.6

were randomly tagged from each treatment to take different observations. Plant height (cm) was measured with the help of meter scale in randomly selected tagged plants at harvest stage. The number of leaves per plant was recorded by counting the fully opened leaves at critical stages and number of plants was counted from one meter row length in second row of each plot. The number of tillers per plant was recorded in tagged plants and expressed as an average of each treatment. Biological yield represent theweight of sun-dried plants of net plot along with ear heads and expressed in t/ha. Green fodder yield is immediate weight of the fresh harvest of pearl millet crop. Dry matter content of sample was measured by taking a pre-weighed aluminum tray/envelope paper. Tray was placed in hot air oven at 60-70°C for 48-72 hr or until getting a constant weight (AOAC, 2005). The loss in moisture content after drying was estimated DM. The crude protein content of samples was calculated by multiplying the N content with the factor 6.25 (Mariotti *et al.,* 2008).

Statistical analysis

Data generated from the lysimeter experiments were subjected to the statistical analyses of variance appropriate to the experimental design. All the recorded data were analysed using analysis of variance (ANOVA) technique (SAS) for split-split plot design using SAS 9.2 software (SAS Institute, 2001) and pair wise comparisons were made using Tukey's test at $p \leq 0.05$.

RESULTS

Changes in soil salinity

The initial (before sowing of first pearl millet crop and final (after harvest of second crop) soil EC_e and pH_s of experimental lysimeter plots are presented in Figure 1. The soil salinity decreased significantly from its initial values to final across all treatments. The soil EC_e was recorded significantly lower in Cut-soiler constructed PSSD plots in comparison to without Cut-soiler plots, but the sol EC_e was significantly higher at final stage where EC_e in Cut-soiler treatments was 1.57 dS/m than without Cut-soler (2.92 dS/m). The EC_e of soil was significantly higher in sandy loam saline soil than heavy texture soil. While comparing different salinity levels of irrigation water, it was observed that the higher salinity of irrigation water had significantly increased the EC_e of soil. After harvest of second pearl millet crop, the increase in soil EC_e at 8 dS/m was 2.17 over 4 *dS/m* EC_{iw} (1.86). The respective EC_e with application of 12 dS/m EC_{iw} was 2.7 dS/m. There was a slight increase in final soil pH_s over the initial values, but no significant difference was recorded among various treatments.

Plant height (cm)

Plant height of pearl millet at harvest as affected by study years, Cut-soiler, soil type and irrigation water salinity treatments is presented in (Table 2). Plant height (cm) was significantly greater in study year 2020 (201.02 cm) as compared to 196.35 cm in year 2019. The plant height under Cut-soiler treatment was significantly greater (205.04 cm) than without Cut-soiler (192.32 cm). The increment in plant height, at harvesting stage in Cut-soiler treatments, was 6.6 %. Similarly, between two soil types, the heavy textured soil recorded significantly taller plants than the light textured sandy loam saline soils (201.68 and 195.69 cm). The plant height decreased significantly with the increase in salinity of irrigation water from 4 dS/m to 8 dS/m and further to 12 dS/m. Pearl millet plants acquired maximum height at 4 dS/m; EC_{iw}

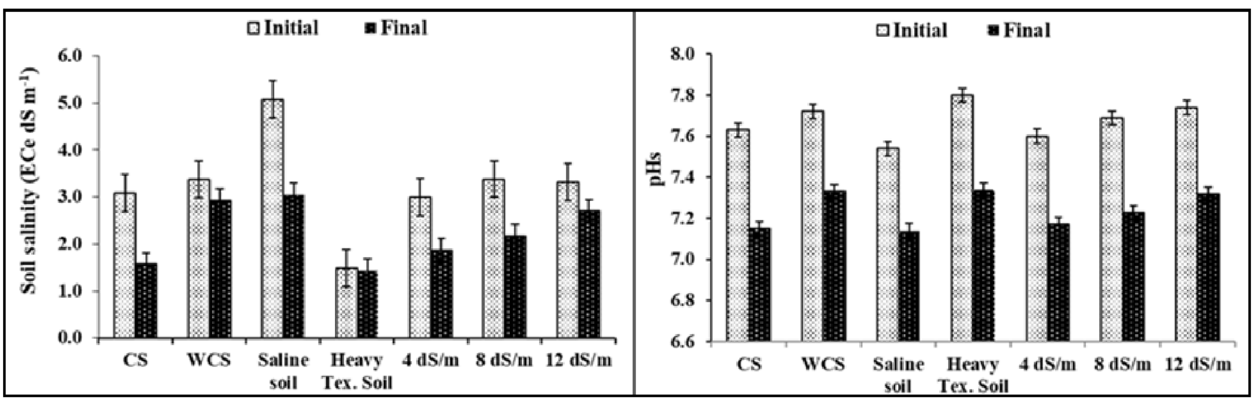

Fig. 1. Effect of Cut-soiler, soil type and irrigation water salinity on ECe and pHs before sowing and after harvest of pearl millet crop.

(201.02 cm), followed by 8 dS/m; EC_{iw} (198.96 cm) and dS/m; EC_{iw} (196.07 cm) at harvesting stage, respectively.

Number of leaves per plant

The number of leaves per plant at vegetative, flowering and harvest stages (Table 2) varied significantly between two years of study. More number of leaves at vegetative (13.48), flowering (33.75) and harvest (22.62) stages were observed in 2020 in comparison to year 2019 (12.87, 33.37 and 22.15, respectively), although the difference at harvest stage remained non-significant. The Cut-soiler PSSD caused significant variation in number of leaves (per plant). The higher numbers of leaves *i.e.* 14.09, 35.58 and 24.14 were counted at vegetative stage, flowering stage and harvest stage, respectively under Cut-soiler than without Cut-soiler (12.26, 31.53 and 20.63, respectively). Impact of soil type was also significant on number of leaves at all the three stages. The highest number of leaves was counted in heavy textured soil at the all three growth stages (13.77, 34.65 and 23.37) in comparison to light textured saline soils (12.58, 32.47 and 21.40). The increase in irrigation water salinity significantly reduced the number of leaves. The highest number of leaves per plant were recorded at 4 dS/m; EC_{iw} (13.74, 34.29 and 23.44) followed by 8 dS/m; EC_{iw} (13.12, 33.56 and 22.29) and 12 dS/m; EC_{iw} (12.67, 32.83 and 21.43) at the three growth stages, respectively.

Number of effective tillers per meter row length

The number of effective tillers per meter row length (m.r.l.) differed significantly ($p=0.0157$) between two studied years *i.e.* more number of effective tillers were recorded in 2020 (9.33) as compared to (8.68) in 2019. In case of Cut-soiler, significantly ($p=0.0011$) higher number of effective tillers (9.82) were counted as compared to without Cut-soiler (8.19). The heavy textured soil produced higher number of effective tillers (9.97) than light textured saline soil (8.04). Further among irrigation water salinity levels, EC_{iw}; 4 dS/m was found superior in terms of number of leaves (9.65) over EC_{iw}; 8 dS/m (9.07) and EC_{iw}; 12 dS/m (8.30).

Plant density (m.r.l.)

The plant density per meter row length (m.r.l.) (Table 2) did not vary with study year, Cut-soiler and soil type. But lower salinity of irrigation water i.e. 4 dS/m recorded higher plant density (7.06 per m.r.l.), that was at par to 8 dS/m (6.95 per m.r.l.) and reduced to 6.67 at 12 dS/m EC_{iw}.

Biological yield (t/ha)

The biological yield in 2020 was (12.58 t/ha) was significantly higher than 2019 (11.64 t/ha). The Cut-soiler treatment produced 12.64% higher biological

TABLE 2
Effect of study year, Cut-soiler, soil type and irrigation water salinity on growth attributes of pearl millet

Treatments/Traits	Plant height (cm)	No. of leaves per plant			No. of effective tiller (m.r.l)	Plant density (m.r.l) 30 DAS
	harvesting stage	vegetative stage	flowering stage	harvesting stage		
Years						
2019	196.35^{B}	12.87^{B}	33.37^{B}	22.15	8.68^{B}	6.83
2020	201.02^{A}	13.48^{A}	33.75^{A}	22.62	9.33^{A}	6.95
CD (*P*=0.05)	1.17±0.37	0.31±0.1	0.24±0.08	NS	0.42±0.13	NS
Cut-soiler						
Cut-soiler	205.04^{A}	14.09^{A}	35.58^{A}	24.14^{A}	9.82^{A}	6.84
Without Cut-soiler	192.32^{B}	12.26^{B}	31.53^{B}	20.63^{B}	8.19^{B}	6.94
CD (*P*=0.05)	1.17±0.37	0.31±0.1	0.24±0.08	0.93±0.29	0.42±0.13	NS
Soil type						
Saline soil	195.69^{B}	12.58^{B}	32.47^{B}	21.40^{B}	8.04^{B}	6.86
Heavy textured soil	201.68^{A}	13.77^{A}	34.65^{A}	23.37^{A}	9.97^{A}	6.93
CD (*P*=0.05)	0.37±0.18	0.12±0.06	0.12±0.06	0.34±0.16	0.31±0.15	NS
Irrigation water salinity						
S_1 (4 dS m^{-1})	201.02^{A}	13.74^{A}	34.29^{A}	23.44^{A}	9.65^{A}	7.06^{A}
S_2 (8 dS m^{-1})	198.96^{B}	13.12^{B}	33.56^{B}	22.29^{B}	9.07^{B}	6.95^{A}
S_3 (12 dS m^{-1})	196.07^{C}	12.67^{C}	32.83^{C}	21.43^{C}	8.30^{C}	6.67^{B}
CD (*P*=0.05)	0.45±0.22	0.15±0.07	0.15±0.07	0.42±0.2	0.38±0.18	0.13±0.06

yield (12.83 t/ha) than without Cut-soiler (11.39 t/ha). The biological yield in light textured saline soil (11.35 t/ha) was 11.81% lower than heavy textured soil (12.87 t/ha). The biological yield was decreased significantly from application of 4 dS/m saline irrigation water (12.72 t/ha) to 8 dS/m (12.20 t/ha) and further to 12 dS/m (11.41 t/ha) (Table 3).

Green fodder yield (t/ha)

Data on green fodder yield, as influenced by various treatments, are furnished in Table 3. Significantly higher green fodder yield (29.84 t/ha) was recorded in 2020 as compared to in 2019 (29.10 t/ha). The Cut-soiler treatment produced significantly higher green fodder yield (30.24 t/ha) than without Cut-soiler (28.70 t/ha). The green fodder yield in light textured saline soil (29.09 t/ha) was lower than heavy textured soil (29.85 t/ha). The green fodder yield decreased significantly with increase in salinity of applied irrigation from 29.73 t/ha in EC_{iw}: 4 dS/m to 29.45 t/ha in EC_{iw}; 8 dS/m and further to 29.24 t/ha in EC_{iw}; 12 dS/m.

Dry matter yield (t/ha)

Significantly higher dry matter content (9.98 t/ha) was recorded in 2020 as compared to in 2019 (9.43 t/ha) (Table 3). The Cut-soiler treatment produced significantly higher dry matter yield (10.04 t/ha) than without Cut-soiler (9.37 t/ha). The dry matter yield in light textured saline soil (9.45 t/ha) was lower than heavy textured soil (9.96 t/ha). The dry matter yield decreased significantly with increase in salinity of applied irrigation from 9.90 t/ha in EC_{iw}; 4 dS/m to 9.71 t/ha in EC_{iw}; 8 dS/m and further to 9.51 t/ha in EC_{iw}; 12 dS/m.

Dry matter content (%)

Dry matter content (%) was affected significantly by cultivation years (Table 3). Between the year of study, 2020 (25.72 %) showed lower dry matter content as compared to 2019 (26.97 %). The Cut-soiler treatment produced significantly lower dry matter content (25.32 %) than without Cut-soiler (27.37 %). The dry matter content in light textured saline soil (26.77 %) was higher than heavy textured soil (25.92 %). The dry matter content increased significantly with increase in salinity of applied irrigation from 26.12 % in EC_{iw}: 4 dS/m to 26.32 % in EC_{iw}; 8 dS/m and further to 26.59 % in EC_{iw}; 12 dS/m.

Crude protein content (%)

The statistical analysis of data (Table 3) indicated that crude protein content (CP) of stover was affected significantly by cultivation years. Between the year of study, 2020 (3.61%) showed higher CP as compared to 2019 (3.54%). The Cut-soiler treatment produced significantly higher CP (3.90 %) than without Cut-soiler (3.25 %). The CP in light textured saline soil (3.40 %) was lower than heavy textured soil (3.74 %). The CP decreased significantly with increase in salinity of applied irrigation from 3.69 % in EC_{iw}: 4 dS/m to 3.59 % in EC_{iw}; 8 dS/m and further to 3.44 % in EC_{iw}; 12 dS/m.

DISCUSSION

The differences in soil salinity in different treatments were because of salt removal effect of Cut-soiler PSSD constructed in July 2018. The soil salinity under Cut-soiler PSSD continued to decrease significantly and much more prominent differences noted in Cut-soiler, soil type and applied irrigation water salinity treatments. The effect of shallow sub surface drainage was also reported earlier buy (Okuda *et al.,* 2018). The effect of Cut-soiler and soil type and irrigation water salinity is visible in performance of pearl millet. Present results revealed that greater height, more number of leaves per plant, number of higher tillers per meter row length and finally better growth attributes at all studied growth stages of pearl millet were recorded under Cut-soiler constructed PSSD treatment over control (Table 2). Relatively better performance of pearl millet was noticed in study year 2020 and such differences in the growth parameters in two study years were mainly due to occurrence of differential rainfall and consequent drainage of salts in the two study years (Table 1). The year 2020-21 received higher rainfall (1108.3 mm) than 2019-20 (730.4). The higher rainfall during pearl millet season in April to October 2020 (589.6 mm) than previous cropping season (117 mm) caused higher leaching in rainy season. Higher rainfall during rainy season of 2020-21 further resulted in higher leaching and removal of salts through the Cut-soiler PSSD and hence lower salt accumulation was noticed during 2020-21 season compared to previous season. The Cut-soiler PSSD improved the drainage function in both soil types

TABLE 3
Effect of study year, Cut-soiler, soil type and irrigation water salinity on biological yield, green fodder yield, dry matter yield, dry matter content and crude protein (%)

Treatments/Traits	Biological yield (t/ha)	Green fodder yield (t/ha)	Dry matter yield (t/ha)	Dry matter content (%)	Crude protein (%)
Years					
2019	11.64^{B}	29.10^{B}	9.43^{B}	26.97^{A}	3.54^{B}
2020	12.58^{A}	29.84^{A}	9.98^{A}	25.72^{B}	3.61^{A}
CD (P=0.05)	0.3±0.1	0.18±0.06	0.1±0.03	0.04±0.01	0.02±0.01
Cut-soiler					
Cut-soiler	12.83^{A}	30.24^{A}	10.04^{A}	25.32^{B}	3.90^{A}
Without Cut-soiler	11.39^{B}	28.70^{B}	9.37^{B}	27.37^{A}	3.25^{B}
CD (P=0.05)	0.3±0.1	0.18±0.06	0.1±0.03	0.04±0.01	0.02±0.01
Soil type					
Saline soil	11.35^{B}	29.09^{B}	9.45^{B}	26.77^{A}	3.40^{B}
Heavy textured soil	12.87^{A}	29.85^{A}	9.96^{A}	25.92^{B}	3.74^{A}
CD (P=0.05)	0.19±0.09	0.04±0.02	0.05±0.02	0.02±0.01	0.02±0.01
Irrigation water salinity					
4 dS m^{-1}	12.72^{A}	29.73^{A}	9.90^{A}	26.12^{C}	3.69^{A}
8 dS m^{-1}	12.20^{B}	29.45^{B}	9.71^{B}	26.32^{B}	3.59^{B}
12 dS m^{-1}	11.41^{C}	29.24^{C}	9.51^{C}	26.59^{A}	3.44^{C}
CD (P=0.05)	0.23±0.11	0.05±0.02	0.06±0.03	0.02±0.01	0.03±0.01

and all irrigation water quality treatments, therefore increased outflow of water and thus salts, especially soluble salts resulted in lower soil salinity, enhanced water uptake that improved water potential under Cut-soiler treatment. The improved soil chemical and water availability environment for plant growth had helped in better growth of pearl millet crop. All the studied growth parameters indicated higher growth of pearl millet under Cut-soiler PSSD at all the studied growth stages. The rainfall amount and events have further supplemented to fasten the leaching process as well as enhanced dilution of the salts, accumulated by saline water irrigation, in crop rhizosphere. Enhanced growth performance and biomass yields of crops due to congenial edaphic and soil environmental conditions have been documented earlier also (Meena and Singh., 2019). High salinity especially in the initial growth stages was particularly harmful to plants (Minhas, 1996). In this study, the soil salinity under Cut-soiler operation conditions was reduced significantly (Fig.1). Earlier also, Mathew *et al.,* (2001) reported significant increase in plant growth parameters such as plant density and height of rice under provision of subsurface drainage. They attributed this positive realization to effective salinity alleviating outcome of improved drainage and concluded that subsurface drainage could be helpful in uniform crop growth that contributes to significant increase in crop production in saline areas.

High forage yield is closely associated with high values for plant height, number of leaves and leaf area. These results are similar to the results of (Hassan *et al.,* 2014) who observed that varieties differed significantly for number of leaves per tiller. Salt stress caused inhibitory effects on biological, green fodder, dry matter yields and contents at higher salinity stress. Inhibitory effects of higher salt stress on yields and crude protein (%) were mainly caused as a result of osmotic shock, ion toxicity and nutritional imbalance that caused reduction in photosynthetic activity and other physiological abnormalities (Ali and Awan 2004). Similar findings of reduction in crop yield under salinity were reported by Yadav *et al.,* (2020). Saeidi *et al.,* (2015) have also reported lower biological yield under salt stress. This might be due to the lower nutrient uptake and translocation of photosynthates from source to sink that resulted into poor growth as reported earlier by Tripathi *et al.,* (2010).

CONCLUSION

Cut-soiler technology could be remunerative alternative for management of dry land salinity management. Cut-soiler PSSD resulted in higher outflow of salts with drainage after applied irrigation and rainfall events and reduced soil salinity by ~49 % during the study period. Such reduction in soil salinity led to improved pearl millet growth through enhancement in plant height, no of leaves, no of effective tillers, plant density, and higher biological (12.64%) and green fodder yields (5.36 %)as well as 20% higher CP content in fodder.

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