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Impact of saline water on fodder yield of oat and soil properties

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Abstract

Supply of food, fiber and fuel for growing population urge the agricultural user to exploit and optimize the usage of saline water resources. Therefore, a three years study (2013 to 2016) was conducted to explore the salinity tolerance potential of oat crop by using the irrigation water with different salinity levels. Oat crop was sown in cemented blocks with five treatments i.e. T_1= control (tap water), T_2= EC_{iw} 4.0 dS m^{-1},T_3= EC_{iw} 6.0 dS m^{-1}, T_4= EC_{iw} 8.0 dS m^{-1}, T_5= EC_{iw} 10.0 dS m^{-1}. All the recorded data for plant height (14.93%), fresh fodder yield (32.75%) dry fodder yield (50.22%) and moisture % in leaves (2.11%) showed that a significant reduction occurred in T_5 (EC_{iw} 10.0 dS m^{-1}) as compared to control. Soil properties pH_s, $EC_e$and SAR were also negatively affected by continuous use of saline water and higher level of EC_{iw}(10.0 dS m^{-1}) in T_5 showed more detrimental effects on soil properties and proved more hazardous for oat production.

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Introduction

Presently world population growth rate is 2 % and it is estimated that after every 35 years water demand will be doubled to the present (Naeimi and Zehtabian, 2011). Hence, in arid to semi-aridareas not land but scarcity of good quality water will determine agricultural production. In future, supply of sweet water will be limited due to increasing demand of industries and non-agriculture sectors (Ostera, 1994). This situation is compelling the farming community to pumped the ground water to meet crop water requirement, nevertheless, 70-80 % tube wells pumped the water of poor quality (Murtaza *et al.*, 2009).Consequently, farmers must rely on this saline water to meet the increasing demand of food, fiber and fuel for growing population (Elagib, 2014; Guo *et al.*,2014).

Hence, exploring the salinity tolerance potential of conventional agronomic crops with use of saline water is a feasible and practical bio saline approach which can increase the productivity of agriculture system. In Pakistan livestock is backbone of agriculture, however, currently there is a vide gap between the demand and supply of green fodder to feed rapidly expanding livestock industry. This situation become worsened in winter season when supply of fodder is negligible. Oat is soft, palatable and rich in crude protein, promising fodder crop which can provide green fodder for 60-70 days during lean periods. When mixed with berseem it provides a balanced feed to milch animals (Younis and Azam, 2003). Oat crop is documented as salt tolerant crop (Yadav and Kumar, 1997). Verma and Yadava (1986) studied the salinity tolerance of twelve oat varieties i.e. V_1= S-2688, V_2= UPO-201, V_3= Sierra, V_4= S-3021, V_5= Chauripatti, V_6= JHO-815, V_7= Colabagh, V_8= JHO-816, V_9= JHO-802, V_{10}= JHO-801, V_{11}= Kent and V_{12}= JHO-810. They developed five salinity levels (40, 80, 120, 160 and 200 me/L) in petri dishes. They reported that JHO-816, UPO-201, JHO-802 and JHO-815 were relatively more salt tolerant at germination and seedling stages. Kumari *et al.*(2014) evaluated the effect of saline water EC_{iw} ranges from 0.69, 2, 4 and 6 dS m^{-1} and four nitrogen levels (0, 50, 100 and 125% recommended dose of N) on the fresh fodder yield and quality of fodder oats. They reported that oat fodder can grow successfully with saline water of 4 dS $m^{-1}$when nitrogen is applied at the rate of 188 kg/ha. Moreover, saline water with 2 dS m^{-1}did not affected the quality parameters of oat fodder. Similarly, in another study Kumar and Sharma (1995) stated that oat can grow successfully without any significant reduction in yield with saline water of 5 dS m^{-1}. Yadav *et al.* (2006) evaluated the effect of marginal quality water {(EC_{iw} = 4.6-7.4 dS m^{-1} and SAR 14-22(mmol L^{-1}) ^{½}} on five fodder crop rotation T_1= oat-sorghum, T_2= Egyptian clover-sorghum, T_3= ryegrass–sorghum, T_4= Indian clover–sorghum and T_5= Persian clover-sorghum. They reported Reductions in fodder yield with use of saline water alone throughout season were 85, 68, 54, 42, 36 and 26% in Indian clover, Egyptian clover, Persian clover, oat, rye grass and sorghum respectively as compared to good quality water.

Saqib *et al.* (2108) studied the effect of saline water {EC_{iw} (2 and 3.5dS m^{-1}) and RSC (2.50, 3.75 and5 me L^{-1})} on growth of garlic plant. They reported that higher level of saline water (EC_{iw} = 3.5 dS m^{-1} + SAR = 5 me L^{-1}) decreases the biomass yield and bulb yield up to 13.69 % and 13.30% respectively over the control.

Therefore, a three years study was planned to explore the salinity tolerance potential of oat fodder crop when irrigated with different levels of salinity.

Materials and method

A three years experiment was carried out from 2013 to 2016 at Soil Salinity Research Institute, Pindi Bhattian, Pakistan to study the effect of saline water on oat fodder crop. Treatment used were; T_1 = Control (tap water), T_2=EC_{iw} 4.0 dSm^{-1}, T_3=EC_{iw} 6.0 dSm^{-1},T_4=EC_{iw} 8.0 dSm^{-1}, T_5=EC_{iw} 10.0 dSm^{-1}. A non-salinized soil was selected and analyzed for pH_s (7.80), EC_e(1.70dS m^{-1}), SAR (7.06 mmol L^{-1})$^{1/2}$. Collected soil was filled in cemented blocks (180 cm length×120 cm wide×90cm height).Experimental design was Completely Randomized Design (CRD) having three replications. The oat variety (CK-1) was sown in 2ndweek of October. Recommended dose of NP @ 95-60 kg ha^{-1} was appliedin the form of urea, single super phosphate (SOP) and sulphate of potash (SOP) respectively. Desired salinity levels of irrigation water were developed artificially in each season by using salt NaCl. Irrigation was applied according to treatments plan and crop requirement. All the standard agronomic management practices were adopted. The data regarding plant height, fresh/dry fodder yield and moisture % in leaves was recorded at maturity. All plant and soil analysis was carried out following the methods of U.S. Salinity Laboratory Staff (1954). Collected data was subjected to analysisof variance according to Steel *et al.* (1997) to sort outsignificant differences among treatments means usingLSD at 5% probability levelusing STATISTIX 8.1 package software.

Results

Plant height

Data regarding the plant height of oat revealed that saline water had negatively affected this growth characteristic (Table 1).

Table 1. Effect of saline water on plant height (cm) of oat fodder.

Treatments	2013-14	2014-15	2015-16	Mean	%decrease/control
T_1- Control(tapwater)	91.75 a	91.0 a	93.50 a	92.08 A	_
T_2- EC_{iw} 4.0 dSm^{-1}	91.25 a	90.0 ab	90.50 a	90.58 A	1.62
T_3- EC_{iw} 6.0 dSm^{-1}	87.50ab	88.0 b	84.75 b	86.75 B	5.78
T_4- EC_{iw} 8.0 dSm^{-1}	84.50 b	84.0 c	80.25 c	82.91 C	9.95
T_5- EC_{iw} 10.0 dSm^{-1}	78.25 c	78.0 d	78.75 c	78.33 D	14.93

Means sharing the same letters are statistically similar at P ≤ 0.05.

Mean value of three seasons showed that maximum plant height (92.08 cm) was achieved in control (tap water) followed by T_2 (EC_{iw} 4.0 dSm^{-1}) and both treatments were statistically ($p < 0.05$) alike. However further increased in salinity of irrigation water decreased the plant height linearly and minimum plant height (78.33 cm) was recorded in T_5 (EC_{iw} 10.0 dSm^{-1}). When compared with control (non-saline) a reduction of 1.62%, 5.78%, 9.95%, 14.93% was observed in T_2, T_3, T_4 and T_5 respectively.

Table 2. Effect of saline water on fresh fodder yield (t ha^{-1}) of oat fodder.

Treatments	2013-14	2014-15	2015-16	Mean	%decrease/control
T_1-Control(tapwater)	61.20 a	68.11 a	70.27 a	66.52 A	_
T_2- EC_{iw} 4.0 dSm^{-1}	60.68 a	67.32 a	49.53 b	59.17 AB	11.04
T_3- EC_{iw} 6.0 dSm^{-1}	57.41 a	62.59 b	49.53 b	56.51 ABC	15.04
T_4- EC_{iw} 8.0 dSm^{-1}	51.04 b	58.29 c	42.62 b	50.65 BC	23.85
T_5- EC_{iw}10.0 dSm^{-1}	43.75 c	52.45 d	38.01 b	44.73 C	32.75

Means sharing the same letters are statistically similar at P ≤ 0.05.

Fresh fodder yield

Average value data in Table 2 exhibited that slightly saline water had no detrimental effect on fresh fodder yield of oat crop, however, increasing levels of EC_{iw} had negative impact on this yield attribute. Maximum fodder yield (66.52 t ha^{-1}) was obtained in non-saline water which was statistically similar to T_2 and T_3. But at the same time fresh fodder yield significantly decreased with highest level of EC_{iw}(10.0 dSm^{-1}) and minimum fodder yield (44.73 t ha^{-1}) was observed in T_5. A significant reduction of 11.04 %, 15.04%, 23.85% and 32.75% was observed in fresh fodder yield of T_2, T_3, T_4 and T_5 respectively when compared with control.

Table 3. Effect of saline water on dry fodder yield (t ha^{-1}) of oat fodder.

Treatments	2013-14	2014-15	2015-16	Mean	% decrease/control
T_1- Control (tap water)	6.31 a	8.83 a	13.08 a	9.40 A	_
T_2- EC_{iw} 4.0 dSm^{-1}	6.28 a	8.73 a	8.34 b	7.78 A	36.23
T_3- EC_{iw} 6.0 dSm^{-1}	6.19 a	8.31 b	7.08 b	7.25 A	45.87
T_4- EC_{iw}8.0 dSm^{-1}	5.73 b	7.92 c	8.11 b	7.19 A	37.99
T_5- EC_{iw} 10.0 dSm^{-1}	5.18 c	7.27 d	6.51 b	6.32 A	50.22

Means sharing the same letters are statistically similar at $P \leq 0.05$.

Dry fodder yield

Results regarding dry fodder yield (Table 3) indicated in each season saline water had pronounced effect on dry matter yield, however, at the same time pooled data of three consecutive seasons showed no significant effect on dry fodder yield. Maximum dry fodder yield (36.23 t ha^{-1}) was produced by non-saline water which was statistically ($p < 0.05$) non-significant from other treatments and minimum dry fodder yield was recorded in T_5 where saline water with EC_{iw} (10.0 dSm^{-1}) was used for irrigation. Compared with control a significant reduction of 36.23 %, 45.87%, 37.99%, 50.22% was observed in dry matter yield of T_2, T_3, T_4 and T_5 respectively.

Table 4. Effect of saline water on moisture (%) of oat fodder.

Treatments	2013-14	2014-15	2015-16	Mean	% decrease/control
T_1- Control (tap water)	89.68 a	87.03 a	81.59 a	86.10 A	_
T_2- EC_{iw} 4.0 dSm^{-1}	89.65 a	87.03 a	80.75 ab	85.81 A	0.33
T_3- EC_{iw} 6.0 dSm^{-1}	89.22 b	86.72 b	79.5 ab	85.14 A	1.11
T_4- EC_{iw} 8.0 dSm^{-1}	88.70 c	86.41 c	77.75 b	84.34 A	2.04
T_5- EC_{iw} 10.0 dSm^{-1}	88.16 d	86.13 d	78.75 ab	84.28 A	2.11

Means sharing the same letters are statistically similar at $P \leq 0.05$.

Moisture (%) in leaves

Pooled data of three seasons (Table 4) showed that moisture % in leaves was not affected ($p < 0.05$) by saline water irrigation. Maximum moisture contents (86.10 %) were noted in control which remain statistically ($p < 0.05$) similar with all other treatments.

Soil properties

Data of soil analysis in each season and end of study revealed that continuous use of saline water had detrimental effects on soil chemical properties and negative effects were more pronounced with increasing salinity levels of irrigation water (Table 5 to 7).

Table 5. Effect of saline water on soil pH_s

Treatments	2013-14	2014-15	2015-16	Mean	% increase/control
T_1- Control (tap water)	7.99	7.96	7.74	7.89	_
T_2- ECiw 4.0 dSm^{-1}	8.00	8.02	8.08	8.03	1.73
T_3- ECiw 6.0 dSm^{-1}	8.03	8.03	8.10	8.05	1.98
T_4- ECiw 8.0 dSm^{-1}	8.08	8.09	8.10	8.09	2.44
T_5- ECiw 10.0 dSm^{-1}	8.08	8.07	8.12	8.09	2.44

Soil pH_s increased linearly with increasing levels of EC_{iw} of irrigation water and maximum increase of 2. 44% was observed with saline water of EC_{iw}, 10 dS m^{-1} i.e. (T_5). Similar trend was observed in soil EC_e and SAR. At the end of study, maximum value of EC_e (6.61 dS m^{-1}) was noted in T_5. As compared to control an increase of 66.99%, 141.79%, 204.88%, 287. 69% was recorded in T_2, T_3, T_4 and T_5 respectively at the end of study. With respect to SAR maximum value of SAR (7.46 (mmol $L^{-1})^{1/2}$) was recorded with highest level of salinity in T_5 i.e.EC_{iw} 10 dS m^{-1}. When compared with control treatment, an increase of 5.62%, 10.88%, 17.79%, 18.90% was recorded in T_2, T_3, T_4 and T_5 respectively at the end of study.

Discussion

Saline water irrigation has detrimental effects on soil health and crop yield, depending upon the amount of dissolved salts and their nature it negatively effects the various plant's physiological activities Plaut*et al.,* 2013). Survival of plants in salinized condition depend on its salinity tolerance mechanisms (Zivkovic, 2007). Results of the current study revealed that saline water irrigation induce a severe diminution in growth of oat crop and ill effects were more noticeable with increasing levels of salinity.

A negative correlation was found between plant height of oat and increasing levels of EC_{iw}.

Table 6. Effect of saline water on soil EC_e(dS m^{-1}).

Treatments	2013-14	2014-15	2015-16	Mean	% increase/control
T_1- Control (tap water)	1.78	1.67	1.67	1.70	_
T_2- EC_{iw} 4.0 dSm^{-1}	2.67	2.93	2.95	2.85	66.99
T_3- EC_{iw} 6.0 dSm^{-1}	3.88	4.25	4.25	4.12	141.79
T_4- EC_{iw} 8.0 dSm^{-1}	5.09	5.24	5.28	5.20	204.88
T_5- EC_{iw} 10.0 dSm^{-1}	6.52	6.64	6.69	6.61	287.69

Minimum plant height was recorded in treatment which was irrigated with highest level of salinity (EC_{iw} 10 dS m^{-1}) and it reduces the plant height by 14.93% over non saline water treatment (tap water). Use of saline waterincreases the concentration of toxic salts in root zone and this reduction in plant height may be explained by the more negative water potential in hyper saline environment (Tester & Davenport, 2003) uptake of toxic Na^+ and Cl^-, oxidative stress, retarding the mobilization rate of metabolites, alteration in hormonal activities (Moosavi*et al.,*2013).

Table 7. Effect of saline water on soil SAR (mmol $L^{-1})^{1/2}$.

Treatments	2013-14	2014-15	2015-16	Mean	% increase/control
T_1- Control (tap water)	7.00	6.05	5.78	6.27	_
T_2- EC_{iw} 4.0 dSm^{-1}	6.27	6.36	7.26	6.63	5.62
T_3- EC_{iw} 6.0 dSm^{-1}	6.64	6.68	7.56	6.96	10.88
T_4- EC_{iw} 8.0 dSm^{-1}	7.09	7.20	7.89	7.39	17.79
T_5- EC_{iw} 10.0 dSm^{-1}	7.23	7.28	7.88	7.46	18.90

Small statures plants due to root zone salinity has been reported by many plant scientists (Al-Khateeb, 2007; Turan*et al.,*2009).Fresh/dry fodder yieldand moisture % in leavesof oat crop was also diminished with increasing salinity of irrigation water which may be ascribed as accumulation of salt in rhizosphere adversely affect uptake of water by roots because of decrease in cellular permeability (Mansour and Stadelmann, 1994) which results in more negativewater potential in plant and consequently meristematic activity and cell elongation is reduced (Dorgham, 1991) leading to a decreased biomass yield. According to Zeng & Shannon (2000) salinity of 1.9 dS m^{-1} in soil solution is enough to cause a substantial reduction in biomass yield. Reduced fodder yield with increasing levels of salinity in irrigation water may be explained by toxic contents of Na^+ and Cl^- in cellular tissue which can cause damages plasma membrane structure (Wang *et al.,*1997)changes the cell metabolism, prevents photosynthetic activity (Taffouo*et al.,*2004) and reduces the protein synthesis (Yang *et al.,* 2002). Reduced biomass production due to hyper salinized environment is reported by many scientists,they stated that decreased crop yieldwas due to disturbances in physiological and biochemical activities under saline conditions. (Andriolo*et al.,*2005; Mensah *et al.,*2006; Unlukara*et al.,*2008; Kim *et al.,*2016) which reinforced the findings of currents study.

Soil analysis data exhibited that saline water negatively affected the soil chemical properties and a linear correlation exist between soil pH_s, EC_e, SAR and salinity levels of irrigation water. Maximum increase over control was 2.44%, 287.69%, 18.90 % in pH_s, EC_e and SAR respectively with use of highest level of salinity i.e. EC_{iw} 10 dS m^{-1}. This sharp increase in soil pH_s, $EC_e$and SAR was due to accumulation of Na^+ which deteriorate the soil properties and negatively affect the crop production (Murtaza *et al.,* 2009; Amir *et al.,* 2108).

Conclusion

Results of current study revealed salinity of irrigation water reduces the plant height, fresh/dry fodder yield and moisture % in leaves of oat crop and extent of reduction increased with increasing levels of salinity and T_5 (EC_{iw}= 10dS m^{-1}) showed more detrimental effects than all other treatments. Hence, further investigations are suggested with reference to efficient utilization of saline water for production of oat fodder according to different salinity levels of irrigation water.

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