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Role of inorganic and organic amendments in ameliorating the effects of brackish water for raya-sunflower production

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Abstract

Arid to semi-arid climate of Pakistan necessitates the artificial irrigation to undertake the agricultural pursuits and farmers are being forced to use the underground water reserves which are 60 to 70 % brackish in nature. The blind use of this resource without any management practice is building up salinity even in the soil that has high potential for crops. Therefore a field study was conducted for three years to evaluate the deleterious effect of brackish water on growth and yield of raya and sunflower crops. Treatments included were; T_1: Brackish water, T_2: Gypsum @ 100% GR of RSC of water, T_3: Gypsum @ 50% GR of RSC of water, T_4: Sulfuric acid @ 100% GR of RSC of water, T_5: Poultry Manure @ 10 t. ha^{-1}, T_6: Press mud @ 10 t. ha^{-1}. A normal soil {(pH_s= 8.09, EC_e = 3.18 dS m^{-1} and SAR= 8.65 (mmol L^{-1})$^{1/2}$} was selected, prepared and leveled. Experiment was laid out in RCBD with three replications. Tube-well water EC_{iw}= 1.34 dS m^{-1}, RSC= 8.50 me L^{-1} and SAR= 12.72 (mmol L^{-1})$^{1/2}$ was used for irrigation. Data regarding plant height grain/achene yield of raya and sunflower crops was recorded at maturity. Soil samples were collected after harvesting of each crop. Pooled data of three years showed that grain yield of raya(1.22 t. ha^{-1}) and sunflower(2.19 t. ha^{-1})was significantly higher in T_2 (Gypsum @ 100% GR of RSC of water) followed byT_5 (Poultry Manure @ 10 t. ha^{-1}). The lowest grain (1.02 t. ha^{-1}) and achene(1.70t. ha^{-1}) yield was recorded in control T_1 (Tube well water). In case of soil analysis pH_s, EC_e and SAR were substantially improved with all the applied organic and inorganic amendments as compared to control.

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Introduction

In Pakistan, 86 million acre foot (MAF) of river water is diverted into irrigation canals (GOP, 2002). Due to increased cropping intensity, more agricultural demand and drought condition, seemingly enormous amount of irrigation water could not keep pace with the crop water requirement. This necessitated the development of unconventional water sources in addition to the efficient use of existing ones. Therefore, ground water is being pumped to meet crop water requirement. To overcome this problem, inadequate supplies of water can be augmented with tube well water, however, 70-80 % tube wells pumped the water of poor quality (Murtaza *et al.*, 2009; Naqushband *et al.,* 2014). So, it is imperative that agricultural user must rely on this poor-quality water to supply food and fiber for a growing population (Elagib, 2014; Guo *et al.*, 2014).

After cereal and sugar crops, oil seed crops are important component of human diet as these are sources of vegetable oil which supplies two times more energy than carbohydrates. It has some essential fatty acids and vitamins (D and E) which are desirable for human body. Vegetable oil is considered better for human health than ghee as it has higher percentage of mono and poly unsaturated fats (Amjad, 2014). In Pakistan, sunflower can be grown successfully in a wide range of climates. It is grown in two seasons, spring and summer. It fixes well in the local cropping systems (Shah *et al.,* 2013).

Poor quality water can be used for crop production provided proper agronomic techniques coupled with chemical amendments are followed like the use of gypsum, FYM and salt tolerant crops (Malik *et al.,* 2015). Saifullah *et al.,*(2002) concluded that gypsum (25- 50 %) with or without FYM was a pre-requisite as well as proved economical for most of the calcareous saline-sodic soils and brackish waters under the agro-climatic conditions of Pakistan. Yaduvanshi and Swarup (2006) suggested that gypsum, organic manures or press mud along with recommended doses of fertilizer must be used to improve production of rice–wheat cropping system in areas having sodic ground water for irrigation. Incorporation of organic contents (Poultry Manure and Press Mud) had positive impacts on soil properties and crop yields and gypsum proved economical amendment for reclamation (Qadir *et al.,* 2017). Determination of optimsed dose of organic amendments is important to avoid the risk of deficiency and/or toxicity by mineral elements associated excessive salts on one hand and to ensure the availability of all necessary elements for plant nutrition during the period of high needs and without compromising the environmental quality on the other hand (Oustani *et al.,* 2015).

Keeping in view, the possibility of using brackish water, the present study was planned to evaluate the comparative effectiveness of different inorganic and organic amendments in reducing the ill effects of brackish water used for the production of raya and sunflower crops.

Materials and Methods:

The field trial was conducted at Soil Salinity Research Institute, Pindi Bhattian for connective three years followings Raya (Rabi) -sunflower (Kharif) crop rotation. The field experiment was carried out to utilize brackish water with EC_{iw}= 1.34 dS m^{-1}, RSC= 8.50 me L^{-1} and SAR= 12.72 (mmol $L^{-1})^{1/2}$. A composite soil sample was collected before the start of experiment and analyzed for {(pH_s= 8.09, EC_e = 3.18 dS m^{-1} and SAR= 8.65 (mmol $L^{-1})^{1/2}$}following the procedures described by Richard, 1954. The experiment was laid out in Randomized Complete Block Design with three replications. Recommended doses of fertilizers @ 100-85-45 kg ha^{-1} and 150-100-62 kg ha^{-1} were applied to Raya and Sunflower respectively. The treatments were T_1 = Brackish water alone, T_2 = Brackish water + Gypsum @ 100% GR of water on RSC basis, T_3= Brackish water + Gypsum @ 50% GR of water on RSC basis, T_4= Brackish water + Sulfuric acid @ 100% GR of water on RSC basis, T_5= Brackish water + Poultry Manure @ 10 t. ha^{-1}, T_6= Brackish water + Press Mud @ 10 t. ha^{-1}.

The amendments gypsum, poultry manure and press mud were applied one month before sowing of Raya crop (once in a year year). Raya and Sunflower crops were rotated each year. Sulfuric acid was applied with each irrigation. Standard cultural practices and plant protection measures were adopted. The soil samples were collected from each treatment plot after harvest of each crop and analyzed for pH_s, EC_e and SAR. The collected crop data (Raya and Sunflower) was statistically analyzed. The treatment mean comparison was made using Least Significant Difference Test @ 5% Probability (Steel *et al.,* 1997) using STATISTIX 8.1 package software.

Results and discussions

Effect of amendments on raya growth

The data showed that the continuous irrigation with brackish water had negative impact on raya plant growth while at the same time organic and inorganic amendments alleviated the detrimental effects of brackish water and remarkably improved the plant growth. Data regarding plant height showed that maximum mean value for plant height (166.53 cm) was observed with gypsum application@ 100% GR of RSC of water, however, it was statistically ($P < 0.05$) non-significant with all other amendments(Table-1).

Table 1. Effect of amendments on raya plant height (cm).

Treatments	1st Year	2nd Year	3rd Year	MEAN
Brackish water	107.50 c	191 a	169 a	155.83 B
Gypsum @ 100% GR of RSC of water	122.60 a	196 a	181 a	166.53 A
Gypsum @ 50% GR of RSC of water	122.20 a	196 a	175 a	164.40 A
Sulfuric acid @ 100% GR of RSC of water	119.80 a	194 a	172 a	161.93 AB
Poultry Manure @ 10 t. ha^{-1}	112.60 b	198 a	178 a	162.87 A
Press mud @ 10 t. ha^{-1}	110.90 bc	195 a	178 a	161.30 AB

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

While lowest mean plant height(155.83 cm) was recorded with continuous irrigation of brackish water (control). As far as grain yield of Raya was concerned, brackish water significantly ($P < 0.05$) affected the grain yield while simultaneously all the amendments showed their ameliorative effect in mitigating the ill effects of brackish water (Table-2).

Table 2. Effect of amendments on raya grain yield (t. ha^{-1}).

Treatments	1st Year	2nd Year	3rd Year	MEAN
Brackish water	1.52 c	0.77 b	0.79c	1.02 C
Gypsum @ 100% GR of RSC of water	1.66 a	0.96 a	1.06a	1.22 A
Gypsum @ 50% GR of RSC of water	1.60 abc	0.86 ab	0.89bc	1.11 B
Sulfuric acid @ 100% GR of RSC of water	1.63 ab	0.88 ab	0.86c	1.12 B
Poultry Manure @ 10 t. ha^{-1}	1.58 abc	0.94 a	1.02a	1.18 AB
Press mud @ 10 t. ha^{-1}	1.55 bc	0.90 ab	0.98ab	1.14 AB

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

Maximum grain yield (1.22 t. ha^{-1}) was produced by gypsum@ 100% GR of RSC of water followed by poultry manure and both treatments remain at par ($P < 0.05$). Whereas minimum grain yield (1.02 t. ha^{-1}) was recorded in control (brackish water). Similar findings were reported by Abro *et al.*(2007)they stated that inorganic (gypsum) and organic amendments (FYM, rice husk) had ameliorative effects on the soil properties, improving soil porosity and allowing more root penetration, more nutrients

available, more nutrient uptake resulting in better crop growth and yield. Oustani *et al.* (2015) suggested that supplementation with organic fertilizers can be effectively used as strategy to alleviate adverse effects of salinity and to support the growth of crops under saline conditions. Among organic amendments, poultry manure showed its superiority over press mud in increasing plant height and grain yield. It might be attributed to rapid decomposition, more solubility and release of nutrients from poultry manure.

Table 3. Effect of amendments on sunflower plant height (cm).

Treatments	1st Year	2nd Year	3rd Year	MEAN
Brackish water	108.70 a	109.20 b	107.37 d	108.42 C
Gypsum @ 100% GR of RSC of water	112.30 a	113.30 a	118.10 a	114.57 A
Gypsum @ 50% GR of RSC of water	110.90 a	112.10 a	110.23 c	111.08 BC
Sulfuric acid @ 100% GR of RSC of water	112.20 a	111.80 ab	110.17 c	111.39 BC
Poultry Manure @ 10 t. ha^{-1}	110.70 a	112.90 a	111.17 bc	111.59 AB
Press mud @ 10 t. ha^{-1}	111.40 a	110.80 ab	112.23 b	111.48 B

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

Effect of amendments on sunflower growth

Data in (Table 3) displayed that continuous irrigation with brackish water had negative impact on sunflower growth and gypsum proved more superior among all the applied treatments in alleviating the adverse effect of this brackish water. Data regarding plant height showed that maximum plant height of 114.57 cm was produced by gypsum@ 100% GR of RSC of water, which was statistically($P < 0.05$) alike with poultry manuring, and minimum plant height of 108.42cm was produced by brackish water. Similar trend was observed in achene yield, maximum achene yield of 2.19t. $ha^{-1}$was produced with gypsum application @ 100% GR of RSC of water followed by poultry manure(Table 4).

Table 4. Effect of amendments on sunflower achene yield (t. ha^{-1}).

Treatments	1st Year	2nd Year	3rd Year	MEAN
Brackish water	1.82 a	1.67 c	1.62 d	1.70 C
Gypsum @ 100% GR of RSC of water	2.23 a	2.08 a	2.26 a	2.19 A
Gypsum @ 50% GR of RSC of water	2.07 ab	1.75 bc	1.89 b	1.90 B
Sulfuric acid @ 100% GR of RSC of water	2.16 a	1.84 abc	1.92 b	1.97 B
Poultry Manure @ 10 t. ha^{-1}	2.20 a	1.96 ab	1.80 c	1.98 B
Press mud @ 10 t. ha^{-1}	2.09 ab	1.71 bc	1.85 bc	1.88 B

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

Whereas minimum achene yield (1.70 t. ha^{-1}) was observed in control (brackish water).The use of amendments improved plant height and achene yield by reducing the ill effects of brackish water on soil physic-chemical properties and enhancing the availability of nutrients to the plants. Qadir *et al.* (2017) reported that gypsum application enhanced the grain yield, biomass yield in wheat and rice. Oustani *et al.*(2015) reported that the application of poultry manure significantly increased yield and yield parameters as compared with control. The lowest plant height and achene yield were observed in the treatment with brackish water alone. Salts present in the brackish water might have affected plant growth and yield by reducing the ability of roots to absorb water due to osmotic pressure effects, their toxicity to the plants and nutritional imbalances (De Pascale *et al.*, 2013; Plaut *et al.*, 2013).

Table 5. Effect of amendments on soil chemical properties at the end of study (average of three years).

Treatments	pHs	ECe	SAR (mmol $L^{-1})^{1/2}$
Brackish water	8.23 (-1.73)	3.68 (-15.72)	13.97 (-61.50)
Gypsum @ 100% GR of RSC of water	7.97 (1.48)	3.00 (5.66)	7.80 (9.82)
Gypsum @ 50% GR of RSC of water	8.06 (0.37)	3.15 (0.94)	8.6 (0.57)
Sulfuric acid @ 100% GR of RSC of water	8.07 (0.24)	3.16 (0.62)	8.62 (0.34)
Poultry Manure @ 10 t. ha^{-1}	8.00 (1.11)	3.17 (0.31)	8.3 (4.04)
Press mud @ 10 t. ha^{-1}	8.02 (0.86)	3.17 (0.31)	8.4 (2.89)

The values in parenthesis represent the percent decrease (-)/increase (+) in the respective soil properties.

Soil Properties

Pool data of soil analysis after three years of experimentation showed that continuous use of brackish water negatively affect the soil properties while at the same time all the remedial strategies used substantially improved the soil chemical properties (Table 5).

Among all the treatments maximum reduction of 1.48% in pH was observed with gypsum application @ 100% GR of RSC of water followed by poultry manure application (1.11 %), whereas, press mud reduces the pH value by 0.86 %.

A slight increase (1.73 %) in pH was noted with brackish water. Similarly maximum reduction of 5.66% and 9.82 % was noted in EC_e and SAR respectively with addition of gypsum @ 100% GR of RSC of water. Irrigation with brackish water negatively affected these properties and an increase of 15.72% and 61.50% was recorded in EC_e and SAR respectively. Similar findings were reported by Qadir *et al.,* (2017)they observed reduction in soil pH with gypsum and organic amendments.

The increase in EC_e and SAR with the use of brackish water was perhaps due to swelling and partial dispersion of clay particles by the excessive concentration of Na^+ in brackish water. Ameliorative effects of amendments on soil properties may be ascribed as amendments release higher concentration of ions like Ca^{2+}, K^+ etc. which reduced the ill effects of brackish water due to leaching of Na^+ from the soil complex (Kahlon *et al.*, 2012).

Conclusion

When canal or good quality water is not available or in short supplies, brackish water can be used for subsequent crop production after neutralizing the negative effect of brackish water. Gypsum application @ 100% GR of RSC of water and poultry manure @ 10 t. ha^{-1} found more efficient over others treatments in the term of plant height and grain/ achene yield of raya and sun flower, soil chemical properties and can be successfully used to control the development of salinity/ sodicity in soil due to continuous use of brackish water.

Abbreviations

Used: EC_e (electrical conductivity of soil extract); EC_{iw} (electrical conductivity of irrigation water); pH_s (pH of soil saturated paste); RSC (residual sodium carbonate); SAR (sodium absorption ratio); GR (gypsum requirement).

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