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Utilization of brackish and canal water for reclamation and crop production

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Abstract

In Pakistan 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. However this precious natural reserve can be an effective alternate for soil reclamation. In present study a saline-sodic field (pH_s = 9.30, EC_e = 10.4 dS m^{-1} and SAR = 121.96 (mmol $L^{-1})^{1/2}$, GR =3.40 t. ha^{-1}} was selected, leveled and prepared. Gypsum was applied @ 0, 75, 100 and 125 % of GR. Each of this treatment was combined with brackish and canal water separately in split plot design. Gypsum was applied, mixed and leaching was provided either with brackish (EC =1.80 dS m^{-1} RSC = 5.8 mmol L^{-1} and SAR = 9.8 (mmol L^{-1} $)^{1/2}$ or canal water (EC_{iw} = 0.23 dS m^{-1} RSC= nil and SAR = 0.14 (mmol L^{-1} $)^{1/2}$ as per treatments. Rice and wheat crops were grown in sequence for two years. Paddy and wheat grain yield data were recorded at maturity. The recorded increase over control with gypsum (125 % GR) was 294 % in paddy and 182 % in wheat with brackish water while corresponding values for canal water were 177 and 143 %. The end value of EC_e recorded after two year was lesser than critical limit of 4 dS m^{-1} in all treatments except control even in brackish water. The pH_s and SAR also reduced with brackish water + gypsum application @125 % GR. The bulk density decreased from 7.1 to 20.0 % in brackish water and 11.18 to 19.08 % with canal water. More over an increase of 278 to 610 % in hydraulic conductivity was recorded with brackish water whereas the enhancement of this parameter with canal water varied from 370 to 576 %. It was concluded that brackish water can be utilized for reclamation of sandy clay loam soil and subsequent crop production provided that the application of gypsum is increased by 25 % of soil GR.

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Introduction

At present, 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 which is generally inferior to canal water. But its use is imperative to meet the food and fiber requirements of the population.

Due to the unprecedented drought situation, the water supply for irrigation purpose has worsened. In view of the prevailing drought situation, installation of tube wells/open wells have been given due emphasis by the farmers. Pumpage of this water used for irrigation may vary greatly in quality depending upon type and quantity of dissolved salts.

The salts are present in irrigation water in relatively small but significant amounts. However, 70-75 % tube wells pump water of poor quality (Ghafoor *et al.,* 1991) while 80 % water samples of district Kasur in Punjab were unfit for irrigation and suggested application of organic and inorganic amendments like pressmud, poultry manure, farm yard manure and gypsum (Mehboob *et al.,* 2011). The quality of ground water limits its use for irrigation and soil reclamation purposes presently (Aslam, 2002).While studying the suitability of ground water for irrigation purpose Waheed *et al.* (2010) suggested that recommendations regarding irrigation water must be with respect to textural class for long time cultivation of soil. Whereas, Keshavarzi *et al.* (2010) recommended that management of irrigation water must be carried out to minimize the login of salts to soil. It was also emphasized that monitoring of water quality is of great concern for preventing the hazards of irrigation water for sustainability of soil health and crop productivity (Ali *etal,* 2009; Kashif *et al.,* 2009).

Poor quality water can be used for crop production on a variety of soils provided proper agronomic techniques coupled with chemical amendments are followed like the use of gypsum, FYM and salt tolerant crops (Qadir *et al.,* 2001). Saifullah *et al.* (2002) studied the effect of tube well water alone, gypsum 25 % SGR (first two crops), FYM (25 t ha^{-1}), and combination of FYM and gypsum. They 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 for sustainable utilization of low quality soil and water resources. The results suggested that gypsum or FYM/press mud along with recommended doses of fertilizer must be used to sustain the productivity of rice–wheat system in areas having sodic ground water for irrigation (Yaduvanshi and Swarup, 2006). Therefore, the present study was conducted with following objectives:

Feasibility of brackish tube well water use for reclamation and subsequent crop production.
Monitoring of the gradual improvement in soil health.

Materials and methods

The research work was carried out in the farmer's field at Havaily Karim dad, Pindi Bhattian (Punjab), for two consequtive years in rice- wheat rotation to devise the effective and economical technology for reclamation of salt affected soils and improvement of soil health using brackish water. A saline sodic soil was selected, leveled and prepared. The composite soil samples were collected from 0-15 to 15-30 cm depth for analysis. The experiment was laid out according to the treatment in split plot design with four replications. The treatments tested were as under:

1. Irrigation water
a) Canal water, b) brackish water
2. Gypsum@0,75,100 and125% of GR

The gypsum was applied as per treatment followed by leaching with canal water (EC_{iw} = 0.23 dS m^{-1}, RSC = nil and SAR = 0.14 (mmol L^{-1} $)^{1/2}$and tube well water (EC_{iw} = 1.80 dS m^{-1}, SAR = 9.8 (mmol $L^{-1})^{1/2}$ and RSC

5.8 mmole L^{-1}) according to the treatments for 15 days to remove the salts. The soil samples were also collected before transplanting of rice. Field was ploughed and prepared for nursery transplanting followed by irrigation. Rice nursery (30 days old) was transplanted keeping the row to row and plant to plant distance 22 x 22 cm. Recommended dose of fertilizer (110-90-70 NPK Kg ha^{-1}) was used to grow rice crop. Half of the recommended nitrogen (N) and full dose of phosphorus (P_2O_5) and potash (K_2O) were applied at transplanting while the remaining half was applied at 30 days after transplanting (DAT). *Macheiti weedicide* was applied seven days after transplanting of rice seedling to control the weed growth. Padan insecticide was applied 45 DAT to check the attack of stem borer. Sundaphos insecticide was sprayed to cover the risk of rice leaf roller and ensure the good yield of rice. Zinc sulphate was applied to avoid the deficiency of Zn. At maturity, biomass and paddy yield data was recorded. Same field was prepared and no amendment was applied. Wheat seed were treated with benlate to avoid the effect of fungal disease and was sown with single row drill in the same layout plan in all the treatments. Fertilizer was added to wheat according to recommended dose (120-90-70 NPKKg ha^{-1}). Single super phosphate, potassium sulphate and half of the recommended dose of urea were applied at sowing, while remaining urea was applied at first irrigation. Pumasuper and isoprotone weedicides were applied 30 days after sowing of wheat.

After harvesting of wheat, second rice and wheat crops were grown in the same layout plan without application of amendments and similar data were recorded. Soil samples were collected from 0-15 and 15-30 cm depth after harvesting of each crop. The samples were air dried, ground, passed through 2 mm sieve and stored in plastic bottles and analysed for pH, EC_e, SAR, HC, % pore space according to U.S. Salinity Laboratory Staff (1954) and bulk density (d_b) by (Klute,1986). All the data was subjected to analysis of variance following the method of Steel *et al.* (1997) to sort out significant differences among treatments at 5 % probability level using STATISTIX 8.1 package software.

Results and discussion

Effect of brackish water on paddy and grain yield of wheat

Water is also one of the major inputs required for reclamation of salt affected soils. The first preference is to utilize good quality water for leaching of salts effectively because there is not much addition of salts with the irrigation water that have to be used in huge quantity. But unluckily good quality water does not meet even the requirement of crop production. Hence, farming community cannot spare good quality water for reclamation.

Table 1. Percent increase/decrease over control after four crops in paddy/wheat grains and soil parameters in utilization of brackish water for soil reclamation and crop production in salt affected soils.

Irrigation Sources	Treatments	Increase			Decrease			
		Paddy	Grain	HC	BD	pHs	EC_e	SAR
Brackish water	T_2gypsum75%	153.8	82.2	278	7.10	4.44	26.83	19.62
	T_3gypsum100%	227.7	135.5	494	13.55	5.5	24.39	40.05
	T_4 gypsum125%	293.8	182.2	610	20.0	6.66	34.15	61.85
Canal water	T_2gypsum75%	123.2	95.3	370	11.18	3.41	30.0	33.01
	T_3gypsum100%	165.3	139.8	500	19.08	5.68	40.0	57.93
	T_4 gypsum125%	176.8	143.0	576	19.08	6.82	50.0	67.32

The only alternative under this situation is utilization of brackish water. However, utilization of this water also causes accumulation of more salts and Na^+. The ideal approach will be neutralizing the effect of Na^+ being added with the water and leaching of all soluble salts. Taking into consideration steady state approach, it could be possible because salts will be leached down even with brackish water, provided that quantity of salts in water is lesser than the soil. Of course, keeping in view the Na^+ coming through water, additional amount of gypsum has to be applied. The results of the investigation on this aspect proved this hypothesis that if 25 % more gypsum was added, the reclamation and yield level of canal water could be obtained rather there was some more yield when brackish water was used with 25 % additional gypsum.

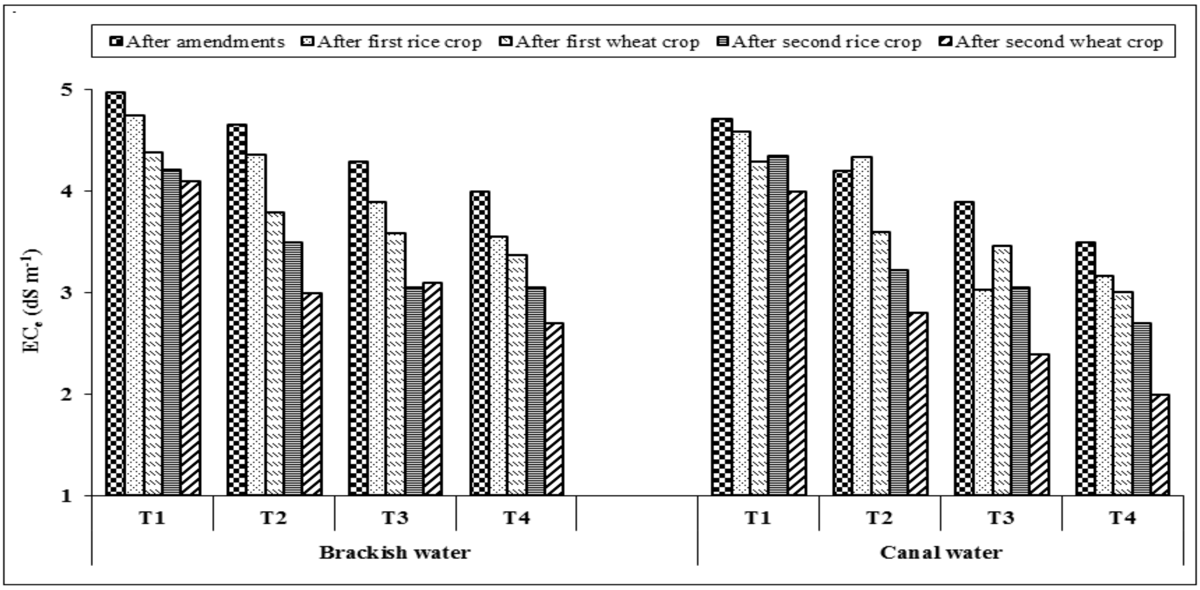

Fig. 1. EC_e changes with gypsum combined with brackish or canal water.

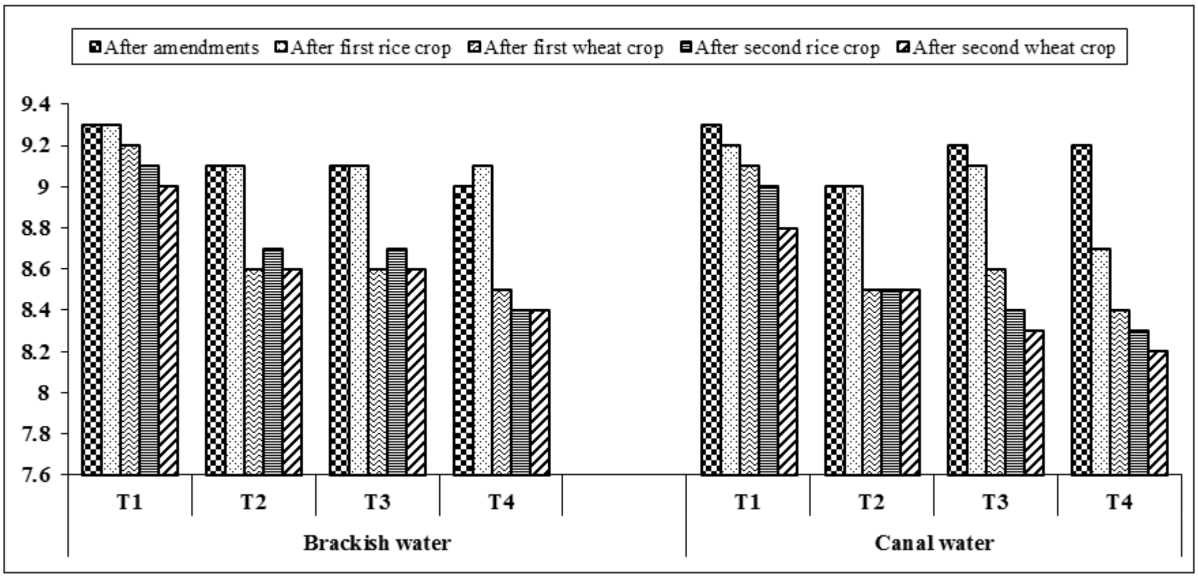

Fig. 2. pH_s Changes with gypsum combined with brackish or canal water.

The recorded increase over control with gypsum (125 % GR) was 294 % in paddy and 182 % in wheat with brackish water while corresponding value for canal water were 177 and 143 % (Table 1).

If good quality water is not available, the brackish water with lesser parameter of salinity/sodicity than soil can also be utilized but gypsum addition has to be increased by 25 %. A significant yield of rice was obtained when grown in saline sodic soil after application of FYM and gypsum and irrigated with sewage and ground water (Hussain *et al.,* 1997).

Soil Electrical Conductivity (EC_e)

When irrigation water is applied in excessive quantities to the soil having high EC_e than water, both will equalize in salt content after reaching the steady state (dilution approach). The only condition is that there should be significant difference in salt content of soil and water, the latter being lesser in EC. However, if the water also contains Na^+ in excess quantities, it has to be neutralized through application of Ca^{2+} source like gypsum. If applied Ca^{2+} takes care of both soil and water Na^+, the water can safely be used for reclamation.

The collected data of the experiment have supported this hypothesis. It has been observed that original EC_e (10. 44 dSm^{-1}) of the experimental soil reduced significantly (Fig-1) in two years.

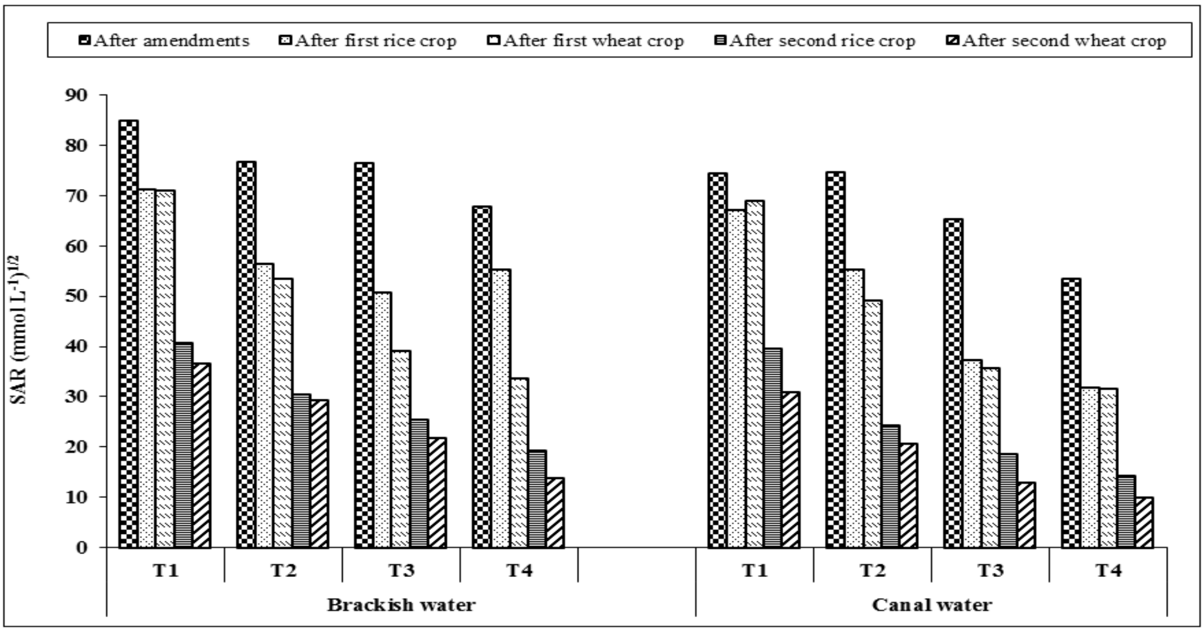

Fig. 3. SAR changes with gypsum combined with brackish or canal water.

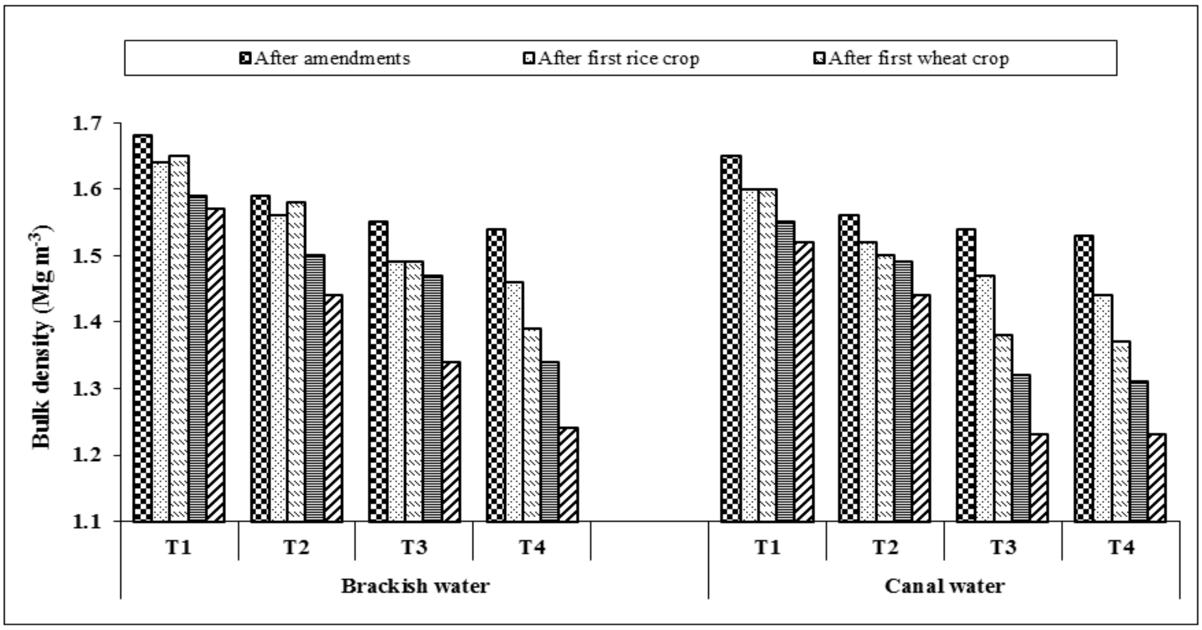

Fig. 4. Bulk density changes with gypsum combined with brackish or canal water.

The end values recorded after two years were lesser than critical limit of 4 dSm^{-1} in all the treatments except control even in brackish water [ECiw1.80 dSm^{-1} RSC 5.8 (m mol L^{-1}) and SAR 9.8 (m mol $L^{-1})^{1/2}$]. The percent decrease was recorded to be 26.83, 24.39 and 34.15 % with gypsum doses of 75 %, 100 % and 125 % GR respectively in case of brackish water while respective values for reduction in EC_e with canal water were 30 %, 40 % and 50 % (Table -1). The decrease in soil EC_e was due to leaching of salts after application of water subsequent to addition of amendments. Apparently there was no adverse problem of drainage and salts have left the soil ecosystem.

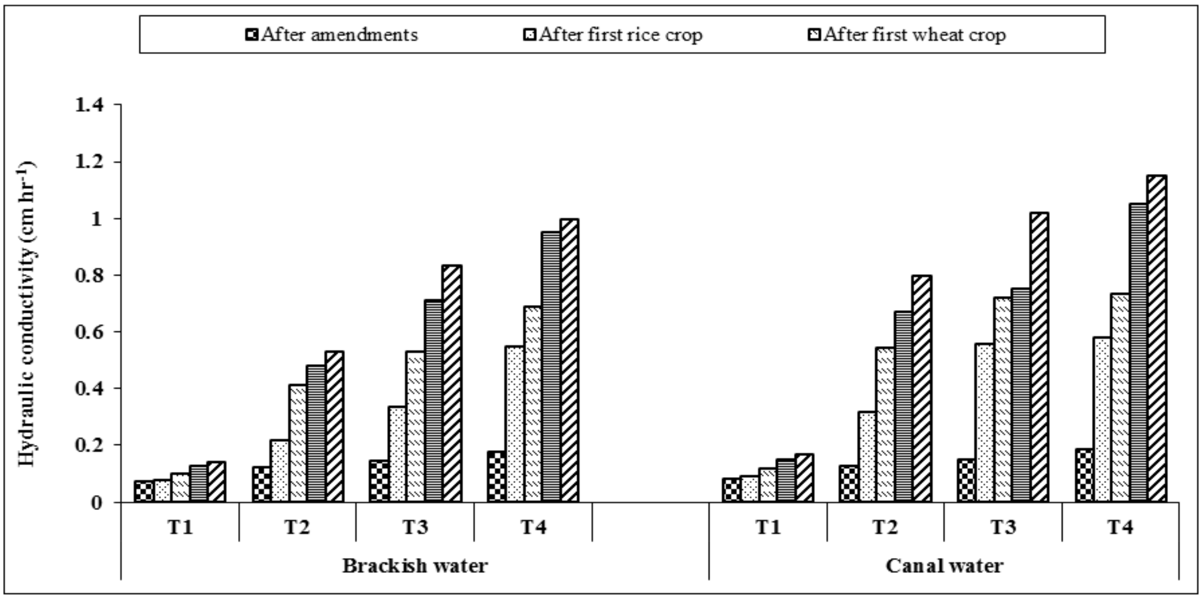

Fig. 5. Hydraulic conductivity changes with gypsum combined with brackish or canal water.

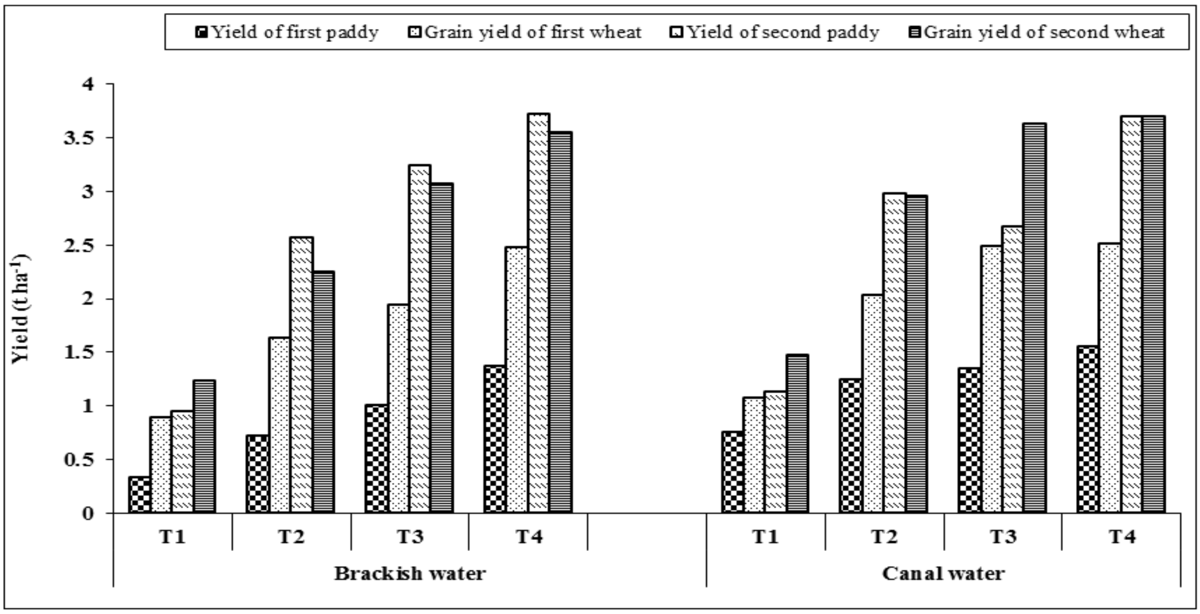

Fig. 6. Yield response to gypsum combined with brackish or canal water.

The reuse of saline/sodic water for amelioration of salt affected soil and subsequent crop production has been claimed to decrease disposal problem of such water. Gypsum addition also made possible the safe use of even tile drain water (EC_{iw} 2.9 to3.4 dSm^{-1}, SAR 12.0-19.4 mmol $L^{-1})^{1/2}$ (Qadir *et al.*, 1998; Qadir *et al.*, 2001). Saifullah *et al.* (2002) have reported that tube well water with gypsum can be used under the agro climatic condition of Pakistan.

It has been estimated that in general one foot of flooded irrigation is required to remove 75 % of the soluble salts from the upper one-foot soil layer (Chhabra, 1996).

Soil pH

The pH of sodic soil and most often that of saline/sodic soil is more than 8.5. Application of Ca (as gypsum) removes the excessive sodium from clay complex as well as soil solution and pH of soil is again reverted to the safe limit of less than 8.5.

The use of water, especially sodic or saline sodic can also increase the soil pH but its effect can be controlled if gypsum is also added simultaneously to counteract its negative effects. Recorded data on soil pH favour this visualized situation.

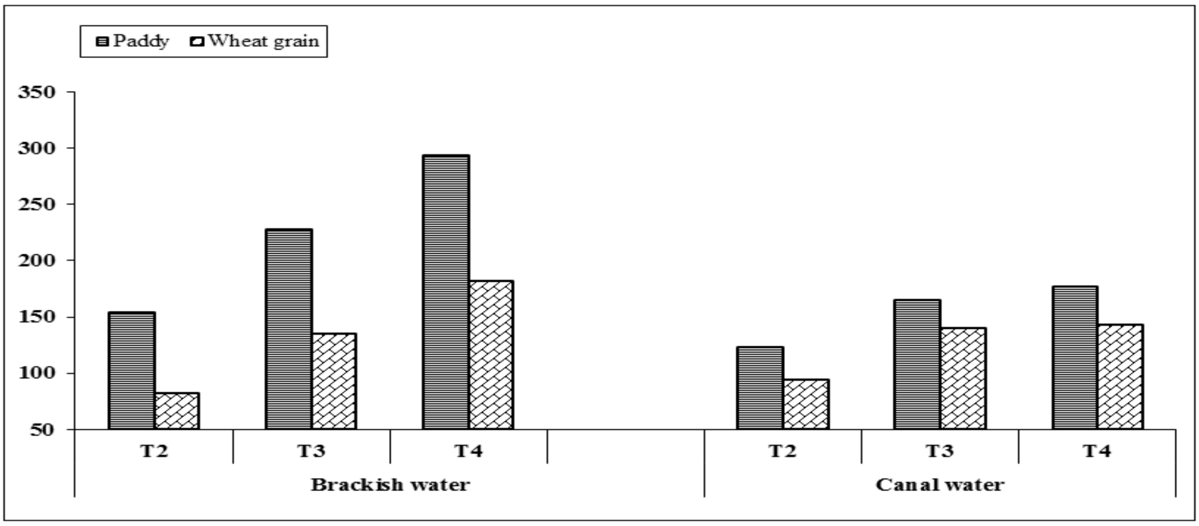

Fig. 7. Percent increase over control in yield with gypsum combined with brackish or canal water.

It was observed that pH of the experimental soil decreased from 9.3 to 8.6 or less than that in different doses of gypsum (Fig-2). The recorded decreases were from 4.44 to 6.66 % in case of brackish water and 3.41 to 6.82 % with canal water (Fig. 8).

This indicated that gypsum application not only decreased the pH of saline sodic soil but also checked the expected increase due to utilization of brackish water. The highest dose of gypsum (125 % GR) proved best in this regard, especially when the irrigation source was brackish water. However, gypsum 100 % GR was sufficient in case of canal water. The use of gypsum, FYM and press mud significantly decreased the soil pH and SAR. The recommended doses of fertilizers must be used along with these amendments to sustain the productivity of rice-wheat system in areas having sodic ground water for irrigation (Yaduvanshi and Swarup 2006).

Sodium adsorption ratio (SAR)

The SAR of original soil was determined as 121.9 (m mol $L^{-1})^{1/2}$ that gradually decreased after application of amendments as well as growing of crops and reached nearer (14.0 m mol $L^{-1})^{1/2}$ to critical limit (13.0 SAR) with brackish water + gypsum application (125 % GR) while its value in the canal water irrigation was 10.1 (m mol $L^{-1})^{1/2}$ after two years. The lower doses of gypsum (75 and 100 % GR) were slightly inferior to that. But control plots were still having more than 30 SAR in either source of irrigation (Fig. 3).

The excessive amount of sodium in the soil solution caused very high values of SAR. But addition of Ca source (gypsum) and subsequent leaching with any type of water enhanced removal of Na^+ from clay complex and subsequent leaching from the soil solution.

The efficacy of Na^+ removal and sequestering to the down profile depended upon the corresponding quantities of added gypsum. Because brackish ground water also contained more sodium than canal water therefore, higher level of gypsum equalized to the lower dose when used with canal water. With these strategies SAR reduction varied from 19.62 to 61.87 % in case of brackish water whereas decrease in this parameter with canal water ranged from 33.01to 67.32 % (Table-1). The decrease was the highest with gypsum application level (125 % GR) while reduced with lesser quantity. Saleem *et al.* (2002) also recorded significant reduction in soil SAR by all the tested doses of gypsum as well as $CaCl_2$. There was subsequent high decrease in SAR of saline sodic soil due to removal of $Na^+$with applied FYM and gypsum (Hussain *et al.*, 1997).

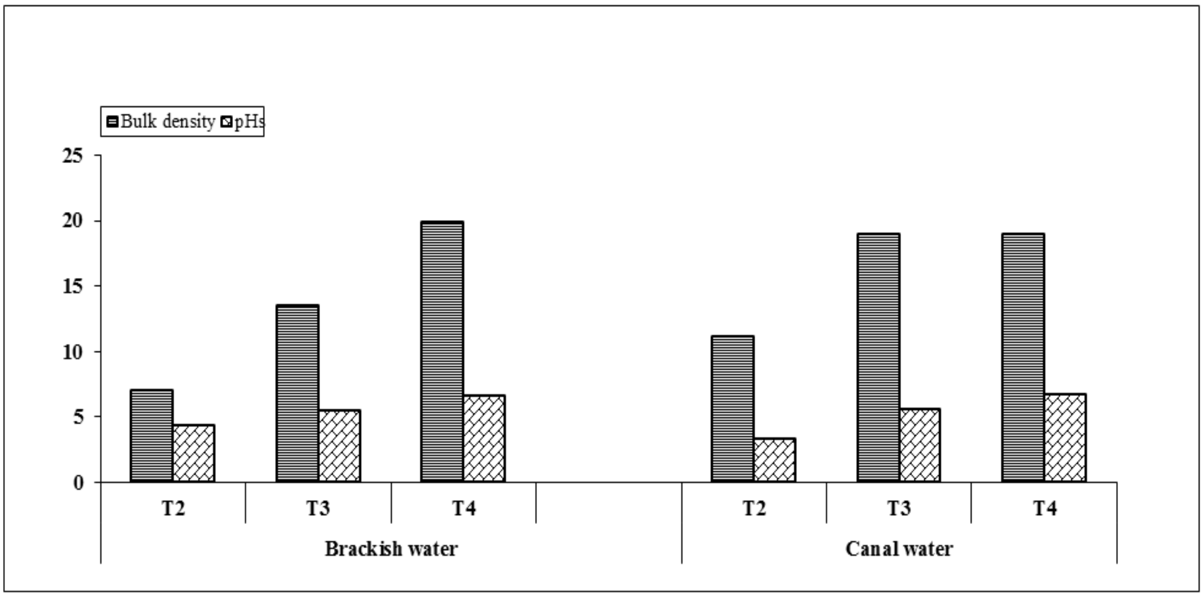

Fig. 8. Percent decrease over control in soil bulk density and pH_s with gypsum combined with brackish and canal water.

Soil bulk density and % pore space

The use of saline sodic water is regarded as appropriate at least during initial stages for reclamation for promoting flocculation and increasing permeability when soil is sodic or saline sodic with impaired physical properties (Troe, 1999). Shainberg *et al.* (1989) reported wide use of gypsum to improve soil porosity through sustaining electrolytes concentration.

The flocculation of clay particles improves porosity and decreases numerical values of BD. The results of the present study supported this view. The value of BD for the experimental soil was 1.73 Mg m^{-3} that reduced to various degrees depending upon quantity of gypsum applied.

There was nonsignificant difference between brackish water (1.24 Mg m^{-3}) and canal water (1.23 Mg m^{-3}) at the end of two years (Fig-4). The range of decreasing in Db was 7.10 to 20.0 % in brackish water and 11.18 to 19.08 % with canal water (Table-1). The decrease in BD was corresponding increase in porosity, as the latter is derived property from the former. Petter and Kelling (2002) reported a reduction and dispersion as the results of decrease in BD and increase in porosity.

Keeping in view the results of the present investigation and findings of the other researchers it become very clear that BD and porosity of saline sodic soil can highly be restored with an appropriate dose of gypsum even though irrigation water is saline sodic in nature. Gypsum is the most commonly used amendment to improve flocculation and macro porosity, reduced bulk density and increased permeability (Sri ramachandra sekaran and Ravichandran, 1995).

Hydraulic conductivity (HC)

The hydraulic character (infiltration rate, permeability and hydraulic conductivity) of the soil depends on soil texture, structure. organic matter content and total porosity. The sodicity breaks structure of soil and the passage of water is retarded due to dispersion (Qadir and Schubert, 2002).

Whenever a calcium source is used for soil rehabilitation, the process is reversed and soil coagulation is revived that results in conspicuous increase in soil porosity. Therefore, the passing of water through the profile under consideration is eased and the magnitude of hydraulic conductivity increased considerably.

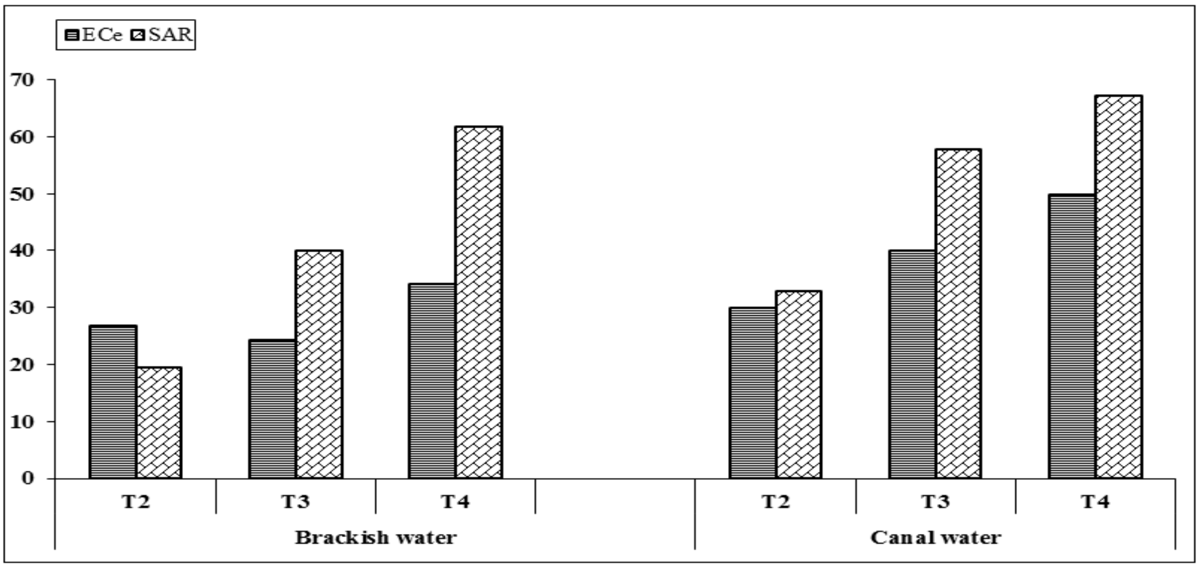

Fig. 9. Percent decrease over control in EC_e and SAR with gypsum combined with brackish and canal water.

The findings from this study are in line of above hypothesis. An increase of 278 to 610 % in HC was recorded when the irrigation water was brackish; whereas the enhancement of this parameter with canal water varied from 370 to 576 % (Table-1).

The impact of gypsum correlated to the quantities applied (Fig -5). Hussain *et al.* (2001) reported that gypsum + H_2SO_4 + FYM decreased BD and increased porosity, void ratio, water permeability and hydraulic conductivity enormously.

Abbreviations used

EC_e (electrical conductivity of soil extract); pHs (pH of soil saturated paste); SAR (sodium absorption ratio); GR (gypsum requirement); HC (hydraulic conductivity); BD (bulk density)

Conclusions

When canal or good quality water is not available or in short supplies, brackish water can be used for reclamation of salt affected soils and subsequent crop production. To neutralize the negative effect of brackish water, gypsum application has to be increased by 25 % of original gypsum requirement. This strategy was successful to mitigate the deleterious effects and salinity indicators i.e soil EC_e, pH and SAR were brought to normal. Gypsum addition also recorded 294 % more yield of paddy and 182 % wheat grain over control, at the same timethe respective increases with canal water were 177 and 143 percent.

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