Soil & Environ. 26(2): 164-171, 2007

Effect of gypsum and farmyard manure on soil properties and wheat crop irrigated with brackish water

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Abstract

A study was conducted on a farmer's field at village Majokay, Charsadda in Peshawar valley (NWFP) during Rabi 2004-05, in order to investigate the effect of gypsum and FYM on the properties of saline-sodic soils and yield of wheat crop irrigated with brackish tubewell water. Treatment combinations were control (T_1), FYM @ 20 t ha^{-1} (T_2), gypsum @ 50% GR (T_3), gypsum @ 50% GR + 10 tons FYM ha^{-1} (T_4), gypsum @ 100% GR (T_5) and gypsum @ 100% GR + 10 tons FYM ha^{-1} (T_6) arranged in RCB design with three replications. Gypsum was calculated on the basis of water gypsum requirement. Results showed that gypsum at half rate and manure individually improved wheat yield, though non-significantly, to the tune of 70 and 45%, respectively over control. Significantly higher increases occurred with their combined application or with gypsum at full rate. 1000-grain weight showed significant increases with all the treatments over control. Gypsum application at full rate gave 14.3% increase in grain yield than that at half rate. Regarding growth parameters, the effect of manure was non-significant whereas gypsum combined with manure significantly improved growth over control. Maximum increases in the number of spikes m^{-2}, number of leaves plant^{-1}, number of grains spike^{-1}, grain yield, straw yield, 1000-grain weight and harvest index were 128, 46, 48, 133, 34, 47 and 76%, respectively in case of combined application of gypsum @ 100% GR and manure @ 10 tons ha^{-1} over control. The treatments also improved soil properties by reducing pH, EC, SAR and gypsum requirement. Combined application of manure with full rate of gypsum resulted in reducing these parameters by 9, 18, 55 and 85%, respectively as compared to control. It may be concluded that manure and gypsum both in combination are most effective in mitigating the ill-effect of brackish water, improving soil conditions and increasing wheat yield raised with brackish tube well water.

Key words: Farm yard manure, gypsum, soil properties, wheat, brackish water

Introduction

Salinity, sodicity and water logging are the most serious problems affecting the irrigated agriculture and limit crop production over a large area of Pakistan. The present estimates show that nearly 6 m ha area of Pakistan is in the grip of salinity and sodicity (Manzoor and Salim, 2001). It has been recognized that major damage occurs due to these problems, where crop productivity is either completely eliminated or is greatly reduced. Crop production in the arid and semi-arid regions is dependent on irrigated agriculture. The hot and dry climates of these regions require that the irrigation water should not contain soluble salts in amounts that are harmful to plants or have adverse effects on soil properties. Water of such quality is usually not available in sufficient quantities to satisfy the water requirements of all the crops grown. Over 100 MAF of water being diverted into canals, net water available at the water course head is only 70.3 MAF, against the requirement of 134 MAF. The deficit to the tune of 34 MAF is met through tubewells but over 70% of tubewells pump water of poor quality (Qureshi and Barrett-Lennard, 1998). Under these conditions the farmers are forced to use irrigation water of salt content resulting in poor growth and lower yields of most crops. Indiscriminate use of such water can often lead to crop failures and to the development of saline or sodic soils which, in turn, require expensive treatments to make them productive again. However, when saline water is skillfully used, it can contribute to the successful production of a variety of crops.

Salinity problem related to water quality occurs when the total quantity of salts in irrigation water is such that accumulate salts in the root zone to the extent to adversely affect crop yields. Ground waters in arid and semi-arid regions are generally higher in salinity varying from less than 1 dS m^{-1} to more than 12-15 dS m^{-1}. Under favorable conditions groundwater with salinity of more than 10 dS m^{-1} has been used for the production of semi-tolerant crops like wheat in coarse textured soils with only slight yield reductions. On the other hand unfavorable soil and climatic conditions and/or poor management have resulted in serious salinity problems even with the use of water of as low salinity as 0.4 to 0.5 dS m^{-1} (Paliwal, 1972; Marchanda, 1976).

Prolonged use of certain irrigation water results in reduced crop yields due to deterioration in the soil physical properties. The adverse effect of irrigation water quality on soil physical properties is associated with the accumulation of sodium ion on the soil exchange complex which imparts

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instability to the soil aggregates and whose disruption followed by dispersion of clay particles results in clogging of soil pores. Sodium adsorption ratio (SAR) of the irrigation water has been suggested as a measure of the sodicity/alkali hazard of irrigation water (Richards, 1954). For SAR values greater than 6 to 9, the irrigation water could be expected to cause permeability problems in soils, which contain swelling type clay minerals (Ghafoor *et al*., 2004).

Soil amendments are materials, such as gypsum or calcium chloride, that directly supply soluble calcium for the replacement of exchangeable sodium (Alawi, *et al*., 1980) or other substances, such as sulphuric acid and sulphur (Mughra *et al*., 1996), that indirectly through chemical or biological action, make the relatively insoluble calcium carbonate commonly found in sodic soils, available for replacement of sodium. Organic matter (i.e. straw, crop residues and green manures), decomposition and plant root action also help dissolve the calcium compounds found in most soils, thus promoting reclamation but this is relatively a slow process (Goel, 1999). The kind and quantity of a chemical amendment to be used for replacement of exchangeable sodium in the soils depend on the soil characteristics including the extent of soil deterioration, desired level of soil improvement including crops intended to be grown and economic considerations.

The scarcity of irrigation water presently being felt will further multiply with passage of time as pressure on land and consequent demand of water increases. It is therefore, highly desirable to use our water resources scientifically and learn to live with saline conditions so as to meet the challenges of 21st century.

Keeping the above scenario in mind, this research was initiated to manage brackish tube well water so as to keep the soil productive on sustainable basis and to combat the ill effect of use of such water.

Materials and Methods

The research study was conducted on a farmer's field at village Majokay, district Charsadda in Peshawar valley (NWFP, Pakistan) during Rabi season 2004-05, with the objectives to investigate the effect of various amendments on yield of wheat crop and on properties of saline-sodic soils irrigated with brackish tubewell water.

The soil under study was saline sodic having alkaline pH of 9.5, EC 6 dS m^{-1}, SAR 46 and sandy loam texture (Table 1). Each treatment got an area of 64 m^2. Treatment combinations were 1) control, 2) FYM @ 20 t ha^{-1}, 3) gypsum @ 50% GR, 4) gypsum @ 50% GR + 10 tons FYM ha^{-1}, 5) gypsum @ 100% GR and 6) gypsum @ 100% GR + 10 tons FYM ha^{-1}. These six treatments were randomly assigned to the plots in three replications arranged in RCB design as described by Gomez and Gomez (1984).

The quantity of the required gypsum was calculated on the basis of the SAR of water i.e. the relative concentrations of Na^+ and Ca^{2+} + Mg^{2+} in $mmol_c$ L^{-1} of the tubewell water as devised by Qureshi *et al*. (1996).

Half dose of N with full of P and K @ 120:90:60 N, P_2O_5 and K_2O kg ha^{-1} to all the treatments was applied before crop sowing and the remaining half dose of N as urea was applied before spike initiation.

Water sampling

To determine the water quality status, water sample from the tubewell under study was collected in plastic bottle of one litre with screw cap. Before taking the sample, the bottle was washed properly, labeled with the name of farmer and location with waterproof ink. Prior to sampling, bottle was rinsed several times with water from which sampling was being made and filled a small portion of the bottle from the water after running the well for 5-10 minutes. The bottle was filled with the addition of water bit by bit after intervals of about 5 minutes. The bottle thus filled was capped and brought to the laboratory for chemical analysis. Water sample was analyzed for EC, pH, SAR, K and residual sodium carbonate (RSC) calculated according to the procedures given by Richard (1954). Gypsum Requirement (GR) of water was calculated using the method reported by Qureshi *et al*. (1996).

Wheat growth and yield

Wheat was grown as test crop to see whether amendments had done well or not in reducing harmful effects of brackish irrigation water. The data on number of leaves $plant^{-1}$, number of spikes m^{-2}, number of grains $spike^{-1}$, 1000-grain weight, grain yield, straw yield and harvest index of wheat were recorded at appropriate stages of crop growth during the year 2004-05.

The crop was harvested on 14th May 2005. Data collected were analyzed statistically using Fisher's analysis of variance technique and differences among treatment means were compared by LSD test (Steel and Torrie, 1980).

Soil sampling

Composite soil sample at 0-20 cm depth was collected from experimental soil before treatment application. After crop harvesting, soil samples at 0-20 cm depth from each treatment were collected separately. These samples were also brought to the laboratory, dried at room temperature, ground to pass through 2 mm sieve, labeled and were stored for analyses.

Laboratory analysis

Electrical conductivity (EC) in soil extract and in water sample was determined by EC meter according to the method given in Ryan *et al*. (2001). Soil pH was determined using pH meter by the method of McLean (1982). Soil texture was determined by the procedure given by Tagar and Bhatti (1996). Sodium (Na^+) was determined by flame photometer and $Ca^{2+}{}_{+}\ Mg^{2+}$ concentrations were determined by titration method. The SAR in soil extract or water sample was calculated using the following expression.

$$SAR = Na^+ / \{(Ca^{2+} + Mg^{2+})/_2\}^{0.5}$$

Gypsum requirements (GR) of soil samples, soluble K^+ in soil extract or water sample and CO_3^{2-} and HCO_3^- concentrations by titration procedure were determined by the method as described by Richards (1954). Soil organic mater was determined using the method as described by Nelson and Sommers (1982). Lime content was determined by acid neutralization method (Ryan *et al*., 2001).

Results and Discussion

The research study was conducted to mitigate the harmful effects of brackish irrigation water by applying gypsum and farmyard manure alone or in combination. Data concerning various plant parameters, viz. growth and yield components of wheat and physico-chemical properties of amended soils are hereby presented and discussed. The salinity sodicity status and other properties of the native soil are given in Table 1, while the chemical properties of tubewell irrigation water used in the experiment are given in Table 2a.

Comparing with the established guidelines for irrigation water quality (Table 2b), pH of the irrigation water used in this study was in the normal range, EC_w was marginal whereas RSC and SAR were hazardous and beyond the safe limits.

Effects of amendments on the growth of wheat

Results pertaining to wheat growth and yield are presented and discussed as under:

Average number of spikes at maturity recorded (Table 3) in different treatments ranged from 172 to 400 spikes m^{-2}. Both the amendments in different combinations increased the number of spikes significantly over control. Maximum increase of 132% was obtained with full rate of gypsum. Beneficial effect of amendments may be attributed to their ameliorative effects in mitigating the effect of salts. Reduction in spike bearing plants capacity with increasing salinity has also been reported by Maas *et al*. (1996).

Number of leaves $plant^{-1}$ was significantly affected by most of the amended treatments (Table 3). Remarkable increases occurred when manure was added along with either rate of gypsum. Maximum increase of 46% over control was obtained with combined application of manure and gypsum at full rate. Number of leaves per plant is a good indicator of the plant health as the photosynthetic activities occurring in leaves contribute towards yield of crops (Fageria *et al*., 1997). Manure and gypsum improve soil properties for prolific root growth of plants which may have contributed to the vegetative growth of plants. The findings regarding number of leaves $plant^{-1}$ are in line with the work of Grewel (1984), who found gypsum and FYM in improving soil health and hence good plant growth.

Treatment means of number of grains $spike^{-1}$ were statistically non-significant. However, there existed a trend of increase in the number of grains per spike. Increase in number of grains $spike^{-1}$ was 48, 36, 34, 28 and 22% in T_6, T_5, T_4, T_3 and T_2, respectively as compared to control. FYM applied with half rate of gypsum had 4.81% more grains than the gypsum applied at half rate alone. Similarly, FYM applied with full rate of gypsum had 8.5% more grains than the full rate of gypsum applied alone. Gypsum along with FYM was the best treatment in obtaining maximum number of filled spikelets, which might be due to the lower value of Na^+ concentrations in these treatments as compared to control. The results are also supported by the findings of Singh (1985).

Effects of amendments on the yield of wheat

The data presented in Table 4 showed that mean grain yield of wheat in T_6 was significantly ($P < 0.05$) higher from T_1 and T_2 only. Application of either FYM or gypsum at half rate, though statistically non-significant, increased yield by 45 and 70%, respectively over control. Significant increases were recorded in the treatment of gypsum at full rate or when FYM was added along with either rate of gypsum. Application of FYM gave 9% increase in grain yield with half rate of gypsum and 20% with full rate of gypsum as compared with gypsum alone. Gypsum application at full rate gave 14.3% higher grain yield than at half rate. Maximum increase of 133% over control was recorded in FYM combined with full rate of gypsum. These results suggest that gypsum and FYM amendments helped in increasing the yield of wheat, which may be attributed to directly nutritional effect as well as indirectly through improving soil properties. Similar findings were also reported by Singh (1985), Wassif *et al*. (1995) and Mughra *et al*. (1996).

The data of straw yield of wheat crop indicated in Table 4 showed that maximum straw yield was obtained by the combined application of FYM and gypsum at full rate and minimum in the control. Treatment means were non-significantly different among each other, however, T_6 gave

Table 1. Physico-chemical properties of the native soil prior to experimentation

Property	Unit	Concentration
pH	-------	9.50
EC	dS m^{-1}	5.60
Na^+	$mmol_c L^{-1}$	45.00
K^+	$mmol_c L^{-1}$	1.00
$Ca^{2+} + Mg^{2+}$	$mmol_c L^{-1}$	1.92
CO_3^{2-}	$mmol_c L^{-1}$	3.23
HCO_3^-	$mmol_c L^{-1}$	14.81
Cl^-	$mmol_c L^{-1}$	15.57
SO_4^{2-}	$mmol_c L^{-1}$	19. 35
Sodium Adsorption Ratio	$(mmol_c L^{-1})^{1/2}$	46.00
$CaCO_3$	%	6.10
Soil Organic matter	%	0.35
Sand	%	56
Silt	%	25
Clay	%	19
Textural class	------	Sandy loam
Gypsum Requirement	tons ha^{-1}	18.28

Table 2a. Properties of the irrigation water used in the experiment

Parameter	Unit	Concentration
pH	----	8.07
EC_w	dS m^{-1}	2.70
Na^+	$mmol_c L^{-1}$	13.00
$Ca^{2+} + Mg^{2+}$	$mmol_c L^{-1}$	0.71
SAR	$(mmol_c L^{-1})^{1/2}$	22.03
CO_3^{2-}	$mmol_c L^{-1}$	2.60
HCO_3^-	$mmol_c L^{-1}$	5.1
RSC	$mmol_c L^{-1}$	7.00
K^+	$mmol_c L^{-1}$	10.26

Table 2b. Guidelines for irrigation water quality

Class	EC dS m^{-1}	SAR	RSC	Reference
Good	<1.35	< 10	< 2.5	Hussain, 1978
Marginal	1.35-2.70	10-15	2.5-5.0	Hussain, 1978
Hazardous	> 2.70	> 15	> 5.0	Hussain, 1978
Normal pH range 6.5-8.4				Ayers and Westcot, 1985

35, T_5 24, T_4 21, and T_2 and T_3 25%, respectively higher straw yield as compared to control (T_1). Application of FYM with full rate of gypsum gave 9.14% increase in straw yield over the full rate of gypsum alone. These results suggest that both these amendments helped in increasing wheat straw yield also, attributed to nutritional as well as ameliorative effects as stated by Srivastava and Srivastava (1994).

All the treatments gave significant increases in 1000-grain weight as compared to control (Table 4). Gypsum application produced heavier grains than manure did. Maximum 1000-grain weight of 39.07 g followed by 36.11 g were obtained in treatments T_6 and T_5, representing an increase of 43 and 36%, respectively over control. The application of FYM gave 1.3% increase in 1000-grain weight with half rate of gypsum and 8% increase when used with full rate of gypsum. Gypsum application at full rate gave 9.3% higher 1000-grain weight than at half recommended rate. These results suggest that both these amendments were quite effective in boosting wheat yield through increasing grain weight. The results are in conformity with those reported by Tiwari and Jain, (1992).

The data indicated that gypsum at full rate alone or in combination with manure significantly improved harvest index as compared to control (Table 4). A maximum value of harvest index was obtained in treatment T_6 representing an increase of 49% over control. The results indicate that

Table 3. Effect of amendments on growth parameters of wheat crop

Treatments	Number of Spikes m^{-2}	Number of leaves $Plant^{-1}$	Grains $Spike^{-1}$
Control	172.30 b[†]	8.00 c	36.93 b
FYM @ 20 t ha^{-1}	283.70 ab	9.45 bc	45.13 ab
Gypsum @ 50% GR	307.30 a	9.24 bc	47.13 ab
Gypsum @ 50% GR+10 t ha^{-1} FYM	367.30 a	9.63 b	49.40 ab
Gypsum @ 100% GR	400.00 a	10.54 ab	50.00 ab
Gypsum @ 100% GR+10 t ha^{-1} FYM	394.00 a	11.70 a	54.73 a
$LSD_{(0.05)}$	124.4	1.581	14.992

[†]Means sharing similar letter(s) within columns do not differ statistically at P<0.05.

Table 4. Effect of amendments on the yield parameters of wheat crop

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	1000-Grain weight (g)	Harvest index
Control	1375 c[†]	4792	26.52 e	22.30 b
FYM @ 20 t ha^{-1}	2000 bc	6000	29.73 d	25.00 ab
Gypsum @ 50%GR	2333 abc	6000	33.02 c	28.00 ab
Gypsum @ 50% GR+ 10 t ha^{-}FYM	2542 ab	5792	33.43 c	30.50 ab
Gypsum @ 100% GR	2667 ab	5916	36.11 b	31.07 a
Gypsum @ 100% GR+10 t ha^{-1} FYM	3208 a	6458	39.07 a	33.19 a
$LSD_{0.05}$	1063	N.S	1.241	8.683

[†]Means sharing similar letter(s) do not differ statistically at P < 0.05.

Table 5. Effect of amendments on the uptake of nutrients by wheat crop

Treatments	SO_4^{2-}	P	K	Zn	Fe	Mn
	g kg^{-1}			mg kg^{-1}		
Control	0.80 e[†]	3.109 d	24.95	32.90 b	221.0 b	43.90 d
FYM 20 t ha^{-1}	1.20 de	3.51 cd	27.75	33.17 b	235.0 b	46.03 d
Gyp 50% GR	1.50 cd	3.75 bc	27.69	40.37 b	241.3 b	75.03 c
Gyp 50% + 10 t ha^{-1} FYM	2.00 c	3.95 abc	27.43	76.17 a	265.7 b	82.30 b
Gyp 100% GR	2.60 b	4.12 ab	27.00	37.67 b	367.0 a	72.37 c
Gyp 100% +10 t ha^{-1} FYM	3.30 a	4.36 a	27.42	90.53 a	348.0 a	95.63 a
$LSD_{(0.05)}$	0.57	0.449	N.S.	23.04	69.48	6.47

[†]Means sharing similar letter(s) do not differ statistically at P < 0.05.

plots having full rate of gypsum and manure applied together had avoided the osmotic shock as well as specific-ion toxicities and supplied the crop with ample nutrition thereby increasing reproductive growth to a greater extent as compared to control. Vegetative nourishment thus produced higher values of harvest index. These outcomes corroborate the work of Minhas *et al*. (1991).

Effects of amendments application on the nutrient composition of plants

Gypsum application significantly increased P uptake which was further improved by the application of FYM also (Table 5). Gypsum along with FYM helped improve P uptake by counteracting the nutrient imbalances within the plants. Similar results were also reported by Sharma (1986). ANOVA of the results pertaining to leaf K showed non-significant differences (P < 0.05) among treatment means. However, T_2 and T_3 had 11, T_4 10, T_6 9.8 and T_5 8.2%, respectively higher K concentration of wheat leaves than control. Half rate of gypsum resulted in 78% more SO_4^{2-} over control and a further increase of 30% was obtained when FYM was also supplemented. Similarly, 205% higher SO_4^{2-} was recorded with full rate of gypsum, and when manure was supplemented a further increase of 27% was observed. FYM supplemented plots had the highest SO_4^{2-} uptake as compared to the plots treated with only gypsum or FYM, which might be due to the fact that organic matter provides good amount of plant available SO_4^{2-}. Mughra *et al*. (1996) and Singh (1985) also reported similar results.

The data showed that Zn concentration was increased significantly with application of amendments especially when used together. It might be due to the fact that FYM and gypsum tends to lower the pH of the soil which favors the solubility of Zn (Lindsay, 1979). Gypsum at full rate either alone or in combination with manure was effective in improving Fe uptake by plants. Due to the application of

Table 6. Effect of amendments on Soil pH, Electrical Conductivity (EC), SAR and Gypsum Requirement of soils

Treatments	Soil pH	EC ($dS\ m^{-1}$)	SAR	Gypsum Requirement (tons ha^{-1})
Control	9.00 a[†]	4.56 a	35.48 a	13.93 a
FYM @ 20 t ha^{-1}	8.89 a	4.49 b	30.05 a	12.68 b
Gypsum @ 50% GR	8.83 ab	4.43 c	21.54 b	12.25 c
Gyp 50% GR + 10 t ha^{-1} FYM	8.63 bc	3.94 d	19.68 b	10.63 d
Gypsum @ 100% GR	8.45 c	3.89 d	17.99 bc	8.91 e
Gyp 100% GR + 10 t ha^{-1} FYM	8.15 d	3.73 e	12.12 c	2.11 f
$LSD_{(0.05)}$	0.230	0.057	7.23	0.05

[†]Means sharing similar letter(s) do not differ statistically at P<0.05.

gypsum and FYM, the worse effect of irrigation water regarding EC_w was reduced which favored the uptake of Mn ad Fe as reported by Padole *et al*. (1995).

Effects of amendments on soil properties

Table 6 indicated that neither FYM nor gypsum at half rate reduced soil pH significantly. Their combined application or gypsum at full rate, however, had a significant effect on lowering the pH of surface soil. The lowest significant ($P < 0.05$) pH value was attained in T_6 compared to other treatments closely followed by T_5 and T_4 represented 9, 6 and 4% reduction, respectively from control. The results suggested that decrease in soil pH value with gypsum occurred due to replacement of exchangeable Na^+ by Ca^{2+}. Decrease in pH was more remarkable in combined application of gypsum and FYM treatments. Because both are good contributors to the cause, gypsum provides Ca^{2+} to replace the sorbed Na^+ and manure further boosts the process by producing organic acids and CO_2 to dissolve native $CaCO_3$ to liberate more Ca^{2+} for replacement of Na^+. This result is in agreement with the works of Alawi *et al*. (1980), Singh (1985) and Tiwari and Jain, (1992).

The data in Table 6 demonstrated that all the treatments decreased soil EC significantly. Perusal of the data showed that FYM alone or gypsum at half rate caused slight reduction (1.5 and 2.9%, respectively) in EC, while major reduction (13.6, 14.7 and 18.2%, respectively) occurred due to their combined application or with gypsum at full rate. The results showed that amendments have significantly flushed down the toxic concentrations of soil soluble ions thereby decreasing soil conductivity (Alawi *et al*., 1980). FYM when applied with full dose of gypsum produced better results as compared to application with half dose, thus the former combination worked efficiently. Favorable effect of the manure and gypsum on decreasing EC may be attributed to the improvement in porosity and infiltration which might have resulted enhanced salts leaching. These results are also supported by the findings of Ghafoor *et al*. (1986) and Sharma *et al*. (1981).

The data presented in Table 6 indicated that gypsum alone or in combination with manure was effective in reducing SAR significantly ($P < 0.05$). FYM alone, on the other hand, had no significant effect. Maximum reduction of 66% in SAR was obtained with combined application of gypsum 100% and FYM 10 tons ha^{-1}. The reduction in SAR may be the result of increased $Ca^{2+} + Mg^{2+}$ and/or decreased Na^+ with the application of amendments. The FYM application enhanced the efficiency of gypsum in reducing the soluble Na^+ concentrations more when applied with full of the recommended dose than the application with half dose, so it will not be out of place to say that FYM effect is more pronounced with gypsum in decreasing pH, EC_e and SAR and increasing $Ca^{2+} + Mg^{2+}$. Similar findings were also reported by Ghafoor and Muhammad (1981). Muhammad and Khaliq (1975) and Shad and Hashmi (1970) showed that gypsum + manure was more effective in reclaiming calcareous saline sodic soils than gypsum or manure alone.

Date regarding gypsum requirement of the soil showed highly significant ($P<0.05$) differences in the treatment means (Table 6). The data demonstrated soil improvement by decreasing its gypsum requirement. The FYM alone reduced gypsum requirement by 9% from control. Gypsum, on the other hand, decreased it by 12 % with half rate and by 36% with full rate. Combination of both the amendments resulted in remarkable decrease in GR by flushing out Na^+ through the supply of Ca^{2+}. It is clear from the data that the treatments which have lowered SAR a big deal, have got minimum gypsum requirement. This can be attributed to the fact that these treatments have got low concentration of sorbed Na^+ on the exchange site of the soils and thus highlighting the efficiency of different amendments in combating the ill-effects of the brackish water. Beneficial effect of gypsum on soil improvement was also reported by Verma and Abrol (1980).

Conclusion

It may be conclude that amendments such as gypsum and manure proved to be effective, especially when used in combination, in improving properties of salt affected soils and wheat yields irrigated with brackish tube well waters.

Acknowledgement

The authors are grateful to ALP Secretariat, PARC, Islamabad for funding the coordinated project on the "Management of salt affected soils and brackish waters in Pakistan, Component NWFP – AUP" which made it possible to conduct this study.

References

Agriculture Statistics of Pakistan. 2004-05. Govt. of Pakistan. Ministry of Food, Agri. and Livestock. (MINFAL), Economic Wing, Islamabad.

Alawi, B.J., J.L. Stroehlem, E.A. Hanlon and F. Turner. 1980. Quality of irrigation water and effect of sulphuric acid and gypsum on soil properties and Sudangrass yield. *Soil Science* 129: 315-319.

Ayers, R.S. and D.W. Westcot. 1985. Water Quality for Agriculture. FAO Irrigation and Drainage Papers 29(Rev. 1). FAO, Rome.

Fageria, N.K., V.C. Baligar and C.A. Jones. 1997. Growth and Mineral Nutrition of Field Crops. 2nd Ed. Marcel Dekker Inc. N.Y. USA. p. 264-265.

Ghafoor, A., M. Qadir and G. Murtaza. 2004. Salt-Affected Soils: Principles of Management. (1st Ed.). Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad.

Ghafoor, A., S. Muhammad and G. Mujtaba. 1986. Comparison of gypsum, sulfuric acid, hydrochloric acid and calcium chloride for reclaiming the subsoil calcareous saline-sodic Khurrianwala soil series. *Journal of Agriculture Research* 24: 179-183.

Ghafoor, A. and S. Muhammad. 1981. Comparison of H_2SO_4, HCl, HNO_3 and gypsum for reclaiming saline sodic soil and for plant growth. Bulletin on Irrigation and Drainage Flood Control Research Council, Pakistan. 11: 69-75.

Goel, C.L. 1999. Effect of organic and inorganic amendments on saline-sodic soils irrigated with high RSC waters. *Indian Journal of Agricultural Sciences* 46: 535-538.

Gomez, K.A. and A.A. Gomez. 1984. Statistical Procedures for Agricultural Research (2nd Ed.). John Willey & Sons. NewYork (USA).

Grewel, A. 1984. Reclamation of saline-sodic soils and the possibility of utilizing saline waters for leaching and irrigation. *Soil Science* 86: 254-261.

Hussain, G. 1978. Determination of irrigation water quality standards. Ph.D thesis, CSU, Fort Collins, Co, USA.

Hussain, N., G.D. Khan, S.M. Mehdi, G. Sarwar, M.S. Dogar, T. Hussain and F.R. Lamm. 1995. Use of brackish water for sustained crop production. Microirrigation for a changing world: conserving resources-preserving the environment. p. 129-134. *In*: Proc. 5th International Micro-irrigation Congress, Orlando, Florida, USA, April 2-6, 1995.

Maas, E.V., S.M. Lesch, L.E. Francosis and C.M. Grieve. 1996. Contribution of amendments to yield of salt stressed wheat. *Crop Science* 36: 142-149.

Manzoor, A. and M. Salim. 2001. The use of gypsum for sodic soils. *Farming Outlook* 1(2): 13-16.

Marchanda, H.R. 1976. Quality of ground waters of Haryana. Haryana Agricultural University, Hissar, India. 160 p.

McLean, E.O. 1982. Soil pH and lime requirement. p. 199-224. In: Methods of Soil analysis, Parts 2: Chemical and Microbiological Properties. A.L. Page, R.H. Miller and D.R. Keeney (eds.), American Society of Agronomy, Madison, WI, USA.

Minhas, P.S., D.R. Sharma and Y.P. Singh. 1991. Response of rice and wheat to applied gypsum and farmyard manure on an alkali water irrigated soil. *Journal of Indian Society of Soil Science* 43(3): 452-455.

Mughra, S.E., F.A. Hashem and M.M. Wasif. 1996. The use of sulphur and organic manure for controlling soil salinity and pollution under high saline water irrigation. *Egyptian Journal of Soil Science* 36(1-4): 249-288.

Muhammad, S. and A. Khaliq. 1975. Comparison of various chemical and organic amendments for reclaiming saline sodic soils. *Bulletin on Irrigation and Drainage Flood Control Research Council, Pakistan* 5: 50-54.

Nelson, D.W. and L.E. Sommer. 1982. Total Carbon, Organic Carbon and Organic matter. p. 539-577. In: Methods of soil Analysis, part, II (2nd Ed). A.L. Page, R. H. Miller and D.R. Keenay (eds.). American Society of Agronomy, Madison, WI, USA.

Paliwal, K.V. 1972. Irrigation with saline water. Water Technology Center. Indian Agriculture Research Institute, New Delhi, 198 p.

Qureshi, R.H., A. Hassan and A. Ghafoor. 1996. Use of drainage water for halophyte production. p. 237-260. *In*: Halophytes and Bio-Saline agriculture. C.A. Redouance, C.V. Malcolm and A. Hamdy (eds.). Marcel Dekker, Inc. New York, USA.

Qureshi, R.H. and E.G. Barrett-Lennard. 1998. Saline Agriculture for Irrigated Land in Pakistan: A handbook. Australian Centre for Internationa. Agriculture Research, Canberra, Australia. p. 112.

Richards, L.A. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agric. US Handbook 60, Washington, D.C.

Ryan, J. 2000. Soil and plant analysis in the Mediterranean region: Limitation and potential. *Communications in Soil Science and Plant Analysis* 31(11-14): 2147-2154.

Ryan, J., G. Estefan and A. Rashid. 2001. Soil and plant analysis laboratory manual. 2nd Ed. International Center for Agricultural Research in the Dry Areas (ICARDA) Aleppo, Syria. p. 40-41.

Shad, Y.A. and A.K. Hashmi. 1970. Effect of certain amendments on physical and chemical properties of saline sodic soils. *Pakistan Journal of Agricultural Sciences* 7: 240-246.

Sharma, D.P., K.K. Mehta and J.S.P. Yadav. 1981. Effect of reclamation practices on soil properties and crop growth on farmers' fields – A case study. *Journal of Indian Society of Soil Science* 29(3): 356-360.

Singh, M.V. 1985. Effect of gypsum and farmyard manure on the yield of rice and wheat in a saline-sodic soil. CSSRI Annual Report.

Srivastava, A.K. and O.P. Srivastava. 1994. Available manganese in salt affected soils. *Indian Journal of Agricultural Sciences* 42(1): 36-39.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. 2nd Ed. McGraw Hill New York.

Tagar, S.D. and A.U. Bhatti. 1996. Physical properties of soils. p. 115-146. In: Soil Science. E. Bashir and R. Bentel (eds.), National Book Foundation Islamabad, Pakistan.

Tiwari, S.K. and B.L. Jain. 1992. Relative efficiency of gypsum, farmyard manure and pyrites under percolation conditions in reclamation of alkali soil. *Annals of Agriculture Research* 17(2): 44-19.

Verma, K.S. and I.P. Abrol. 1980. Effect of gypsum and pyrites on soil properties in a highly sodic soil. *Indian Journal of Agricultural Sciences* 50: 844-851.

Wassif, M.M., M.K. Shabana and S.M. Saad. 1995. Influence of some soil amendments on calcareous soil properties and the production of wheat under saline irrigation water. *Egyptian Journal of Soil Science* (4): 439-451.