EFFECT OF DIFFERENT AMENDMENTS ON CROP PRODUCTION UNDER POOR QUALITY TUBEWELL WATER

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ABSTRACT

The experiment was conducted on a farmer's field in Majokay area, district Charsadda during 2004 to assess the beneficial effects of different amendments on poor quality tube well irrigation water. Rice was used as test crop. There were five treatments in the experiments consisting of; control (T_1), gypsum at 50 % of the requirement (T_2), 50 % gypsum + 10 tons FYM ha^{-1} (T_3), 100 % gypsum (T_4), and 100 % gypsum + 10 tons FYM ha^{-1} (T_5). The experiment was laid out using randomized complete block design with three replications. Soil samples were collected before treatment application and after harvesting the crop for the analysis of physico-chemical properties. The results pertaining to yield parameters show that paddy yield ranged from 968 kg ha^{-1} observed in control to 1940 kg ha^{-1} in T_5. The later treatment also had a harvest index of 33.92 significantly higher than the lowest value (22.72) found in control. Similarly, T_5 gained maximum 1000-grain weight of 24.73 g and the minimum was in control (19.86 g). Application of FYM boosted the effect of gypsum in obtaining maximum values of these indices. The results on soil chemical properties viz. pH and EC were highly significant among various treatments. By comparing the results it was noted that pH was reduced from 10.00 to 9.21 and EC was reduced from 6.00 dS m^{-1} to 3.90 dS m^{-1} in T_5. The data show that soil organic matter was increased by gypsum application, but prominent increase occurred when gypsum was supplemented with FYM. Combined application of manure with full rate of gypsum proved to improve paddy yield under brackish irrigation water.

INTRODUCTION

Growth and yields of crops are influenced by a number of soil and climatic factors but the most important one is the shortage of irrigation water. Water becomes a crucial resource in agrarian economies such as Pakistan, where almost 75% of total cropped area is under irrigation, which corresponds to 19.9 million hectares. Due to limited good quality water resources and poor management practices, about 11 Mha of our land are lying as cultivable waste (Federal Bureau of Statistics, 1987). In order to increase cultivable land, crop yields and cropping intensity, development of non-conventional source of irrigation water appears all that important.

Underground waters of arid regions are usually saline and are thought to be unsuitable for irrigation purpose. Similarly in saline areas of Pakistan a large number of tube wells are pumping water having a relatively high salt concentration. The use of such brackish water for irrigation purpose results in the gradual build-up of salts in the soil and an ultimate reduction in the yield of crops. However, brackish waters can be successfully used by adopting soil, water and crop-based technologies. These technologies primarily consist of treating waters and soil with gypsum or pyrite through soil or water application, inclusion of sodicity tolerant crops in the cropping systems, alternate and conjunctive use of canal and brackish water for irrigation and adequate additions of inorganic and organic fertilizers etc.

At present, due to shortage of surface water several options are available for the improvement of poor quality water. The strategy can be adopted in case of saline as well as saline sodic waters. Infiltration problems are caused by low salinity or by excessive sodium (high SAR) in the irrigation water. Such water can be improved through the use of chemical amendments such as gypsum, sulfuric acid, sulfur and calcium chloride. The amendments can be applied through irrigation water or through soil. In addition, physical methods such as leaching, addition of organic matter to the soil and deep tillage can also be employed to improve infiltration problems. The scarcity of water presently being felt will further multiply with time as pressure on land and consequent demand of water increases. It is

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therefore, necessary to use water resources scientifically.

Keeping the above scenario in mind, the present research was conducted to manage brackish ground water, to keep the soil productive on sustainable basis and to combat the ill effects of the use of such water.

MATERIALS AND METHODS

Research study was conducted on a farmer's field at Majokay area, district Charsadda during Kharif 2004 in order to investigate the effect of various amendments on the yield of rice crop and properties of saline-sodic soils irrigated with brackish tube well water. The soil under study had a pH of 10, EC 6.0 dS m^{-1}, SAR 42.62 and was sandy loam in texture. Area of experimental plot was 1000 m^2, while each treatment got an area of 64 m^2. The effectiveness of gypsum at full recommended rate has been documented well. Efforts, however, were made in this research to supplement manure with two levels of gypsum and to study the effect of gypsum alone as well as in combination with manure. The five treatments namely, control where no amendment was used (T1), gypsum at the rate of 50 % of the requirement (T2), gypsum at 50 % + 10 tons FYM ha^{-1} (T3), gypsum at 100% of the requirement (T4), and gypsum at 100 % + 10 tons FYM ha^{-1} (T5) were randomly arranged in RCB design with three replications.

The quantity of the required gypsum was calculated on the basis of the SAR of water as stated by Qureshi *et al*. (1996). Basal dose of N, P and K @ 120:90:60 kg ha^{-1} as urea, TSP and KCl, respectively was applied. Nitrogen was applied in split doses, while P and K were broadcast in full doses. Half of the nitrogen was applied along with P and K at the time of transplantation and the remaining half N at panicle initiation stage.

Growth and Yield Data

Rice was grown as test crop to see whether amendments had done well or not in reducing harmful effects of brackish irrigation water. The data recorded at appropriate growth stages of the crop were leaf area index (LAI), plant height at maturity (cm), panicle bearing tillers per plant**,** 1000-grain weight (gm), paddy yield (kg ha^{-1}), straw yield and harvest index (H.I.). Following formulae were used to calculate (LAI) and (H.I.):

LAI= (Number of plants per treatment x total number of leaves per plant x leaf area per tiller) ÷ (area of the treatment).

H.I. = (Economical Paddy yield x 100) ÷Biological yield

For the data of former three parameters 10 plants were randomly selected and their average data were recorded. The seedlings were transplanted on 8^{th} July and the crop was harvested on 4^{th} November 2004 and the data collected were analyzed statistically by using analysis of variance technique and differences among treatment means were compared by LSD test (Steel and Torrie, 1980).

Samples Collection and Analysis

To determine water quality status a composite sample of the tube well water under study was collected in one liter bottle. The bottle was rinsed with the water from which sample was being made. The bottle was filled from water of running tube well bit by bit with intervals of 5-10 minutes. The bottle thus filled was capped and brought to the laboratory for chemical analysis. After crop harvesting a total of 15 soil samples (one from each treatment) were collected and were brought to the laboratory, dried at room temperature, ground to pass through 2mm sieve, labeled and stored for analyses.

Electrical conductivity (EC) in 1:1 soil-water extract and pH were determined according to the methods given in Ryan *et al.* (2000). Soluble cations (Na^+, $Ca^{2+}$$_+$ Mg^{2+}) concentrations in soil extract and water samples were determined by titration (Richard, 1954). Gypsum requirement in water sample was determined according to the method reported by Qureshi *et al.* (1996). Soil organic mater was determined using the methods as described by Nelson and Sommer (1982). AB-DTPA extractable P was determined employing the method developed by Soltanpouer and Workman (1979).

RESULTS AND DISCUSSION

The research was conducted to study the influence of gypsum and farm yard manure in reducing harmful effects of brackish irrigation water. The properties of the soils before experiment and that of tube well irrigation water used in the experiment are given in Tables I and II, respectively. The results show that the soils were saline sodic, calcareous and had low organic matter. EC and pH of the irrigation water fell in normal range, RSC marginally hazardous while SAR beyond the safe limits in accordance with the guidelines given by Hussain (1978).

Effect of Amendments on Growth and Yield Components of Rice Panicle Bearing Tillers per Plant

Data in Table III, regarding panicle bearing tillers show that maximum tillers (14.36) were observed in the treatment of 100 % gypsum + 10 tons FYM ha^{-1}(T_5) followed by (14.26) in the treatment of 50% gypsum + 10 tons FYM ha^{-1} (T_3) being.

Table I ***Soils physico-chemical properties prior to treatment application***

Property	Unit	Concentration
pH	--	10.00
EC	$dS\ m^{-1}$	6.00
Na^+	$mmol_c\ L^{-1}$	52.00
K^+	$mmol_c\ L^{-1}$	1.00
$Ca^{2+} + Mg^{2+}$	$mmol_c\ L^{-1}$	2.96
CO_3^{2-}	$mmol_c\ L^{-1}$	3.00
HCO_3^-	$mmol_c\ L^{-1}$	11.10
Cl^-	$mmol_c\ L^{-1}$	20.87
SO_4^{2-}	$mmol_c\ L^{-1}$	17.83
Sodium Adsorption Ratio	--	42.98
$CaCO_3$	%	5.48
Organic matter	%	0.22
Phosphorus	$mg\ kg^{-1}$	21
Textural class	--	Sandy loam
Gypsum Requirement	$tons\ ha^{-1}$	30.28

Table II ***Properties of irrigation water used in the experiment***

Parameter	Unit	Concentration
pH	--	8.03
EC_w	$dS\ m^{-1}$	1.00
Na^+	$mmol_c\ L^{-1}$	13.00
$Ca^{2+} + Mg^{2+}$	$mmol_c\ L^{-1}$	0.61
SAR	--	23.63
CO_3^{2-}	$mmol_c\ L^{-1}$	0.42
HCO_3^-	$mmol_c\ L^{-1}$	7.48
RSC	--	7.29
K^+	$mmol_c\ L^{-1}$	0.22
P	$mg\ L^{-1}$	0.74

significantly different from 11.60 found in control (T_1) and 11.48 in the treatment of 100 % gypsum (T_4), while non-significant as compared to 12.87 in the treatment of 50% gypsum (T_2). It is evident from the data that gypsum application alone did not affect panicles. Gypsum added along with FYM, however improved number of panicles significantly. This might be due to more P uptake by plants favoured by FYM. Working in saline-sodic conditions, similar results of tillering and panicle bearing tillers have also been reported by Zakir *et al.* (1997) and Malik *et al.* (1992).

Number of Grains per Panicle

It is clear from the data that all the treatments increased number of grains significantly over control. Gypsum at 50 % + 10 tons FYM ha^{-1} (T_3) and 100 % gypsum + 10 tons FYM ha^{-1} (T_5) had maximum number of grains $panicle^{-1}$, significantly higher than the rest of treatments. Gypsum along with FYM was the best in obtaining maximum number of filled spikelets, which might be due to the reduction in sodicity (lower value of Na^+ concentrations) in these treatments as compared to control (Zakir *et al.*, 1997).

Leaf Area Index (LAI)

The data of LAI are presented in Table III. The data manifest the superiority of chemical and organic amendments over control. On average leaf area index of 1.04 in the treatment of 100 % gypsum + FYM (T_5) was significantly higher than control (T_1), and gypsum applied treatments (T_2 and T_4). The treatment receiving 50 % gypsum + 10 tons FYM ha^{-1} (T_3) had LAI of 0.95 and was at par with that of T_5 treatment. There was no significant difference in T_2, T_3 and T_4 treatments regarding their effect on LAI. The results suggest that combined use of gypsum and FYM significantly improved LAI.

Plant Height

Maximum plant height obtained in T_5 was significantly different from T_1, T_2, and T_4. The results show that gypsum application alone did not affect plant height. FYM along with gypsum significantly increased plant height which may be attributed to the nutritive effect of FYM. The results are in conformity with those of Zakir *et al.* (1997).

Table III ***Effect of amendments on growth parameters of rice crop***

Treatments	**Panicle bearing tillers**	**Grains per panicle**	**Leaf area index**	**Plant height (cm)**
1. Control	10.60 c	75.90 d	0.58 c	62.03 c
2. Gypsum @ 50%GR	12.87 ab	96.64 c	0.74bc	65.81 bc
3. Gyp 50% +FYM10 t ha^{-1}	14.26 a	121.46 a	0.95 ab	76.00 ab
4. Gypsum @ 100%GR	11.48 bc	108.56 b	0.74 bc	65.54 bc
5. Gyp 100%+ FYM 10 t ha^{-1}	14.36 a	126.14 a	1.04 a	82.13 a
$LSD_{(0.05)}$	2.13	8.68	0.25	10.53

Means followed by same letter(s) are statistically non-significantly different at 5% level of probability.

Paddy Yield

The data presented in Table IV show that paddy yield increased with increasing level of gypsum. Yields of 1081 and 1673 kg ha^{-1} were obtained with 50% gypsum (T_2) and 100 % gypsum (T_4), respectively. Treatments receiving 50% gypsum + FYM (T_3) had significantly higher yield than T_1 and T_2 only, while 100% gypsum + FYM (T_5) gave significantly higher yield over rest of the treatments. Maximum paddy yield was obtained in T_5 followed by T_3 representing an increase of 100% and 76%, respectively over control.

Application of FYM gave 57% increase in paddy yield with half rate of gypsum and 16% increase when used with full rate of gypsum as compared with gypsum alone. Gypsum application at full rate gave 55% increase in paddy yield than at half rate. The results suggest that both these amendments helped in increasing the yield of rice, which may be attributed to nutritional effect as well as indirectly through improving soil properties (Ghafoor *et al.* 2004; Malik *et al.* 1992). The results are also in full conformity with those of Swarup (1985), who obtained maximum yield of rice with gypsum and manure at higher pH values ranged from 9.5 to 10.6 and ESP ranging from 60-70.

Straw Yield

The data (Table IV) show that maximum straw yield was obtained by the combined application of FYM and gypsum at full rate and minimum was obtained in the control. Straw yield obtained in T_5 and T_3 represented an increase of 34.3% and 31.6% over control respectively. Application of FYM gave 29.32% increase in straw yield with half rate of gypsum and 3.66% increase when used with full rate of gypsum. The effect of both these amendments on straw yield was not additive. Gypsum application at full rate gave 28% increase in straw yield over half the rate. Half rate of gypsum did not increase straw yield. It was effective only when FYM was supplemented. The results suggest that both these amendments helped in increasing the straw yield of rice, as a nutritional effect and indirectly soil ameliorating effect (Malik *et al.*, 1992).

1000-Grain Weight

Gypsum application increased 1000-grain weight of paddy. Data show that the means of treatments T_3, T_4 and T_5 were non-significant among themselves but significantly higher than T_1 and T_2 means. Maximum of 1000-grain weight of 24.74 g, followed by 24.36 g were obtained in treatments T_5 and T_3 representing an increase of 41% and 39% over control respectively. The application of FYM gave 16% increase in 1000-grain weight with half rate of gypsum and only 2% increase when used with full rate. Gypsum application at full rate gave 15% increase in 1000-grain weight than at half rate. The results suggest that both these amendments helped in boosting rice yield through 1000-grain weight. Similar results were also reported by Tiwari and Jain, (1992).

Harvest Index (H.I)

Data in Table IV show that all the treatments except T_2 have improved harvest index as compared to control. T_5 had significantly higher H.I. than rest of the treatments followed by T_3 and T_4, which were non-significant between themselves, but significantly higher than T_1 and T_2. Maximum value of harvest index obtained in T_5 represented an increase of 50% over control. The application of FYM gave 21% increase in harvest index with half rate of gypsum and 11% increase when used with full rate of gypsum. Gypsum application at full rate gave 22% increase in harvest index than half rate. The results indicate that plots where gypsum and manure applied together have avoided the osmotic effect as well as specific-ion toxicities in the soils and applied the crop with ample nutrition thereby increasing reproductive growth to a greater extent as compared to vegetative nourishment thus produced higher values of harvest index. These outcomes corroborate the work of Malik *et al.* (1992).

Table IV ***Effect of amendments on the yield parameters of rice crop***

Treatments	**Paddy yield (kg ha^{-1})**	**Straw yield (kg ha^{-1})**	**1000-Grain weight(g)**	**Harvest index**
1. Control	968 c	4258 b	19.86 c	22.72 c
2. Gypsum@50%GR	1081 c	4334 b	21.06 b	24.93 c
3.Gyp 50% + FYM 10 t/ha	1701 b	5605 a	24.36 a	30.35 b
4. Gypsum@100% GR	1673 b	5518 a	24.24 a	30.34 b
5. Gyp 100% + FYM 10 t/ha	1940 a	5720 a	24.73 a	33.92 a
$LSD_{(0.05)}$	166	379.04	0.84	2.23

Means followed by same letter(s) are not significantly different at 5% level of probability.

Effect of Amendments on Physico-Chemical Properties of Soils

Soil pH Table V indicate that the amendments had a significant effect on reducing pH of surface soil (0-20 cm depth). Minimum soil pH observed in T_5 (9.21) followed by T_3 (9.56), represented a decrease of 7.62 % and 4.11% respectively than control. The application of FYM brought about 1.34 % decreases in the soil pH when applied with half dose of gypsum and 4% decrease when used with full rate of gypsum. Gypsum application at full rate showed 1.23% decrease in the soil reaction than that at half rate. The results suggest that reduction in soil pH occurred with subsequent increase in applied gypsum, due to replacement of exchangeable Na^+ by Ca^{2+}. Decrease in pH was 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 boosted the process by producing organic acids and CO_2 to solubilise the native $CaCO_3$ to liberate more Ca^{2+} and replace Na^+. The results are in agreement with the work of Ghafoor *et al*. (2004).

Electrical conductivity (EC)

Minimum value of soil EC in T_5 followed by T_3 represented a decline of 30% and 24.32%, respectively than control (Table V). The application of FYM brought about 19.07% decreases in the soil EC when applied with half rate of gypsum and 11% decrease when used with full rate of gypsum. Gypsum application at full rate showed 15.60% decreases in EC than that at half rate. The results show that amendments have significantly flushed out the toxic concentrations of soluble salts thereby decreasing soil conductivity. FYM when applied with half gypsum produced better results as compared to application with full dose because FYM is also a good source of anions and cations as well as gypsum too is a salt, thus the combination at higher level of gypsum did not work as efficiently as in case of T_3.

Table V ***Effect of amendments on pH, EC and organic matter of soils***

Treatments	Soil pH	EC (dSm^{-1})	Organic matter (%)
1. Control	9.97 a	5.55 a	0.29 d
2. Gypsum@50%GR	9.69 b	5.19 b	0.38 c
3. Gypsum 50 % + FYM 10 t/ha	9.56 c	4.20 d	1.68 b
4. Gypsum@100% GR	9.57 c	4.38 c	0.40 c
5. Gypsum 100% + FYM 10 t/ha	9.21 d	3.90 e	1.79 a
LSD (0.05)	0.029	0.019	0.059

Means followed by same letter(s) are not significantly different at 5% level of probability.

Organic Matter

It is obvious from the results (Table V) that gypsum alone had no appreciable effect on the organic matter content in soil. Significant variations had occurred in treatments where FYM was used in combination with gypsum i.e., T_3 and T_5. Highest organic matter content was found in T_5 (1.79%), followed by T_3 (1.68%), both of these were significantly higher than rest of the treatments. This might be due to the addition of FYM to the soil. Though T_2 and T_4 did not vary significantly in their organic matter content, but still T_4 had 5.26% more organic matter than T_2. This might be due to better soil environment resulted from gypsum in higher amounts (T_4) to let the roots grow and respire in good fashion. Same reasoning can be applied on T_3 and T_5, because the later has 6.54 % more soil organic matter than T_3 (Wassif *et al.* 1995).

Soluble Na^+

Amendments have reduced soluble Na^+ concentration of surface soil significantly. Minimum value of Na^+ observed in T_5 followed by T_3 represented a decrease of 38.80% and 36.40% respectively than control (Table VI). The application of FYM brought about 28.16% decreases in Na^+ with half gypsum and 6.27 % decreases with full rate. Gypsum application at full rate showed 26.42 % decreases in the soil Na^+ than that at half rate.

Soluble Calcium + Magnesium

Application of amendments had considerably increased the soluble Ca^{2+} + Mg^{2+} concentrations in the experimental soils (Table VI). Maximum concentration of Ca^{2+} + Mg^{2+} observed in T_5 followed by T_3 represented increases of 129% and 88%, respectively over control. Application of FYM brought about 65% increase in the Ca^{2+} + Mg^{2+} when applied with half rate of gypsum and 53.33 % increase when used with full rate. Gypsum application at full rate showed 31 % increase in Ca^{2+} + Mg^{2+} than that at half rate.

Soluble Potassium (K)

Soluble K^+ concentration decreased with increasing level of gypsum, and FYM treated plots T_3 and T_5 accumulated significantly higher potassium than rest of treatments. Control had significantly higher K^+ concentration than T_2 and T_4, which may be due to leaching of K^+ in gypsum treated plots. FYM mixed plots had more K^+ concentration, attributed to its release upon decomposition and hence its concentration increased in soil extract. Similar results have been reported by Chaudhry *et al.* (1999).

Soil Phosphorus (P)

Data (Table VI) manifested that treatment means of soil P were significantly different than control. Highest concentration of P was in T_4 followed by T_2, T_5, T_3 and T_1. It is obvious that FYM treated plots have lower amounts of P than gypsum treated plots which might be due to more plant uptake because of good soil structure as compared to gypsum treated plots. The results are in conformity with those of Minhas *et al*. (1995).

Table VI ***Effect of amendments on soluble cations and extractable phosphorus of soils***

Treatments	Na^+	$Ca^{2+} + Mg^{2+}$	K^+	P
		(mmol$_c$ L^{-1})		(mg kg^{-1})
1. Control	50.70 a	3.51 e	0.85 b	7.92 e
2. Gypsum@50%GR	44.88 b	4.00 d	0.72 c	11.02 b
3. Gypsum 50% + FYM 10 t ha^{-1}	32.24 d	6.60 b	1.26 a	9.37 d
4. Gypsum@100% GR	33.02 c	5.25 c	0.40 d	12.78 a
5.Gypsum 100% + FYM 10 t ha^{-1}	31.01 e	8.05 a	1.28 a	10.02 c
$LSD_{(0.05)}$	0.64	0.11	0.10	0.097

Means followed by same letter(s) are not significantly different at 5% level of probability.

CONCLUSION

Combined application of manure with full rate of gypsum resulted in significantly higher paddy yield under brackish tube well water. Application of amendments such as gypsum and farmyard manure significantly reduced harmful effects of brackish water by lowering the values of EC, pH, and SAR of the experimental soil. Soil organic matter and potassium contents increased significantly while lime content decreased due to combined application of manure and gypsum.

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