EFFECT OF VARIOUS LEVELS OF GYPSUM APPLICATION ON THE RECLAMATION OF SALT AFFECTED SOIL GROWN UNDER RICE FOLLOWED BY WHEAT CROP

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ABSTRACT

Pot experiment was conducted to evaluate the effect of various doses of gypsum on the yield of crops and properties of salt affected soils at Agricultural Research Institute (A.R.I.) Tarnab, Peshawar during 2000-2001. Sodic soil in bulk was collected from Nowshera area and homogenized after grinding. Earthen pots eighteen (18) in number were filled with this soil. There were six treatments comprising of gypsum @ 0, 25, 50, 75, 100 and 200 % of the gypsum requirement (G.R.). Each treatment was replicated three times. Rice seedlings were transplanted in the pots having been added the required amount of gypsum. pH, electrical conductivity (EC), and sodium adsorption ratio (SAR) were monitored in the first 9 leachates, received after irrigations. After the harvest of rice, every pot soil was analyzed for pH, EC and G.R. Then every pot soil was remixed and wheat was grown in it at field capacity with out further addition of gypsum. Initial 5 leachates of drained water of all the pots were collected after respective irrigations and checked for the same characteristics, which were done during rice crop. The results showed that pH, EC, and SAR of the leachate samples were decreased with increasing level of gypsum and with the number of leachates. EC and SAR decreased considerably relative to pH. Gypsum application in different doses increased yield of rice by 9.8 to 25.3% and that of wheat crop by 10-80% over control treatment. Maximum increase occurred with the application rate of 200% of G.R. in both the cases. The data further indicated that soils were also improved with gypsum application especially with respect to pH and SAR. It was found that pH of soils was decreased considerably with increasing level of gypsum. G.R. of the gypsum treated pots after rice crop decreased by 40-89%, while after wheat crop they showed nil requirement of gypsum.

INTRODUCTION

Salinity cause reduction in crop yield on about 10 mha of worlds irrigated land (Rhoades and Loveday 1990). One of the major reasons of low productivity of crops grown under saline sodic conditions is the salt toxicity. In Pakistan 6.2-6.67 m ha land is affected with various levels of salinity, but having predominance of sodium salts with varying levels and mixtures of salts (GOP 1996, Khan 1998).

Various amendments like gypsum, sulphur, acids, press mud and farm yard manure (FYM) may be used for reclamation of these soils (Muhammad 1990, Sharma *et al*. 1996, Biggar 1996, Haq *et al*., 2001). The use of gypsum as a source of Ca^{2+} is a well-established practice for the amelioration and management of sodium saturated water/soils (Bresler *et al., 1982).* Being easily available and cheap source of calcium gypsum is commonly used in Pakistan. Because of low solubility of gypsum and calcareous nature of soils its efficiency is reduced. However, its effect in the amelioration process continues for few months until the whole of gypsum reacts with the exchangeable sodium (Na) of the soil.

One of the approaches for the economic utilization of moderately salt affected land is to grow salt tolerant crop varieties along with the suitable management of cultural practices. Being moderately salt tolerant, rice is being recommended for cultivation during the amelioration of salt affected soil (Hassan *et al*. 2001). Verma and Abrol (1980) while comparing gypsum and pyrite at requirement rates of 25, 50, 75 and 100% gypsum requirement (G.R.) for rice-wheat rotation on sodic loam soil showed gypsum to be far better than pyrite at all rates of application. Singh *et al*. (1981) reported that surface application of gypsum @ 25 or 50% GR before transplanting of rice gave higher grain yield. Siddique *et al*. (1988) investigated that effect of gypsum @ 75% G.R. and 67 kg ha^{-1} fertilizer application gave maximum yield of rice, followed by 50% G.R treatment at same fertilizer doze on saline sodic soil. Chhabra (1999) reported that in rice-wheat cropping sequence gypsum application to alkaline soil increased the yield of rice and wheat up to significant level.

Keeping in view the ameliorating effect of gypsum on sodic soils, rice crop was selected to monitor its response to various levels of gypsum under sodic conditions along with physical and chemical characteristics of soil in pot culture as influenced by the crop and chemical amendment. In this respect the residual effect of gypsum was also evaluated by growing wheat crop in the same pots.

MATERIALS AND METHODS

Bulk sodic soil was brought from Khwishkey Mera (district Nowshera) and was analyzed in the laboratory for various physical and chemical characteristics before the application of treatments

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(Table I). After laboratory analysis the same soil was allocated to18 earthen pots, each having an area of 0.047 m^2 with a narrow outlet at about 2 inches above the bottom for collecting leachates after various irrigations. Every pot was filled and packed by hand exactly with 15 kg soil.

Rice crop

Full basal doze of phosphorous and potassium @ 90:60 kg ha^{-1} and half of the nitrogen from recommended doze (120 kg ha^{-1}) along with various levels of gypsum were applied to all pots and mixed thoroughly before planting rice seedlings. The second half of the nitrogen was administered to the crop when it was near to ear rising. Treatments detail is given in Table II.

The pots were flooded with equal amount of water and then equal numbers of rice seedlings were sown in the standing water. The water was forced to remain in the pots for 24 hours, after which the first leachate was received in beakers and was transferred to plastic bottles for the determination of pH, EC and SAR. This way nine lechates were obtained after various irrigations given at different times and were analyzed in the laboratory for necessary parameters. On maturity, the crop was harvested and grain yield and fresh biomass data were calculated and analyzed the variations on percentage basis. Also post harvest soil analysis was carried out for pH, EC and G.R.

Wheat crop

The same soil in every pot was remixed, repacked and was irrigated. At field capacity, wheat was sown in the last week of November, 2000. No gypsum was added to any pot, however NPK @ 120:90:60 kg ha^{-1} was given. P & K full dose and N half dose were applied at the time of sowing while the 2nd half of N was administrated at the time of tillering.

A total of four leachates were obtained after different irrigations. Every leachate was analyzed for pH, EC and G.R. The crop was harvested on its full maturity. The data for grain and fresh biomass were taken, analyzed and interpreted. Post harvest analysis of the pot soils was carried out for pH, EC and G.R.

RESULTS AND DISCUSSION

Leachates study (rice case)

The data regarding leachates as affected by various level of gypsum application to pots are listed in Table III.

The pH of the leachates collected from control pots did not show any significant decrease even after ninth collection, however by adding and increasing the level of gypsum, the average value of pH decreased moderately i.e. from 9.07 (control) to 8.18 (T6, 200% G.R. treatment). It might be due to release of frequent Ca ions by gypsum and their reaction with Na ions to replace them from soil and bring them to solution. Moreover the SO_4 ions of gypsum probably have contributed towards lowering the pH. The number of leachates had no effect on decrease of pH. EC of the leachates indicated a trend of decrease with increasing level of gypsum application. Its value was higher in the few initial collections compared to others. This decrease in EC with higher level of gypsum treatments might be due to quick action of gypsum in dissolving insoluble salts and flushing them with frequent leachates. SAR values decreased with gypsum application. It was lowest i.e.16.9 mmol L^{-1} with 200% G.R treatment as compared to that 32.5 m mole L^{-1} of control treatment. It showed gradual decrease with increasing leachates number. It might be due to the gypsum steady reaction with sodium of soil to replace it.

Leachates study (wheat case)

The leachate study in wheat case has been presented in Table IV. Looking at Table IV in pH column it is concluded that increasing leaching process the pH of leachate is decreased from the original 9.00 to 7.90 with T_2 and 7.10 with T_6 after fourth leachate. In the first leachate the pH did not show any significant difference with any of the treatment. Similarly the control treatment (T_1) showed a slight increase in pH with the number of leachates i.e. pH 8.27 with first leachate increased up to 8.50 with the fourth leachate. Any how its original pH 9.00 was reduced to 8.27 to 8.50 with the leachates 1 – 4. In all other leachates, the pH showed a decrease than the original value with every number of leaching. The treatment from T_2 to T_6 also showed a gradual decrease of pH.

Looking at EC it is evident that an increase in leachate increased the EC and this trend was also shown by every treatment of gypsum i.e. T_2 to T_6. The highest increase in EC was exhibited by T5 and T6. So it is concluded that increasing gypsum quantity to a saline sodic soil increases its ability to solubilise the salts. Similarly increasing water to such soils also helps in solubilising various salts.

From the SAR column of Table IV, one can observe that with the increase of leachates, the SAR shows the trend of decrease in all the treatments. It means that SAR was higher in the initial leachates. Increasing gypsum quantity has also decreased the SAR values. So we can conclude that SAR has inverse relation to gypsum addition.

Grain Yield and Biomass (Rice)

The results in Table V show that the yield of paddy and fresh stalk were greatly affected by different doses of gypsum application. The maximum grain

yield of 25.3 gm pot^{-1} was produced by the treatment No. 6 which had received 200% gypsum of the soil requirement. It was followed by the treatment No.5 that had received 100 % gypsum of the soil requirement. The grain yield in this treatment was recorded 24.70 gm pot^{-1}. The percent increase over control for T_5 and T_6 were noted as 44.2 and 47.7 respectively. Muhammad *et al*. (1987), Aslam *et al*. (1990), and Hassan *et al*. (2001), have also shown similar results. Fresh stalk was produced more by the treatment No.4, followed by the treatment No.6. Both gave yield of 40.6 and 38.0 g pot^{-1} respectively and the increase over control for these both pots were observed as 31.9 % and 25.3 %, respectively. Aslam *et al*. (2001) revealed that paddy and straw yield as well as paddy-straw ratio improved consistently with increasing supply of calcium.

Residual Effect on the Yield of Wheat Crop

The residual effect on the yield of wheat crop along with other parameters such as yield, fresh biomass and tillers pot^{-1} are presented in Table VI. From Table VI, it is evident that every level of gypsum had a profound residual effect on the grain yield of wheat but the most effective treatments were T_6, T_5 and T_4, which had received gypsum during previous rice crop at 200%, 100% and 75% of the soil G.R. The treatment showed 80%, 75.5% and 75.5% increase over control respectively. It is therefore concluded that gypsum application to a sodic soil at the rate of 75% of its G.R. had an effect on grain yield at par with the treatments receiving gypsum as 100% and 200% of their G.R. Hence T_4 (75% G.R.) could be considered not only equally effective but also economical as compared to other treatments. These results are well in conformity with those as described by Ahmad *et al*. (2001), who reported that wheat yield increase noted in gypsum applied @ 150 and 200% G.R. were statistically similar but higher than gypsum @ 100% G.R. Chaudhry (2001), also concluded that gypsum application to rice and wheat crops @ 75% G.R. enhanced the paddy and grain yield by 18 and 17% respectively. Numbers of tillers were increased by the T_4 as 17.4% over control (T_1). All others had no effect on tillers number.

Post Harvest Analysis (Rice)

Post-harvest data of soil for pH, EC, and G.R. have been given in Table VII which reveals that gypsum had a profound effect on all the above three variables. The pH of soil from its original value 9.2 dropped to 8.0 indicating 13 % decrease. The maximum decrease was noted in T6 followed by T_5 and T_4. The results in respect of pH are well supported by the findings of Hassan *et al*. (2001), who concluded that gypsum application to sandy loam salt affected soil grown on rice reduced its pH. Post harvest G.R. of these pots treatments showed the similar trend, as the decrease was noted 89 %, 78 %, and 63 % respectively. EC of the soil was also influenced by gradual increase of gypsum application. It increased from 0.42 dS m^{-1} (control) to 0.94 dS m^{-1} (T_6). This increase was 124 % more than control. These results can be supported by the findings of Ali and Kahlown (2001) who stated that addition of gypsum initially increases the EC of the soil. Therefore they recommended that either extra irrigation should be applied or high delta crop should be grown.

Post Harvest Analysis (Wheat)

The post harvest analysis data have been shown in Table VIII. It revealed that pH was greatly influenced after wheat crop. The previous pH after rice crop that ranged from 8.00 – 9.00 was dropped to the range of 7.3 to 7.9 after wheat crop. It means that the pH of the soil was almost corrected. The EC after wheat crop ranged from 1.18 – 2.26 dS m^{-1} compared to previous EC after rice crop (0.42 – 0.94 dS m^{-1}). The increase in EC after wheat crop could be attributed to gypsum slow solubility process in soil for months and its ability to enhance the salts into soluble form with passage of time. These results are well supported by the finding of Haq *et al*. (2001). The G.R. of all the gypsum treated pot soils became zero after wheat crop, which were in the range of 1.04 - 9.12 tons ha^{-1} after the rice crop. These results are similar to those as stated by Haq *et al*. (2001). The control pot though showed a good reduction in G.R after every crop i.e. from its original value 14 to 9.12 tons ha^{-1} after rice and from 9.12 to 8.0 tons ha^{-1} after wheat crop; anyhow there still existed sodium, which needs to be replaced by gypsum application. It is concluded that gypsum at its exact rate to any saline-sodic or sodic soil could reclaim it with the passage of time or at least after two crops cultivation.

CONCLUSION

Gypsum application was found effective an amendment for treating sodic soils as it not only increased the yields of rice and wheat crops but also improved soil properties by reducing pH and SAR. Ameliorative effect of gypsum is expected when more number of irrigations are applied with the provision of good drainage allowing the salts to flush out of the soil profile.

Table I. ***Physico-Chemical characteristics of the composite soil sample prior to the application of treatments.***

Texture	Clay loam
pH	9.2
EC (dS m^{-1})	0.70
G.R (ton ha^{-1})	14
P (mg kg^{-1})	16.1
K (mg kg^{-1})	270
Organic matter (%)	0.86
N (%)	0.043
$CaCO_3$ (%)	4.50

Table II. ***Detail of different treatments***

Treatment	**N (kg ha^{-1})**	**P_2O_5 (kg ha^{-1})**	**K_2O (kg ha^{-1})**	**Gypsum applied (tons ha^{-1})**
T_1 (control)	120	90	60	0.0(0% G.R)
T_2	120	90	60	3.5(25% G.R)
T_3	120	90	60	7(50% G.R)
T_4	120	90	60	10.5(75% G.R)
T_5	120	90	60	14.0(100% G.R)
T_6	120	90	60	28.0(200% G.R)

Table III. ***Leachates analysis for important characteristics as influenced by various levels of gypsum application to rice crop***

Important parameters	Treats.	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	Mean
		Leachates									
pH	T_1	9.10	9.0	8.53	9.10	9.17	9.17	9.23	9.20	9.20	9.07
	T_2	8.50	8.63	8.16	8.80	8.37	8.27	8.60	9.23	8.70	8.58
	T_3	8.30	8.40	8.33	8.63	8.67	8.13	8.30	8.93	8.73	8.49
	T_4	8.60	8.40	8.43	8.27	8.13	7.83	7.47	8.60	8.17	8.21
	T_5	8.50	8.40	8.70	8.40	8.37	8.07	8.13	8.70	8.53	8.42
	T_6	8.67	8.50	8.50	8.20	7.73	7.50	7.63	8.33	8.57	8.18
EC (dS m^{-1})	T_1	8.70	22.81	14.38	10.34	9.40	8.70	6.88	4.88	3.53	9.96
	T_2	19.95	12.65	11.34	9.64	9.73	5.73	4.10	6.07	3.31	8.50
	T_3	8.87	11.67	8.79	8.15	6.70	5.10	4.83	3.77	2.95	6.87
	T_4	12.18	10.87	7.45	5.46	5.40	3.53	3.63	3.34	3.05	6.10
	T_5	11.05	15.50	8.58	8.36	8.63	7.30	7.40	6.94	6.05	8.87
	T_6	9.13	8.53	7.28	4.68	3.63	3.07	3.47	3.55	3.05	5.15
SAR(mmol L^{-1})	T_1	51.3	68.1	17.4	43.2	26.2	22.8	21.7	24.5	19.5	32.5
	T_2	64.2	50.1	14.1	33.8	28.3	15.2	11.4	16.9	16.3	27.1
	T_3	49.0	37.7	12.0	27.2	14.5	12.3	12.4	21.8	10.7	20.7
	T_4	50.9	48.2	9.8	19.32	16.7	16.0	6.8	17.9	10.5	19.5
	T_5	91.0	56.0	12.5	19.2	21.7	17.6	8.3	13.3	10.5	23.8
	T_6	63.4	47.6	15.0	12.6	8.7	16.3	6.3	11.2	12.2	16.9

Table IV ***Leachate analysis for important characteristics as influenced by residual of gypsum in wheat pot culture.***

Important parameters		Treatment	L_1	L_2	L_3	L_4	Mean
pH	9.07	T_1	8.27	8.30	8.40	8.50	8.37
	8.58	T_2	8.13	8.70	8.00	7.90	8.18
	8.49	T_3	8.10	7.87	7.93	7.95	7.96
	8.21	T_4	8.12	8.10	7.90	7.80	7.98
	8.42	T_5	8.14	7.77	7.87	7.60	7.84
	8.18	T6	8.30	7.90	7.90	7.10	7.80
EC (dSm^{-1})	9.96	T_1	2.82	2.97	3.03	5.20	3.51
	8.50	T_2	3.17	3.28	3.47	4.51	3.61
	6.87	T3	3.17	3.32	4.14	4.30	3.73
	6.10	T_4	3.53	4.79	5.11	5.62	4.76
	8.87	T_5	3.63	5.00	5.87	6.23	5.18
	5.15	T_6	3.94	5.03	5.23	6.23	5.11
SAR (mmol L^{-1})	32.5	T_1	9.06	6.90	4.66	4.03	6.16
	27.1	T_2	6.52	4.93	4.41	3.93	4.95
	20.7	T_3	5.20	4.69	4.21	3.37	4.37
	19.5	T_4	5.80	4.16	3.40	3.32	4.17
	23.8	T_5	6.20	4.08	3.33	2.38	4.00
	16.9	T_6	5.39	4.00	2.33	2.04	3.44

Note: - The figures in column 2 present the mean value of the concerned characteristics determined from leachates of the previous crop (rice).

Table V. ***Yield of paddy rice and fresh stock affected by various doses of gypsum application***

Treatments	**Grain yield g pot^{-1}**	**% inc. over control**	**Fresh stalk yield g pot^{-1}**	**% inc. over control**
T_1	17.13	-	30.33	-
T_2	18.93	10.5	33.33	9.8
T_3	22.32	30.3	33.70	10.1
T_4	24.10	40.70	40.60	31.9
T_5	24.70	44.2	37.30	23.0
T_6	25.30	47.7	38.00	25.3

Table VI. Grain ***yield, tillers pot^{-1} and fresh biomass pot^{-1} as affected by gypsum application***

Treatments	**Grain yield (g pot^{-1})**	**Tillers pot^{-1}**	**Fresh biomass (g pot^{-1})**
T_1	9.4	23.0 -	70.63
T_2	10.34 (10)	23.0 -	58.77
T_3	11.51 (22.4)	24.0 (4.3)	70.40
T_4	16.50 (75.5)	27.0 (17.4)	64.41
T_5	16.50 (75.5)	21.0 -	68.67
T_6	16.92 (80.0)	24.0 (4.3)	69.20

Note: - the figures in parenthesis show the percent increase over control.

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