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Gypsum Efficiency in the Amelioration of Saline Sodic/Sodic Soils

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ABSTRACT

Agriculture plays a pivotal role in the economy of Pakistan, which is mainly dependent on irrigated agriculture. Its sustainability is confronted with the problems of waterlogging and salinity which appeared due to inadequate drainage facilities, unlined water channels, improper agriculture practices followed by the farmers deferred operation and maintenance of the Salinity Control and Reclamation Projects (SCARPs) and inadequate water supplies. In a survey conducted by WAPDA during 1977-79, it was reported that about 28% of the surveyed area (16.24 million ha) is affected by surface salinity. In case of profile salinity/sodicity, the situation is even more serious and there are 11, 24 and 3% saline, sodic and sodic soils, respectively. Saline soils (11%) can be reclaimed by simple leaching with excessive water but for the reclamation of about 27% saline-sodic and sodic soils application of some chemical/biological amendments is imperative because to have a potential production, the soil must be physically, chemically and biologically healthy for plant growth. Gypsum being easily available and cheap can be used for the reclamation of saline sodic and sodic soils efficiently provided irrigation water is available. The gypsum applied will replace the sodium (Na^+) with calcium (Ca^{++}) from the soil exchange complex and will be leached down below root zone with irrigation water resulting in better and productive soil and more crop yield per unit area. Efficiency of gypsum in the reclamation of saline-sodic and sodic soil varies considerably depending upon the type of the soil to be reclaimed, the methods of gypsum application, the fineness of the gypsum particles, combination of gypsum with other amendments and breaking of the soil hard pan, if exists. Use of gypsum in combination with FYM, finer gypsum (80-100 mesh) and breaking of soil hard pan were significantly better in improving the physical and chemical properties of soil and crops yield. The impacts of gypsum application technologies like different methods and doses of gypsum application, combined application with other amendments, breaking of soil hard pan on physical and chemical properties of soil and crops yield have been discussed in this paper.

Key Words: Gypsum; Rice; Wheat; Saline-sodic soil; Sodic soil

INTRODUCTION

The sustainability of irrigated agriculture is confronted with the problems of waterlogging and salinity as productive lands have gone out of cultivation due to these problems. Saline and sodic soils occur naturally in arid and semi arid climatic conditions (Szabolcs, 1994). As water development brings more land into irrigation, the salinity problem expands (Bresler *et al.*, 1982; Shainberg & Shalhevet, 1984; Kielen, 1996). The injurious effects of excessive salts are through reduced water uptake, nutritional imbalances and toxic effects of some of the ions. In order to reclaim and bring the salt affected lands back to their full production levels, excessive salts need to be leached down below root zone with the application of good quality water.

Reclamation of salt affected soils involves a series of suitable techniques. It varies according to the nature and problem of soil, underground water quality and depth, quality and quantity of irrigation water, soil permeability, calcareousness and gypsum contents of soil, level of reclamation, crops to be grown, availability and economics of the reclaments. For reclamation of saline-sodic soils, gypsum is commonly applied as amendment for replacing the sodium with calcium from the soil exchange complex. Much of the cost of gypsum is associated with its grinding and fineness. In this paper, the effects of different methods of gypsum application, its doses, fineness, breaking of hard pan etc. on soil and crops have been discussed. The broad objective of this paper is to evaluate the efficiency of gypsum doses, methods of application, fineness of gypsum and mechanical methods on the reclamation of saline sodic/sodic soil and crops yield.

MATERIALS AND METHODS

The studies reviewed in this paper were carried out under different soil and climatic conditions. Initial physical and chemical properties of soil were determined in order to evaluate the treatment effect on soil. During experimentation, the soil samples were also collected, dried, sieved and analyzed for EC_e and SAR (U.S. Salinity Laboratory Staff, 1954). The effects on infiltration rates and crops yields were also evaluated.

RESULTS AND DISCUSSION

1. Effect of gypsum and sulfuric acid

1.1. Infiltration rate of soil. It is evident from Table I that the maximum increase in infiltration rate (214%) over initial infiltration rate was observed in soils treated with Gypsum @ 50% GR + 50 t ha^{-1} FYM followed by 137, 135, 129 and 54% in T-5, T-2, T-4 and T-1, respectively in a period of four years. This indicated that amendments and organic matter had helped in increasing the infiltration rate of soil.

Table I. Effect of different treatments on the infiltration rate of soil

Treatments	Initial	Mean	% increase over initial infiltration rate
T-1	0.52	0.80	54
T-2	0.52	1.22	135
T-3	0.52	1.63	214
T-4	0.52	1.19	129
T-5	0.52	1.23	137

T-1= Control; T-2= Gypsum @ 50% GR; T-3= Gypsum @ 50% GR + 50 t ha^{-1} FYM; T-4= H_2SO_4 eq to 1/10 GR; T-5= H_2SO_4 eq. to 1/10 GR + 50 t ha^{-1} FYM (Source: Chaudhry & Rafique, 1990)

1.2. Sodium adsorption ratio (SAR) of 0-15 cm soil. The SAR was significantly lower in T-2, T-3 and T-5 (Table II) as compared with T-1 and T-4. The data revealed that SAR in all treatments except control was brought below safe limits. The T-3 was more efficient in reducing the SAR of soil compared with other treatments.

Table II. Effect of different treatments on the SAR of 0-15 cm soil depth

Treatments	Pre-Rice S_1	Post Wheat S_9	% decrease in S_9 over S_1
T-1	40.87	14.15	65
T-2	35.13	8.63	75
T-3	39.47	7.44	81
T-4	41.60	10.11	76
T-5	35.00	9.73	72

T-1= Control; T-2= Gypsum @ 50% GR; T-3= Gypsum @ 50% GR + 50 t ha^{-1} FYM; T-4= H_2SO_4 eq to 1/10 GR; T-5= H_2SO_4 eq. to 1/10 GR + 50 t ha^{-1} FYM (Source: Chaudhry & Rafique, 1990); LSD Treatments 1% = 2.07; S_1= Initial soil sampling (before the start of the experiment); S_9= 9th soil sampling (after the termination of the experiment)

1.3. Crops yield. The data presented in Table III indicate that paddy and wheat grain yield was considerably higher in T-3 and other treatments where amendments were applied as compared with control. On an average, higher yield of 66% over control was achieved where gypsum @ 50% GR in combination with 50 t ha^{-1} FYM was applied followed by 60, 46 and 26% in T-5, T-4 and T-2, respectively. Like paddy yield, wheat grain yield was 102% higher in T-3 over control followed by T-5, T-4 and T-2 where increase was 99, 94 and 89%. Combination of gypsum with FYM accelerated the reclamation process and consequently increased crop yield.

Table III. Effect of different treatments on crops yield (kg ha^{-1})

Treat.	Paddy		Wheat Grain	
	Mean yield	% increase over control	Mean yield	% increase over control
T-1	2468 (c)	-	1820 (b)	-
T-2	3820 (ab)	26	3443 (a)	89
T-3	4101 (a)	66	3678 (a)	102
T-4	3592 (b)	46	3531 (a)	94
T-5	3956 (ab)	60	3628 (a)	99

T-1= Control; T-2= Gypsum @ 50% GR; T-3= Gypsum @ 50% GR + 50 t ha^{-1} FYM; T-4= H_2SO_4 eq to 1/10 GR; T-5= H_2SO_4 eq. to 1/10 GR + 50 t ha^{-1} FYM (Source: Chaudhry & Rafique, 1990); LSD Treatments 1% = 417.45

2. Effect of different mesh sized gypsum

2.1. Infiltration rate of soil. The infiltration rate of soil was significantly affected by different treatments. On an average, the maximum infiltration rate of 0.75 cm hr^{-1} was found in T-5 followed by T-6, T-7, T-4, T-8, T-9, T-3, T-2 and T-1 (Table IV). The increase was possibly due to the application of gypsum and addition of organic matter crop residues. Maximum increase of 47% was found in T-5, which was significantly higher than T-1, T-2, T-3 and T-4.

Table IV. Effect of different mesh sizes of gypsum on the infiltration rate of soil

Treatments	Mean	% increase over T-1
T-1	0.51 d	-
T-2	0.58 cd	14
T-3	0.60 bcd	18
T-4	0.67 abc	31
T-5	0.75 a	47
T-6	0.73 ab	43
T-7	0.69 abc	35
T-8	0.65 abc	28
T-9	0.65 abc	28

T-1= Control; T-2= Gypsum coarser than 40 mesh _1/; T-3= Gypsum 40-60 mesh _1/; T-4= Gypsum 60-80 mesh _1/; T-5= Gypsum 80-100 mesh _1/; T-6= Gypsum Powder-Quaidabad Factory _1/; T-7= Gypsum Powder-Khewra Factory _1/; T-8= Gypsum Powder-Khewra Factory _2/; T-9= H_2SO_4 eq.to 25 % GR of Soil (Source: Chaudhry & Ihsanullah, 1989); LSD Treatments 1% = 0.132; _1_/= 100 % GR; _2_/= 50 % GR

2.2. Sodium adsorption ratio of soil. The SAR of soil was significantly affected by degree of gypsum fineness. In T-5, the SAR was reduced below safe limits after second rice crop; whereas, in all other gypsum treatments, this condition was achieved after third rice crop. The maximum reduction of 91% was observed in T-9 (Table V) where H_2SO_4 eq. to 25% GR of soil was applied and was followed by T-5 (80-100 mesh size gypsum).

Table V. Effect of different mesh size gypsum on SAR of soil (0-15 cm)

Treatments	Pre rice S_1	Post wheat S_7	% decrease over S_1
T-1	54.46	24.64	55
T-2	53.72	10.99	80
T-3	52.53	9.25	82
T-4	46.63	6.35	86
T-5	51.95	5.68	89
T-6	66.92	8.62	87
T-7	70.03	7.42	89
T-8	65.47	9.51	86
T-9	99.83	9.34	91

T-1= Control; T-2= Gypsum coarser than 40 mesh _1/; T-3= Gypsum 40-60 mesh _1/; T-4= Gypsum 60-80 mesh _1/; T-5= Gypsum 80-100 mesh _1/; T-6= Gypsum Powder-Quaidabad Factory _1/; T-7= Gypsum Powder-Khewra Factory _1/; T-8= Gypsum Powder-Khewra Factory _2/; T-9= H_2SO_4 eq.to 25 % GR of Soil (Source: Chaudhry & Ihsanullah, 1989); LSD Treatments 1% = 9.09; _1_/= 100 % GR; _2_/= 50 % GR; S_1= Initial soil sampling (before the start of the experiment); S_7= 7th soil sampling (after the termination of the experiment)

2.3. Crop yield. It is evident from Table VI that on an average the maximum paddy and wheat grain yield of 2355 and 2062 kg ha^{-1}, respectively was found in T-5 where gypsum of 80-100 mesh was applied.

Table VI. Effect of different mesh size gypsum on crops yield

Treatments	Paddy		Wheat grain	
	Yield kg ha^{-1}	% increase over control	Yield kg ha^{-1}	% increase over control
T-1	1424 (e)	-	999 (d)	-
T-2	1703 (de)	20	1301 (c)	30
T-3	1813 (cde)	27	1347 (c)	35
T-4	2118 (abcd)	49	1661 (b)	66
T-5	2355 (a)	65	2062 (a)	106
T-6	2287 (ab)	61	1937 (a)	94
T-7	2115 (abcd)	49	1611 (a)	61
T-8	1899 (bcd)	33	1366 (e)	37
T-9	2178 (acd)	53	1442 (bc)	44

T-1= Control; T-2= Gypsum coarser than 40 mesh _1/; T-3= Gypsum 40-60 mesh _1/; T-4= Gypsum 60-80 mesh _1/; T-5= Gypsum 80-100 mesh _1/; T-6= Gypsum Powder-Quaidabad Factory _1/; T-7= Gypsum Powder-Khewra Factory _1/; T-8= Gypsum Powder-Khewra Factory _2/; T-9= H_2SO_4 eq.to 25 % GR of Soil (Source: Chaudhry & Ihsanullah, 1989); LSD Treatments (paddy) 1% = 431.14, (Wheat) 1% = 244.22; _1_/= 100 % GR; _2_/= 50 % GR

There was maximum increase of 65 and 106% in paddy and wheat grain yield over control, respectively. In almost all treatments, there was increase in the paddy and wheat grain yield over control. This increase ranged between 20-65% in case of paddy and 30-106% in wheat grains.

3. Effect of different grades of gypsum and method of application

3.1. Paddy yield. The paddy yield was significantly affected by different treatments. The maximum paddy yield was with T-3 followed by T-2, T-4, T-5 and T-1, respectively (Table VII). On an average, the highest yield was obtained with T-3 where gypsum @ 50% GR was applied in standing water and it was 116% higher than the yield under control. Similarly, the yield was 77, 51 and 41% higher under T-2, T-4 and T-5 as compared to T-5 indicating the beneficial effects of gypsum application.

Table VII. Effect of different grades and methods of application of gypsum on crops yield

Treatments	Paddy		Wheat Grain	
	Ave. yield	% increase over control	Ave. yield	% increase over control
T-1	373	-	476	-
T-2	661	77	1057	122
T-3	804	116	1731	264
T-4	563	51	868	82
T-5	524	41	795	67

T-1= Control; T-2= 50% GR of soil (Powder); T-3= 50% GR of soil in standing water (Powder); T-4= 50% GR of soil (5 cm. size grade); T-5= 50% GR of soil (10 cm.size grade) (Source: Chaudhry *et al.,* 1986)

3.2. Wheat grain yield. Like paddy yield on an average, the wheat grain yield was highest in T-3 where gypsum was applied in standing water (Table VII). The yield obtained under T-2 was also considerably higher from the yields under T-4 and T-5 indicating that finer gypsum were better for improving the soil and consequently improving the wheat yield. The yield was 122, 264, 82 and 67% higher over control in T-2, T-3, T-4 and T-5, respectively.

4. Effect of Biotic and Chemical Amendments. The effects of biotic and chemical amendments was studied in combination with irrigation applied after harvesting the kallar grass (*Leptochloa fusca*) in order to utilize the CO_2 being produced during decomposition of roots for solubilization of the $CaCO_3$ present in the soil.

4.1. $CaCO_3$ content of soil. The data presented in Table VIII reveal that the $CaCO_3$ contents of soil without gypsum application were significantly decreased within about five years period which confirms the hypothesis (Robbins, 1986) of solubilizing calcium from $CaCO_3$ by tapping CO_2 in the soil by applying irrigation when the organic matter within the soil is decaying. Irrigation timings were non significant but maximum decrease of 66% in $CaCO_3$ content of 0-90 cm soil depth was observed when irrigation after nine days of harvesting of kallar grass was applied. Similarly, in case of gypsum applied plots the decrease in $CaCO_3$ content was significant. Maximum reduction of 68% in $CaCO_3$ contents was found in T-3 and followed by 62% reduction in treatment T-2. Reduction in $CaCO_3$ content was observed in all treatments irrespective of gypsum application. On an average, this reduction was above 50% in 0-90 cm soil depth.

Table VIII. Effect of treatments on $CaCO_3$ content of soil (0-90 cm soil)

Treat.	Non Gypsum			Gypsum		
	Initial %	Final %	% decrease	Initial %	Final %	% decrease
T-1	12.9	4.5	65	12.2	4.9	60
T-2	12.2	4.8	61	12.2	4.6	62
T-3	13.9	4.8	66	13.6	4.2	68
T-4	13.6	4.6	66	11.8	5.2	56

T-1= Irrigation after 3 days of harvesting; T-2= Irrigation after 6 days of harvesting; T-3= Irrigation after 9 days of harvesting; T-4= Irrigation after 12 days harvesting (Source: Hamid *et al.,* 1993)

4.2. Crop yields. On an average, higher wheat grain yield was obtained in T-4 and T-3 in non-gypsum and gypsum applied plots, respectively (Table IX). The wheat grain yield was significantly higher in gypsum treatment plots compared with non-gypsum and on an average the yield was 16% higher in gypsum treated plots.

Like the wheat grain yield, paddy yield was also not significantly affected by irrigation timings. However, slightly higher yield of paddy was obtained in T-2 in non-gypsum plots and in T-3 in gypsum plots. The paddy yield in gypsum was 17% higher than the yield obtained from non-gypsum plots.

Table IX. Effect of treatments on crop yields

Treatment		Wheat, kg ha^{-1}		Paddy, kg ha^{-1}	
Irrigation	Amend.	Mean	% increase	Mean	% increase
T-1	NG	2732	-	2401	-
	G	3105	14	2670	11
T-2	NG	2711	-	2660	-
	G	3277	21	3029	14
T-3	NG	2553	-	2656	-
	G	3291	29	3056	15
T-4	NG	2880	-	2447	-
	G	3206	11	2664	9

T-1= Irrigation after 3 days of harvesting; T-2= Irrigation after 6 days of harvesting; T-3= Irrigation after 9 days of harvesting; T-4= Irrigation after 12 days harvesting; NG= Non gypsum; G = Gypsum

5. Effect of physical and chemical methods on crops yield in saline-sodic soil.

5.1. Paddy yield. The data presented in Table X indicate that the maximum paddy yield was obtained with 75% gypsum application. In case of physical methods, the highest yield of 4120 kg ha^{-1} was obtained where sub-soiling was done. It was followed by chisel plough, tine cultivator and disk plough, respectively.

5.2. Wheat grains yield. The mean values presented in Table XI indicate that higher dose of gypsum (75%) reclaimed the soil more efficiently and yield was 17% more than the lower dose i.e. 50% gypsum application. Similarly, sub-soiled performed better as compared with other mechanical treatments. The yield in sub-soiled plots was followed by chisel plow, disk plow and tine cultivator.

Table X. Effect of different treatments on paddy yield

Treatments	Level	Yield kg ha^{-1}	% increase/decrease
Gypsum	50% GR	3552	-
	75% GR	4173	18
Tillage	Tine Cultivator	3660	-
	Disk plough	3550	-3
	Chisel plough	4115	12
	sub-soiler	4120	13

Source: Sabir *et al.* (1999)

Table XI. Effect of different treatments on wheat grains yield

Treatments	Level	Yield kg ha^{-1}	% increase
Gypsum	50%	2867 (b)	-
	75%	3351 (a)	17
Tillage	Tine Cultivator	2743 (b)	-
	Disk plough	3070 (ab)	12
	chisel plough	3090 (ab)	13
	sub soiler	3530 (a)	29

Source: Sabir *et al.* (1999)

CONCLUSIONS

1. Infiltration rate was significantly affected and maximum increase was observed/recorded with the application of gypsum with FYM.
2. Significantly higher yield was obtained with gypsum + FYM.
3. Finer gypsum (80-100) mesh) was better for rapid reduction in SAR, maximum wheat and paddy yield.
4. There was significant decrease in $CaCO_3$ content of soil and maximum decrease was in irrigation nine days after harvesting.
5. Gypsum application increased wheat grains (16%) and paddy (17%).
6. Sub-Soiler gave better yield over other mechanical treatments.

RECOMMENDATIONS

1. Use of FYM/green manure be encouraged during reclamation of saline-sodic and sodic soils.
2. Calcium carbonate content of soil be utilized for reclamation of saline-sodic soil by solubilizing it

by traping CO_2.

3. During reclamation of salt affected soils having hard layers, sub-soiler be used for achieving rapid reclamation.

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