Wheat Yield and Chemical Composition as Influenced by Integrated Use of Gypsum, Pressmud and FYM in Saline-Sodic Soil

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Summary: Crop yields are limited under salt-affected soils receiving saline irrigation water. A field experiment was conducted on silty clay loam saline sodic soil [fine loamy, mixed, hyperthermic Typic Haplustepts, ECe = 8.03-11.76 dS m^{-1}, SAR=15.8–17.9] to investigate the effect of gypsum (G), pressmud (PM), and farmyard manure (FYM) applied alone or in various combinations on soil reclamation and mitigating the adverse effects of saline tube-well waters (EC_{iw} = 5.5 dSm^{-1}, SAR = 10.0). Treatments included the amendments (AM) ;G (6.0 Mg ha^{-1}), PM (7.0 Mg ha^{-1}), G+PM (3.0 + 3.5 Mg ha^{-1}) equivalent to 100% gypsum requirement (GR) applied alone or with 4.0 Mg ha^{-1} FYM in two factorial [4 AM x 2 FYM] RCB design with three replications. Sole application of G, PM, and G+PM significantly increased wheat plant height, grain and biomass yield by 24-28%, 27-36%, and 37-39% over control which further increased to 42-46%, 68-87% and 61-73%, respectively, when these AM were applied in combination with 4.0 Mg FYM ha^{-1}. Wheat leaf K and Ca+Mg concentrations increased while Na was depressed by G and PM but was highest in FYM treated plants. Due to increases in tissue [K], the K:Na ratio was higher in G and PM treated plots and lowest in control and FYM alone. The K:Na ratio in tissue was positively correlated to Ca+Mg:Na ratio ($r^2 = 0.53$) and K:Na ratio ($r^2 = 0.43$) in the soil solution. The post harvest soil SAR significantly ($P < 0.01$) decreased from 13.03 in control to 5.40, 7.73 and 6.27 with G, PM and G+PM treated plots, respectively. Water soluble K increased by 2-3 times with sole AM and 4-5 times with AM+FYM applications. In spite of saline irrigation the lower SAR values and high K values revealed the significant role of AM application for better management of these soils. The comparable increases in wheat grain yield and decreases in post harvest soil SAR and EC suggest that PM could be as effective as gypsum in these saline-sodic soils. The combined use of PM+G equivalent to 100% GR along with FYM is advised for the reclamation and mitigating the adverse effect of saline irrigation in these areas and for obtaining economical yields on sustainable basis.

Introduction

Brackish under ground water coupled with low rainfall and higher evapo-transpiration rate is the main cause of soil salinity in the eastern side of Lachi, district Kohat, Khyber Pakhtunkhwa [1]. Detailed study of the area revealed salinity build up throughout the soil profile [2] because of continued irrigation with the only available saline tubewell waters having EC 4.5 to 6.4 dS m^{-1} and SAR > 10. Such salinity development also prevails in other parts of the country where 75% of ground water used for irrigation is of poor quality due to high EC_{iw}, RSC and/or SAR [3] that has caused sodicity problem over $3x10^6$ ha area in Pakistan [4]. With proper management practices these brackish waters can be applied to soil with minimal adverse effect on crop and soils [5-12]. It has been observed that a good crop yield could be obtained if saline water is blended in appropriate ratio with good quality water [13, 14]. But the study area has no alternate irrigation resources except seasonal rainfall. And as such, addition of organic and inorganic amendments and to some extent appropriate agronomic practices can prevent soil deterioration by maintaining better soil physical and chemical conditions.

Amendments such as gypsum supply Ca into soil solution upon dissolution or indirectly after a series of chemical and biological reactions in case of elemental S, acids, and $Al_2(SO_4)_3$ to replace Na from soil exchange complex and improve soil physical properties and result in leaching of Na-salts. Gypsum [10, 15-21], pressmud [22-25], and FYM [10, 11, 26, 27] have been successfully used for amelioration of sodic and saline-sodic soils and to mitigate the adverse effect of saline irrigation [10, 11, 28-30]. However, the relative effectiveness and suitability of amendments in reclamation of sodic soils depends on the irrigation water electrolyte concentrations and composition [31] in addition to soil physico-chemical and biological properties. Hence amelioration of sodic and saline-sodic soil is highly site specific that explains for the differential response of different soils to various amendments and for the superiority of one amendment over another in diverse soil, water and climatic conditions. For instance the effect of gypsum was more pronounced in increasing cane yield under sodic (30%) compared to saline-sodic irrigations (13%) but FYM was more effective under saline-sodic (38%) than under sodic irrigation (23%) [10].

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PM reclaimed soil less efficiently than FYM [32] but on contrast Haq *et al.,* [24] reported that application of only 2.5 Mg PM ha^{-1} produced higher yield of rice as compared to 10 Mg ha^{-1} FYM.

The combined application of inorganic and organic amendments like FYM [33], green manures [34] and residue straw [35, 36] improve their effectiveness. Decaying organic matter increases soil CO_2 concentrations and liberates H^+ when dissolves in water. The released H^+ enhances $CaCO_3$ dissolution and releases more Ca for Na exchange [35, 37]. Moreover, organic materials improve the soil physico-chemical properties [27, 34, 38] that accelerates exchange of cations on soil solids and leaching of salts from the root zone. Combined application of gypsum with FYM [32, 39, 40] enhanced its ameliorating effect. Hydraulic conductivity of saline-sodic soil improved in the order of gypsum + green manure > gypsum > green manure > control [34] indicating the effect of green manuring on soil physical condition. The conjunctive uses of 25 Mg ha^{-1} FYM plus 12.4 Mg ha^{-1} gypsum significantly improved soil pH, ECe, ESP, infiltration rate, osmotic potential and available water capacity of sodic soils as compared to their alone application [41]. Combined application of PM+G+FYM produced the highest yield followed by alone PM that were 94 and 60% higher than control, respectively [24].

These reports show variable effects of amendments depending type and amount of amendment, degree of salinity-sodicity and quality of irrigation waters. Since the amount of required amendments, their relative effectiveness and extent of soil reclamation is highly site specific, an experiment was conducted to evaluate gypsum (G), pressmud (PM) and G+PM alone or with FYM in reclamation of saline sodic soil irrigated with brackish under ground waters.

Results and Discussion

Plant Height and Grain and Biomass Yield of Wheat

Analyses of variance based on two factorial RCB design [4 AM x 2 FYM] showed that both AM and FYM significantly ($P < 0.01$) enhanced wheat plant height and grain and biomass yield under saline-sodic soils conditions. Interactions of AM x FYM was significant only for grain yield (Table-1).

The highest plant height of 115 cm, grain yield of 2741 kg ha^{-1} and biomass yield of 11824 kg ha^{-1} were recorded in G+PM+FYM treatment followed by G+FYM in case of grain yield and PM+FYM in biomass. The combined treatment of G+PM+FYM had significantly higher grain yield than PM+FYM but non-significantly higher than G+FYM (Table-1).

Table-1: Analyses of variance [4 AM x 2 FYM x 3 R] showing F values for wheat growth and yield and [Na], [K] and [Ca+Mg] grown in silty clay loam saline sodic soil treated with G, PM, an G+PM alone or with FYM.

Parameters	**--------------------- Source of variations------------------**			
	AM	**FYM**	**AM x FYM**	**CV%**
D.F.	**03**	**01**	**03**	
Plant height	**65.76****	**75.07****	**1.58ns**	**3.49**
Grain yield	**32.73****	**104.28****	**3.21***	**6.78**
Biomass yield	**15.48****	**22.51****	**0.57ns**	
Na	**155.17****	**0.73ns**	**10.41****	**6.18**
K	**21.84****	**8.69****	**0.85ns**	**3.81**
Ca+Mg	**127.92****	**281.60****	**8.11****	**2.44**
K:Na	**65.66****	**10.39****	**10.10****	**8.65**
Ca+Mg:Na	**104.49****	**12.72****	**9.83****	**7.46**

↑*,**, significant at $P < 0.05$, 0.01 and NS non significant.

As compared to control, G, PM and G+PM significantly increased wheat plant height by 24-28%, grain yield by 27-36% and biomass yield by 37-39% when applied without FYM and by 42-46%, 68-87% and 61-73%, respectively with these amendments plus 4.0 Mg ha^{-1} FYM. The data demonstrated that addition of FYM with G, PM and G+PM promoted plant height by 16-20%, grain yield by 31-42% and biomass yield by 22-36%, respectively as compared to these amendments when applied alone (Fig. 1). The beneficial effect of conjunctive use of chemical amendments with FYM is further evident from the data averaged over amendments (Table-2).

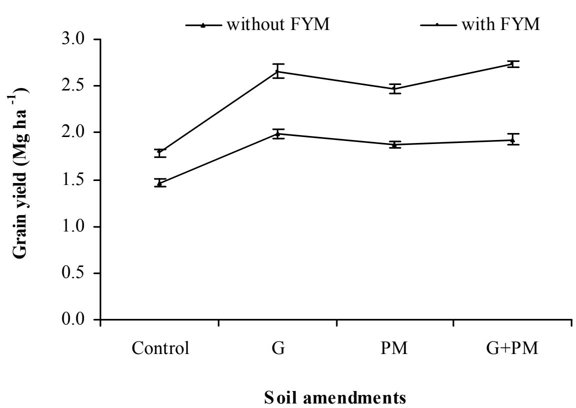

Fig. 1: Wheat grain yield as influenced by different soil amendments applied on 100% GR basis in silty clay loam saline sodic soil. G stands for gypsum while PM for Pressmud. G, PM and G+PM were applied at 6.0, 7.0 and 3.0+3.5 Mg ha^{-1}, respectively.

Table-2: Wheat plant growth and yield and tissue [Na], [K], and [Ca+Mg] grown in silty-clay loam saline-sodic soil treated with G, PM, and G+PM alone or with FYM.

G	PM	FYM	Plant height	Grain yield	Biomass yield	Na	K	Ca+Mg	K:Na	Ca+Mg:Na
------- Mg ha^{-1}-------			cm	------kg ha^{-1}-------		----------mmol$_c$ kg^{-1}----------			-	-
0	0	0	79	1465	6873	84.8	553.8	735.8	6.53	8.68
6	0	0	98	1992	9578	57.8	617.9	950.7	10.69	16.45
0	7	0	101	1874	9437	53.2	635.9	1000.7	11.95	18.81
3	3.5	0	99	1924	9560	48.7	587.2	900.8	12.06	18.50
0	0	4	87	1782	8105	92.8	562.4	666.7	6.06	7.18
6	0	4	112	2657	11073	42.6	661.8	800.4	15.54	18.79
0	7	4	113	2463	11904	54.6	677.8	831.3	12.41	15.23
3	3.5	4	115	2741	11824	49.3	605.1	735.3	12.27	14.91
LSD$_{(P < 0.05)}$			6.13	251.8	1685.1	6.54	40.85	35.42	1.66	1.94
---Average across FYM---										
0	0	-	83	1624	7489	88.8	558.1	701.3	6.30	7.9
6	0	-	105	2325	10326	50.2	639.9	875.6	13.11	17.6
0	7	-	107	2169	10671	53.9	656.9	916.0	12.18	17.0
3	3.5	-	107	2333	10692	49.0	596.2	818.1	12.17	16.7
LSD$_{(P < 0.05)}$			4.33	177.6	1192.1	4.63	28.88	25.05	1.17	1.37
--Average across amendments ---										
-	-	0	94 b	1814 b	8862 b	61.1a	599b	897a	10.31	15.6a
-	-	4	107 a	2411 a	10727 a	59.8b	627a	758b	11.57	14.0b

↑Values followed by similar letters are statistically similar

This increase in crop growth due to the integrated effect of chemical and organic amendments could be associated with displacement of exchangeable Na from solid phase, improvement in soil physical and chemical conditions, which resulted in enhanced plant growth and yield [33, 41, 42]. Choudhary *et. al.,* [10] reported higher yields of cane with FYM+G throughout 10 years of cropping continuously irrigated with highly sodic (EC_{iw} = 1.43 dS m^{-1}, SAR = 19.8, RSC = 10) and saline-sodic (EC_{iw} = 2.90 dS m^{-1}, SAR = 31.2, RSC = 11.4) waters as compared to alone gypsum or FYM. The higher wheat growth and yield obtained with combined application of PM+G+FYM was in line with the findings of [24, 43] who reported higher yield of rice in other areas of this province with integrated application of all these amendments. The enhancement in growth and yield of wheat with both chemical and organic amendments could be attributed to their ameliorating capabilities in combating the adverse effects of sodic and saline-sodic saline irrigation [10, 39, 44] and correcting the nutrient balances in soil [10, 27, 45]. The plant and soil analysis provided in Table-2 and the positive relationships between Ca+Mg:Na ratio in soil saturation extract and plant K:Na (Fig. 2) and soil K:Na and plant K:Na ratio (Fig. 3) support this contention.

Wheat Leaf Na, K and Ca+Mg Concentrations and Ratios of K:Na and Ca+Mg:Na

The ANOVA revealed that application of chemical amendments, FYM and their interaction significantly (P < 0.01) affected the [Na] (concentrations of Na), [K], and [Ca+Mg], and ratios of K:Na and Ca+Mg:Na in wheat leaf tissues except FYM and AMxFYM which did not change leaf [Na] and [K], respectively (Table-3).

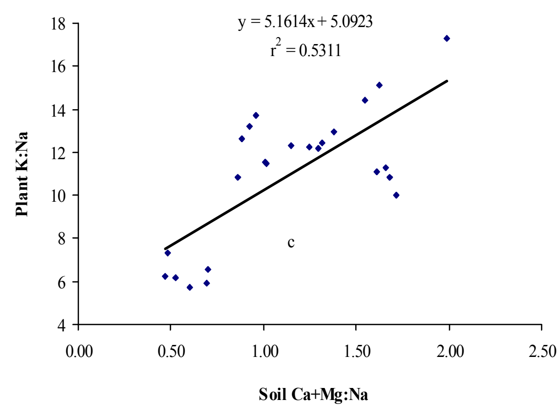

Fig. 2: Relationship of post harvest treated soil Ca+Mg:Na with plant K:Na.

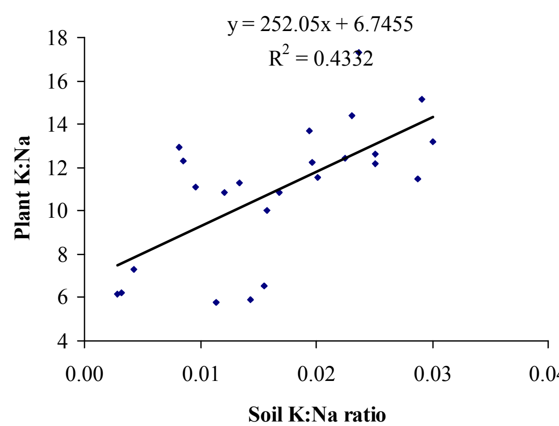

Fig. 3: Relationship between post harvest treated soil K:Na and plant K:Na ratio.

Table-3: Analyses of variance [4AM x 2FYM x 3R] showing F-values for post harvest pH_e, EC_e, [Na], [K], [Ca+Mg], and [SAR] in saturation extract of silty clay loam saline-sodic soil treated with G, PM, and G+PM alone or with FYM.

SOV	D.F.	pHe	ECe	Na	K	Ca+Mg	SAR
Replications	2	0.88ns	0.82ns	0.02ns	0.06ns	1.03ns	0.10ns
Amendments (AM)	3	0.58ns	4.98*	84.96**	33.92**	54.54**	141.45**
FYM	1	0.67ns	0.31ns	0.57ns	201.49**	1.24ns	3.25ns
AM x FYM	3	2.74ns	0.34ns	2.45ns	3.08ns	1.48ns	5.25*
CV%		1.33	7.43	6.87	11.99	8.01	7.59

Application of G and PM whether applied alone in full dose or combined in half equivalent amount depressed [Na] and promoted [K] and [Ca+Mg] as compared to control and as well as to FYM applied at the rate of 4.0 Mg ha^{-1}. The lowest [Na] of 42.6 mmol kg^{-1} DM was observed in treatments receiving 6.0 Mg G ha^{-1} plus 4.0 Mg ha^{-1} FYM followed by G+PM and G+PM+FYM which were statistically similar with each other but significantly lower than control. The highest value of 92.8 mmol Na kg^{-1} was observed in the treatments of FYM when applied alone, which was significantly higher than control. The leaf [K] and [Ca+Mg] were higher in the treatments which received G or PM alone. The [K] was lowest in control and highest in plots treated with 7.0 Mg ha^{-1} PM plus 4.0 Mg ha^{-1} FYM followed by G+FYM and PM applied alone.

The treatments receiving full dose of either G or PM plus FYM had higher [Ca+Mg]. The [Ca+Mg] were highest (1000 $mmol_c$ kg^{-1} DM) with 7.0 Mg ha^{-1} PM when applied alone but decreased with FYM to 666 $mmol_c$ kg^{-1}. Close comparison of the tissue cation concentrations data with biomass suggests that the relative increases in yield with treatments did induce variations in the cation concentration but in a selective manner. The [Ca+Mg] were higher in treatments receiving full dose alone or PM+G in equal proportion than control and from those treated with FYM. The addition of FYM tended to depress [Ca+Mg] for example in treatments receiving alone PM had 1000 $mmol_c$ Ca+Mg kg^{-1} DM which reduced to 831 $mmol_c$ kg^{-1} in PM+FYM treated plots. The depressing effect of [Ca+Mg] with FYM appears to be strongly associated with dilution effect caused by the much more higher yield obtained with addition of FYM (Table-2). The positive effect of PM on K and that of G+PM on Ca+Mg is understandable given the composition of PM which contains 1376 mg AB-DTPA extractable K kg^{-1} and 9.0 $mmol_c$ L^{-1} water soluble Ca+Mg in 1:5 water suspension (reported elsewhere). The post harvest soil showing higher values of K in PM and PM+FYM treatments (Table-4) strongly corroborate this observation.

Table-4: Post harvest soil pHe, ECe, Na, K, CA+Mg and SAR of saline sodic soil treated with G, PM, and G+PM alone or with FYM.

Gypsum	PM	FYM	pHe	ECe	Na	K	Ca+Mg	SAR
----- Mg ha^{-1}-------				dSm^{-1}	-------------$mmol_cL^{-1}$-------			-
0	0	0	7.75	6.45	43.57	0.15	21.47	13.03
6	0	0	7.84	6.57	24.10	0.33	40.60	5.40
0	7	0	7.98	5.52	28.30	0.53	26.60	7.73
3	3.5	0	7.84	6.68	26.30	0.23	36.00	6.27
0	0	4	7.96	6.33	39.50	0.54	26.20	10.96
6	0	4	7.90	6.33	23.00	0.58	39.40	5.25
0	7	4	7.85	5.73	28.70	0.80	27.00	7.71
3	3.5	4	7.84	6.41	28.50	0.64	36.70	6.75
$LSD_{(P<0.05)}$			ns	ns	ns	0.10	ns	1.05
---------------------------------Average across FYM-------------------------------								
0	0	-	7.86	6.39	41.54	0.35	23.84	11.99
6	0	-	7.87	6.45	23.55	0.46	40.00	5.33
0	7	-	7.92	5.63	28.50	0.67	26.80	7.72
3	3.5	-	7.84	6.55	27.40	0.44	36.35	6.51
$LSD_{(P<0.05)}$			ns	0.58	2.57	0.07	3.15	0.74
--------------------------------Average across amendments---------------------								
-	-	0	7.85	6.31	30.57	0.31 b	31.17	8.11
-	-	4	7.89	6.20	29.93	0.64 a	32.33	7.67

Since the treatments of gypsum and PM promoted the [K] and [Ca+Mg] and depressed [Na], the ratios of K:Na and Ca+Mg:Na followed similar trend. Highest value of K:Na ratio (15.54) was observed in treatment of 6 Mg ha^{-1} gypsum which had lowest Na of 42.0 mmol kg^{-1} DM. As compared with control or 4.0 Mg ha^{-1} FYM, significantly higher K:Na values were observed in plots treated with PM or G+PM applied alone or with FYM.

Potash plays a major role in cell expansion and osmoregulation [46, 47] and in regulating the stomatal opening of leaves and photosynthesis [48, 49]. The increase in K concentrations in soil solution reportedly suppresses the Na uptake [50, 51]. The Ca ion which plays an important role in cell membrane [52] and signaling in osmoregualtion [53] influenced K:Na selectivity and suppressed the Na toxicity in leaves [54]. Aslam *et. al.,* [55] also reported that Ca improved K uptake which ultimately reduced the Na uptake.

Post Harvest Soil EC_e, SAR and Solution K

Analyses of variance based on [4AM x 2FYM] factorial RCB design showed that application of amendments significantly affected post harvest soil ECe, K, Na, Ca+Mg concentrations and SAR ratio in water saturated paste extract. Addition of FYM and AMxFYM interactions induced significant variation only in K and SAR, respectively (Table-3).

The post harvest soil pH varied between 7.75, and 7.96, and EC_e 5.52, and 6.68 dS m^{-1} that were much lower than pre-treatment analyses (pH = 7.66-8.5, ECe= 8.03 – 11.76 dS m^{-1}, SAR = 15.8 – 17.9) but did not show significant response to amendment applications (Table-4). The [Na] in saturation extract was the highest in control and lower in G, PM, or G+PM treatments and Ca+Mg followed the reverse trend. These variations induced by the amendments were reflected in soil SAR. The post harvest soil SAR drastically ($P < 0.01$) decreased from 13.03 in control to values such as 5.40 and 5.25 in the plots treated with full doses of G and to values of 6.27 and 6.75 in plots treated with G+PM applied in equal ratio. Application of PM at the rate of 7.0 Mg ha^{-1} decreased SAR to 7.73 and 7.71 whereas plots treated with 4.0 Mg ha^{-1} maintained SAR of 10.96 that was significantly lower than control but higher than other treatments.

The [K] in saturation extract was lowest (0.15 mmol L^{-1}) in control and highest (0.80 mmol L^{-1}) in PM+FYM. It appears that plots treated with FYM+PM maintained higher concentrations of K either due to decrease in leaching and or due to their chemical composition. With the exception of the low value of 0.23 mmol L^{-1} K observed with G+PM, all treatments containing PM and FYM maintained 3-4 times higher soluble K in the saturation extract than control.

When data were averaged across FYM levels, addition of all chemical amendments significantly reduced Na and SAR and increased water soluble K and Ca+Mg, as compared to control (Table-4). However, treatments receiving 7.0 Mg ha^{-1} PM maintained relatively higher pH, lower EC, Ca+Mg and higher K, Na and SAR amongst the treatments.

The analysis of soil saturation extracts revealed that gypsum and PM, major source of Ca released Na into the soil solution which was leached down as evident from inverse relationship of Ca+Mg with Na in soil solution (Fig. 4). The resultant higher Ca+Mg:Na and K:Na ratio in the soil solution was reflected in the uptake by plant. As explained in the previous section with increase in the ratio of Ca+Mg:Na in the soil solution the ratio of K:Na in plant also increased and when K:Na ratio in soil solution increased K:Na ratio in plant also increased.

Efficiency of gypsum in the reclamation of saline-sodic soils is governed by percent purity, method and time of application of gypsum and quality of irrigation waters [39, 56]. However, the degree and extent of sodicity, the climatic conditions particularly rainfall and temperature and choice of crops determine the efficiency of ameliorative measures. Many researchers have reported supremacy of G over PM in soil reclamation [23, 43, 57] but on other hand PM produced comparable yields with gypsum [23, 58] that could be attributed to improvement in sodic soil properties. In the present study, both PM and G were equally effective to ameliorate the deteriorative effects of brackish waters by maintaining lower SAR as compared to control or FYM. Integrated use of FYM plus G (41, 59, 60), PM [61] PM+G [62] and PM+G+FYM [50] were reported better than their sole application in term of soil reclamation and crop yields.

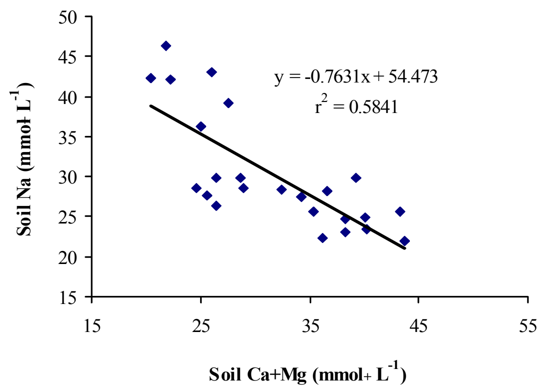

Fig. 4: Relationship of post harvest treated soil [Ca+Mg] with [Na] in saturation extract.

Experimental

To investigate and compare the integrated effect of commonly used amendments (AM) *viz* gypsum (G), pressmud (PM) and farmyard manure (FYM) on the reclamation and management of saline-sodic soils, a field experiment was executed at Nasimabad, Lachi district Kohat. The site was located at 33˚23́ 43″ N and 71˚22́ 14″ E and 435 m elevation from sea level. The plot was saline-sodic having ECe between 8.03 and 11.76 dS m^{-1}, SAR 15.8 – 17.9 and pHe 7.66 - 8.5 being irrigated with saline tube-well waters (EC_{iw} = 5.5 dSm^{-1}, SAR = 10.0). The soil had CEC of 14.80 to 15.8 $cmol_c$ kg^{-1}, strongly calcareous (19.5 to 20% $CaCO_3$) and silty clay loam. The soil was fine loamy, mixed, hyperthermic Typic Haplustepts, gently sloping to level parts with semiarid subtropical submountain continental climatic condition [63]. The X-ray diffraction study of the profile revealed that chlorite, mica and kaolinite were the abundant phyllosilicate minerals with irregularly interstratified mixtures of 2:1 layer silicate such as vermiculite and traces of quartz and feldspars [2].

Treatments included control (no amendments), gypsum (6.0 Mg ha^{-1}), pressmud (7.0 Mg ha^{-1}), gypsum + pressmud (3.0 + 3.5 Mg ha^{-1})

equivalent to 100% gypsum requirement (GR) applied alone or with 4.0 t ha^{-1} FYM. The experiment was laid out according to two factorial [4 AM x 2 FYM] RCB design with three replications. Plot size was kept as 17.0 m^2 (5.0 m wide x 3.4 m long). All treatments were applied on soil surface two weeks before sowing and were thoroughly mixed and plots were irrigated with tube-well brackish waters. When soil attained field capacity, recommended levels of NPK (120:90:60 kg $N:P_2O_5:K_2O$) were applied as urea, triple super phosphate (TSP) and potassium sulfate (SOP). After seed bed was prepared, Wheat [*Triticum aestivum* (L.) Inqilab-91] was sown at the seed rate of 120 kg ha^{-1} with hand driven drill. Three irrigations with tube-well brackish waters were applied during the growing season. The crop was harvested on maturity and the data on plant height, grain and biomass yield were recorded per plot and then converted to Mg ha^{-1}. Plant leaf sample at flowering stage were collected from each pot for leaf tissue analysis. Similarly surface soil samples (0-30 cm) were collected from each plot for post harvest soil analyses to evaluate the effect of various treatments on soil pH, EC, and SAR. Soil and water pH were determined by the procedures of Thomas [64], EC [65] Na, and K by flame photometry and Ca+Mg by EDTA titration as per procedure of Richard [66]. Soil texture was determined by the procedure of Gee and Bauder [67], CEC, gypsum requirement (GR) and lime content as described by Richard [66]. Plant K, and Na were determined by flame photometer (Jenway, PF-7) and Ca+Mg by atomic absorption spectrophotometer (Perkin Elmer 2380) after digesting the sample in 10 mL HNO_3 and 4 mL $HCLO_4$ according to the procedure described by Benton *et. al.,* [68]. All the data were analyzed through Analysis of Variance [69] using statistical package of MSTATC and Microsoft Excel, 2003.

Conclusions

The study revealed that adverse effects of the only available saline-tubewell waters (EC_{iw} of 5.8 dS m^{-1}, SAR = 10) could be mitigated through application of PM, and G, in these saline-sodic soils (SAR = 15-17). Sole application of PM and G increased wheat grain yield by 28-36% over control while 68-87% when these amendments were applied with FYM. The comparable increases in wheat grain yield and improvement in post harvest soil SAR and EC suggested that PM could be as effective as gypsum in such situations. Based on comparatively better performance, the combined use of PM+G each at 50% GR basis along with FYM is advised for the reclamation and ameliorating the adverse effects of saline irrigation in the area and for obtaining economical crop yields on sustainable basis.

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