Pakistan J. Sci. Ind. Res., Vol. 31, No. 8, August 1988

# THE AVAILABILITY OF SOIL PHOSPHORUS AND POTASSIUM IN CALCAREOUS SALINE-SODIC SOILS AS INFLUENCED BY CHEMICAL AMENDMENTS

Bashir Ahmad, Shah Muhammad* and M. Iqbal Makhdum**

*Soil and Water Testing Laboratory, G.T. Road, Sahiwal*

(Received March 7, 1988; revised September 15, 1988)

A field investigation was conducted on Khurrianwala saline-sodic soil series to evaluate the availability of soil phosphorus and potassium during reclamation with chemical amendments (gypsum, $H_2SO_4$, HCl and $CaCl_2$). The treatments were arranged in randomized complete block design with four replication. Two crops viz; rice (kharif 1982) and wheat (Rabi 1982-83) were raised on these plots successively as test crop. Soil samples at 0-15 and 15-30 cm depth were collected after each crop harvest and were analysed for available phosphorus and potassium.

The availability of soil phosphorus increased with acids and was decreased with calcium containing materials. Increase in depth caused a significant decrease in available phosphorus. Availability of potassium increased after rice crops, however, it decreased after wheat crop. The potassium content was higher in upper layer compared to lower one.

*Key words:* Chemical amendments, Reclamation, Saline-sodic soils, Nutrients availability.

## INTRODUCTION

The Indus plain of Pakistan comprising 16.19 million hectares of alluvial soils is endowed with the problems of salinity/aradity and water logging which result in denudation and deterioration of soils. About 60% of the salt-affected soils of Pakistan are saline-sodic and are not easily reclamable because of low permeability to canal water [1].

The nutrients availability is a major limiting factor in calcareous saline sodic soils to harvest maximum potential of a crop species. The use of amendments like gypsum, $H_2SO_4$, HCl and $CaCl_2$ for ameliorization of calcareous saline-sodic soils affect differently in the chemical composition of soil, during reclamation process [2]. Many research workers [3,4] reported that reclamation of sodic soils with gypsum depressed the availability of phosphorus. However, others [5-8] concluded that during reclamation of saline-sodic soils with sulphuric acid and hydrochloric acid, the availability of soil phosphorus increased, while pH and $CaCO_3$ decreased significantly. The soil potassium was little influenced by acid amendments. The available soil potassium was little influenced by acid amendments. The available soil potassium was little influenced under acid treatment in saline-sodic calcareous soil [7-9] with gypsum amendment, however others [10] noted a decreased availability of K in soil under calcium soluble containing amendments.

* Department of Soil Science, University of Agriculture, Faisalabad.

**Central Cotton Research Institute, Multan.

The success of ameliorization depends upon free absorption of nutrients by crops to harvest maximum yield potantial. The application of lime solubilizing agents like $H_2SO_4$ and HCl in calcareous saline-sodic soils cause a significant increase of phosphorus and potassium content in plant tissue and increase uptake [11]. However, research like [8,12-15] concluded that acid based amendments did not influence on potassium absorption pattern, however, *p*-content and uptake increased by wheat grain and straw. The phosphorus content decreased in different plant parts by the addition of gypsum and $CaCl_2$ amendments [9,15,16].

Keeping in view the problems of availability of essential nutrients to plants during reclamation process, an investigation was under taken to evaluate the possible effects of various amendments on the availability of phosphorus nd potassium and their absorption by plants in calcareous saline-sodic soils of khurrianwala soil series.

## MATERIALS AND METHODS

A field experiment was conducted at khurrianwala saline-sodic soil series at Kotla Kohlwan near shah kot (Sheikhupura) during the year 1982-83. The soil samples were collected to determiine the physico-chemical characteristics before and after treatment imposition and results are presented in Table 1 and 2 respectively.

The soils are highly saline sodic and calcareous in nature. The soils are medium in available phosphorus and potassium content and also in texture. The experimental area was levelled and subsoiled crosswise by drawing

Table 1. Physical and chemical characteristics of calcareous saline-sodic khurrianwala soil series of the experimental site.

| Determinations | Values | |
|---|---|---|
| | 0-15 cm depth | 15-30 cm depth |
| pHC | 8.9 | 8.7 |
| ECe mmhos/cm | 13.9 | 10.4 |
| ESP | 64.4 | 64,8 |
| CEC me/100g | 11.1 | 13.6 |
| $CaCO_3$% | 11.4 | 9.1 |
| Gypsum requirement (tons/ha) | 18.8 | 19.8 |
| Available P (ppm) (olsen method | 9.8 | 4.1 |
| Available K (ppm) ($NH_4$ OAC method) | 277.2 | 240.0 |
| Textural class | Sandy clay loam | Loamy clay |
| Particle size distribution | | |
| Sand% | 58 | 48 |
| Silt% | 18 | 22 |
| Clay% | 24 | 30 |

50 ± 5cm deep furrous at a distance of 120-130 cm with the help of a single tine sub soiler. The treatments included control, gypsum at the rate of 75% GR, gypsum at the rate of 100% GR, $H_2SO_4$ at the rate of 75% GR, HCl at the rate of 75% GR and $CaCl_2$ at the rate of 75% GR in four replications, having experimental unit of 300m$^2$ and following randomized complete block design. The rice-wheat-rice relation was adopted. The amendments especially $H_2SO_4$, HCl and $CaCl_2$ were applied in split doses in order to avoid toxic effect of chlorides on crop and the difficulty of application of large doses of acids at one time.

Gypsum requirement was calculated by shcoonovers method of U.S. salinity lab. staff [17]. Composite soil samples from 0-15 and 15-30 depths of each plot were collected before treatments, after rice (Kharif, 1982) and after wheat (Rabi 1982-83). These soil samples were dried, ground, passed through 2mm sieve. The samples were analyzed for available phosphorus [18] potassium and pH adopting methods of U.S. salinity laboratory staff [17].

The rice crop (Kharif 1982) with cultivar Basmati-370 was transplanted on 18th August, 1982. A basal dose of

Table 2. Chemical characteristics of calcareous saline-sodic khurrianwala soil series after imposition of treatments.

| Determination | Values | |
|---|---|---|
| | 0-15 cm depth | 15-30 cm depth |
| pHs | | |
| Control | 8.9 | 8.6 |
| Gypsum (75% GR) | 8.9 | 8.7 |
| Gypsum (100% GR) | 8.8 | 8.7 |
| $H_2SO_4$ (75% GR) | 9.0 | 8.8 |
| HCl (75% GR) | 8.8 | 8.8 |
| $CaCl_2$ (75% GR) | 8.9 | 8.8 |
| Available P (ppm) | | |
| Control | 10.58 | 4.75 |
| Gypsum (75% GR) | 10.18 | 3.98 |
| Gypsum (100% GR) | 9.38 | 3.50 |
| $H_2SO_4$ (75% GR) | 9.40 | 4.32 |
| HCl (75% GR) | 9.40 | 4.32 |
| $CaCl_2$ (75% GR) | 10.10 | 3.80 |
| Available K (ppm) | | |
| Gypsum (75% GR) | 318.8 | 284.9 |
| Gypsum (100% GR) | 370.1 | 234.0 |
| $H_2SO_4$ (75% GR) | 270.1 | 228.2 |
| HCl (75%) GR) | 238.9 | 252.2 |
| $CaCl_2$ (75% GR) | 269.1 | 201.8 |

62 Kg N/ha as urea and 100 Kg $P_2O_5$/ha as single super phosphate was applied at the time of transplanting, while th remaining 62 KG N/ha was top dressed on 15th September, 1982. Zinc sulphate at the rate of 12 Kg/ha was applied to soil on 25th September, 1982. About 160cm of tubewell water was applied to raise the crop and 8.1cm rain was received during crop growth. The crop was harvested on 18th November, 1982.

The wheat crop (Rabi 1982-83) with cultivar LU-26 was sown on 14th December, 1982 in the residual moisture from rice with a basal dose of 75 Kg N/ha as urea and 112 Kg $P_2O_5$/ha as single super phosphate. The remaining 75 Kg N/ha was top dressed on 23rd January, 1983. About 40cm of tubewell water was applied to wheat crop while 23.4 cm rain helped the crop growth and soil reclamation. The crop was harvested during second week of May, 1983.

The grain and straw samples of wheat (Rabi 1982-83) were collected randomly from each treatment. The sample were analyzed for phosphorus and potassium concentration in plant tissues according to methods [17].

Data were subjected to analysis of variance technique and mean values obtained for each treatment were compared by using the duncan's multiple range test at 5% probability level [19].

## RESULTS AND DISCUSSION

Data in Table 3 show that various chemical amendments and soil depths caused significant effect on availability of soil phosphorus and potassium however, interaction of both was non-significant. The available P was higher in the upper layer compared to lower one. Acidation of soil increased availability of soil P while soluble calcium decreased it compared to control. A maximum increase of 3.03 ppm P (44.5%) was observed with HCl treatment followed by 2.16 ppm P (31.5%) under $H_2SO_4$ amendment (Table 1 and 2) and did not differ significantly from each other after rice crop. The P availability reduction was 2.44 ppm (35.4%) and 1.55 ppm (23.8) with gypsum of 75 and 100% GR rate respectively (Table 2 and 3) under rabi wheat (1982-83). Maximum increase of 2.8 ppm P (41.4%) was found with HCl treatment followed by 34% increase with $H_2SO_4$ amendment but their differences were non-significant (Table 3). The increase in available P of calcareous saline-sodic soil with acids may be due to reduction in pH, [2] and increased solubility of in-organic soil phosphates [5-8]. The decrease in availability of P with gypsum might be due to immobilization of soluble P by $CaSO_4$ into insoluble form of phosphorus, the common ion effect and the removal of P by the growing plants [3,14,4].

Table 4 shows that various amendments produced significant influence on available potassium and depths were non-significant after rice crop (Kharif 1982). The mean values for both the depths indicated statistically higher status of available potassium in the upper layer compared to lowr layer. The mean values of treatments showed that there was no definite trend of available potassium in various treatments. Similar results were observed by Baig [7] with acid and by Sharma *et al.* [9] with gypsum amendment, while Afzal [10] noted a decreased availability of K in soil under calcium soluble amendments.

However, there is appreciable increase in available K after rice crop (Table 4) compared to available K (Table 1). The differences created after amendments application and growth of rice crop might be due to dominance of quartz and mica [21]. As the clay lattice of these minerals expand under flooded condition and thus fixed potassium was released in the soil solution.

Table 3 Available soil phosphorus (ppm) during reclamation of calcareous saline-sodic khurrianwala soil series after rice and wheat crops (av of 4 repeats).

| Amendments | Rice after crop Kharif, 1982 | | | Wheat after crop Rabi, 1982-83 | | |
|---|---|---|---|---|---|---|
| | 0-15 | 15-30 | Mean | 0-15 | 15-30 | Mean |
| Control | 11.62 | 5.15 | 8.39ab | 12.18 | 4.10 | 8.14a |
| Gypsum (75% GR) | 7.38 | 1.90 | 4.64c | 7.35 | 1.92 | 4.64a |
| Gypsum (100% GR) | 8.55 | 3.08 | 5.82bc | 7.22 | 2.60 | 4.19c |
| $H_2SO_4$ (75% GR) | 13.22 | 4.82 | 9.02ab | 13.50 | 4.48 | 9.19a |
| HCl (75% GR) | 14.45 | 5.22 | 9.84a | 14.88 | 4.38 | 9.63a |
| $CaCl_2$ (75% GR) | 9.95 | 3.45 | 6.70abc | 9.80 | 3.28 | 6.04bc |
| Mean | 10.86a | 3.94a | | 10.82a | | 3.3ab |

| | Treatments | | Depth | | Treat. depth. | |
|---|---|---|---|---|---|---|
| | Rice | Wheat | Rice | Wheat | Rice | Wheat |
| Stat. Sign | Sig | H. sig | H. sig | H. sig | N. sig | N. sig |
| LSD (P = 0.05) | 3.01 | 2.79 | 1.75 | 1.61 | – | – |
| S. E. ± | 1.48 | 1.37 | 0.86 | 0.79 | 2.10 | 1.94 |

Means sharing the same letter do not differ significantly at P = 0.05).

Data in Table 4 further depict that changes in soil potassium status were non-significant under different amendment, however, potassium differed significantly due to depths after wheat crop (Rabi 1982-83). Control treatment maintained higher K content after wheat than after rice crop harvest. Table 4 clearly demonstrated that available K decreased after wheat harvest compared to rice harvest (Kharif, 1982). This decrease may be due to K uptake by wheat crop and K fixation under alterante wetting and drying during wheat crop [22].

Table 4 shows that acids and soluble calcium amendments did not affect the availability of K and these results differ than those of Baig [7] where K content increased under acid reclamation of calcareous alkaline soil. Sharma *et al.* [9] also did not find any effect of K availability in calcareous saline-sodic soils with the application of gypsum amendment.

Table 5 shows that amendments and soil depths caused significant effect on soil pH. The soil pH was higher in the lower depth compared to upper one. The addition of amendments decreased pH compared to control. The acids were more efficient in decreasing soil pH compared to soluble calcium amendments. The reduction in soil pH was almost similar under both crops. These results corroborates with those of Sharma *et al* [9], Ryan *et al* [6] and Afzal [10] who observed reduction in soil pH during reclamation process by chemical amendments.

Data presented in Table 6 show that in general the acid application enhanced phosphorus concentration in wheat grain while that of gypsum and $CaCl_2$ depressed it. The maximum value of 0.406% P was observed under HCl treatment whereas minimum of 0.359% P was shown for $CaCl_2$ treatment. The amendments gypsum (75, 100% GR) and $CaCl_2$ were statistically non-significant amongst themselves, while HCl was significant as compared to gypsum and $CaCl_2$.

The lower concentration of P in wheat grain may be due to decreased availability of soil phosphorus by addition of gypsum and $CaCl_2$ in calcareous soils [15]. The addition of acids in calcareous soil caused increased availability of P, which resulted in higher P content in wheat grain under acid treatments [8].

Table 6 further shows that K content in wheat grain remained statistically non-significant due to treatments. The probable reasons may be that availability of K in soil solution which was independent of acids and calcium containing amendments [13]. However, others [15] observed decrease in K content in wheat grain with application of gypsum to calcareous saline-sodic soil.

Table 4. Available soil potassium (ppm) during reclamation of calcareous saltine-sodic khurrianwala soils series after rice and wheat crops. (av. of 4 repeats).

| Amendments | Rice after crop Kharif, 1982 | | | Wheat after crop Rabi, 1982-83 | | |
|---|---|---|---|---|---|---|
| | 0-15 | 15-30 | Mean | 0-15 | 15-30 | Mean |
| Control | 440.7 | 352.9 | 386.8a | 407.5 | 347.1 | 377.3 |
| Gypsum (75% GR) | 401.7 | 319.8 | 360.8ab | 339.3 | 323.7 | 331.5 |
| Gypsum (100% GR) | 362.7 | 376.4 | 369.5ab | 321.8 | 317.8 | 319.8 |
| $H_2SO_4$ (75% GR) | 345.2 | 312.0 | 328.6b | 352.9 | 315.9 | 334.4 |
| HCl (75% GR) | 429.0 | 382.0 | 405.6a | 351.0 | 360.8 | 355.9 |
| $CaCl_2$ (75% GR) | 401.7 | 312.0 | 356.9ab | 374.4 | 312.0 | 343.2 |
| Mean | 396.8a | 342.6b | | 357.8a | 329.6b | |

| | Treatments | | Depth | | Treat x depth | |
|---|---|---|---|---|---|---|
| | Rice | Wheat | Rice | Wheat | Rice | Depth |
| Stat. sign. | Sig | N. sig. | H. Sig | Sig | N. Sig. | N. Sig. |
| LSD (P = o.05) | 48.0 | – | 27.7 | 18.3 | | – |
| S. E. ± | 23.6 | 22.0 | 13.6 | 8.9 | 33.4 | 31.2 |

Mean sharing the same letter do not differ significantly at P = 0.05

Table 5. pHs of calcareous saline-sodic khurrianwala soil series during reclamation after rice and wheat crop (av. of 4 repeats).

| Amendments | After rice Kharif, 1982 | | | After wheat rabi, 1982-83 | | |
|---|---|---|---|---|---|---|
| | 0-15 cm | 15-30 cm | Mean | 0-15 cm | 15-30 cm | Mean |
| Control | 8.5 | 8.7 | 8.6a | 8.4 | 8.7 | 8.6a |
| Gypsum (75% GR) | 8.0 | 8.3 | 8.2b | 7.9 | 8.2 | 8.1b |
| Gypsum (100% GR) | 7.9 | 8.2 | 8.1b | 7.8 | 8.1 | 8.0b |
| $H_2SO_4$ (75% GR) | 7.8 | 8.0 | 7.9bc | 7.8 | 8.0 | 7.9b |
| HCl (75% GR) | 7.7 | 7.8 | 7.8bc | 7.7 | 7.9 | 7.8bc |
| $HcCl_2$ (75% GR) | 8.0 | 8.1 | 8.1b | 7.9 | 8.1 | 8.0b |
| Mean | 7.9a | 8.2b | | 7.9a | 8.2b | |

| | Treatments | | Depth | | Treat. depth. | |
|---|---|---|---|---|---|---|
| | Rice | Wheat | Rice | Wheat | Rice | Wheat |
| Stat. Sig. | H. Sig. | H. sig | Sig. | Sig. | N. sig. | N. sig |
| LSD (P = 0.05) | 0.24 | 0.21 | 0.24 | 0.22 | – | – |
| S. E. ± | 0.11 | 0.11 | 0.11 | 0.10 | 0.10 | 0.54 |

Means sharing the same letter do not differ significantly at P = 0.05.

Table 6. Phosphorus and potassium concentration(%) in wheat grain as affected by four amendments during reclamation of calcarious saline-sodic khurrianwala soil series. (average of 4 repeats).

| Amendments | Nutrients concentration % | |
|---|---|---|
| | P | K |
| Control | 0.375 ab | 0.207 |
| Gypsum (75% GR) | 0.360 b | 0.208 |
| Gypsum (100% GR) | 0.362 b | 0.225 |
| $H_2SO_4$ (75% GR) | 0.402 ab | 0.214 |
| HCl (75% GR) | 0.406 a | 0.223 |
| $CaCl_2$ (75% GR) | 0.359 b | 0.217 |
| S. E. ± | 0.012 | 0.0134 |

Means sharing the same letter do not differ significantly at P = 0.05.

Table 7. Phosphorus and potassium concentration (%) in wheat straw as affected by four amendments during reclamatin of calcareous saline-sodic khurrianwala soil series. (average of 4 repeats).

| Amendments | Nutrients concentration (%) | |
|---|---|---|
| | P | K |
| Control | 0.077 | 1.115 |
| Gypsum (75% GR) | 0.072 | 1.084 |
| Gypsum (100%) GR) | 0.072 | 1.245 |
| $H_2SO_4$ (75% GR) | 0.083 | 1.140 |
| HCl (75% GR) | 0.090 | 1.190 |
| $CaCl_2$ (75% GR) | 0.069 | 1.086 |
| S.E. ± | 0.025 | 0.082 |

Data in Table 7 indicate that various amendments produced statistically non-significant effect on phosphorus content in wheat straw. The slight decrease in P content may be due to decreased soil availability of P in gypsum added calcareous soil [15]. However, soil acidification caused little increase in P content in wheat straw, due to increased available soil P by reducing pH and dissolution of insoluble phosphate compounds [10].

Table 7 also depicts that K content also remained statistically unaffected due to various amendmentsts. However, addition of acids increased K content, while addition of $CaCl_2$ and gypsum (75% GR) decreased it. The results corroborates with those of [13-18] who concluded that addition of gypsum and acids in the soil did not influence the K concentration in plant organs of sorghum and maize, due to non-availability of K in soil.

Table 8 represents a significant effect of amendments on the total phosphorus uptake by wheat grain and straw. Statistically, HCl (75% GR) treatment differed greatly from all other amendments. However, total P uptake increased with acids and gypsum (75 and 100% GR) with the exception of $CaCl_2$. The results are with those of [10, 14-16] who revealed the increased uptake of phosphorus by tomato, sorghum and wheat plants growing on calcareous alkaline soil with added acids. Sherma *et al.* [9] also found increased P uptake by rice plant on calcareous gypsum added soils. So the increased uptake of P was attributed to the increased yield of rice plant [8].

Table 8. Total uptake of phosphorus and potassium (kg/ha) by wheat as affected by four amendments during reclamation of calcareous saline-sodic khurrianwala soil series. (Average of 4 repeats).

| Amendments | Nutrients up take (Kgs/ha) | |
|---|---|---|
| | P | K |
| Control | 1.11 b | 45.31 |
| Gypsum (75% GR) | 14.05 ab | 62.74 |
| Gypsum (100% GR) | 13.30 b | 64.58 |
| $H_2SO_4$ (75% GR) | 15.65 ab | 62.22 |
| HCl (75% GR) | 19.00 a | 66.72 |
| $CaCl_2$ (75% GR) | 10.72 | 43.89 |
| S.E. ± | 1.70 | 14.14 |

Means sharing the same letter do not differ significantly at P = 0.05.

Data in Table 8 also show that potassium uptake by wheat grain and straw remained statistically unaffected due to treatments. The potassium content in wheat plant also remained unaffected due to various amendments (Table 6 and 7), hence likewise total K uptake remained unaffected due to treatments. Many other research workers [12,13] also concludded that K content in sesbania and maize plant as well as in soil remained unaffected due to acid treatments and thus total K uptake also remained unaffected.

## REFERENCES


1. S. Muhammad, Workshop on Membrane Biophysics and Development of salt tolerance in plants. Univ. Agri. Faisalabad. (1981) pp. 47-67.
2. T. Hussain and M.A. Main, Pakistan J. Soil Sci., **1**, 19 (1983).
3. P.H. Hsu and M.L. Jackson, Soil Sci. **90**, 16 (1960).
4. M.A. Bajwa, S.P.S. Brar and V. Kumar, Indian J. Ecol., **9**, 41 (1982).
5. J. Rvan and J.L. Strohlein, Soil Sci. Soc. Amer. Proc. 43, 73 1 (1979).
6. J. Ryan, J.L. Strohlein and S. Miyamoto, J. Range Management **28**, 411 (1975).
7. M.A. Baig. M.Sc. Thesis, [Univ. Agri. Faisalabad (1980)] pp. 1-33.
8. M. Younas, M. Sc. Thesis, [Univ. Agri. Faisalabad (1982)] pp. 1-49.
9. R.A. Sharma, B.S. Bhargava, S.K. Rastogi and R.S. Churayya, Indian J. Agri. Res., **9**, 102 (1975).
10. M. Afzal M. Sc. Thesis, [Univ. of Agri. Faisalabad (1976)] pp. 1-41.
11. S.R. Poonia and D.R. Bhumbla, plant and soil, **40**, (1-3), 557 (1971).
12. P.D. Christensen and P.J. Lyerly, Soil Sci. Soc. Amer. Proc., **18**, 433 (1954).
13. M.A. Baig, M.Sc. Thesis, [Univ. of Agri Faisalabad (1980)] pp 1-42.
14. J. Ryan, S. Miyamoto and J.L. Strohlein, Plant and soil, **46**, 629 (1977).
15. K.S. Verma and I.P. Ibrol, Indian J. Agri. Sci. **50**, 925 (1980).
16. E.A. Magid, M.A. Mustafa and I. Ayed, Exptl. Agri. **18**, 177 (1982).
17. U.S. salinity Lab. Staff, USDA Handbook 60, Ist Ed. pp 1-160, Washington, DC, USA (1954).
18. F.S. Watanabe and S.R. Olsen, soil Sci. Sco. Amer. Proc. **29**, 677 (1965).
19. D.G. Duncan, Biometrics **11**, 1 (1965).
20. R. Chahabra, I.P. Abrol and M. Singh, Proc. Int. Symp. Salt Affected Soils. pp. 413-422, Central Soil Salinity Research Institute, Karnal, India (1982).
21. B.L. Mc Neal, Soil Sci. **102**, 53 (1966).
22. E. Grissinger and C.D. Jeffries, Soil Sci. Soc. Amer. Proc. 21, 409 (1957).