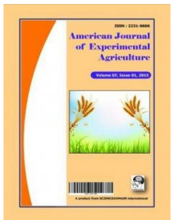

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Application of Different Reclamation Methods on Salt Affected Soils for Crop Production

P. I. Ezeaku[1*], J. Ene[1] and Joshua A. Shehu[1]

[1]*Department of Soil Science, University of Nigeria Nsukka, Nasarawa State Ministry of Agriculture, Lafia, Nigeria.*

Authors' contributions

This work was carried out in collaboration between all authors. Author JAS designed the study, wrote the protocol and wrote the first draft of the manuscript. Author PIE reviewed the experimental design and all the drafts of the manuscript. Authors JAS and PIE managed the analyses of the study. Authors JAS and PIE identified the plants. Authors JAS and JE performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Effects of salic conditions on soil properties under a given land use type and the methods for reclamation has not received the desired research attention in Nigeria. Understanding of how soil properties and crop yield respond to the influence of salic conditions is needed for employment of location-specific management strategies for the economic agricultural production. This study was conducted on salt affected soils during 2011/2012 and 2012/2013 crop years to investigate the soil physico-chemical properties and their effects on two maize cultivar growth and yield. Three approaches were employed to reclaim the salt affected soils in order to increase their efficiency and reduce the time of reclamation. Soils were sampled at two depth intervals: surface (0-15 cm depth) and subsurface (15-30 cm) for physical and chemical analysis. The experimental design was randomized complete block design (RCBD). The treatments were arranged in RCBD and replicated thrice. The treatment applications were 100% gypsum ($CaS0_4$) Gypsum requirement (GR); 25 Mg ha^{-1}gypsum + farm yard manure (FYM) and chiseling. Leaching with irrigation water was done over a period of 2-4 hours per week. During the two cropping seasons, rice and millet crops were grown.

**Corresponding author: E-mail: peter.ezeaku@unn.edu.ng;*

Data collected were analysed statistically following ANOVA technique and treatment differences were evaluated using LSD test. Pre-cultivation soil analysis revealed a mean soil bulk density value of 2.37 g cm^{-3} and a value of 17.46 for total porosity. Soil pH showed alkalinity (>pH 7.5) with high values of exchangeable bases and base saturation. Post-cultivation results show that highest yields of rice and millet were obtained from application of 100% gypsum. Yields obtained from gypsum + FYM treatments were, however, statistically similar. Yields from control treatment were consistently low. First millet post-harvest (2011/2012 crop year) soil test showed a reduction in electrical conductivity (ECe) value in all treatment plots except in control. The values of soil pH and sodium adsorption ratio (SAR) reduced after second millet harvest in 2012/2013 cropping season. The study found that soil chemical properties in control treatment did not improve, while combined use of gypsum + FYM + Chiseling appeared most effective in improving the soil conditions for land use sustainability.

Keywords: Maize/millet land use; soil salinity; improved methods; reclamation; sustainability.

1. INTRODUCTION

Fluctuations in climatic conditions result to salinity and sodicity of the soils of arid and semi-arid regions. The presence of sodium salts in the soil does not create a problem per se but the excess of it. As water evaporates from the surface of the soil, salts dissolved in water accumulate slowly and gradually on the surface of the soil. Sometimes they precipitate and accumulate on the surface of the soil. It is reported that the accumulation causes damages to soil physico-chemical properties and crop productivity [1,2].

Capillary action from the saline water table and higher concentration of salt water in the soil are the causes of increases in soil salinity. It is reported that approximately 932 million ha of land available for agriculture worldwide are affected by salinity and sodicity [3]. Of this area, 23% of arable land is affected by salinity, while 10% is affected by saline-sodic conditions.

Concentrated sodium ions in soils have been observed to cause damage to plant tissues, resulting to reduction in plant growth and sometimes plant death [4,5]. Hence, alkaline cultivated soils result to low maize crop yields [6]. Poor crop growth and performance has been associated to soil nutritional disorders (K^+, Ca^{2+}, and Zn^{2+} deficiency and Na^+ toxicity) [7]. The report further showed that Na^+ was the dominant cation in the exchange complex and may deteriorate the soil's physical properties. Reclamation of such soils is essentially through application of soluble source of calcium (Ca^{2+}), which is sourced from gypsum. Gypsum has been shown to be most commonly used for reclamation of sodic soils and for the improvement of soil water infiltration [8].

The emphasis on economic agricultural production is based on application of appropriate and sustainable management practices. It is reported that reclamation of salt affected soils can be achieved with different approaches [6]. Chemical, biological and agronomic techniques are the prominent ones. Combinations of these approaches increase the reclamation efficiency and also reduce the time of reclamation. Other benefits in the use of these integrated approaches include increased crop production and fertilizer use efficiency. It is reported that use of soil amendment preferably gypsum and organic manure resulted to maximum and sustained crop yields, improved soil health and agricultural input use efficiency [9].

Some physical methods of reclaiming salt affected soils include: deep tillage, sub soiling, sanding, periodic water application to flush salt out through the soil column and use of acid forming fertilizers to raise the acid status of the soils. It is reported that subsoiling [50+5 cm crosswise furrows (20-150 cm apart)] and rice-wheat crop rotation were found most effective in reclaiming saline-sodic soils [10].

Some soils in Keana community of Nasarawa State of Nigeria are affected by saline conditions. The community has long history of mining and processing the saline salt for economic reason. The locales mostly employ the use of crude methods in the mining business. The presence of higher concentration of salts on the soils would have consequent effect on cultivated crops and overall agricultural productivity of the area. Better understanding of how application of different methods could reclaim saline soils for sustainable maize/millet production is needed in applying location-specific management actions. The aims of the study were: to quantify the status of salinity of the soils; and test the efficacy of the applied reclamation methods on the improvement of salt-affected soils' productivity, over two crop (maize/millet cultivar) production cycles.

2. MATERIALS AND METHODS

2.1 Description of the Study Location

The study was conducted in 2012 and 2013 crop years at the salt mining village in Keana town, which serves as the Headquarter of Keana Local Government Area (LGA) of Nasarawas State, North Central Nigeria. Keana L.G.A has a population of 253, 186 (10). It is located Latitude 8°05' 00" E; Longitude 8°45' 27" N and altitude of 600m above sea level, masl (Ministry of Land and Survey, 2006). The weather is that of tropical humid type with distinct rainy and dry seasons. Keana has a mean annual rainfall of 1553.28 mm; mean annual maximum temperature of 34.12°C, minimum of 22.60°C [11].

The area is characterized by a gently undulating topography with a soil type of mostly loam [12]. Cereal cropping system of maize, millet, sorghum and rice is the main agricultural land use of the area.

2.2 Field and Laboratory Techniques

The field study site was identified after a reconnaissance visit to know the nature of the salt affected soils and type of reclamation measures to take; drainage characteristics, topography and presence of hard pan. The first site was one hectare of land under no cultivation of crops and quite adjacent to the salt water pond. Soil samples were randomly taken from the fields at the depth of 0-15 and 15-30 cm following difference in vegetation pattern. These depths represented the depth of tillage where most nutrients and organic matter are found [13]. Samples for the field were composited and bulked, taken to the laboratory, air dried and passed through 2 mm mesh for physical and chemical determinations. Water samples were taken from the salt pond for determination of Na^+, ca^{2+} and Mg^{2+} load.

Second field study was cultivation of the selected field soil. The land was cleared, leveled and plots prepared. Leveling was to ensure uniform application of water and prevention of accumulation of water in the field. The experimental design was randomized complete block design (RCBD). The treatments and their combinations were arranged in RCBD and replicated thrice. The following treatments were used for the experiment: T_1 = Control; T_2 = Gypsum @100% GR; T_3= T_2+ Light cultivation (chiseling); T_4= T_2+ farm yard manure (FYM) @ 25tha^{-1}; T_5= T_2+ chiseling + FYM@ 25tha^{-1}. The soils in $T_3$and T_5were tilled with ox driven chisel plow whereas other treatments were prepared manually with hoe. The gypsum and FYM were applied with subsequent leaching with drainage water.

Rice and millet were grown in sequence for two years (2011/2012 and 2012/2013 crop years). The yield data was recorded at maturity and analyzed statistically using critical difference (CD) test [14]. Post-harvest soil samples were collected from 0-30 cm soil depth after each harvest. This depth is reasoned to provide favorable environment for feeder crops that are not deep rooted. It is noted that soil physical and chemical characteristics at the two depths (0-15 and 15-30 cm) are usually related to cereal crop yield.

Other field studies include soil sampling. Twelve core samplers (volume = 96.6 cm^3) were used to collect undisturbed soil samples. They were properly labeled for easy identification in the laboratory. They were weighed; oven-dried for 24 hours at 105°C and re-weighed. The weights obtained thereafter were used to determine bulk density, porosity and moisture content parameters. These physical characteristic determinations were done at Agronomy laboratory of College of Agriculture, Lafia, Nasarawa State, Nigeria.

2.3 Laboratory Determinations

Soil samples from the field were air-dried, gently crushed and sieved through a 2 mm mesh and analyzed in the laboratory for the following properties: Soil particle size distribution, soil p^H, total N, Organic carbon, available P, exchangeable bases (Ca, Mg, Na and K), and cation exchange capacity (CEC). Total acidity, basic saturation and sodium adsorption ratio were also determined.

Particle size distribution (textures) was obtained by the hydrometer method [15]. Soil pH was determined using Beekman Zeromatic p^H meter after equilibrating for 30 minutes [10]. Organic carbon, total N and available phosphorus were measured by wet-oxidation method [16,17], Micro kjeldahl method [18], respectively. N_a and K were obtained by using the flame photometer, while soluble Ca^{2+} and Mg^{2+} were determined by atomic absorption spectrophotometer (AAS) [19]. These determinations including soluble salt content (TSS) were done at the standard laboratory of Federal College of Land Resources Technology, Kuru, Jos, Nigeria.

In terms of physical determinations, Bulk density was obtained by Blake and Hartge method [20], while percentage moisture content was calculate as:

$$\frac{\text{Weight of wet soil-weight of oven dry soil}}{\text{Weight of wet soil}} \times \frac{100}{1};$$

Percentage porosity =

$$\frac{\text{wt. of wet soil-oven dry wt.}}{\text{Volume of sampler}} \times \frac{100}{1};$$

Exchangeable sodium percentage (ESP) =

$$\frac{\text{Exch. Sodium ions}}{\text{Soil CEC}} \times \frac{100}{1}$$

Sodium adsorption ratio (SAR) = $\frac{Na}{(\text{Ca2+ + Mg++})2}$

Gypsum requirement according to Schoonover's method was used.

2.4 Statistical Analysis

The data collected were analysed statistically following ANOVA technique and treatment differences were evaluated using least significant difference ($LSD_{0.05}$) test.

3. RESULTS AND DISCUSSION

3.1 Effects of Treatment on Soil Physical Properties

The results of the pre-treatment soil analysis are shown in Table 1. The soil has loamy sand texture. Sand fraction was predominant in relation to other size fractions in the study site. The values of bulk density (a measure of soil structure), range from 2.30 gcm^{-3} to 2.52 gcm^{-3} with a mean value of 2.37 g cm^{-3}. Mean percentage moisture content was 7, while that of percentage porosity was 17.5 (range: 9.2 – 26.5%).

Low values of infiltration rates and percentage porosity obtained in the study soils have implication to agriculture. Water retention will be high. This is not surprising because alkalinity usually make soils impermeable to water and air. Soils with good water retention and without salinity favor rice production. However, if soils are affected by salinity, leaching of the salts can be enhanced through application of gypsum +FYM + Chiseling to better improve soil porosity and hydraulic conductivity.

The results of pre-cultivation soil chemical analysis show that soil p^H range from 7.40 to 7.90 with a mean of 7.7 (Table 2). Soils with such high pH values are alkaline. Soils with high alkalinity may be associated to large quantities of exchangeable bases (Ca = 18.64 $Cmolkg^{-1}$; Mg = 1.535 $Cmolkg^{-1}$; K = 4.925 $Cmolkg^{-1}$ and Na =4.305 $Cmolkg^{-1}$) and high percentage base saturation (86.8%) as obtained in the soils studied (Table 2). Value of sodium adsorption ratio and exchangeable sodium percentage was found to be 1.68 and 12.75%, respectively. These values are low and a further confirmation that the soil was alkaline (Table 2).

The results of the water analysis in Table 3 show the following elemental values: 43.066 (Ca^{2+}), 3.965 mg L^{-1} (Mg^{2+}), and 1.7400 (Na^{+}). These values of exchangeable cations are high, an indication that the water was alkaline.

3.2 Treatment Effects on Soil Chemical Properties

The value of soil pH was above 7.5 and could be regarded as high and alkaline in character. It is reported that high soil pH denotes high preponderance of sodium (Na^{+}) among the basic cations and carbonate/bicarbonate among the anions. Sodium value decreased in all the treatment plots except in that of control as could be seen in Figs. 1 and 2.

The leaching of the soils with pure water and the application of the treatments as soil amendments during the transplanting of rice in 2012 increased significantly the soil pH.

Table 1. Mean saline-soil physicalpoperties at Kean location

Core	Sand (%)	Silt (%)	Clay (%)	Textural class	Bulk density (gcm^{-3})	Moisture content (%)	Porosity (%)
A	54	36	10	Loamy sand (LS)	2.33	5	12.21 21.36
B	57	34	9	LS	2.44	8	16.27
C	55	36	9	LS	2.30	6	19.33
D	56	36	8	LS	2.37	8	26.45
E	58	36	6	LS	2.52	11	9.16
F	50	39	11	LS	2.30	4	17.46
Mean	55	36.2	8.8	LS	2.37	7	
				LS			

Table 2. Mean saline-soilchemical properties at Kean location

Particle size analysis					Exchangeable bases Cmol/kg				%		ppm	Cmol/kg			%		%
Depth (cm)	Sand %	Silt %	Clay %	Textl. class	Ca	Mg	K	Na	OC	TN	P	CEC	pH (H_2O)	Exch. Acidity	BS	SAR	Esp
0-15	80	18	2	LS	18.54	1.60	5.37	3.83	0.74	0.070	43.75	36.0	7.40	0.10	81.50	1.21	10.64
15-30	78	18	4	,,	18.74	1.47	4.48	4.78	0.74	0.053	43.75	32.0	7.90	1.10	92.09	2.18	14.94
Mean	79	18	3	,,	18.64	1.54	4.93	4.31	0.74	0.062	43.75	34.0	7.65	0.60	86.79	1.68	12.75

NB: ESP = Exchangeable sodium percentage, SAR = Sodium adsorption ratio, TN = Total nitrogen, P = phosphorus, BS = base saturation, LS = loamy sand, Ca = calcium, Mg = magnesium, k = potassium, Na = sodium, OC= organic carbon

Table 3. Mean saline water chemical properties at Keana location

Element	mg L^{-1}
Magnesium (Mg^{2+})	3.9647
Calcium (Ca^{2+})	43.0664
Sodium (Na^{+})	1.7400

Specifically, the increased soil pH was higher in plots treated with gypsum (T_2) alone when compared to T_3 (gypsum + chiseling), T_4 and T_5 (gypsum + fym + chiseling).

The cultivation of maize/millet and the application of the soil reclamation treatments particularly gypsum at 100% and in combination with FYM reduced soil pH and other soil properties that promote salinity and sodicity except in control where the soil pH value remained greater than 8.5. It was observed that soil p^H values started decreasing gradually after harvesting of each crop. In all the treatment plots except control, the soil p^H reduced to less than 8.0.

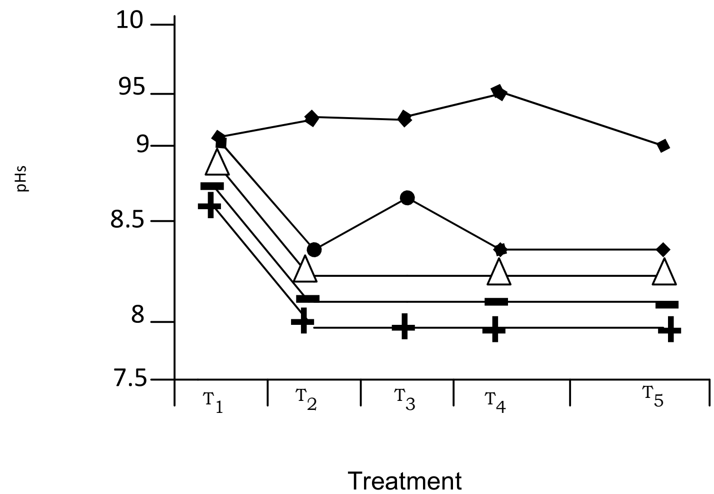


Fig. 1. Pre- and post-cropping soil analysis for soil pH at surface depth (0-15 cm)
Key: □ Original analysis; ○ Post rice 2012; ∆ Post millet 2011-2012; − Post rice 2013; + Post millet 2012-13

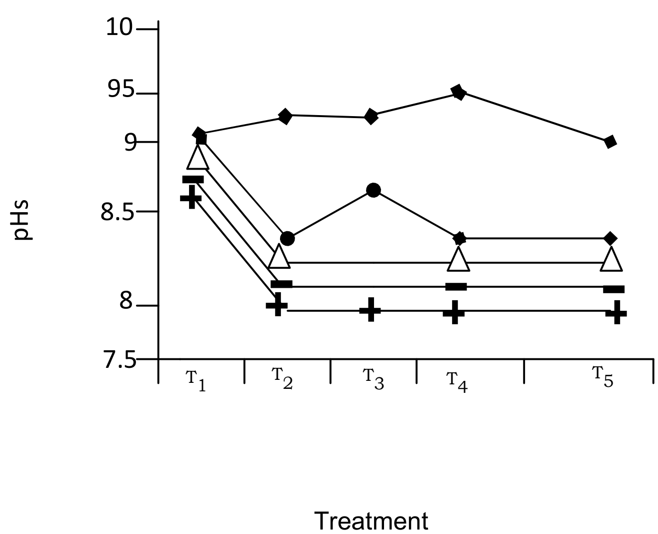


Fig. 2. Pre- and post-cropping soil analysis for soil pHs at sub-surface depth (15-30 cm)
Key: □ Original analysis; ○ Post rice 2012; ∆ Post millet 2011-2012;− Post rice 2013; + Post millet 2012-13

The results also show that soil pH at the subsurface depth (15-30 cm) reduced in all treatments plots, except in control, after harvesting millet in the 2012/2013 crop years. The removal of carbonates and bicarbonates of Na^+ to a greater extent during the crop production cycle and application of the reclamation treatments may have contributed to the lowering of the soil pH. These study findings are in tandem with earlier report [21], which noted that the application of gypsum at $12tha^{-1}$ and other cultural practices during reclamation of dense sodic soil decreased soil p^H values from 10.2 to 9.1.

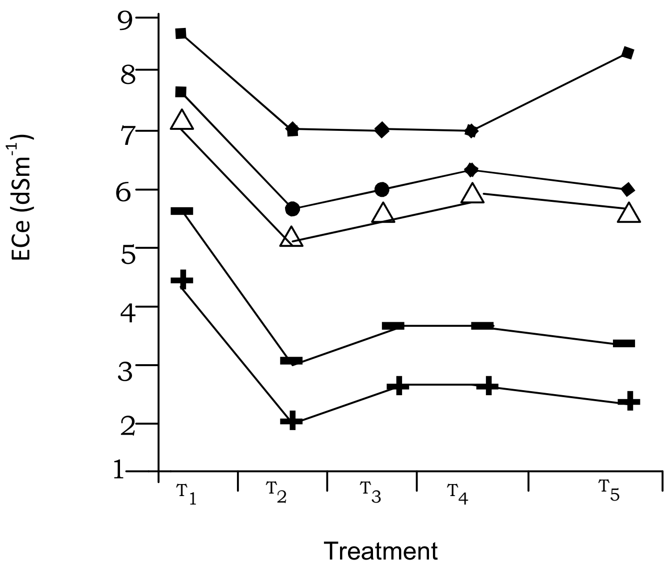


Fig. 3. Pre- and post-cropping soil analysis for ECe at the surface depth (0-15 cm)
Key: □ Original analysis; ○ Post rice 2012; ∆ Post millet 2011-2012; − Post rice 2013; + Post millet 2012-13

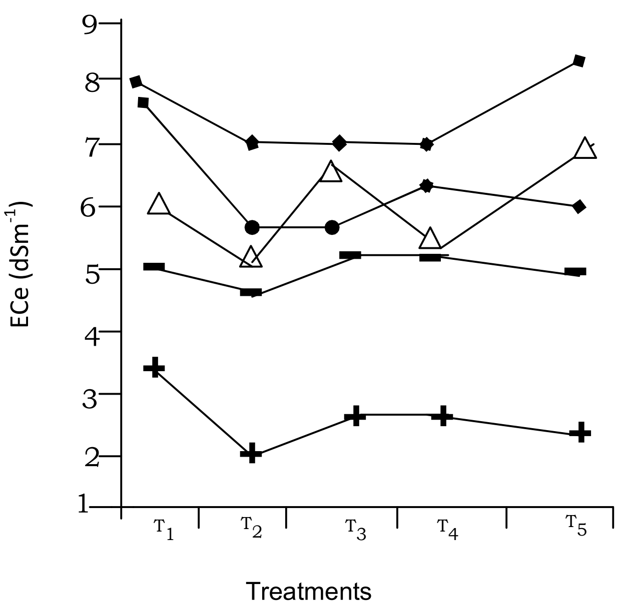


Fig. 4. Pre- and post-cropping soil analysis forECe (15-30cm)
Key: □ Original analysis (Pre-); ○ Post rice 2012; ∆ Post millet 2011-2012; − Post rice 2013; + Post millet 2012-13

The results of electrical conductivity of the soils at two depth intervals (0-15; 15-30 cm) are shown in Figs. 3 and 4. The application of gypsum at 100% GR (T_2) alone or a combination of gypum + FYM (T_4) significantly (p=0.05) decreased electrical conductivity (ECe) of the soils excluding those of the control plots. The decrease in ECe might be attributed to the loamy sand texture of the soil. A related study reported decrease in ECe when either gypsum at 100% alone and/or a combination of gypum + FYM (T_4) are applied. The report showed rapid decrease of ECe from 2.1 to 0.8 d.Sm^{-1}on applications of reclamation treatments at first year of cropping [22]. However, the rate of amelioration was found slower in subsequent amendments application. The report further showed that ECe was higher in the lower soil depth than in the upper soil depth, suggesting downward movement of salt due to reclamation process. This report synergizes with the finding in this study, which shows decrease of ECe after harvesting of first rice in 2011 crop year. However, after crop harvest in 2012/2013, the value of ECe gradually decreased to a tolerable level in the lower soil depth.

Figs. 5 and 6 present results of sodium adsorption ratio (SAR). The application of the different treatments significantly (p=0.05) decreased SAR. The magnitude of the decrease in SAR was of the following treatment order:T5 (gypsum + fym +chiseling) > T_4 (gypsum + fym) > T_2 (gypsum) alone. The lower magnitude of T_2 (gypsam @ 100% GR) in decreasing SAR might be associated to slow reaction of gypsum. It was observed that after harvesting the first rice crop, SAR reduction was more with T_4 (gypum + fym @ $25tha^{-1}$) application. This suggests that T4 was the most efficient reclamation treatment than the rest.

After harvesting of 3rd rice cropped in 2013, SAR decreased to safe limits in all treatments except control. Significant reduction in SAR means removal of exchangeable Na from the soil complex. Under such situation, the soil could be regarded as being reclaimed. The study also found that the rate of decrease of SAR was greater in top soil layer than in subsoil depth. The decreasing pattern could be associated to the decreasing ca^{2+}: Na ratio in the soil solution, which phenomenally moves down the profile to displace sodium (Na^+).These results are synonymous with a previous report [23].

3.3 Treatments Effect on Crop Yields

Data on biomass and grain yield of rice and millet are presented in Table 4.The results show that leaching of the soil with pure water, application of the ameliorative treatments, including timely weeding significantly increased rice and millet biomass in 2012 when compared with those of control. The increase in biomass was higher in plots treated with gypsum (T_2) alone and $T_4$when compared to T_3 (gypsum + chiseling) and T_5 (gypsum + fym + chiseling).

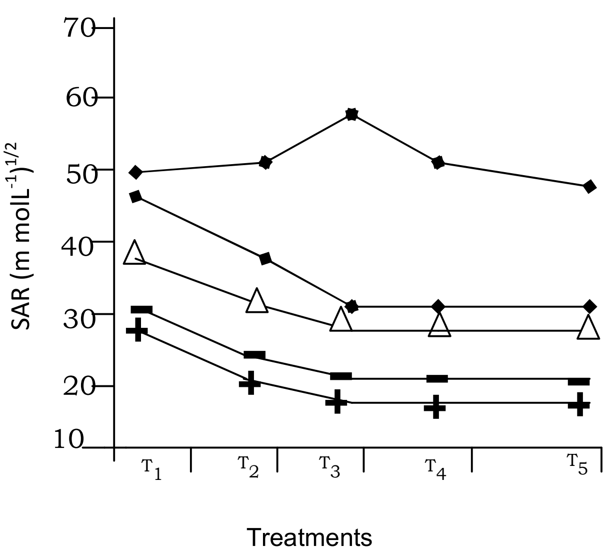


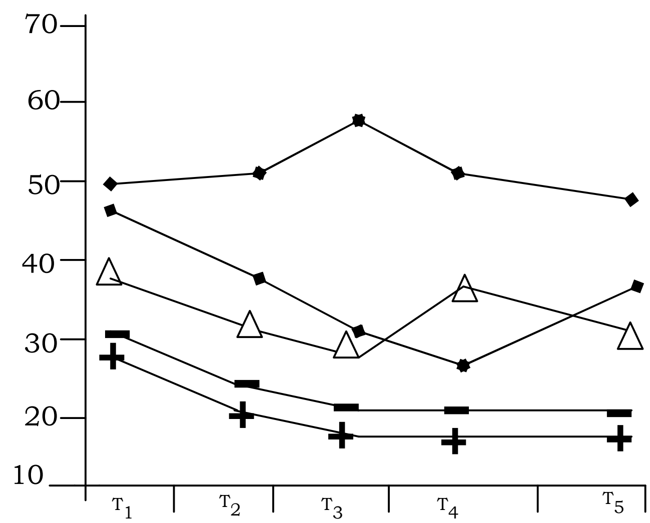
Fig. 5. Pre- and post-cropping soil analysis for SAR at the surface depth (0-15 cm)

Key: □ Original analysis; ○ Post rice 2012; ∆ Post millet 2011-2012;− Post rice 2013; + Post millet 2012-13

It was observed that application of the treatments decreased rice paddy yield in the magnitude order of 1.02 Mg ha^{-1} (bioremediation)< 1.41 Mg ha^{-1} (subsoiling)< 1.84 Mg ha^{-1} (gypsum + subsoiling)< 1.99 Mg ha^{-1} (gypsum).

In 2011/2012 crop year, millet grain yield (2.72 $Mgha^{-1}$) was higher in Gypsum + subsoiling treated plots followed by subsoiling (1.79 $Mgha^{-1}$). Lowest yield was obtained in bioremediated (1.46 $Mgha^{-1}$) plots. However, the millet grain yield reduced during 2012/2013in FYM treated plots when compared to gypsum alone. The reduction in millet yield could be due to fading effect of farm yard manure (fym) with passage of time.

The study found that plots treated with gypsum + farm yard manure + chiseling produced consistently higher biomass and grain yield of rice/millet in all the years than those produced in Gypsum + chiseling treatment plots. However plots treated with gypsum + chiseling produced higher cereal crop yields than control (T_1) plots. Other treatment plots equally produced biomass and grain yields but not to the magnitude of T5. These results suggest that the applied treatments had significant effect in improving the saline soil properties and crop productivity. The use of gypsum + H_2S04 + Farm yard manure was reported as the most superior combination for enhancement of crop yield and improvement of soil physico-chemical properties of salt affected soil [23].



Treatment

Fig. 6. Pre- and post-cropping soil analysis for SAR (15-30 cm soil depth)

Key: □ Original analysis; ○ Post rice 2012; ∆ Post millet 2011-2012; − Post rice 2013; + Post millet 2012-13

Table 4. Biomass and grain yield of Paddy and Millet ($Mgha^{-1}$) during 2012-13 crop years

Treatment	Rice 2012		Millet 2012-13		Rice 2012		Millet 2012-13	
	biomass	paddy	biomass	grain	biomass	paddy	biomass	grain
T_1	6.84^{C}	1.04^{c}	8.22^{c}	2.13^{c}	10.33^{c}	1.62^{c}	6.97^{c}	2.06^{c}
T_2	13.30^{ab}	2.70^{a}	8.40^{bc}	2.61^{a}	18.35^{a}	3.00^{11}	10.66^{a}	3.08^{a}
T_3	11.13^{b}	2.05^{b}	7.82^{c}	1.96^{d}	14.41^{b}	2.38^{b}	8.54^{b}	2.76^{b}
T_4	13.96^{a}	2.72^{a}	10.21^{a}	2.60^{a}	17.24^{a}	3.10^{a}	10.36^{a}	2.96^{ab}
T_5	12.81^{ab}	2.39^{ab}	9.10^{6}	2.41^{b}	17.91^{a}	2.94^{a}	8.86^{b}	2.83^{ab}
LSD	2.476	0.5485	0.6.948	0.1096	1.740	0.3857	0.3471	0.2146

Means sharing same letters are statistically at par at 5% level of probability

4. CONCLUSION

The study showed that rice/millet biomass and grain yield were higher when gypsum at 100% treatment was applied alone, followed by gypsum + farm yard manure. Gypsum therefore proved the best treatment. Treatment 5 (Gypsum + farm yard manure + chiseling) performed better on improving the soil properties. Most important management options are disposing of saline drainage water and reclaiming fields whose productivity is limited by salinity [24]. In saline soils with high enough salt levels which can damage plants and reduce growth, reclamation with excess water is recommended, provided there are good quality water and adequate drainage. The excess salts must be removed from the root zone. The initial salt content of the soil, desired level of soil salinity after leaching, depth to which reclamation is desired and soil characteristics are major factors that determine the amount of water needed for reclamation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Nasarawa Agricultural Development Program (NADP). Weather Records.P4-16 National Population Commission, 2006. Bulletin 13. 2005;1-6.
2. Sharma RK, Sharma TK. Irrigation Engineering (including Hydrology). S. Chand and co. Ltd. Ram Nagar, New Delhi-110055. 2004;210.
3. Steel RGD, Torrie JH. Principles and Procedures of statistics. A Biometrical Approach.2nd ed. McGraw Hill Book. Coy, Inc. N.Y. USA. 1980; 663ppt xxi.
4. Food and Agricultural Organization, FAO. Irrigation Water Management. Corporate Document Repository. Agricultural Department, FAO, Rome;1985.
5. Frazen D. Managing Saline Soils in North Dakota. In: NDSU Extension service. SL-1087 (revised). 2003;108.
6. Szabolcs I. Salt affected soils. 274, Boca Raton, CRC Press. USDA, Natural Resources Conservation Service (2002). Soil Conservationists. Salinity Management Guide - Salt Management; 1989. Available:http://www.launionsweb.org/salinity.htm
7. Dara SS. Environmental chemistry and pollution control. Int. Science Publication. John Wiley and Sons; 2004.
8. Gupta RK, Singh CP, Abrol IP. Disolution of gypsum in alkali solution. Soil Science. 1985;140:382-6.
9. US Salinity Laboratory Staff, USSLS. Diagnosis and Improvement of Saline and Alkali Soils. USDA Handbook No 60. Washington D.C. USA; 1954.
10. Mclean EO. Soil pH and Lime Requirements. In: A.L. Pape (ed) Methods of Soil Analysis. Part 2.2nd ed. Agron.Monogr. 9 ASA and SSSA, Madison W.I. 1982;199-224.
11. Nelson DW, Sommers CE. Total Carbon, Organic Carbon and Organic Matters. In: A.C. Pageand C.A. Black (eds). Methods of Soil Analysis Part 2, 2nd ed. Agron. Monogr. 9 ASA and SSA, Madison, W.I. 1982;539-579.
12. Ahmadu Bellow University, ABU. Soils of Assakio, Awe, Doma, Keana, Lafia and Obi. Ahamdu Bellow University Press. 1983;16-39.
13. Ezeaku PI, Akamigbo FOR, Asadu CLA. Maize yield predictions based on soil fertility parameters in Southeastern Nigeria. Journal of Agro Technology and Extension. 2002;2(2):30-38.
14. Swarp A. Chemistry of sodic soils and management. In: Advances in sodic land reclamation. INT. Conf. on Sustainable Management of Sodic Lands, Lucknow. 2004;27-52.
15. Day PR. Particle Fractionation and Particle Size Analysis. In C.A. Black (ed). Methods of Soil Analysis.Part 1.Agron. Monogr.9 ASA. Madison, W.I. 1965;545-567.
16. Olsen SA, Sommers CE. Phosphorus. *In*: A.L. Page, C.A. Black (eds) Methods of Soil Analysis. Part 2.2nd ed. Agron. Monogr. ASA and SSSA, Madison, W.I. 1982;403-430.
17. Odiete I, Ejekwolu CA, Aadamu JU, Adegboye MA. Different ratios of P-fertilization on some yield indices of Irish potato (Nicola spp) under a typicHaplustalfs at kuru, Jos. Production Agriculture &Technology. 2006;2(1):14-20.
18. Bremmer YM, Mulvaney CS. Total N. In: Page et al. (Ed.) Methods of Soil Analysis, Part 1. Agron.Monogr.9 ASA and SSSA. Madison, W.I. 1982;595-626.
19. Rao DIN, Singh NF, Gupta RK, Tyagi NK. Salinity Management for Sustainable

agriculture. Control Sol. Salinity Res. Inst., Kamal, India. 1994;314.
20. Blake GR, Hartge KH. Bulk density. In Methods of Soil Analysis, part 1, A. Klute (ed) Agron. No 9. USA Madison W.I. 1986;370-373.
21. Mohammed S, Kaliq A. Comparisons of Various Chemicals and Organic Amendments for Acclaiming Saline/sodic soils. Bull. Irrig. Rain. Flood Control Res. Council. 1975;5:50-4.
22. Sharma DP, Melita KK, Yador JSP. Effect of reclamation practices on soil properties and Crop growth on Farmers field. J. Indian Soc. Soil Sci.1982;29:35-60.
23. Hussain N, Hassan N, Irshadular G, Mojeed F. Evaluation of amendments for the improvement of physical properties of sodic soil. Int. J. Agric. Bio. 2001;3:319-22.
24. Mitchell JP, Shennan C, Singer MJ, Peters DW, Miller RO, Prichard T, Grattan SR, Rhoahes JD, May DM, Munk DS. Impact of gypsum and winter cover crops on soil physical properties and crop productivity when irrigation with saline Water. Agric. Water Manage. 2000;45:55–71.

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