Salt Affected Soils Evaluation and Reclamative Approaches for Crop Cultivation in Keana, Northcentral Nigeria

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Abstract

In this study, a field experiment was conducted on salt (saline) affected soils during the cropping seasons of 2004/2005 and 2005/2006 to evaluate the soil properties, determine their effects on two test crop performances, and its reclaim ability under three different approaches. Reclamative approaches were employed not only to increase efficiency but also reduce the time of reclamation. Soil samples were collected from the surface (0-15) and subsurface (15-30cm) soils for laboratory determinations. The soils were treated to gypsum (CaS04) at 100% GR alone; gypsum plus farm yard manure (FYM) at 25t/ha and chiseling. Leaching with irrigation water over a period of 2-4 hours per week was done. Rice and millet crops were grown for the two crop years. Result of pre-cultivation soils showed that the physical properties of bulk density had a mean value of 2.37gcm^{-3} and a low total porosity value of 17.46. Chemically, the soils are high in acidity (>pH 7.5) and then large quantities of exchangeable bases and high base saturation. Post-cultivation results show that gypsum application proved to be the best treatment giving highest grain yield of rice and millet. However, this treatment followed statistically similar results with gypsum + FYM. No application (control) remained low. Chemically, the pHs was reduced after harvesting of second crop (millet 2005-06). Electrical conductivity (ECe) was reduced after growing of first millet crop except control. The reduction of sodium adsorption ration (SAR) was more after the 2nd crop. The soil parameters in control treatment did not improve. The study concluded that continuation of gypsum + FYM + Chiseling was more effective in improving the soil condition for sustainable land use.

Keywords: Salinity, Reclamation, Gypsum, Farm yard manure, Cereal, Tropics

Introduction

Arid and semi-arid regions have always been characterized by permanent features of salinity and sodicity due to vagaries of climatic conditions (high temperature and low rainfall) that necessitate net movement of water upwards. The earth contains a considerable amount of sodium salts, which mere existence in the soil does not create a problem. However, it is the excessive salts that dissolved in water that accumulate slowly and gradually on the surface of the soil as the water evaporates that cause damages to soil properties and crop performance.

Soil salinity increases due to capillary rise from the saline water table and concentration of salt water in the field. Instances bound in Pakistan. Khan (1998) reported that about 6.68 million hectare (mha) land areas were salt affected and out of these 3.77 mha was saline and 2.91 mha was saline-sodic. This area in expected to increase with spread of water logging and salinity due to increase in canal irrigation and extensive exploitation of poor quality water for agriculture in non-canal commands. In India, Sharma and Sharma (2004) reported that about 6.73mha area was lying barren or produced very low and uneconomically yield of various crops due to excessive accumulation of salts.

Franzen (2003) reported that cultivation of crops especially maize in alkaline soils ultimately resulted in low crop yields. Earlier, Gary *et al* (1980) and FAO (1985) observed that concentrated sodium ion caused damage to plant tissue thus reduced plant growth and sometimes plant death. Similarly, Dara (2004) noted that nutritional disorders (Na^+, Ca^{2+}, and Zn^{2+} deficiency and Na^+ toxicity) resulted in poor crop growth. Arising from their studies, the dominant cation in the exchange complex was Na^+ and may deteriorate the soil's physical properties, thus, soluble source of Ca^+ was essential for reclamation of such soils. Gupta *et al.* (1985) noted that gypsum was the source of Ca^{2+} most commonly used to reclaim sodic soils and improve soil water infiltration.

The appropriate management of the constrained soil resources for the economic agricultural production is the main emphasis in agriculture. There are different approaches for reclamation of salt affected soils. The prominent ones are chemical, biological and agronomic. The combination of these approaches not only increases the efficiency but also reduce the time of reclamation. The crop production and fertilizer efficiency of these soils can be increased by integrated approaches i.e. use of amendment preferably gypsum and organic manure which helps in maximizing and sustaining yields, improving soil health and input use efficiency (Swarp, 2004).

The physical methods of soil reclamation include deep ploughing, sub soiling, sanding, flushing salt out through the soil by applying water periodically and use of acid forming fertilizers to raise the acid status of the soils. Mohammed and Ghafor (1986) reported that subsoiling (50+5cm crosswise furrows (20-150cm apart) and rice-wheat crop rotation successfully reclaimed two calcareous saline-sodic soils within a period of three years.

In Keana, a town in north central Nigeria, the community has long history of salt mining and processing but due to crude methods employed, the soils mighty have been affected. This would have consequent effect on cultivated crops and overall agricultural productivity of the area.

The objectives of the study were to: examine the extent of salinity of the soils; determine the efficiency of the applied reclamative approaches in improving the productivity of the salt affected soils under two crop production cycles.

Materials and Methods

Description of the study location: The study was conducted in 2005 and 2006 crop years at the salt mining village in keana town, which serves as the headquarter of Keana Local Government Area (LGA) of Nasarawa State, North Central Nigeria. Keana L.G.A has a population of 253, 186 (National Population Commission, Nasarawa State, 2006). It is located Latitude $8^0 05^' 00^{''}$ E; Longitude $8^0 45^' 27^{''}$ N and altitude of 600m above sea level, als (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 1553.28mm; mean annual maximum temperature of 34.12^0C, minimum of 22.60^0C (NADP, 2005).

The area is characterized by a gently undulating topography with a soil type of mostly loam (ABU, 1983). Cereal cropping system of maize, millet, sorghum and rice is the main agricultural use of the land.

Field and laboratory techniques: The field study site was identified after a reconnaissance visit to know nature of salt affected soils and type of reclamation measures to take; drainage characteristics, topography and presence of hard pan. The first site was an 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 (Ezeaku *et al.*, 2002). Samples for the field were composited and bulked, taken to the laboratory, air dried for physical and chemical determinations. Water samples were taken from the salt pond for determination of the Na^+, ca^{2+} and Mg^{2+} load.

Second field study was cultivation of the selected field. The land was cleared, leveled and plots prepared. Leveling was to ensure uniform application of water and prevention of accumulation of water in the filed. Treatments were arranged in randomized complete block design (RCBD) with three replications. 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_5 were 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. The yield data was recorded at maturity and analyzed statistically using critical difference (CD) test (Steel and Torrie, 1980).

Post harvest soil samples were collected from 0-30cm soil depth after each harvest. This depth is reasoned to provide favorable environment for feeder crops that are not deep rooted. Ezeaku *et al.* (2002) earlier noted that soil physical and chemical characteristics at the two depths (0-15 and 15-30cm) are usually related to cereal crop yield.

Other field studies: Twelve core samplers were used to collect undisturbed soil samples. They were properly labeled for easy identification in the laboratory.

Table 1: Soil Physical properties of Kean saline soils

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

They were weighed; oven-dried for 24 hours at 105^0C and re-weighed. The weights obtained there after 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.

Laboratory determinations: Soil samples from the field were air-dried, gently crushed and sieved through a 2mm mesh and analyzed in the laboratory for the following properties. Soil particle size distribution, soil pH, 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 (Day, 1965). Soil pH was determined using Beekman Zeromatic pH meter after equilibrating for 30 minutes (Mclean, 1982). Organic carbon, total N and available phosphorus were measured by wet-oxidation method (Nelson and Sommers, 1982; Olsen and Sommers, 1982), Micro kjeldahl method (Bremmer and Mulvaney, 1982), 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) (Odiete *et al.*, 2006). 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 the method of Blake and Hartge (1986), while percentage moisture content was calculate as:

Weight of wet soil-weight of oven dry soil ÷ Weight of wet soil x 100;

Percentage porosity = wt. of wet soil-oven dry wt. ÷ Volume of sampler x 100;

Exchangeable sodium percentage (ESP) = Exch. Sodium ions ÷ Soil CEC x 100

Sodium adsorption ratio (SAR) = Na ÷ $(Ca^{2+} + Mg^{++})^2$

Gypsum requirement according to Schoonover's method (US Salinity Laboratory Staff, 1954) was used. Means, standard deviation (SD), standard error (SE+) and figures were computed using a statistical package, version 5.5 (Statsoff, 1998).

Results and Discussion

The results of the pre-treatment soil analysis showed that the soil has loamy sand texture with bulk density of the undisturbed soil (mean value of 2.37gcm^{-3}); an indication of hard structure (Table 1). The implication to agriculture is that enough water will not be retained. This trend was substantiated by low values of infiltration rates and percentage porosity (19.46%) obtained. This may be associated to alkaline nature of soils which usually make soils impermeable to water and air. However, soil analysis of cultivated soils had better physical properties that will favor crops production in terms of soils texture, porosity and water retention.

In terms of pre-cultivation soil chemical analysis, the soil had high pH range of 7.40 to 7.90 indicating alkalinity (Table 2). Further presence of large quantities of exchangeable bases (Ca = 18.64Cmolkg^{-1}; Mg = 1.535Cmolkg^{-1}; K = 4.925 Cmolkg^{-1} and Na =4.305Cmolkg^{-1}) and high base saturation (86.79%) confirmed the alkalinity nature of the soils. Low sodium adsorption ratio and exchangeable sodium percentage (1.675 and 12.75%, respectively) also confirmed that the soil was alkaline (Table 2).

The result of the water analysis showed that the degree of impurities in the water sample was very negligible. The only elements identified were Ca (43.0664 mg/litre) and Mg (3.9647mg/litre) (Table 3).

Table 2: Physical and chemical properties of keana saline soils

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

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

Table 3: Chemical properties of the saline water

Element	Mg/Litre
Magnesium (Mg)	3.9647
Calcium (Ca)	43.0664

This suggested that the water was alkaline and may serve as the major sources of high basic cations found in the soil.

Effects of treatment on soil chemical properties: The results showed that the soils were high in soil pH_s. High soil pH denoted the dominance of sodium among the cations and carbonate /bicarbonates among the anions. These important chemical parameters decreased in all the treatments except the control (Figures 1 and 2). Crop cultivation and application of gypsum alone or in combination with FYM reduced these parameters. However, pH value was greater than 8.5 in control, gypsum + chiseling, and gypsum + FYM + chiseling treatments.

The gradual decrease in pH values was observed after harvesting of each crop. The pH values reduced to <8.0 in all the treatments as compared to the control. As far as the lower depth (15 – 30 cm) was concerned, the pH also reduced in all treatments after harvesting millet in the 2005 - 2006 crop years. This may be attributed to the removal of carbonates and bicarbonates of Na to a greater extent during reclamation. Similar results were obtained by Mohammed and Khaliq (1975).

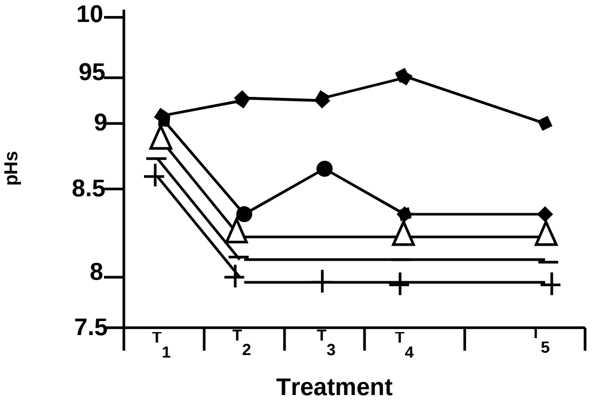

Fig 1: Original and post crop soil analysis for pHs (0-15cm) Key: □ Original analysis; ○ Post rice 2005; ∆ Post millet 2004-2005; − Post rice 2006; + Post millet 2005-06

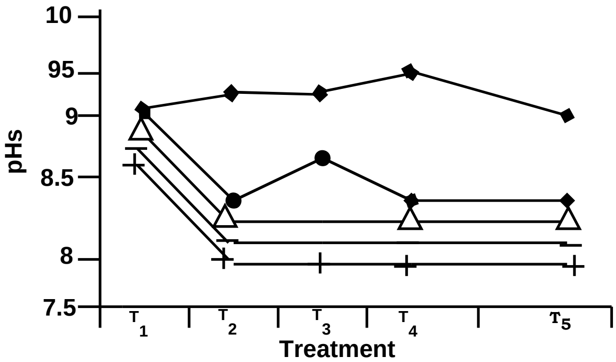

Fig 2: Original and post crop soil analysis for pHs (15-30cm) Key: □ Original analysis; ○ Post rice 2005; ∆ post millet 2004-2005; − post rice 2006; + post millet 2005-06

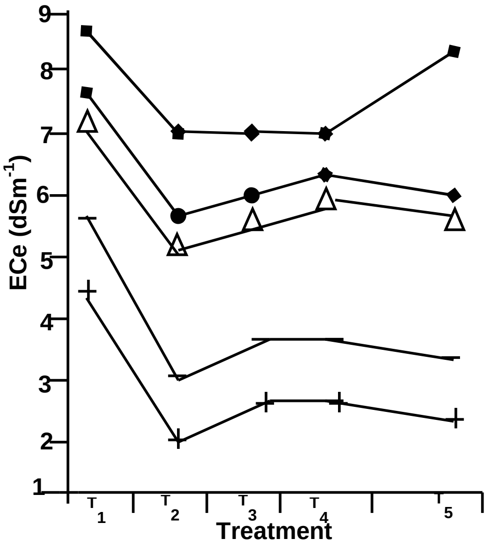

Fig. 3: Original and Post crop soil analysis for ECe (0-15cm) Key: □ Original analysis; ○ Post rice 2005; ∆ post millet 2004-2005; − post rice 2006; + post millet 2005-2006

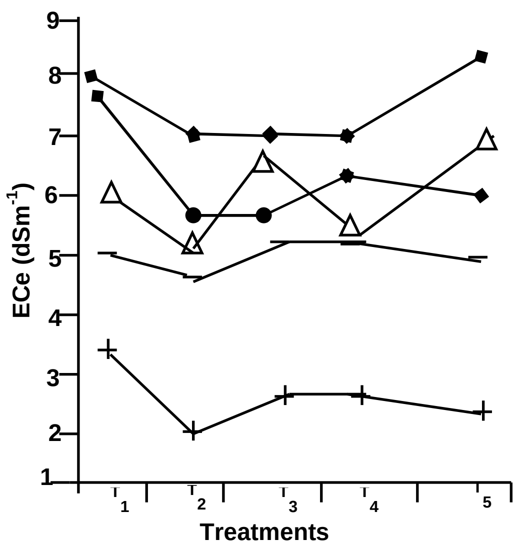

Fig 4: Original and post crop soil analysis for ECe (15-30cm) Key: □ Original analysis; ○ Post rice 2005; ∆ post millet 2004 – 2005; − post rice 2006; + post millet 2005 – 2006

A significant decrease in electrical conductivity (ECe) (Figures 3 and 4) was observed when gypsum @100%GR (T_2) was applied alone or gypsum + FYM (T_4). The decrease in ECe might be due to light texture of the soil. However, a little decrease was observed in the control plots. The best treatment appeared to be the combination of all treatments (T_5) i.e. gypsum +FYM + Chiseling. Possible reason may be the improvement in porosity and hydraulic conductivity which resulted in enhanced leaching of salts.

Decrease in ECe was also reported by Sharma *et al.* (1982). The application of gypsum @12tha^{-1} and other cultural practices during reclamation of dense sodic soil decreased pH values from 10.2 to 9.1. ECe decreased from 2.1 to 0.8 d.Sm^{-1} more rapidly during first year of reclamation but later on, the effect of amendments was still evident but the rate of amelioration was slow (Rao *et al*., 1994). The ECe was higher in the lower depth than the upper depth indicating the downward movement of salt due to reclamation process after harvesting of first rice crop. It decreased gradually and reached a tolerable level in the lower depth also after 2005-2006.

Sodium adsorption ratio (SAR); the SAR decreased significantly with the different treatments (Figures 5 and 6). However, the decrease in SAR was more with treatments 5 (gypsum + fym +chiseling) than T_4 (gypsum + fym) and T_2 (gypsum) alone.

The less reduction is SAR in only T_2 (gypsam @ 100% GR) treated plots might be due to slow reaction of gypsum. The most effective treatments were the combination of all the three practices and T_4 (gypsum + fym @ 25tha^{-1}) for reduction of SAR after harvesting the first rice crop. The soil was reclaimed and SAR decreased to safe limits in all treatments except control after harvesting of 3rd crop (rice) in 2006. The decrease in SAR was essentially due to removal of exchangeable Na from the soil complex. The results are in agreement with those of Hussain *et al* (2001). The rate of decrease in SAR was greater in upper soil layer than in lower depth. This pattern was attributed to the decreasing ca^{2+}: Na – ratio in the soil solution as it moved down the profile displacing exchangeable sodium (Na^+).

Effect of treatments on crop yields: Data in Table 4 indicate that biomass of rice and millet was significantly increased when different amendments and cultural practices were applied before transplanting of rice in 2005 with subsequent leaching than control. This increase was higher in gypsum (T_2) alone or T_4 as compared to T_3 (gypsum + chiseling) or T_5 (gypsum + fym + chiseling). Similar results (Mohammed *et al*., 1990) were also reported on two calcareous sodic soils in 4 years of cropping. The average rice paddy yield from both the soils was in the order: gypsum (1.99 Mgha^{-1}) >gypsum + subsoiling (1.84 Mgha^{-1}) > subsoiling (1.41Mgha^{-1}) > bioremediation (1.02 Mgha^{-1}). Gypsum + subsoiling treatments had similar values for wheat grain yield (2.72Mgha^{-1}) followed by subsoling (1.79Mgha^{-1}) and bioremediation (1.46Mgha^{-1}).

The millet grain yield reduced during 2004-05 in FYM treatments as compared to gypsum alone. The reduction in yield might be due to fading effect of farm yard manure (fym) with passage of time. Gypsum + chiseling remained inferior in production of biomass, paddy and grain yield of millet in all the years than gypsum + farm yard manure + chiseling. However significant increase was found in gypsum + chiseling than control (T_1). The gradual increase in biomass as well as in paddy and millet grain yield in other treatments may be the result of improved soil properties. The results were in line with those of Hussein *et al* (2001) who concluded that most superior combination was gypsum + H_2S04 + Farm yard manure. The improvement in physical and chemical properties of salt affected soil was the major reason for enhancement of crop yield.

Conclusion: The study revealed that gypsum application alone proved the best treatment followed by gypsum + farm yard manure in increasing rice and millet yield, while gypsum + farm yard manure + chiseling performed better in improving the soil properties.

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