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Research article

Effects of Gypsum Application Rates on Sodic Soils and Performance of Maize *(Zea-mays)* Plants

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ABSTRACT

Sodicity is one of the major constraints of maize production in Baga area. A pot experiment was carried out in the screen house of the Faculty of Agriculture, University of Maiduguri to determine the effects of gypsum application rates on the amelioration of sodic soils and performance of maize. Composite soil samples were collected from Baga, Kukawa LGA of Borno state. The experiment consisted of 4 treatments (0.0 t/ha, 5.0 t/ha, 10.0 t/ha and 15.0 t/ha of gypsum, which are equivalent to 10, 20 and 30 g/3 kg soil), replicated 3 times. Maize seeds were sown to the treated pots and leached twice in a week in accordance with leaching requirements. Data collected were plant heights, shoot, root and total dry matter weights. The effects of gypsum rates on chemical properties were also determined. The results showed that 15.0 t/ha produced the highest plant height, shoot, root and total dry matter weights. There was a reduction in post-harvest soil chemical properties including pH, EC, OC, N, Na, K, SAR and ESP, but increase in Ca and Mg contents of the soil were observed. It could therefore be concluded that, application of gypsum at 15 t/ha has the potential of ameliorating sodicity problems in sodic soils of Baga for sustainable maize production.

Keywords: Sodicity, Gypsum, Application rates, Maize, Performance, Baga, Nigeria

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Introduction

Soil degradation due to sodification has been reckoned as a major treat to irrigated agriculture and a present concern to most farming communities around the globe (Lal, 2001). FAO (2005) reported that, nearly one million hectares of land around the World were having some degree of sodification problems. Management of sodium affected soils is considered as an important part of agricultural food security programs. Sodicity is the process of accumulation of sodium salt in the soil as a result of application of irrigation water that contains sodium salt.

At present, gypsum is one of the commonly used means of managing sodic soils in addition to pyrite and elemental sulphur. Gypsum materials are easily soluble, less costly, readily available and easy to handle. Studies have shown that application of high rates of gypsum on sodic soils reduces the amount of Na^+ from the soil column and causes substantial decrease in soil electrical conductivity (EC) and sodium adsorption ratio (SAR). Mohammed and Iqbal (2007) recently reported that when gypsum is incorporated with some organic sources, it can reclaim sodic soils. Gypsum is also being reported as successful in reducing adverse effects of some soil properties that facilitates sodicity. As earlier reported by Mohammed and Iqbal (2007), physical properties of soils such as bulk density, porosity, void ratio, water permeability and hydraulic conductivity were significantly improved, when farmyard manure (FYM) of 10 t/ha in combination with gypsum were applied. It also resulted in high yield of rice, maize and wheat grown on the sodic soils. Gypsum causes Ca^{2+} ions to be released from Gypsum ($CaSO_4$), when applied on maize fields; it helps in cell division and elongation of maize plants, strengthening of cell wall, regulation of protein synthesis, and aging process in maize. Gypsum reduces the susceptibility of pests and diseases. It is also necessary for proper functioning of the growing points, particularly root tips of maize plants.

Despite the severe effects of soil sodicity on crop production in the study area, little or no scientific work has been carried out to quantify these effects with appropriate measures to ameliorate the sodicity problems. This study therefore, is aimed at evaluating the effects of gypsum application rates in ameliorating sodicity problems in sodic soils of Baga area, Borno state towards achieving sustainable maize production.

Materials and Methods

Experimental site and location

A pot experiment was carried out at the University of Maiduguri, Faculty of Agriculture screen house located at latitudes 10^o.05’N and longitudes 13^o.05’E (Rayar, 1983). Maiduguri is situated in the north-eastern part

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of Nigeria with a semi-arid agro-ecology, having long term (1961-1990) mean annual rainfall of 553 mm and a very hot dry climate. Rainfall is unimodal, occurring in mid-June and end of September (Grema and Hess, 1994).

Soil sample collection and preparation

Soil samples were collected at 0-15 cm depths and then bulked, adequate portion of which was taken as a representative sample. Another set of soil samples were collected for the pot experiment.

Experimental design and treatments

The experimental design used for this study was the completely randomised design (CRD) with 4 treatments (T_o, T_1, T_2 and T_3), replicated 3 times to give a total of 12 pots. The treatments (T_0, T_1, T_2 and T_3) consisted of 3 different quantity of gypsum (10, 20, and 30 g/3kg soil respectively, which represents 5, 10 and 15 t/ha application rates) and a control (0 g), with 3 replications.

Cultural Practices

Sowing and thinning

The maize seeds were planted on April 4th, 2013 in pots at a seed rate of 2-3 seeds/pot and were later thinned to 2 seedlings per pot.

Leaching

26 cm^3 of water was used to leach each pot at an interval of 3 days from sowing till harvest, in order to leach away the accumulated salt residues from the root zone of the crop.

Field Data Collection

The data collected from the pot experiment were plant height, shoot and root dry matter weights. Physico-chemical properties of the soils at before and after harvest were also determined in the laboratory.

Plant heights

Heights of plants in the treatment pots were measured at 2, 4, and 6 weeks after planting (WAP) using a meter tape from the point of emergence to the upper growing points of the plants, and the mean plant heights were obtained for each treatment.

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Plant dry weights (shoot)

Dry weights of the 2 plants per treatment pot was weighed using a weighing balance at 2, 4, and 6 WAP by cutting the plant shoots from the base using a knife and later dried in an electric oven for 24 hours at 65^{o}C, and the mean weights per plant per pot were carefully recorded.

Root dry weight

The root dry weight of each pot was also weighed using a weighing balance after carefully uprooting the plants. The root was dried in an electric oven for 24 hours at 65^{o}C and the mean weight per treatment pot was appropriately recorded.

Soil analysis

The soil samples collected were oven dried, crushed and sieved through 2mm sieve and kept in labelled polythene bags for determination of soil physical and chemical properties. Soil organic matter was determined by wet-dichrometer oxidation method, total nitrogen was determined by micro-kjeldahl approach, and available P was determined by molybdenum blue colorimeter after Bray-1 extraction. Exchangeable cations were extracted with ammonium acetate, and Ca and Mg were determined by EDTA titration. SAR and ESP were determined using Tel, and Hagarty (1984) procedure as:

$$SAR = [Na^+] / \sqrt{\frac{[Ca^{2+}] + [Mg^{2+}]}{2}}$$

$$ESP = \frac{exchangeable\ sodium\ (meq/100gsoil)}{cation\ exchange\ capacity\ (meq/100gsoil)} \times 100$$

Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA), and the differences among means were tested using the least significant difference (LSD) at 5% probability level.

Results and Discussion

Properties of soils of the experimental area

The results of the physico-chemical properties of the soils before treatment application are presented in Table 1. The results revealed that the soil is sodic, with a pH of 9.5, which imply a strongly alkali soil. The soil

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also had high EC, low calcium (Ca) and magnesium (Mg), with high sodium (Na) and potassium (K). Similarly, nitrogen (N), and organic matter (OM) contents of the soils were high.

The observed high pH (soil reaction) was likely due to the presence of high concentration of Na^+, and low Mg and Ca contents in the soil, as was similarly reported by Dregne *et al.* (1976). Tel (1984) also reported that low Ca and Mg are also caused by presence of high concentration of Na^+ ions on the soil surface, which serves as a dispersing agent that displaces the Ca and Mg contents in a soil. The observed high content of N in the soil of the area was perhaps due to surrounding grasses, kitchen waste, and acacia plants, which increases the rate of mineralization that causes increase in concentration of N, and OM contents.

Effects of gypsum application rates on maize height

The results of gypsum application rates on plant heights at 1, 3, 5, and 7 WAP are presented in Table 2. The results of this experiment showed that at 1WAP, there was no-significant (P>0.05) difference between control treatment and plants treated with 10 g of gypsum rate. Also, there was no-significant difference (P>0.05) between 20 and 30 g treatments. This means that, the tallest plant height was observed at 30 g treatment application rate and the shortest height was observed in the control treatment. Similarly, at 3 WAP, there was still no significant (P>0.05) difference between control and 10 g application rate. In addition, the 20 and 30 g rates showed no-significant difference. However, the tallest plant height was observed with 30 and 20 g treatment application rates, while the shortest plant height was observed at control treatment (Table 2).

Furthermore, at 5 WAP, the results showed that, the 10, 20 and 30 g treatments were not significantly (P>0.05) varied from one another. However, the control treatment was significantly different from all the treatments (10, 20, and 30 g) at (P<0.05). This indicated that the tallest plant heights were observed with treatments 30, 20 and 10 g, while the shortest plant heights were observed only in the control treatment (Table 2). In a similar pattern, at 7 WAP, the results showed that there was significant difference among all the treatments (control, 10 g, 20 g and 30 g). This result indicated that, the 30 g treatment gave the tallest plant height, while the control treatment had the shortest plant height. The observed variations within the treatments at various stages of growth could have been as a result of environmental factors and differences in the rates of applied gypsum, which is in conformity with the findings of FAO (2008).

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Effects of gypsum application rate on maize shoot and root dry matter (DM)

The result of the effects of gypsum application rates on maize shoot and root dry matter (DM) is presented in Table 3. The results of the experiment showed significant difference between the treatments (control, 10, 20, and 30 g) with respect to the effects of gypsum application rates on shoot dry matter (SDM) of maize plants.

The results on the effect of gypsum application rates on root dry matter (RDM) of maize showed no-significant (P>0.05) differences between the control and 10 g application rate. There were significant differences between the RDM with 30 and 20 g treatments at P> 0.05. This result showed that 30 g treatment recorded the highest SDM and RDM, while control treatment had the least SDM and RDM (Table 3). The observed variations in the SDM among the treatments could have been as a result of the stem length and number of leaves that received 30 g gypsum rate, and which appeared greater than those of the other treatments. The control treatment had shorter shoot, stem and fewer leaves.

Effects of gypsum application rates on physico-chemical properties of the soils after treatment applications

The results of the effect of gypsum application rates on physiochemical properties of the soil after harvest are shown in Table 4. The results revealed that, the effect of gypsum application rates on Ca, showed significant (P>0.05) difference between the treatments, while the 30 g treatment rate had the highest concentration of Ca. This variation could have been due to differences in quantity of gypsum applied.

The effects of gypsum application rate on Mg showed no significant (P>0.05) difference between the 30 and 20 g treatments, while control and 10 g treatments were significantly different. This indicates that 30 g treatment gave the highest concentration of Mg among the treatments, while the control treatment had the lowest Mg content (Table 4). In addition, the effects of gypsum application rates on K, showed no significant (P>0.05) difference between 30 and 20 g treatment rates, while there was significant (P>0.05) difference between the control and 10 g treatments. This result further indicates that, the control treatment had the highest concentration of K among the treatments, while 30 g application rate had the lowest K value (Table 4).

Also, the results of the effects of gypsum application rates on sodium adsorption ratio (SAR) and exchangeable sodium percent (ESP) revealed that, SAR values were significantly (P>0.05) different among the treatments. From the results, the control treatment had the highest concentration of SAR and ESP, while 30 g

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treatment gave the lowest concentrations of SAR and ESP (Table 4). This was perhaps due to application of Na in the irrigation water, which was probably counteracted by application of gypsum. In nature, soil structure depends on the balance of Ca^{2+} and Mg^{2+} in relation to Na^{+}. Soil particle aggregates, when Ca^{2+} and/or Mg^{2+} are increased relative to Na^{+}, thereby decreasing the SAR. However, soil particles often disperse, if the concentration of $Ca^{2+} + Mg^{2+}$ decreases relative to the concentration of Na^{+}. The observed interactions among these elements likely reduced through application of gypsum.

Results in Table 4 further revealed that, there was no significant effect of different gypsum application rates on N content in the soils. However, gypsum application rates influence on Na^{+} content of the soil, was significantly ($P<0.05$) different among the treatments. This indicated that control treatment had higher Na, while 30 g treatment had the least Na content. This could have been as a result of the use of salt contaminated water for irrigation.

The results of the effects of gypsum application rate on pH and EC showed a significant ($P<0.05$) difference among the treatments. The result showed that the control treatment had slightly alkaline conditions, while the other treatments influenced the soils to have neutral reactions (pH).

Conclusion

The study revealed that the soils of Baga area are sodic. Hence, addition of gypsum at the rate of 30 g (15 t/ha gypsum) with adequate leaching gave the best results, and should therefore be employed for sustainable maize production in the area. It is however recommended that further studies on the sodic soils of Baga area, should test for the efficacy of other sodicity amendment sources such as pyrite, elemental sulphur, and OM applications for the amelioration of sodicity problems in the study area.

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Table1: Physiochemical properties of the soil before treatment application

parameter	Ca (meq)	Mg (meq)	K (meq)	Na (meq)	N (%)	%OC	%OM	pH	EC dS/m	SAR	ESP
Values	2.20	1.43	2.32	12.02	0.36	2.20	3.80	9.50	800	13.4	16.1

Table 2: Effect of gypsum application rates on maize plant height

Gypsum Rate (g)	1WAP	3WAP	5WAP	7WAP
Control (0)	4.167	8.200	9.467	19.067
10	4.267	8.467	14.100	20.200
20	5.033	9.067	15.333	21.233
30	5.167	9.133	16.567	23.200
LSD (0.05)	*	*	NS	*

Key: * significant at 5% probability level, NS- not significant, WAP-weeks after planting

Table 3: Effect of gypsum application rates on maize shoot and root dry matter

Gypsum Rate (g)	SDM	RDM
Control (0)	4.167	2.900
10	5.067	3.100
20	6.033	3.533
30	6.500	4.067
LSD (0.05)	*	*

SDM = shoot dry matter, RDM = root dry matter, *- significant at 5% probability level

Table 4: Effect of gypsum application rates on soil chemical properties

Gypsum Rate (g)	pH	EC	Ca	Mg	K	N	Na	OC	OM	SAR	ESP
Control	8.20	750	2.27	1.30	1.73	0.09	7.15	0.62	1.34	8.89	14.4
10	8.00	700	5.56	2.71	1.03	0.08	6.23	0.81	1.21	7.20	14.3
20	7.20	680	7.20	3.15	0.20	0.07	0.06	0.24	2.07	5.56	13.6
30	7.02	640	8.89	3.20	0.06	0.06	4.13	0.67	1.06	2.27	13.2
LSD(0.05)	*	*	*	*	*	NS	*	**	*	*	*

Key: *- significant at 5% probability level, NS- not significant, EC-µS/cm, Ca, Mg, Na, K-meq/100g, N, OC, OM-%,

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