



Effect of Gypsum on Rice Growth in Three Salt-affected Agricultural Soils in the Ho-Keta Plain

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Authors' contributions

This work was carried out in collaboration among all authors. Author LS designed the study, wrote the protocol and wrote the first draft of the manuscript. Author EO managed the literature searches Author EOB edited the draft. Author AT managed the statistical analysis of the study. All the authors read and approved the final manuscript.

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ABSTRACT

Aims: To assess the growth attribute of NERRICA- L19 rice in three salt-affected Agricultural soils amended with Gypsum from the Ho- Keta plain in the Volta region, Ghana.

Study Design: Complete Randomized Design.

Place and Duration of Study: Soil Research Institute, Kwadaso, Kumasi between June 2016 and July 2019.

Methodology: Approximately 2.6 kg of the soil samples were taken from three different sites, namely, Anyako, Anyenui and Atiehife and were mixed thoroughly with different rates 0%, 75% and 100% of Gypsum, (CaSO₄.2H₂O) and filled into thirty six perforated polyvinyl plastic pots. The pots were saturated with water and incubated for 24 h. Twenty-one-day old seedlings of NERRICA- L 19 rice were transplanted into the pots, arranged in a randomized complete design and leached for four weeks. Core sample of the soils from each pot were taken and analyzed at the end of the experiment. Data on growth attributes (plant height, number of leaves and number of tillers) and leave tissue compositions (Ca, Mg, K, Na, P and N) were measured.

Results: The study revealed that Gypsum rates at (75 and 100%) increased the growth attributes and tissue concentrations of NERRICA- L 19 rice compared to the control. Growth parameters, such as plant height, number of leaves and tiller for Anyako, Anyenui and Atiehife soils, increased as Gypsum levels increased with significant differences in the height of the plants and the number of plant leaves recorded ($P = 0.05$). However there was no significant difference in tillers growth recorded for Atiehife soil, compared to Anyako and Anyenui soils ($P = 0.05$). The chemical constituents of the leave tissue, showed high composition of calcium and potassium than magnesium, while the composition of sodium decreased. The concentration of calcium, magnesium and potassium increased significantly at ($P = 0.05$) in Anyako and Atiehife soils with no-significant level in Anyenui soil. The trend was the same for the concentration of sodium.

The concentration of nitrogen and phosphorus increased as the level of treatment increased. In respect to P accumulation, the differences were not significant in Atiehife soils, but was significant in Anyako and Anyenui soils.

Conclusion: Gypsum application significantly enhanced nutrient uptake and increased the growth attributes of NERRICA - L19 rice compared to the control. Atiehife soil responded better to the reclamation process than the remaining soils, showing high growth performance. Gypsum applied at the rate of 16.92 kg/ha was recommended for adoption.

Keywords: Osmotic potential; reclamation; amended; progeny; degraded.

1. INTRODUCTION

The constraint to crop growth and development is often caused by high soil-water osmotic potential as influenced by excess accumulation of exchangeable sodium and salt [1]. Soils affected by salt, often degrade with absolute changes in soil reaction (pH) and the concentration of ions present either in soil solution or at the soils exchangeable sites. These changes influence ion-specific effects and imbalances in plant nutrition. The cumulative effect however, leads to adverse impact on the growth of plant roots, soil microbial activities, and ultimately on crop yield and productivity [2,3,4,5]

The adoption of a chemical to ameliorate salt-affected soil is a well-established technology. The direct source of calcium commonly used is calcium chloride ($\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$), mined gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) and phosphor gypsum (by-product in the manufacture of phosphorous fertilizers). Research have shown that, the application of a soluble calcium amendment, combined with good drainage and tillage can reduce the harmful effect of high sodium content and reclaim sodic soils [6,7,8]. Among the chemical ameliorants, agricultural gypsum is often used primarily because it is comparatively cheap, readily available, has low solubility, it is easy to apply and requires less time and water more than the other amendments [9,10].

The adverse condition developed, can be effectively managed and utilized, by planting an appropriate moderate salt tolerant crop alongside with a chemical ameliorant [11]. According to

Muhammad and Riaz [12] gypsum in conjunction with other amendments effectively decreases electrical conductivity of salt-affected soils cultivated with rice under submerged condition where high leaching of soluble salts is achieved.

Rice, is one of the most potential staple food crop in the world which is usually adopted during reclamation of degraded salt-affected lands [13]. However, rice consumption in Ghana far outstrip the domestic production capacity, enabling approximately 70 % of rice import from other countries [14]. The country, though, with an envious capacity to produce more than 300,000 tonnes of rice yearly is constrained to utilize less than 10 % of the potential wetlands [14]. NERRICA- L 19 rice has been recommended by [15, 16] as a progeny with viable characteristics and developed under the complex embryo technique from *Oryza sativa japonica* variety (WAB 56-104) and an African *Oryza glaberrima* variety (CG 14). The significance of this crop, has been reported by [17,18] that it mitigate soil-water osmotic stress, a mechanism which maximizes water uptake and minimizes its loss, as well as reduce the toxic effect of sodium ionic stress through exclusion from the leave tissues and stored in the vacuoles. The crop was adopted, for the purpose of this experiment because of the extent of arable land degraded in the plain and also to test the crop performance in salt-affected soils.

The study, was aimed to assess the growth attributes of NERRICA- L 19 rice, in three salt-affected Agricultural soils amended with Gypsum in the Ho-Keta plains in the Volta Region.

2. MATERIALS AND METHODS

2.1 Soil Sampling and Analysis

The experimental site and soil description has previously been described by [19].

Pre-germinated 21-day old NERICA- L 19 rice seedlings were transplanted into pots amended with different rates of gypsum at 0 %, 75 % and 100 % which is equivalent to 10.14 and 13.49 g/pot [19], arranged in a completely randomized design and replicated four times in a greenhouse making a total of 36 pots. Dissolved Nitrogen, phosphorus and potassium fertilizers were applied at the rate of 90 kg N ha⁻¹ as urea, 45 kg ha⁻¹ as TSP (Triple super phosphate) and 45 kg ha⁻¹ as muriate of potash equivalent to 0.34 N: 0.39 P: 0.16 K kg pot⁻¹.

At the time of transplanting, half of nitrogen fertilizer rate and all of P and K were applied to the pots. Top dressing with 45 kg N ha⁻¹ was done two weeks after transplanting, to ensure non-limiting nutrient supply. Intermittent irrigation schedule was used such that at the end of each week 120 mL of water was added to each pot, while ensuring standard irrigation requirement of rice did not exceed the soil infiltration rate.

2.1.1 Plant sampling and analysis

Growth parameters such as plant height, number of leaves and number of tillers were taken from each plant one week after transplanting and continued at weekly intervals for a period of four successive weeks. Data on plant development were collected during the growing period. Successive plant height was taken by measuring the leave height from the base of the plant at soil level to the tip of the longest leave, whereas data on the number of leaves and tillers was obtained by counting and identifying successive leaves and tillers with indelible colored makers.

Destructive biomass sampling was carried out at 2, and 4 weeks after planting (WAP) for the determination of above ground biomass.

The plant tops were harvested by cutting at the soil level. The fresh weights were taken and oven-dried at 70 °C for 72 h for dry matter. The samples were milled (< 1mm) and ashed at 550 °C, followed by dissolution in 2 M hydrochloric acid (HCl). The concentrations of Ca, Mg, K and Na as well as total nitrogen, and phosphorus in the plant sample, were measured using different

procedures and methods. Total N was measured by micro Kjeldhal's digestion method [20]. Phosphorus concentration in the extract was determined using the molybdenum-blue procedure [21]. Concentrations of calcium (Ca) and magnesium (Mg) were determined by EDTA titration and that of sodium and potassium determined by flame photometry.

2.1.1.1 Statistical analysis

Data collected were subjected to Analysis of Variance (ANOVA) to determine significant differences in main treatments and possible interactions using GenStat 12th Edition. Treatment means were separated using Least Significant Difference (Duncan Multiple Range Test) test at 5 % level of significance.

3. RESULTS AND DISCUSSION

3.1 Growth of NERICA- L19 Rice

The growth parameters recorded, increased for Anyako, Anyenui, and Atiehife soils, as gypsum levels increased (Fig. 1-3), with significant differences in the height of the plants and the number of plant leaves recorded ($P = 0.05$). However there was no significant difference in the growth of the tillers recorded for Atiehife soil, compared to Anyako and Anyenui soils ($P = 0.05$).

The fresh and dry weights of the shoot, for each of the soils increased with increment in the level of gypsum (Table 1).

The adverse effect of increased salt concentration, affected the efficiency of nutrient uptake. This became evident in the control pots and could be attributed to the antagonistic absorption of Na⁺ at the expense of K⁺ [22]. This trend was confirmed by [23] who associated a decrease in plant height, number of leaves and tillers to high salinity levels.

Growth attribute in rice is partly measured by plant height, number of leaves and tillers. The overall improvement in growth was possibly achieved by the reclamation effect of gypsum addition [24,25,26].

3.1.1 Tissue composition of NERICA L9 rice

The chemical constituents of the leave tissue (Table 2) showed high composition of calcium and potassium than magnesium, while the

composition of sodium decreased. The concentration of calcium, magnesium and potassium became increasingly significant at ($P=0.05$) in Anyako and Atiehife soils with non-significant level in Anyenui soil. A similar trend was observed, with a decrease in the concentration of sodium. The concentration of nitrogen and phosphorus increased as the level of treatment increased. In respect of P accumulation, the differences were not significant in Atiehife soils, but was significant in Anyako and Anyenui soils.

Addition of Gypsum to soil contributes calcium and sulphur to improve nutrient availability, conserve soil nitrogen and possibly decrease sodium toxicity. High calcium concentration in the soils facilitated the displacement and leaching of sodium. This largely caused a reduction of

sodium (Na) in the rice tissue by a selective mechanism of K transport relative to sodium [27].

Gypsum however, increased the concentration of calcium, phosphorus and potassium but decreased that of sodium, while nitrogen was efficiently utilized. An indication very consistent with the findings of [22] who stated that increased concentration of calcium in soil solution increase the selectivity of potassium at the expense of sodium. High Magnesium in the leaf tissue could be attributed to displacement into solution by calcium, which enhanced its availability for absorption by the rice plant.

High calcium levels also influenced the absorption of NH_4^+ , a mechanism which enhanced tillering and the efficient use of nitrogen [28].

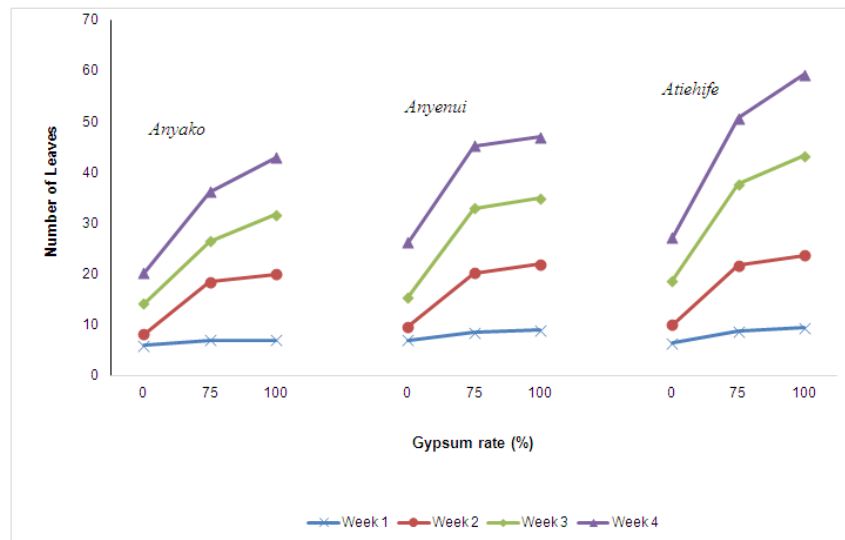


Fig 1. Effect of soil and gypsum on the number of leaves of rice plant at different growth stages

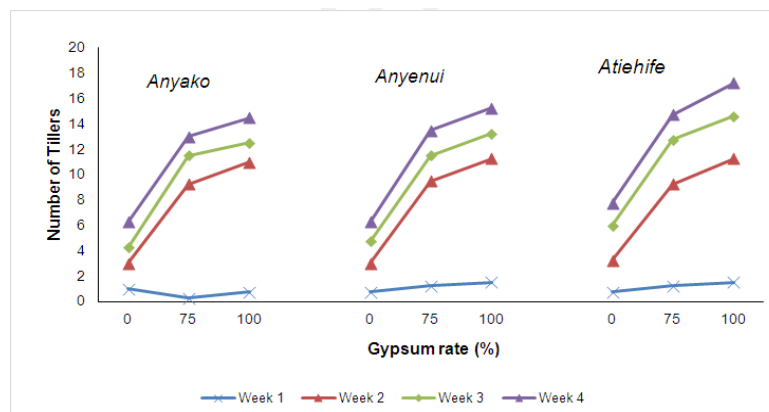


Fig. 2. Effect of different treatment on the number of tillers of the rice plant with growth duration

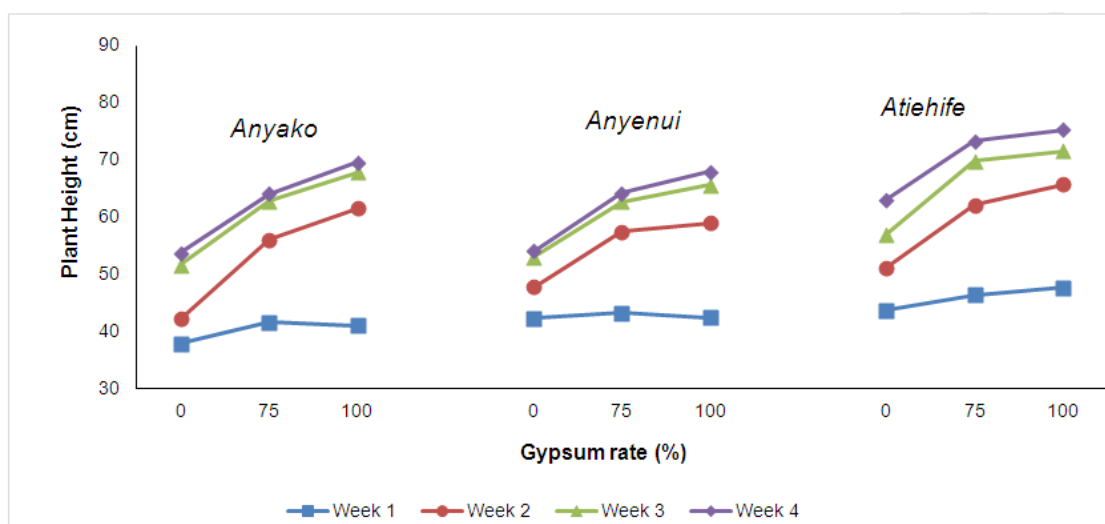


Fig. 3. Effect of soil and gypsum on plant height (cm) of rice at different growth stages

Table 1. Effect of gypsum on plant biomass

Soil	Gypsum rate (%)	Fresh Shoot Weight	Dry Shoot Weight
		----- g /pot-----	
Anyako	0	2.28	1.54
	75	6.66	5.76
	100	8.45	7.32
Anyenui	0	2.98	1.80
	75	7.52	6.38
	100	9.45	8.06
Atiehife	0	3.72	2.74
	75	8.68	7.51
	100	10.48	9.21
LSD (5 %) Soil (S)		0.79	0.84
LSD (5 %) Gypsum (G)		0.79	0.84
LSD (S × G)		1.37	1.5
CV (%)		10.00	9.60

LSD (Least Significant Difference) CV (Coefficient of variation)

Table 2. Effect of gypsum and soil on tissue composition of NERRICA L 19 rice after harvest

Soil	Gypsum Rate (%)	Ca	Mg	Na	K	N	P
		----- % -----					
Anyako	0	0.13	0.18	3.26	3.99	0.93	0.19
	75	0.33	0.19	1.14	6.47	1.53	0.26
	100	0.36	0.22	0.67	7.76	1.78	0.31
Anyenui	0	0.15	0.16	1.88	5.44	1.06	0.18
	75	0.25	0.13	1.06	7.27	1.65	0.28
	100	0.34	0.13	0.64	7.97	1.86	0.33
Atiehife	0	0.15	0.13	2.49	2.82	1.26	0.21
	75	0.59	0.19	0.96	4.61	1.81	0.25
	100	0.71	0.21	0.68	7.12	2.07	0.28
LSD (5 %) Soil (S)		0.038	0.026	0.149	0.559	0.062	0.020
LSD (5 %) Gypsum (G)		0.038	0.026	0.149	0.559	0.062	0.020
LSD (S × G)		0.066	0.045	0.259	0.968	0.108	0.035
CV (%)		13.7	18.0	12.6	11.2	4.8	9.6

LSD (Least Significant Difference) CV (Coefficient of variation)

Availability of phosphorus in soils is affected by the level of soil pH, organic matter and organic acid produced. Total P accumulated in the leaf tissue increased with applied Gypsum. This increased the solubility of Ca-phosphate complex formed, as soil pH decreased because hydrolysis of the clay colloid was affected [29,30].

4. CONCLUSION

The study revealed that Gypsum application significantly enhanced nutrient uptake and increased the growth attributes of NERICA L19 rice compared to the control. The observed trend was attributed to soil reclamation. It can be concluded that Atiehife soil responded better to the reclamation process than the remaining soils, showing high growth performance. The pattern of growth and reclamation was in the order; Atiehife > Anyenui > Anyako.

Considering the difference in the margin of growth for Gypsum applied at 75 % and 100 % Gypsum applied at the rate of 16.92 kg/ha was recommended to farmers to meet their economic needs and ensure sustainability.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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