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DEMONSTRATION OF SOIL SALINITY AND SODICITY REMEDIATION TECHNIQUES USING RICE CROP (ORYZA SATIVA) IN KANO RIVER IRRIGATION SCHEME (KRIS)

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ABSTRACT

Soil salinity is a huge problem in irrigated fields globally. In KRIS, the salinity problem has been reported over a considerable period and has been found to increase at an alarming rate which greatly affects the soil's productive capacity. The effect of remediation techniques was assessed through participatory testing and demonstration of soil salinity and sodicity using rice in KRIS. The experimental trial plots were selected based on physical observations, information from the farm owners, and the preliminary soil chemical analysis results. Three (3) sets of experiments were established at 3 different locations that were assessed to be saline, saline-sodic, and sodic conditions, respectively. The treatment materials used were (Gypsum, Rice husk, Millet chaff, and Farmyard Manure) using Randomized Complete Block Design (RCBD) at five distinct levels and a control plot. The results show that the Rice husk, millet chaff, gypsum, and farmyard manure have exhibited different capabilities in reducing the adverse effect of salinity and sodicity. Under all situations (salinity, sodicity, and saline-sodic), millet chaff and rice husk have been performing in improving the growth and yield of rice. Similarly, gypsum has shown a good ability to remedy the sodic soils although it is not affordable and accessible for local farmers. It was observed that millet chaff application at level 2 (8.8 ton/ha) produced the highest yield of 4.75 ton/ha. Also, the highest yield next to Millet Chaff was Rice Husk at level 1 (6.8 tons/ha) produced 4.40 tons/ha. The study found that rice husk and millet chaff have higher efficacy in suppressing the effect of saline, sodic and saline-sodic soils. Thus, the application of these materials should be encouraged and enlighten the farmers at KRIS to adopt them for the control of soil salinity and sodicity problem.

KEYWORDS: Salinity, Sodicity, Remediation Techniques, Rice, KRIS.

1.0 INTRODUCTION

Saline soil is generally defined as one in which the electrical conductivity (EC) of the saturation extract (ECe) in the root zone exceeds 4 dS/m (approximately 40mM NaCl) at 25^oC and has exchangeable sodium of 15%. The yield of most crop plants is reduced at this ECe value, though many crops exhibit yield reduction at lower ECe. It has been estimated that worldwide, 20% of total cultivated and 33% of irrigated agricultural lands are affected by high salinity. Furthermore, the salinized areas are increasing at a rate of 10% annually for various reasons, including low precipitation, high surface evaporation, weathering of native rocks, irrigation with saline water, and poor cultural practices. It has been estimated that more than 50% of the arable land would be salinized by the year 2050 (Shrivastava & Kumar, 2015). The urgency of feeding the world's growing population while combating soil pollution, salinization, and desertification has given plant and soil productivity research vital importance. The problem of soil salinization is a scourge for agricultural productivity worldwide. Crops grown on saline soils suffer on an account of high osmotic stress, nutritional disorders and toxicities, poor soil physical conditions, and reduced crop productivity (Shrivastava & Kumar, 2015). To avoid or reduce the risk of salinization, it is important to monitor the soil salinity and keep it below the plant salinity tolerance threshold (Bouksila et al., 2013).

Soil salinity is an enormous problem in irrigated fields. In dry regions of the world, the soils are frequently saline with low agricultural potential. In these areas, most crops are grown under irrigation, and to exacerbate the problem, inadequate irrigation management leads to secondary salinization that affects 20% of irrigated land worldwide. Salts in the soil occur as ions (electrically charged forms of atoms or compounds). Ions are released from weathering minerals in the soil. They may also be applied through irrigation water or as fertilizers, or sometimes migrate upward in the soil from shallow groundwater. When precipitation is insufficient to leach ions from the soil profile, salts accumulate in the soil resulting in soil salinity. All soils contain some water-soluble salts. Plants absorb essential nutrients in the form of soluble salts, but excessive accumulation strongly suppresses plant growth. Salinization is recognized as the main threat to environmental resources and human health in many countries, affecting almost one billion hectares (ha) globally representing about 7% of the earth's continental extent (Fipps, 2003). The beginning of the 21st century is marked by global scarcity of water resources, environmental pollution, and increased salinization of soil and water. The increasing human population and reduction in land available for cultivation are two threats to agricultural sustainability (Shrivastava & Kumar, 2015). Various environmental stresses such as high winds, extreme temperatures, soil salinity, drought, and flood have affected the production and cultivation of crops.

This area revolves Kura, Bunkure, and Garun Mallam local government areas, and is known for Vegetables, rice, and maize production activities. The main aim of the scheme is to boost agricultural production and the general well-being of the inhabitant of the state. Despite the socio-economic importance of KRIS to the government as a source of revenue and people who rely on it for their livelihood, there is a significant concern about the sustainability of the scheme due to land degradation. Presently, most soils within the Kano River Irrigation Scheme (KRIS) are experiencing increasing levels of salinity due to excessive fertilizer application, acid rain, mineral weathering, irrigation, and other human-related activities (Macumber, 1991; SPORE, 1995 Kumar and Shrivastava, 2015). These problems coupled with other managerial issues negatively affect the level of rice and vegetable outputs which constitute the main crop produced in the scheme. Experts have warned that if this problem is left unchecked the historic scheme will be degraded thereby threatening the livelihoods of those who rely on it.

2.0 METHODOLOGY

2.1 Study Location

The Kano River Irrigation Scheme (KRIS) was initiated with the construction of the Tiga Dam between 1970 and 1974 to irrigate a total area of about 62,000 ha in two phases. The first phase with a potential of 22,000 ha irrigated area was completed in 1974 (Kadawa Scheme) and continues to be largely operational. The irrigation system is by gravity from the Tiga Dam through an 18 km long concrete-lined, main irrigation canal and a 320 km long main drain. Other smaller irrigation schemes in the region are Watari, Thomas, Jehavade, and Jigawa (Oyebode et al.,2014). Although the scheme was initiated by the Kano State Government, the management of the water resources in the scheme was taken over by the Hadejia Jama'are River Basin Development Authority (HJRBDA) following the creation of several states within the former Kano State. The HJRBDA is also responsible for maintaining the irrigation infrastructure, and currently, large-scale rehabilitation of irrigation canals is ongoing in the Kadawa Scheme.

Two (2) categories of land ownership exist in the scheme. At the onset of the scheme, farmers were allocated one-acre plots each, with a considerable portion of the land remaining state-owned. There have been significant changes in land ownership over the years, and large numbers of farmers who were initially landowners now have to rent land from others. The Kano State Agricultural and Rural Development Authority (KNARDA, located in Kano) is responsible for providing extension services to farmers in the scheme. Farmers access inputs from the Kano State Input Supply Company (KNISC) or private dealers in the area. Figure 1 shows KRIS and actual locations of the study area where the salinity and sodicity problem exists.

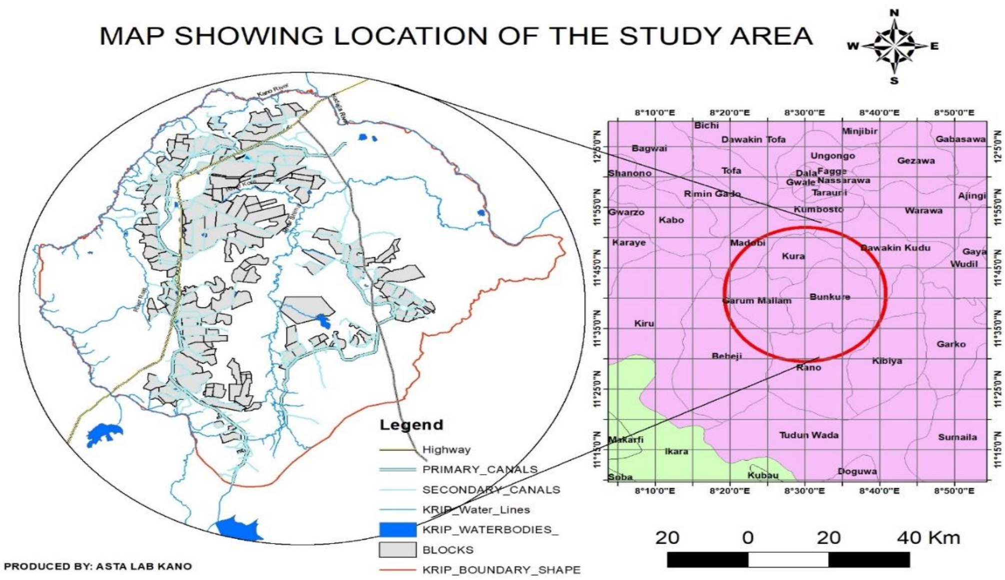


Figure 1 Map of KRIS Showing the Study Location.

2.2 Climate and Seasonality in KRIS

The KRIS is the largest irrigation scheme and the most successful irrigation scheme in the country with a development potential of 61,000 ha of irrigable land.

The project area has three distinct climates

1. The warm rainy season from June to September.
2. The cool dry season from November to February and
3. The hot dry season is from March to May.

Generally, the mean daily air temperature is 26^{o}C with the maximum value of 39^{o}C occurring in April/May and the lowest of 14^{o}C in December. The five months period of rainfall and seven months period of the dry season allows farmers to cultivate crops two to three times per year through irrigation. The crops grown in the area include tomatoes, rice, millet, maize, wheat, and vegetables (Nuhudeen & Adamu, 2016). The warm rainy season is traditionally the farming period for rain-fed crops. Rainfall is highest in July and August during which precipitation exceeds potential evaporation. With the onset of the cool dry season, most rain-fed crops would have been harvested and the northeastern dry, cool, harmattan winds prevail. This season is favorable for the cultivation of wheat, Irish potatoes, and vegetables such as tomatoes and carrots in the area (Raji, 2003).

Previous studies at Kadawa on land use management show that 36 percent of the total land area is effectively managed while 41 percent of the land area is categorized as over-utilized. Within this over-utilized land, the most severe environmental problems are envisaged to be caused by intensive use established on soils of moderate and marginal suitability. Within the Kadawa sub-sector of the KRIS I, serious problems of rising groundwater tables exist as a result of continuous cultivation (Raji, 2003).

The phenological data for both tomato and rice (plant height, number of leaves, number of branches, numbers of flowers) were taken from ten (10) randomly marked tomato plants and the average was taken for each basin weekly. Several plants standing per plot were also recorded until the 5th week. However, Insect infestation occurrence truncated the continuation of the experiment. An effort was made to control the infestation with the application of insecticide (Ampligo, Karate, and salt and oil) which proved aborted as the tomato plant was seriously damaged by leaf miner (Tuta Absoluta) beyond recovery.

2.3 Experimental sites and setup

The experimental trial plots were selected considering the results of salinity maps from the previous studies, physical observations, information from the farm owners, and the preliminary soil chemical analysis results. 3 sets of experiments were set at 3 separate locations having a saline, saline-sodic and sodic conditions, respectively. For all the three sets of trials (i.e., trial on saline, saline-sodic and sodic conditions), 26 by 34 m fields were prepared. The experimental plot layout is shown in Figure 2 for the actual study. The treatment materials (Gypsum, Rice husk, Millet chaff, and Farmyard Manure) were applied using Randomized Complete Block Design (RCBD) at five distinct levels and a control plot. Table 1 shows 5 varied levels of the materials. The fields were then irrigated and left for four weeks to allow decomposition.

Table 1: Varied levels of the treatment materials (tons/ha).

Materials	**Levels (tons/ha)**				
	level 1	**level 2**	**level 3**	**level 4**	**level 5**
Rice Husk (RH)	6.8	8.8	10.8	12.8	14.8
Millet Chaff (MC)	6.8	8.8	10.8	12.8	14.8
Farmyard Manure (FYM)	5	6	**7**	8	9
Gypsum (G)	1	2	3	4	5

For all the 3 sites, rice seedlings were transplanted at a spacing of 25 by 25 cm. Irrigations and subsequent agronomic activities such as weeding, and fertilizer applications were conducted accordingly. Whereas the tomato was planted at a space of 30 by 30 cm based on the average farmers' practice at the KRIS. Figure 3 presents various activities that include the application of salinity remediation materials.

3.0 RESULTS AND DISCUSSION

3.1. Performance of Rice Crop in Saline Soil

The trial results of the effect of indigenous materials (Rice husk, Millet chaff, Farmyard manure) and leaching on saline soil conditions were obtained. The rice yield ranges from 1.35 to 4.75 tons/ha. The results of the various amendments range as follows: Rice Husk (3.40 – 4.40 tons/ha), Millet chaff (3.30 – 4.75 tons/ha), Farmyard manure (2.85 – 3.80 ton/ha), and Leaching (1.85 – 4.20 ton/ha), and the control measured 1.35 ton/ha.

It was observed that millet chaff application at level 2 (8.8 ton/ha) produced the highest yield (4.75 ton/ha) and the result does not show a specific pattern with regards to the rate of application to yield of harvested rice crop. The highest yield next to Millet Chaff was Rice Husk at level 1 (6.8 tons/ha) produced 4.40 tons/ha, the rate of application of the amendment was inversely proportional to the harvested crop yield (Table 2). The application of Leaching seems to be more effective than Farmyard Manure as the highest yield recorded were 4.20 ton/ha at level 5 and 3.8 ton/ha at level 1 respectively and the application follows an almost similar irregular pattern. The analysis of variance shows a significant difference between the treatment and varied levels. This first trial suggests the ineffectiveness of these indigenous materials for saline soil remediation in the affected area.

Figure 4 shows the rice yield obtained from trials 1, 2, and 3, respectively. The results include the three levels of remediation techniques materials and control. It can be observed that rice paddy was higher in the plots treated with rice husk (RH) followed by Millet chaff (MC) and Gypsum (GYP). Similarly, the least rice paddy was obtained from control. This indicated that Rice husk has a high level of efficacy in suppressing salinity followed by Millet chaff and Gypsum. The highest yield from trial 1 of 9.75 ton/ha was obtained from the plot treated with rice husk at level 1 (RH1). Similarly, the higher yield of 8.50 and 9.05 ton/ha was respectively obtained in trials 2 and 3 from the plots treated with rice husk at level 1 (RH1).

Table 2: Rice yield under Trial 1, 2 and 3.

Treatment	Crop Trial 1 (ton/ha)	Crop Trial 2 (ton/ha)	Crop Trial 3 (ton/ha)
GYP1	8.00	7.00	7.50
GYP2	7.50	5.25	6.75
GYP2	6.75	8.25	8.75
MC1	7.50	8.00	7.50
MC2	6.75	5.40	5.00
MC3	8.25	4.00	6.25
RH1	9.75	8.50	9.05
RH2	8.75	8.20	7.85
RH3	6.50	4.00	6.25
Control	**4.20**	**3.75**	**4.10**

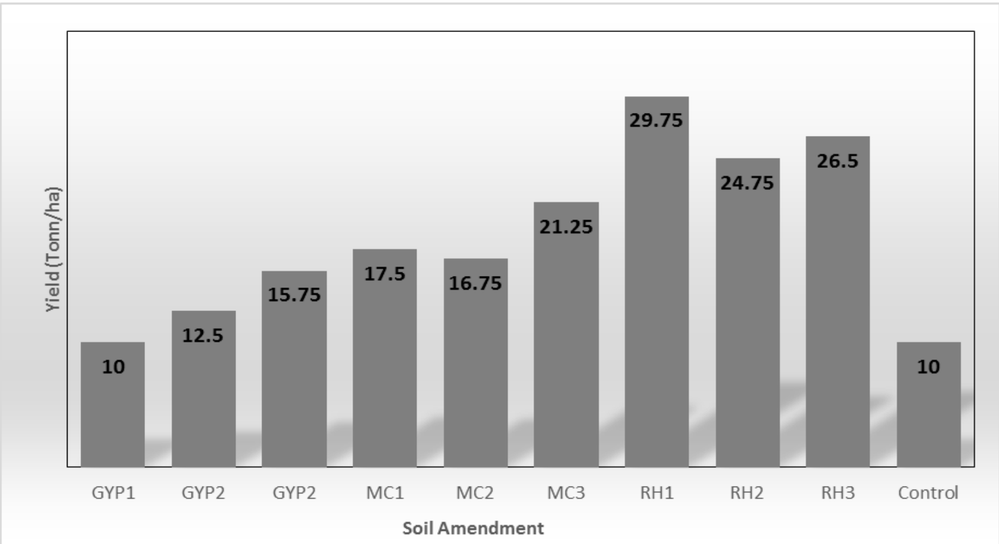
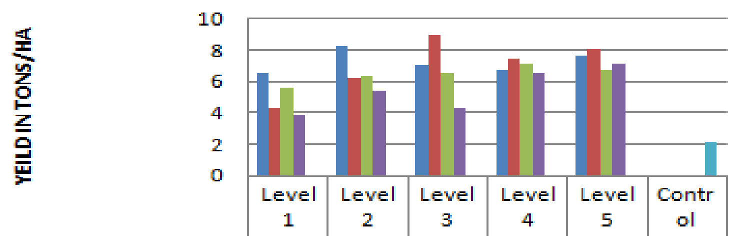


Figure 2: Performance of rice in saline amended soil.

3.2 Performance of Rice Crop on Sodic Soil

Figure 5 presents the effect of indigenous materials (Rice husk, millet chaff, farmyard manure) and gypsum on saline-sodic soil conditions. The result ranges from 2.11 – 8.95 ton/ha with the lowest value (2.11 ton/ha) observed from the control treatment while the highest value (8.95 ton/ha) from millet chaff application. The result of the various amendments range as follows: Rice Husk (6.54 – 8.31 tons/ha), Millet chaff (4.33 – 8.95), Farmyard manure (5.64 – 7.12 ton/ha), and Gypsum (3.87 – 7.12 ton/ha), and the control is 2.11 ton/ha respectively.

The millet chaff application at level 3 contributed to the highest yield (8.95 ton/ha) and the result shows that as the level of application increases, so the yield of the rice crop increases up to the threshold (Level 3) and beyond this threshold, further increase in the application result to decrease in the yield of the crop harvested. The highest yield next to Millet Chaff is Rice Husk with a value of 8.31 ton/ha at level 2 and as it was observed from the result, there was no specific pattern for the rate of application of the amendment to harvested yield. The application of Farmyard Manure and Gypsum gave the same highest yield of 7.12 ton/ha at level 4 and level 5 respectively and the application follows an almost similar pattern which gave a proportionate result between the application of the amendment concerning the yield harvested.



	Level 1	Level 2	Level 3	Level 4	Level 5	Control
Rice Husk (RH)	6.54	8.31	7.04	6.71	7.65	
Millet Chaff (MC)	4.33	6.25	8.95	7.45	8.02	
Farm yard Manure (FYM)	5.64	6.35	6.52	7.12	6.75	
Gypsum (G)	3.87	5.39	4.3	6.5	7.12	
Control (C)						2.11

Figure 3: Response of remediation materials to saline-sodic condition.

As a result of pest infestation on the tomato plots, the yield data has not been recorded, However, the crop phenological parameters were captured at weekly intervals from the first week of transplant to the 5th week for the 3 sets of trials. A weekly increase in the height of tomatoes was recorded for all the treatments with the highest plant height (29.3cm obtained from farmyard manure at level 5 (8t/ha) and one of the lowest values (16.75cm) was recorded at the control plot. All values decreased in week 5 due to the infestation. Record of the number of plant leaves revealed an increase in the number of plant leaves from week 1 to week 3, with the highest value of 113.33 recorded from the rice husk treatment at level 2 (8.8t/ha) while the lowest value of 30.33 was recorded from the control plot on week 1. There was a general and continuous decrease in the number of leaves in week 4 and week 5 due to the infestation of the plants.

Record of the number of branches indicated an increase within the first three weeks except for the control plot which recorded a decrease from week 2. There was a decrease at week 5 due to the infestation of the plants before the plants finally dried off. The result further shows that the control responded quickly to the infestation. There was an increase in the number of flowers shows an increase from week 1 to week 3 and then reduced drastically at week 5. The highest number of flowers (20.67) was recorded at the plot treated with farmyard manure at level 3 (7 tons/ha). At week 3 after transplanting, the lowest mean values of 0.33 and 0.67 number of flowers were recorded at the plot treated with millet chaff at level 2 (8.8 ton/ha) and control, respectively.

A weekly increase in height was recorded for all the treatments in the first three weeks and the highest plant height (22.33cm) was obtained from rice husk at level 4 (12.8 ton/ha) and the lowest value (5.80cm) was recorded at the control plot. The result revealed an increase in the number of plant leaves from week 1 to week 4, with the highest value of 88.33 recorded from the leaching treatment at level 5 while the lowest value of 13 was recorded at the control plot on week 1. For the number of branches, an increase was also recorded within the first three weeks with the highest mean number of branches (12.33) recorded in week 4 in a plot treated with Leaching at level 5, and the lowest value (2) was recorded in the control plot. The number of flowers recorded an increase from week 4 to week 6 and then reduced drastically at week 7. The highest number of flowers (14.67) was recorded at the plot treated with millet chaff at level 1 (6.8 ton/ha). At week 4 after transplanting, the lowest mean values of 0.00 number of flowers were recorded at almost all the treatments except with millet chaff at level 1 (6.8 ton/ha) and leaching at level 3.

The result of the effect of indigenous materials (Rice husk, Millet chaff, Farmyard manure) and leaching on saline soil conditions ranges from 1.35 – 4.75 ton/ha with the lowest value (1.35 ton/ha) observed from the treatment while the highest value (4.75 ton/ha) from Millet chaff application. The result of the various amendments range as follows: Rice Husk (3.40 – 4.40 tons/ha), Millet chaff (3.30 – 4.75 tons/ha), Farmyard manure (2.85 – 3.80 ton/ha), and Leaching (1.85 – 4.20 ton/ha), and the control is 1.35 ton/ha. It was observed that millet chaff application at level 2 (8.8 ton/ha) contributed to the highest yield (4.75 ton/ha) and the result does not show a specific pattern with regards to the rate of application to the yield of rice. The highest yield next to Millet Chaff was recorded from rice husk with a yield of 4.40 ton/ha at level 1 (6.8 ton/ha) and it was observed from the result that, the rate of application of the amendment was inversely proportional to the harvested crop yield. The application of Leaching seems to be more effective than Farmyard Manure as the highest yield recorded were 4.20 ton/ha at level 5 and 3.8 ton/ha at level 1 respectively and the application follows an almost similar irregular pattern.

3.3 Performance of Rice on Saline-Sodic Soil

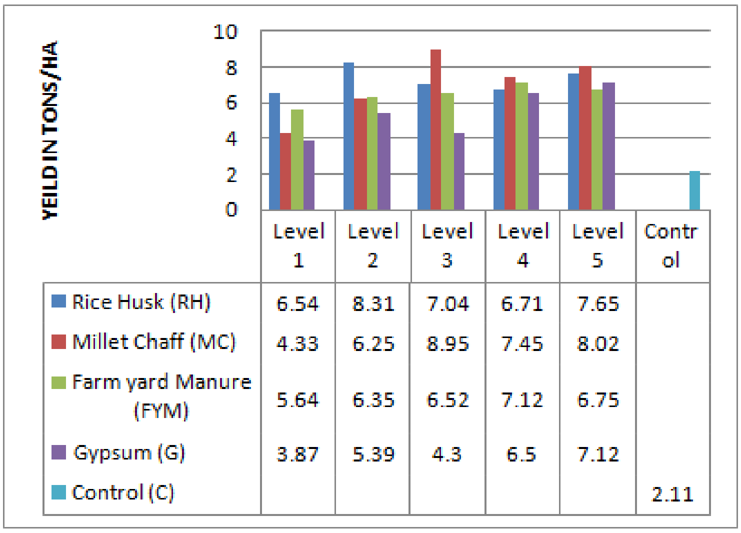
The results revealed a weekly increase for all the treatments with the highest plant height (22.87cm) recorded from rice husk at level 5 (14.8 ton/ha) and the lowest value (5.8cm) was recorded at the control plot. There was an increase in the number of plant leaves from week 1 to week 4, with the highest value of 112.33 recorded from the millet chaff at level 5 (14.8 ton/ha) while the lowest value of 13.00 was recorded at the control plot on the first week. An increase in the number of branches was also recorded, the plot treated with Millet Chaff (MC) at level 5 (14.8 ton/ha) had the highest and the lowest value (2) were recorded in the control, and most of the treatments at level 1.

There was an increase in the number of flowers from week 3 to week 6 and then reduced drastically. The highest mean number of flowers (16.33) was recorded at the plot treated with farmyard manure at level 5 (9 ton/ha). At week 4 after transplanting, the lowest mean values of 0.00 and 0.33 number of flowers were recorded at the control and most of the treatments, respectively. The number of plants standing per plot recorded a decrease from week 1 to week 5. The highest number of plant stands (30) was recorded from the plot treated with farmyard manure at level 5 (9 ton/ha) in week 1 while the lowest mean values of 5 and 6.67 were obtained in gypsum and control treatments respectively and both at week 5.

From the result of the effect of indigenous materials (Rice husk, millet chaff, farmyard manure) and gypsum on saline-sodic soil conditions, a yield of 2.11 – 8.95 ton/ha with the lowest value (2.11 ton/ha) was observed from the control treatment was recorded. The highest value (8.95 ton/ha) was recorded from the millet chaff application. The result of the various amendments range as follows: Rice Husk (6.54 – 8.31 tons/ha), Millet chaff (4.33 – 8.95), Farmyard manure (5.64 – 7.12 ton/ha), and Gypsum (3.87 – 7.12 ton/ha), and the control is 2.11 ton/ha.

The millet chaff application at level 3 contributed to the highest yield (8.95 ton/ha) and the result shows that as the level of application increases, the yield of rice increased up to the threshold (Level 3), and beyond this threshold, further increase in the application resulted to a decrease in the yield. The highest yield next to Millet Chaff was from rice husk treatment with a value of 8.31 ton/ha at level 2 and as it was observed from the result, there was no specific pattern concerning the rate of application of the amendment to harvested yield. The application of Farmyard Manure and Gypsum gave the same highest yield of 7.12 ton/ha at level 4 and level 5 respectively and the application followed an almost similar pattern which gave a proportionate result between the application of the amendment to the yield harvested. The statistical analysis conducted using SPSS software was presented in table 3 which shows highly significant differences between the treatments.

Figure 7 presents the trial results of the effect of indigenous materials (Rice husk, millet chaff, farmyard manure) and gypsum on saline-sodic soil conditions. The result ranges from 2.11 – 8.95 ton/ha with the lowest value (2.11 ton/ha) observed from the control treatment while the highest value (8.95 ton/ha) from millet chaff application. The result of the various amendments range as follows: Rice Husk (6.54 – 8.31 tons/ha), Millet chaff (4.33 – 8.95), Farmyard manure (5.64 – 7.12 ton/ha), and Gypsum (3.87 – 7.12 ton/ha), and the control is 2.11 ton/ha.



	Level 1	Level 2	Level 3	Level 4	Level 5	Control
Rice Husk (RH)	6.54	8.31	7.04	6.71	7.65	
Millet Chaff (MC)	4.33	6.25	8.95	7.45	8.02	
Farm yard Manure (FYM)	5.64	6.35	6.52	7.12	6.75	
Gypsum (G)	3.87	5.39	4.3	6.5	7.12	
Control (C)						2.11

Figure 4: Yield response of rice on saline-sodic soil.

The millet chaff application at level 3 contributed to the highest yield (8.95 ton/ha) and the result shows that as the level of application increases, so the yield of the rice crop increases up to the threshold (Level 3) and beyond this threshold, further increase in the application result to decrease in the yield of the crop harvested. The highest yield next to Millet Chaff is Rice Husk with a value of 8.31 ton/ha at level 2 and as it was observed from the result, there was no specific pattern concerning the rate of application of the amendment to harvested yield. The application of Farm Yard Manure and Gypsum gave the same highest yield of 7.12 ton/ha at level 4 and level 5 respectively and the application follows an almost similar pattern which gave a proportionate result between the application of the amendment for the yield harvested.

4.0 CONCLUSIONS

There are various remediation techniques currently being used by many farmers to curb the ever-increasing problem of salinity and sodicity at the famous KRIS, Nigeria. The remediation materials commonly used and found promising include rice husk, millet chaff, and gypsum, among others. These indigenous approaches proved to be effective in remedying salt-affected soils and the level of effectiveness, viability, and required dosages were established. Similarly, the effect of gypsum as a chemical remediation approach was assessed and compared with the local indigenous materials. This study, therefore, investigates the effectiveness of these salt remediation techniques to validate and encourage their usage as viable materials for reclaiming saline/sodic soils at KRIS. The rice yields have shown high statistical significance under treatments with both indigenous materials and gypsum applications as compared with control conditions where no treatment was given to the planted crops. The study found that rice husk has higher efficacy in suppressing the effect of saline, sodic and saline-sodic soils followed by millet chaff and gypsum. However, the farmers' adoption of such soil salinity remediation techniques could be promoted across the KRIS.

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