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Response of Rice (*Oryza sativa* L.) Varieties to Salicylic Acid, Potassium Silicate and Tamarind Extract in Saline Soils of Kano River Irrigation Scheme Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was carried out in the Eastern and Western sectors of Kano River Irrigation Scheme, Kano State latitude 11º 45'N and 12º 05' N and longitude 8º 45' E and 9º 05' E in the Sudan Savanna Agro-ecology of Nigeria, during the dry season of 2020 and 2021. The experiment was therefore conceived with the aim of introducing improved salt tolerant varieties to farmers in addition to enhancing their tolerance using synthetic and natural plant growth regulators. The treatments consisted of four rice varieties made up of 2 salt tolerant accessions {Arica 1 and Arica

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2, 1 blast resistant variety (Gawal R1) and a variety (FARO 44) as a check} these were factorially combined with foliar application of salicylic acid (0.2g in 1L of water), potassium silicate (16 g/L-1 of K2SiO3), tamarind extract 8% (320ml of extract in 1 liter of water) and a zero control (0). The treatments were laid out in a Randomized Complete Block Design (RCBD) which consisted of 16 treatments replicated six times with a farmer constituting a replication. Results have shown that plant height, leaf area index (LAI), photosynthetically active radiation (PAR), chlorophyll content and the yield were all significantly affected by varietal differences except total number of tillers per plant in 2020. However, in 2021 LAI, PAR and chlorophyll content were not significantly affected by differences due to varieties but the remaining characters differed significantly. Exogenous factors had no effect on all the characters in 2020 but significantly influenced the chlorophyll content, total number of tillers and the yield in 2021. Arica 1 and Faro 44 gave the highest yield. Among the exogenous factors Tamarind extract had significantly heavier paddy yield than the control but was similar to other exogenous factors in terms of effectiveness. Tamarind extract could therefore be suggested to farmers when growing rice under saline or sodic condition in the irrigation scheme due to its lower cost and availability.

Keywords: Growth regulators; irrigation; rice; salinity.

1. INTRODUCTION

Nigeria is the Africa's leading consumer of rice, one of the largest producers of rice in the continent and simultaneously one of the largest rice importers in the world [1]. Nigeria has a total of 5.4 million tonnes of paddy rice in 2017 [2]. Rice is an important food security crop, it is an essential cash crop for it is mainly small-scale producers who commonly sell 80 per cent of total production and consume only 20 per cent. Rice generates more income for Nigerian farmers than any other cash crop in the country [1].

Soil salinity poses a major threat to rice crop productivity. Salinity is found to induce both biochemical and physiological changes causing growth inhibition and yield loss [3,4].

Soil salinity is a potential problem in some parts of Kano River Irrigation Project (KRIP). Saline soils exhibit structural problems such as crusting, hard setting and waterlogging associated with poor infiltration [5]. Visual evidence of salinity, such as crusting and waterlogging have been found on many farmers' fields in Kano River Irrigation Scheme (KRIS). About 73% of farmers in these areas have problems associated with waterlogging and salinity/sodicity [6].

Salinity causes several injuries in plants such as tissue burning, yield reduction, and finally plant death [7]. Salinity leads to the abandoning of land and also reduces production. Farmers, in this case, are restricted to grow only salt tolerant crops. High salt concentrations severely affect rice plants' normal physiology, especially during early stages of growth, and as such, there is need to test some salt tolerant rice varieties.

Most rice farmers in Nigeria are smallholders, applying a low-input strategy to agriculture, with minimum input requirements and low output [8]. Rice productivity in Nigeria is among the lowest within neighbouring countries, with average yields of 1.51 tonne/ha [1].

Despite the importance of rice to the nation, many lands have been abandoned for rice cultivation which have been proven to be due to soil salinity, leading to importation of rice from India, Thailand, United States of America, etc. putting farmers out of work. To ameliorate the effect of soil salinity, foliar application of growth promoters or regulators/ antitranspirants like; salicylic acid, potassium silicate and tamarind extract and the use of some salt tolerant varieties could be used.

Salicylic acid is an endogenous growth regulator [9] and belongs to a group of phenol compounds. It participates in the regulation of physiological processes [10] and also provides protection against biotic and abiotic stress such as salinity [11]. It also has a role in germination under stress condition, although its definite role and the underlying physiological mechanisms have not been fully elucidated [12].

Potassium silicate is a source of highly soluble potassium and silicon. It is used in agricultural production systems primarily as a silica amendment and has the added benefit of supplying small amounts of potassium [13], and also promotes greater tolerance to salinity [14].

Tamarind (*Tamarindus indica* L.) tree plant is available almost everywhere in dry areas of Northern Nigeria, its leaf extract can be utilized as a growth promoter to reduce the risks involved in the use of synthetic growth promoters and also promote organic farming.

The abandoned land due to salinity could be put into use if tolerant varieties are screened. This will increase the level of productivity; reduce the amount of rice importation; increase farmers' income; help to attain food security and increase the economic growth, and development of the nation.

The information obtained will be useful to extension agents and policy makers in respect to rice production.

1.1 Objectives

1. To evaluate the growth and yield of rice varieties as affected by Salicylic acid under the saline soils of Kano River Irrigation Scheme (KRIS).
2. To evaluate the growth and yield of rice varieties as affected by Potassium silicate under the saline soils of KRIS.
3. To evaluate the growth and yield of rice varieties as affected by Tamarind extract under the saline soils of KRIS.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was carried out in the Eastern and Western sectors of Kano River Irrigation Scheme, Kano state, between latitudes 11° 45'N and 12° 05' N and longitude 8° 45' E and 9° 05' E in the Sudan Savanna Agro-ecology of Nigeria, during the dry season of 2020.

2.2 Treatments and Experimental Design

The treatments consisted of four rice varieties made up of 2 salt tolerant accessions (Arica 1 and Arica 2), one blast resistant variety (Gawal R1) and a variety (FARO 44) as a check; these were factorially combined with foliar application of salicylic acid (0.2g in 1L of water), potassium silicate (16 Gl^{-1} of K_2SiO_3), tamarind extract 8% (320ml of extract in 1Lof water) and a zero control (0). The treatments were laid out in a Randomized Complete Block Design (RCBD) which consisted of 16 treatments replicated ten times.

2.2.1 Plot size

The gross plot size was 3m x 3m ($9m^2$), consisting of 225 stands of rice, while the net plot was 3m x 1m ($3m^2$) consisting of 75 stands of rice. A gap of 0.5m was left between plots.

2.2.2 Seed source and description of varieties

The rice varieties were obtained from Africa Rice, these are: Arica 1, Arica 2, Gawal-R1 and Faro 44. The Arica 1 and Arica 2 are both accessions.

i. Faro 44: this variety was released in 1992 with an old variety name as SIPI 692033. It is planted in irrigated swamp/shallow swamp ecologies. It is a long grain type with 100-115 days of grain growth duration. It has a yield potential of 4.0-6.0 t ha^{-1} and also resistant to blast.
ii. Gawal R1: this variety was released in 2017 with an old variety name as Chaotan. It is planted in irrigated swamp/shallow swamp ecologies. It is a long grain type with 90-100 days of grain growth duration. It has a yield potential of 10.4 t ha^{-1} and also resistant to blast.
iii. Arica 1 WAB 2094-WAC 2-TGR 2-B: It is grown in rainfed lowland areas and high yielding over NERICA L19 and BW 348-1. Suitable for Mali and Burkina Faso countries.
iv. Arica 2 WAB-2056-2-FKR 2-5-TGR 1-B: It is grown in rainfed lowland areas and high yielding over BW348-1, NERICA L19 and WITA 12. Suitable for Nigeria and Mali countries.

ARICA stands for Advance Rice Varieties for Africa. Both Arica 1 and Arica 2 have particular advantages of being iron toxicity tolerant, cold tolerant, salt tolerant and good grain quality (high milling recovery, low chalky and short cooking time). Research showed that Arica 1 and Arica 2 respectively showed 20-44% and 50-111% higher yield than NERICA-L 19 which is in wide use.

2.3 Preparation of Exogenous Factors

2.3.1 Tamarind leaf extract

About 5kg of fresh leaves and shoots were crushed with 2 liters of water using mortar and pestle, which were then filtered out as a stock solution after 2 days; the liquid extract of 320ml (8%) was then diluted with one (1) liter of water.

2.3.2 Salicylic acid

Salicylic acid comes in solid crystals. 0.2 grams of salicylic acid was crushed to a fine powder, and then 0.5 liter of water was poured to help dissolve it for a day. And on application the other 0.5 liter of water was applied to balance the one (1) liter of water.

2.3.3 Potassium silicate

Potassium silicate comes in liquid form; 16g of it was weighed which was then diluted with one (1) litre of water.

2.4 Cultural Practices

2.4.1 Nursery practices

The soil was flooded, puddled and slightly raised where a significant amount of rice was sown.

2.4.2 Land preparation

The land was cleared, harrowed and made into basins of 3m x 3m, which were then demarcated by 0.5m between plots and 1m between replications so as to provide easy movement.

2.4.3 Transplanting

The seedlings raised in the nursery were transplanted 5 weeks after sowing and spaced 20cm x 20cm inter and intra row spacing.

2.4.4 Fertilizer application

Fertilizer was applied in two split doses, basal application of NPK 15:15:15 was used to supply 60 kg each of N, P_2O_5, and K_2O at 3 weeks after transplanting while the balance of 60 kg nitrogen was supplied using urea (46% N) as top dressing at 6 weeks after transplanting.

2.4.5 Weed control

The experimental plots were kept weed free using the manual method. This was done at 3rd and 6th weeks after transplanting.

2.4.6 Pest and disease control

During the course of the study, stem borer was identified. The chemical used was Lambda-cyhalothrin insecticide at the rate of 1.5g a.i. /ha in 100L of water. It acts as a contact and systemic poison.

2.4.7 Harvesting

Rice was harvested at physiological maturity stage when the grains were hard and turned yellow or brown in color. The harvesting was done by cutting the rice at the base and threshed by smashing the panicles on a drum and later winnowed and weighed. The plot yield was converted in to yield per hectare by multiplying paddy from the plot by a factor of 3333.33 obtained by dividing 10, 000 m^2 by 3 m^2.

2.5 Data collection

2.5.1 Plant height

The heights of three sampled plants were measured using meter rule from the ground level to the tip of the flag leaf at 9th weeks after transplanting. Mean values for each plot were recorded.

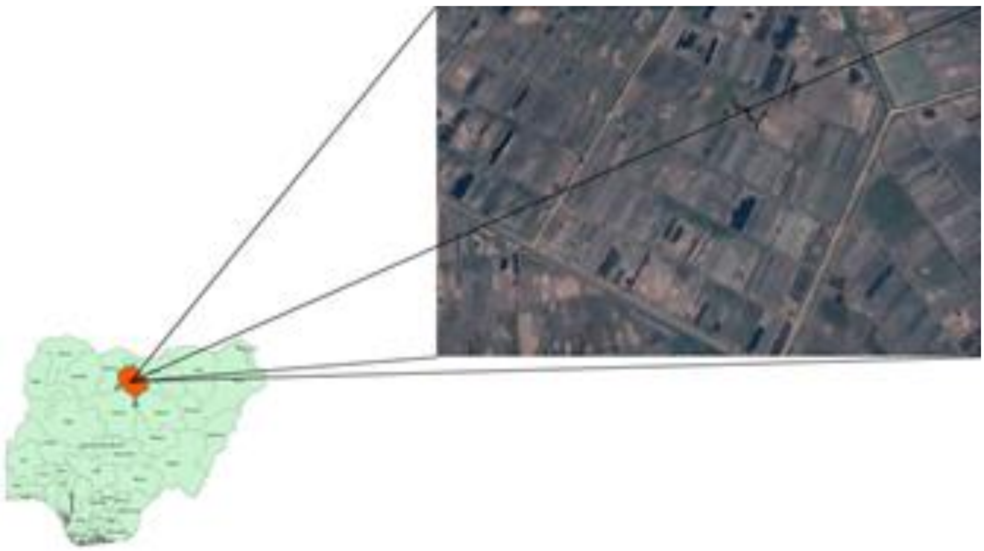

Fig. 1. Experimental site

2.5.2 Leaf area index

The leaf area index of three sampled plants were obtained from the sampled plants by measuring, using AccuPAR model LP-80 PAR/LAI Ceptometer (Decagon Device, Inc. Pullman, USA) at 8th weeks after transplanting.

2.5.3 Photosynthetically active radiation

It was measured..Intercepted photosynthetically active radiation was measured using AccuPAR model LP-80 PAR/LAI Ceptometer (Decagon Device, Inc. Pullman, USA) at 8th weeks after transplanting.

2.5.4 Total number of tillers plant^{-1}

They were counted and recorded from three sampled plants at 9th weeks after transplanting. Mean values for each plot were recorded.

2.5.5 Total chlorophyll content

It was measured at 8th week after transplanting using SPAD (SPAD meter – 502, Konica - Minotta).

2.5.6 Meteorological data

they were collected from Centre for Dryland Agriculture, Geographic Information System (GIS) Laboratory, Bayero University, Kano.

2.5.7 Soil sampling and analysis

Soils of the experimental sites were randomly collected using auger at a depth of 0-20cm before land preparation. The samples were bulked and sampled, then subjected to routine analysis according to standard procedure [15].

2.5.8 Data analysis

Data collected were subjected to analysis of variance (ANOVA) as described by [16] using Genstat 17th edition. The treatment means were separated using Student Newman-Keuls test (SNK) at 5% probability level.

3. RESULTS

3.1 Physical and Chemical Properties of Soil of the Experimental Sites

Results of the soil analysis from the experimental sites (Table 1) show that the soils did not differ much in textural class and other chemical and physical properties. Soil at Garun mallam was sandy loam with particle distribution of sand (648.0 g kg^{-1}), silt (218.0 g kg^{-1}) and clay (134.0 g kg^{-1}). For chemical composition of the soil, nitrogen, phosphorus and organic carbon contents were low. The pH of the area places the soil in a moderately alkaline state. For exchangeable cations; Ca, Mg, and K were medium while Na was low.

Soil at Kura was loam with particle distribution of sand (522.3 g kg^{-1}), silt (334.6 g kg^{-1}) and clay (143. 1 g kg^{-1}). The nitrogen, phosphorus and organic carbon contents of the soil were low. The pH of the area places the soil in a neutral state. For exchangeable cations; Ca was low, Mg and K were medium while Na was low. The salt contents of both areas were above normal range but were not high enough to define the soils as saline, sodic or saline-sodic, but literature showed that plants may be starved of nutrients (Sonon et al*.,* 2015).

Table 1. Physical and chemical properties of soil at Garun Mallam and Kura during 2020 dry season

Properties	Garun Mallam	Kura
Physical %		
Sand	64.80	52.23
Silt	21.80	33.46
Clay	13.40	14.31
Textural Class	Sandy loam	Loam
Chemical		
pH in water	8.16	6.84
EC(dS/m)	0.21	0.22
Organic Carbon (g kg^{-1})	0.47	0.45
Total Nitrogen (g kg^{-1})	0.06	0.04
Available Phosphorus (mg kg^{-1})	5.52	4.29
Exchangeable Bases (cmol^{+} kg^{-1})		
Ca^{2+}	2.30	1.67
Mg^{2+}	0.79	0.79
K^{+}	0.17	0.16
ECEC	3.39	2.75
ESP (%)	2.51	2.93

Analyzed at Center for Dryland Agriculture laboratory

3.2 Effects of Exogenous Factors on Plant Height, LAI, PAR, Chlorophyll Content, Total Number of Tillers and Yield of Rice Varieties

Table 2 shows plant height, leaf area index (LAI), photosynthetically active radiation (PAR), chlorophyll content, total number of tillers and yield of rice varieties as affected by potassium silicate, salicylic acid, tamarind extract and the control in 2020 and 2021 dry season at Kano River Irrigation Project (KRIP). Gawal R1 had significantly taller plants than Arica 1, Arica 2 and Faro 44 which were at par. The exogenous factors had no effect on plant height in 2020. However, in 2021, Arica 1 was significantly taller than Arica 2 and Faro 44 which were statistically similar but significantly taller than Gawal R1. The exogenous factors had no effect on plant height in the same year.

The differences in LAI among the varieties were significant in 2020 only, where Arica 1, Arica 2 and Faro 44 were at par but significantly higher than Gawal R1. The exogenous factors had no significant effect on LAI in both years. Gawal R 1 had significantly more PAR than all the other varieties which were observed to trap the same PAR but the effect of exogenous factors was not significant in 2020. The data for 2021 was not available because we could not get the equipment to measure it at the time. Chlorophyll contents differed significantly among varieties in 2020 only. Arica 1 had the highest chlorophyll content but was at par with Arica 2 and significantly higher than Faro 44 which had significantly higher chlorophyll than Gawal R1. The effect of the exogenous factors was also significant in 2021 only where Potassium silicate and Salicylic acid had statistically similar chlorophyll content but significantly higher than Tamarind extract and the control which were also at par.

The total number of tillers was not affected by varietal differences in 2020, but in 2021, Arica 2 and Faro 44 were statistically similar but had significantly more number of tillers than Gawal R1 which also had significantly more number of tillers t ha^{-1} than Arica 1. The effect of the exogenous factors was not significant in 2020, however, in 2021, Tamarind extract, Salicylic acid and Potassium silicate were at par but Tamarind extract and Salicylic acid gave more number of tillers than the control.

The paddy yield was significantly influenced by differences in varieties of rice in both years. In 2020, Arica 1 gave the highest yield but was at par with Arica 2 and Faro 44, however, Arica 1 and Faro 44 had significantly heavier grains than Gawal R 1. In 2021, Faro 44 had significantly heavier grains than Arica 2 which was significantly heavier than Arica 1 which was also significantly heavier than Gawal R1. The effect of exogenous factors was not significant in 2020, however, in 2021, Tamarind extract had significantly heavier paddy yield than the control but was at par with all the other exogenous factors.

Table 2. Effects of exogenous factors on plant height, LAI, PAR, chlorophyll content, total number of tillers and yield of rice varieties in 2020 and 2021 at KRIP

Treatments	Plant height (m)		LAI		PAR (nm)		Chlorophyll content		Total number of tillers		Yield (kg ha^{-1})	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Rice Var. RV												
Arica 1	0.82_b	0.81a	3.5_a	2.0	162.6_b		43.4_a	21.3	18.4	20.5_c	7249.1_a	7942_c
Arica 2	0.82_b	0.77_b	3.3_a	2.0	171.8_b	NA	42.6_{ab}	19.9	19.1	26.5_a	6603.5_{ab}	9701_b
Faro 44	0.82^b	0.73_b	3.4_a	2.3	156.8_b	NA	42.0_b	18.9	20.2	26.5_a	7161.5_a	9743_a
Gawal R 1	0.90_a	0.71_c	2.2_b	2.0	366.3_a	NA	39.1_c	22.7	19.0	23.4_b	4290.7_b	7861_d
SE ±	0.015	0.014	0.12	0.15	12.41	NA	0.45	1.43	1.07	0.91	284.0	2007
Exogenous Factors (EF)												
Control	0.82	0.75	2.9	2.0	211.0	NA	42.2	37.2_b	19.2	22.5_b	5976.9	7701b
Potassium silicate	0.86	0.73	3.2	2.1	209.3	NA	42.1	43.5_a	20.8	23.4_{ab}	6521.4	8567ab
Salicylic acid	0.84	0.77	3.2	1.9	221.5	NA	41.8	44.8_a	18.8	25.4_a	6618.1	8903ab
Tamarind extract	0.84	0.77	3.1	2.3	215.7	NA	41.1	38.6_b	18.0	25.9_a	6188.6	10,076a
SE ±	0.015	0.014	0.12	0.15	12.4	NA	0.45	1.43	1.07	0.91	284.0	2007
Interaction												
RV X EF	NS	NS	NS	NS	NS	NA	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) in column and row are not significantly different at 5% probability level using Student Newman-Keul Test

Table 3. Meteorological data covering the experimental period at Kura LGA Kano in 2020 and 2021

Month	Temperature °C				Rainfall (mm)		Relative humidity (%)		Wind speed ms^{-1}	
	Minimum		Maximum							
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
March	19.75	19.9	37.27	36.02	0.00	0.37	22.26	26.85	2.64	2.60
April	23.13	21.63	37.12	39.10	120.55	1.11	47.66	25.88	2.71	2.53
May	23.68	23.66	36.18	39.36	185.99	12.71	58.98	41.42	2.28	2.29
June	23.28	25.58	34.67	39.99	158.50	197.40	64.87	39.11	2.10	2.36

Table 4. Meteorological data covering the experimental period at Garun Mallam LGA Kano in 2020 and 2021

Month	Temperature °C				Rainfall (mm)		Relative humidity (%)		Wind speed ms^{-1}	
	Minimum		Maximum							
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
March	19.85	19.14	36.28	34.88	0.00	3.72	27.54	35.95	3.47	3.39
April	22.68	21.37	34.56	37.39	203.77	6.0	57.97	35.94	3.49	3.21
May	23.01	23.17	33.48	36.89	91.89	65.41	68.24	51.87	2.74	2.85
June	22.59	24.87	30.03	37.17	212.65	376.2	72.10	46.69	2.60	3.08

Source: Centre for Dryland Agriculture, BUK, GIS Laboratory

4. DISCUSSION

From the results of the rice experiment the yield was observed to be high (Table 2) this may be as a result of the seed quality, since the seed was obtain directly from Africa Rice and from the varietal description it was reported that Gawal R1 could give a yield up to the level (10 t ha $^{-1}$) we got from in this experiment. Other reasons may be due to higher moisture content as a result of inadequate drying period of the paddy because the rice was harvested during rainy season (Table 3 and 4). Good management of the trial which was jointly managed by the researchers and farmers might have contributed to the high yield that was obtained more over this was similarly reported by other research teams under TRIMING project namely Africa Rice and the one led by Institute for Agricultural Research, Ahmadu Bello University, Zaria who worked on Sustainable Rice Intensification at Bakolori Irrigation Scheme Nigeria.

4.1 Growth and Yield Response of Rice Varieties

The differences among the varieties were significant in 2020 and 2021. Gawal R1 had significantly taller plants than Arica 1, Arica 2 and Faro 44 which were at par. However, in 2021, Arica 1 was significantly taller than Arica 2 and Faro 44 which were statistically similar but significantly taller than Gawal R1. This could be as a result of inherent genetic ability of the varieties. There were significant differences in leaf area index and photosynthetically active radiation due to varietal differences. At Garun mallam Arica 1 recorded the highest LAI in 2020, even though it was statistically similar to Faro 44 and Arica 2. This was expected because resistant varieties grow vigorously, healthy, very active and also able to withstand external factors. Gawal-R1 was statistically higher in PAR in 2020. It is a well-known fact that taller varieties are more likely to trap more solar radiation than shorter varieties which is closely related to its inherent ability. It was by [17] reported a reduction in rate of photosynthesis of a salinity tolerant rice cultivar to be associated with decreased Rubisco activity due to the accumulation of ions in the chloroplast.

Numbers of tillers plant^{-1} was significant in 2021 with Faro 44 and Arica 1 producing more tillers which could be attributed to their genetic make-up. With regards to chlorophyll content, it is considered as an index to measure leaf injury under salt stress [18]. A significant effect was observed statistically at both locations, even though Arica 1 recorded the highest chlorophyll content.

The paddy yield was significantly influenced by differences in varieties of rice in both years. In 2020, Arica 1 gave the highest yield but was at par with Arica 2 and Faro 44, however, Arica 1 and Faro 44 had significantly heavier grains than Gawal R 1. In 2021, Faro 44 had significantly heavier grains than Arica 2 which was significantly heavier than Arica 1 which was also significantly heavier than Gawal R1. The high yield observed in Arica 1 might due to its high LAI and high chlorophyll content that might have facilitated better light interception leading to higher photosynthesis, more dry matter production and grain filling hence higher yield, However, in 2021 Faro 44 might had higher yield due to its high LAI and better tillering ability that ensured better light interception and more grain number and weight for higher yield. Faro 44 being the equivalence of SIPI a local variety used by farmers may be genetically more pure than the farmers SIPI which may have suffered genetic erosion and adulteration over the years. Farmers should therefore be encouraged to purchase and use Faro 44 from reputable sources instead of the seeds they saved.

4.2 Effect of Plant Growth Regulators on Growth and Yield Characters of Rice

Application of plant growth regulators did not significantly affect the growth parameters of rice at both locations. This could be as a result of the treatments being applied once and at later vegetative growth stage prior to booting stage. The treatments should be applied at growth, booting and panicle initiation stages, but due to the COVID-19 pandemic in 2020, the treatments were applied only once. This agrees with the findings of 14 who reported that the role of Si element in vegetative phase do not affect rice growth especially plant height, and in contrast to the findings of [19] who observed that foliar spray of SA at 20 ppm on hybrid rice had a significant effect on plant height. A study by [20] also observed a significant increase in plant height and leaf area when 1.00mM was applied to citrus crop. It was] observed by [21] that the spray of SA at 15 mg/L significantly increased plant height in mung bean. However, in 2021 the total number of tillers were also significantly increased by application of SA and Tamarind extract when compared to the control, this is in agreement with [22] who reported that foliar spray of SA to the foliage of wheat crop enhanced productivity due to an improvement in all growth characteristics. [23] reported that there was a decrease in growth at higher sodium concentrations due to a decrease in the uptake of K^+ and Ca^{2+}, this confirmed what we observed in our experiment where Ca^+ and K^+ concentrations were very low. It was reported [24] that the exogenous spray of SA and $ZnSO_4$ levels had significant effect on number of tillers. Increase in shoot growth in rice by exogenous spray of SA was reported by [10]. Maximum number of productive tillers was found in 0.05% silicon aqueous solution application while minimum in 0.025% silicon aqueous solution application [25]. A similar report by [26] stated that applied silicon enhanced the number of productive tillers and total number of tillers in a quadrant. Significant increase in spikes per panicle when 1.00% silicon aqueous solution was applied to rice plant [25].

An increase in growth parameters of salt affected plants in response to SA might be related to the protective role of SA on membranes that might increase the tolerance of plants to salt stress [27]. It is well known that the promoting effect of SA on leaf area is attributed to its important roles on activating cell division and the biosynthesis of organic foods [20]. In addition, [28] mentioned that enhancing effect of SA on the availability and movement of nutrients could result in stimulating different nutrients in the leaves. Foliar application of SA increased the leaf area of sugarcane [29]. The exogenous application of SA helps in preventing the lowering of indole-3-acetic acid (IAA) and cytokinin levels in salinity stressed wheat plants resulting in the betterment of cell division in root apical meristem, thereby increasing growth and productivity of plants [30]. Exogenous application of SA results in accumulation of abscisic acid (ABA) which contributes to pre-adaptation of seedlings to salinity stress as ABA induces the synthesis of a wide range of anti-stress proteins, thereby providing protection to plants [30].

No significant difference was observed in relation to electrolyte leakage, proline content and chlorophyll content except at Kura where potassium silicate had the highest chlorophyll content. This result is in line with the findings of [31] who reported that silicon increased chlorophyll content, relative water content and visual quality under non saline water and low concentrations of salinity in both short and long term exposures of Kentucky bluegrass. It was observed by [32] that an increase in chlorophyll content when aqueous leaf extract of tamarind was applied to maize plant which was a result of growth promotion effects of chemicals like phenolics, terpenoids, carbohydrate and amino acids present in tamarind leaves which increases growth at low concentrations. It was reported by [33] that plant extract of some tree crops can influence crop growth. A contradictory report concerning electrolyte leakage goes to a strawberry plant being treated with SA which showed far less electrolyte leakage than control plants following salt stress [44]. Data also exist which showed that SA causes increases in the activities of anti-oxidant enzymes which, in turn, protect plants against the generation of Reactive Oxygen Species (ROS) and membrane injury, or may result in the synthesis of other substances which have a protective effect on plants growing under salt stress [45]. Proline on the other hand is one of the important components of the adaptation of plants to salinity; pretreatment with SA will contribute to the accumulation of this amino acid under stress through maintaining an enhanced level of ABA in seedlings [34].

Silicon is an important micronutrient for healthy and competitive growth of all cereals including rice (Brunings et al*.,* 2009). Role of silicon in plant health and growth has been investigated in silicon accumulating crops and it seemed to be effective (Jinab et al*.*, 2008). Research evidences proved that adequate uptake of silicon (Si) can increase the tolerance of agronomic crops especially rice to both biotic and abiotic stresses [35]. Silicon uptake by plants reduces the susceptibility to chewing insects such as stem borer; it might be by rendering plant tissue less digestible or by greatly damaging the mandibles of feeding insects [36]. Silicon deficiency in plants makes them more susceptible to insect feeding, fungal diseases, germs attack and abiotic stresses that adversely affect crop yield and quality. Low silicon uptake has been proved to increase the susceptibility of rice to diseases such as rice blast, leaf blight of rice, brown spot, stem rot and grain discoloration [46].

Many scientists working on role of silicon in plant growth have concluded that reduced amount of silicon in plant develops necrosis, disturbance in leaf photosynthetic efficiency, growth retardation and reduction of grain yield in cereals [37]. Although silicon has not been considered important for vegetative growth but it aids the plant in healthy development under stresses in different grasses especially in rice.

Application of growth regulators did not influence paddy yield in 2020. This was expected because some of the plants were eaten by stray animals at Kura in few instances, thereby retarding the growth of the plant. It could also be because of the environmental stress being experienced by the plant. This contradicts the results of [26] and [38], however, [39], reported that silicon application does not affect paddy yield. Effects of silicon on yield are related to the deposition of the element under the leaf epidermis which results in a physical mechanism of defense, reduces lodging, increases photosynthesis capacity and decreases transpiration losses [40]. However, in 2021 the paddy yield was significantly increased by application of Tamarind extract when compared to the control but was at par with all the other exogenous factors. The result was in agreement with the findings of [32] who observed an increase in grain yield and harvest index of maize when aqueous leaf extract of tamarind was applied, which could be attributed to the presence of pectin in the extract; an important cell wall polysaccharide that allows primary cell wall extension and plant growth [41]. It wasalso observed by [19] in contrast to this that seed yield increased significantly when (40 ppm) of SA treatment was applied over control. It was observed by [42] that SA in treated plants increased grain yield by 13 % over control in rice. The concentration of the exogenous factors used in our research may not have reached the levels that could cause appreciable increase in most of the characters measured or the environment had different climatic and soil variables than that of the authors who reported appreciable increase in these characters [43].

5. CONCLUSION

The paddy yield was significantly influenced by differences in varieties of rice and Arica 1 and Faro 44 gave the highest yield. Among the exogenous factors Tamarind extract had significantly heavier paddy yield than the control but similar to other exogenous factors in terms of effectiveness. Tamarind extract could be suggested to farmers when growing rice under saline or sodic condition in KRIS. Arica 1 and Faro 44 rice varieties are suggested to be grown by farmers under saline or sodic condition in the same location.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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