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Leaf Nutrient Content and Yield of Rice Cultivars under Different Concentrations of Chloride and Sulphate Salts of Sodium

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Abstract*: Identification of high yielding varieties of rice in saline soils is important in increasing its cultivated land area for production. The yield and leaf nutrient content of IR20, POKKALI, IR29 and NERICAI rice varieties were examined at different concentrations of sodium salts to assess their tolerance to soil salinity. Saline solutions of sodium chloride (NaCl) and sodium sulphate (Na_2SO_4) were used to irrigate the plants at concentrations of 0 (control), 5, 10 and 15 ds/m. Panicle length was decreased significant by NaCl solutions only in POKKALI and NERICA1 from 10 ds/m and above compared to the control while Na_2SO_4 did not significantly affect the parameter in all the varieties. Number of tillers/plant was also deceased by NaCl solution in all the varieties except NERICA1. A significant reduction was obtained in IR20 and IR29 from 10 ds/m and above, and at 15 ds/m in POKKALI. Na_2SO_4 however reduced the variable in IR20 and IR29 from 5 ds/m and above while POKKALI differed from 10 ds/m, but no significant difference was observed as compared to the control in NERICA1. There was also variation in the spikelets/plant among the varieties depending on the salt type and concentration. 100-Grain weight/plant reduced significantly only in IR20 at 15 dm/s under NaCl as well as in IR29 and NERICA1 at 15dm/s under Na_2SO_4. Grain length was not affected in any of the varieties by salt treatments. The flag leaf length was also not significantly affected by NaCl treatment but Na_2SO_4 solution at 15 ds/m caused significantly reduced values in all the varieties. There was accumulation of Na^+ in the leaf of salt-treated plants with increasing concentration of salt in all the varieties. Leaf K^+, Ca^{2+} and Mg^{2+} generally decreased in plants exposed to salinity with variation among varieties depending on salt type and concentrations, except in IR29 with increased leaf Mg^{2+} as well as NERICA1 with higher leaf K^+ and Mg^{2+} content under Na_2SO_4 treatment than in the control. There was variability among the varieties depending on salt type and concentrations in the response of the four rice varieties to salinity, but NaCl was more severe than Na_2SO_4.

***Keywords*: Oryza sativa, varieties, soil salinity, tolerance, yield.**

1. INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the family Malvaceae. It is the most important staple food for about half the human race [1].The bulk of world rice production is for food use, although some is used as animal feed and processed for industrial purpose. Nigeria ranks among the top 12 rice consuming countries in the world, with an approximate annual demand of 5 to 6.4 million metric tons per year [2], Unfortunately, much of this consumption capacity is largely catered for by the importation of rice from other rice-producing countries because Nigeria is not yet sufficient in rice production due to the poor local production that is not commensurate with the high consumption pattern [2]. Nigeria is currently the second largest importer of rice in the world, and the largest net importer in Africa, with an estimated 356 billion naira spent annually on rice importation [2].

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Meanwhile, the cultivation and production of this highly priced and very important food crop is dwindling. The arable land area for its production particularly in the developed countries has fallen at an accelerating rate ever since. Much of the land that could be brought into production is characterized by significant agronomic and suitability constraints, and the distribution of land suitable for cropping is skewed against those countries that have most need to raise production [2].

One of the most important factors responsible for loss of soil productivity is high level of salt in soil. Various salts of sodium have been identified to most commonly contribute to soil salinity mainly due to the use of fertilizers, and can be significant in agricultural situations [3]. In addition, arid and semi-arid regions of the world rely largely on irrigation practices for crop production. In Sub-Saharan Africa, the indicators of reduced cultivated land area show considerable expansion with irrigated agricultural areas over the last decade, especially in developing countries [2]. Unfortunately, some of the water for irrigation contained some levels of salt as a result of salt water intrusion, which builds up salt in soil over a period of time. Thus, soil salinization is one of the fast growing problems of agriculture, with about 23% of the world's cultivated and irrigated land being saline, causing reduction in crop productivity and loss of arable land [3]. Soil salinity has been widely reported to negatively affect germination, growth and yield of many crop plants [4], [5], [6], [7], [8]. Salinity affects almost every aspect of the physiology and biochemistry of plants and significantly reduces yield. High exogenous salt concentrations affect seed germination, cause water deficit and imbalance of the cellular ions resulting in ion toxicity and osmotic stress [9]. Salt stress has been reported to cause an inhibition of growth and development, reduction in photosynthesis, respiration and protein synthesis in sensitive species [10], [11].

Unfortunately, the problem of soil salinity will continue as long as irrigation is being practiced, and it is expected that there would be about 30% arable land loss within the next 25 years due to salinity [3]. Many varieties of rice have been developed over time, which can be switched over to by farmers every few years. Farmers in Nigeria find rice more adaptable than a high input staple food like maize and seem to be willing to grow it no matter the constraint they are facing, hence it is possible for Nigeria to be self-sufficient in rice production if salt-tolerant varieties are identified to minimize the negative impact of salinity on their productivity and possibly extend their cultivation to saline soil in coastal areas.

IR20, POKKALI, IR29 AND NERICAI are improved varieties of rice, which are high yielding, early maturing, readily available, maximum tillering ability, maximum grain production, high fertility ratio, improved reproductive development and commonly grown by local farmers in South-Western Nigeria. The research is aimed at identifying the salt-tolerance level of the varieties in terms of yield in order to boost their land cultivated areas, which will contribute to self-sufficiency in rice production to meet domestic needs and possibly produce for export in Nigeria.

2. MATERIALS AND METHODS

2.1 Experimental plants:

Seeds of four rice varieties; IR20, IR29, NERICA1 and POKKALLI were utilized in the experiment. They were collected from the African Rice Centre, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

2.2 Source of soil:

The soil was river sand collected behind the Department of Botany, Obafemi Awolowo University, Ile-Ife, Nigeria. The soil was porous with high leaching rate, thus, excess salt accumulation could be avoided by flooding with water and allowed to drain. Soil samples were dried, passed through a 2-mm sieve, and analyzed for the physico-chemical parameters. Particle distribution was determined using the rapid method; pH was measured in 1:1 soil: water suspension, Nitrogen was determined by the modified Kjeldahl method while phosphorus was assayed by Bray's P1 solution and read on a spectrophotomer. Cations were extracted with 1.0 M ammonium acetate solution at pH 7.0; sodium and potassium contents in the extract were determined by flame photometry while calcium and magnesium were measured by atomic absorption spectrophotometry. Organic carbon was determined by the wet oxidation method while cation exchange capacity (CEC) was by ammonium distillation. All the procedures followed the the standard method of the Association of Official Analytical Chemists [12] at the Department of Soil Science, Faculty of Agriculture, Obafemi Awolowo University, Ile-Ife, Nigeria.

2.3 Preparation of nutrient and salt solutions:

Nutrient solution was prepared following the method described by [13]. Stock solution was prepared by dissolving equimolar amounts of salts of nutrients in 1L distilled water. About 150ml of each stock solution was mixed and made up to 120 litres, which was used to irrigate the plants to provide adequate nutrient for growth. Pure sodium chloride (NaCl) and sodium sulphate (Na_2SO_4) salts obtained from the laboratory of the Department of Botany, Obafemi Awolowo University, Ile Ife, Nigeria were used to prepare solutions of NaCl and Na_2SO_4 salts each at the concentrations of 5, 10 and 15 ds/m by diluting the salt with water gradually until the desired concentrations are achieved using conductivity meter.

2.4 Experimental set up:

Five kilograms (5 kg) of air-dried soil was filled into perforated plastic pots (21 cm diameter and 17 cm depth) and arranged in the screen house of the Department of Botany, Obafemi Awolowo University, Ile Ife, Nigeria (Latitude-7^o28′N, Longitude 4^o 33′E and 272 m above sea level). Five seeds of rice were sown in each pot and watered regularly for germination to take place in March 2015. Plants were thinned to two seedlings per pot at 3 weeks after sowing. Seedlings were nurtured with the nutrient solution with each pot supplied with 200 ml every other day up to 14 days to allow for sufficient growth and adequate nutrient availability before salinization. Salinity treatments commenced at 5 weeks after sowing and each pot received 200 ml of saline solution every 3 days till the end of the experiment. The saline solutions were stored in plastic kegs and kept inside a refrigerator in which no change in concentration was noticed throughout the experimental period. Meanwhile, each pot was flooded with water and allowed to drain once per week.to prevent salt accumulation beyond the desired salinity level in the soil. This was immediately followed by application of 200 ml nutrient solution to prevent nutrient deficiency. The treatments lasted for 3 months and plants were harvested in July 2015.

2.5 Experimental design:

It was a 4 x 4 x 2 factorial experiment with factors of the experiment including rice varieties (IR20, IR29, POKKALI and NERICA 1), salinity concentrations (0, 5, 10 and 15 ds/m) and salt types (NaCl and Na_2SO_4). There were 8 treatments for each variety (4 treatments each for NaCl and Na_2SO_4) with 5 replicates per treatment, which amounted to 160 pots laid out in a randomized complete block design (RCBD). The average temperature, relative humidity and light intensity in the screen house during the experimental period were 30^oC, 40^oF and 14000 lux respectively. There was no rain intrusion throughout the experimental period, only the salt solutions were used for irrigation.

2.6 Measurement of yield:

2.6.1 Panicle length and flag leaf length:

The main culms were tagged at panicle emergence and harvested at maturity after separation from the tiller. The lengths of the panicles and flag leaves were measured with meter rule.

2.6.2 Number of tillers:

Tillers were considered as the young plant arising from the main culm in an alternate pattern and typically including leaves, culm and roots, but which did or did not develop panicle. These were counted and recorded.

2.6.3 Spikelets/Panicle:

The panicles of the main culms were harvested and each floret was pressed between the fingers and thumb to determine if the grain was filled or not. The number of filled and unfilled grains were counted and recorded. The total number of filled and unfilled grains was divided by the number of main culms to get the mean number of spikelets/panicle.

2.6.4 100 Grain weight:

Filled grains were enclosed in labelled envelopes and oven-dried to constant weight. From the dried seeds, 100 seeds of each variety were selected and weighed on an electronic balance and the weight recorded as 100-grain weight.

2.7 Biochemical Analyses:

***2.7.1 Determination of leaf nutrient content**:*

Dried leaves were ground into powder, and 1g powder was transferred into a test tube containing 10 ml of 0.1N acetic acid, and heated in a water bath at 80^0C for 2 hours. The extract was cooled at room temperature, left overnight and thereafter filtered using Whatmanns Number 1 filter paper. Na, K, Mg and Ca were determined using Atomic Absorption Spectrophotometer.

2.8 Statistical Analysis:

Data collected were subjected to One-way Analysis of Variance and means were separated using the Lease Significant Difference (LSD) test at 95% level of significance using the procedure of the Statistical Analysis System version 20.0 [14].

3. RESULTS

The soil used for planting was a river sand with pH 5.9, %clay 6.8, %silt 4.0, %sand 89.2, 3.30g/kg C, 0.14% N, 10.4mg/kg AP, 272.5 mg/kg K, -260.5mg/kg H and 243.5mg/kg CEC. The results showed that panicle length, number of tillers and spikelets/panicle were decreased by NaCl and Na_2SO_4 solutions (Table 1). The decrease in panicle length under NaCl was significant only for POKKALI and NERICA1 from 10 ds/m concentration and above when compared to the control. However, the reduction did not differ in other varieties compared to the control. On the other hand, the reduction observed under Na_2SO_4 solutions did not differ significantly from those irrigated without salt in all the varieties. In plants treated with NaCl, the number of tillers/plant differed from those irrigated without salt in all the varieties except NERICA1. IR20 and IR29 differed significantly from 10 ds/m while POKKALI differed only at 15 ds/m in comparison to the control. In Na_2SO_4 however, IR20 and IR29 differed significantly from concentration of 5 ds/m while POKKALI differed from 10 ds/m, but no significant difference was observed in NERICA1 as compared to the control. The number of spikelets/panicle was significantly reduced in all the varieties under both salts. Under NaCl, significant reduction was observed form 5 dm/s in IR20, IR29 and NERICA1 while it was significant in POKKALI from 10 ds/m. Na_2SO_4 treatment however led to a significant reduction from 5 ds/m in POKKALI and IR29, and at 10ds/m in IR20 and NERICA1, relative to the control. In Table 2, all the varieties showed a decrease in 100-grain weight as salt concentrations increased; the decrease became significant at 15ds/m only in IR20 under NaCl as well as in IR29 and NERICA1 under Na_2SO_4. Meanwhile, grain length was not affected in any of the varieties by salt treatments. The flag leaf length was also not significantly affected by NaCl treatment but Na_2SO_4 solution at 15 ds/m caused significantly reduced values in all the varieties relative to the control (Table 2). The leaf Na^+ content increased with increasing concentration of salt in all the varieties, which differed significantly from those irrigated with salt-free water (Table 3). In addition, leaf K^+ was reduced in all the rice varieties by NaCl treatments. Plants exposed to Na_2SO_4 treatments had significantly lower values of leaf K^+ for only POKKALI and NERICA1 at 5 and 10 ds/m, but did not differ from the control at 15 ds/m. In contrast, leaf K^+ was increased in IR29 by Na_2SO_4 treatments (Table 3). Under NaCl, leaf Mg^+ reduced significantly from 10 ds/m in IR20 but at 15 ds/m in IR29. K^+ was however increased by NaCl treatment in NERICA1 from 10 ds/m while there was no statistical difference in leaf K^+ of POKKALI when compared to the control. On the other hand, Na_2SO_4 application caused significantly lower values of leaf K^+ in all the varieties from 5 ds/m except in POKKALI that did not differ from the control at all concentrations (Table 4). Leaf Ca^+ content was not affected significantly in POKKALI and NERICA1 exposed to NaCl solutions but had a significantly reduced effect on that of IR29 from 5 ds/m, and at 15 ds/m in IR20. Plants subjected to Na_2SO_4 treatments however had significantly reduced leaf Ca^+ in NERICA1 from 10 ds/m, and at 15 ds/m in IR20 and IR29, while POKKALI did not show any significant difference between the control and those subjected to salinity.

TABLE.1: PANICLE LENGTH, NUMBER OF TILLERS AND SPIKELETS/PANICLE OF FOUR RICE CULTIVARS GROWN AT DIFFERENT CONCENTRATIONS OF NaCl AND Na_2SO_4 SOIL SALINITY

	Panicle length (cm)				Number of tillers				Spikelets/Panicle			
NaCl (ds/m)	**IR20**	**POKKALI**	**IR29**	**NERICA1**	**IR20**	**POKKALI**	**IR29**	**NERICA 1**	**IR20**	**POKKALI**	**IR29**	**NERICA1**
0	33.3a	31.7a	31.7a	37.0a	12.7a	8.0a	9.3a	9.0a	187a	94.0a	130.0a	149.0 a
5	33.0a	30.3a	30.3a	32.6a	10.3ab	8.0a	7.0ab	8.0a	128b	94.0a	105.0b	93.0b
10	31.3a	26.3b	28.0a	28.0b	7.0b	8.7a	5.7b	6.7b	85.7c	76.7b	92.0c	93.0b
15	30.7a	25.3b	27.3a	28.3b	6.0b	5.3b	5.0b	5.3b	89.3c	80.0b	76.0d	74.3c
Mean	32.08	28.50	28.5	31.50	9.0	7.50	6.75	7.25	122.7	86.25	100.9	102.2 5
LSD	3.93	5.23	5.23	4.82	2.20	1.59	1.88	1.79	5.82	7.14	13.54	9.52
% red	9.0	3.9	12.0	24.0	50.0	37.5	44.4	44.2	52.4	14.8	41.5	
Na_2SO_4 (ds/m)												
0	35.6a	35.7a	37.7a	34.0a	12.7a	7. 3a	10.67 a	6.0a	128.0a	123.0a	98.0a	98.6a
5	33.3a	34.3a	37.0a	36.0a	8.0b	7.3a	8.67b	5.6a	116.0a	87.0b	84.0b	94.3a
10	33.3a	31.0a	36.7a	31.0a	7.0b	6.7a	6.3c	5.3a	79.6b	78.0b	78.0c	75.3b
15	34.0a	26.7a	28.3a	32.0a	4.7c	5.0b	4.3d	4.3a	79.3b	70.0b	69.0d	68.0b
Mean	34.08	27.91	28.16	33.5	8.08	6.58	7.50	5.3	100.91	89.75	82.67	84.08
LSD	8.83	7.51	9.91	4.74	2.02	1.37	1.85	2.20	11.87	20.53	1.91	11.24
% red	2.8	34.6	24.3	5.8	66.7	28.5	60.0	33.1	38.2	43.1	29.5	

Values are means of 5 replicates. Means with the same letter in the column are not significantly different from each other ($p > 0.05$, LSD test)

TABLE.2: 100 GRAIN WEIGHT, GRAIN LENGTH AND FLAG LEAF LENGTH OF FOUR RICE CULTIVARS GROWN AT DIFFERENT CONCENTRATIONS OF NaCl AND Na_2SO_4 SOIL SALINITY

	100 Grain weight (g)				Grain length (mm)				Flag leaf length (cm)			
NaCl (ds/m)	**IR20**	**POKKALI**	**IR29**	**NERICA1**	**IR20**	**POKKALI**	**IR29**	**NERICA 1**	**IR20**	**POKKALI**	**IR29**	**NERICA1**
0	3.52a	3.64a	3.48a	3.14a	6.38a	6.26a	5.76a	6.30a	34.0a	34.0a	36.0a	35.6a
5	3.33a	3.53a	3.26a	3.36a	6.40a	6.0a	6.0a	6.27a	33.6a	33.0a	35.0a	35.0a
10	3.18a	3.27a	3.17a	3.26a	6.50a	6.6a	6.46a	6.03a	32.3a	32.3a	34.0a	34.3a
15	2.97b	3.03ab	3.10a	3.10ab	6.13a	6.0a	6.20a	6.16a	32.0a	32.0a	33.0a	33.7a
Mean	3.25	3.37	3.25	3.21	6.35	6.20	6.11	6.19	32.97	33.76	34.5	34.64
LSD	0.11	0.05	0.08	0.30	0.95	1.01	0.46	0.98	2.95	1.73	1.50	1.75
Na_2SO_4 (ds/m)												
0	3.47a	3.48a	3.38a	3.33a	6.67a	6.13a	6.06a	6.63a	30.0b	32.5a	34.2a	35.0a
5	3.37a	3.35a	3.22a	3.32a	5.57a	6.3a	6.26a	6.20a	33.6a	34.21a	34.0a	36.0a
10	3.17a	3.25a	3.04ab	3.14a	5.57a	6.53a	5.50a	6.8a	34.0a	34.0a	35.0a	35.0a
15	3.07a	3.15a	2.98b	2.99b	6.70a	5.40a	6.33a	6.8a	28.0b	28.1b	24.0b	28.0b
Mean	3.27	3.31	3.15	3.19	6.12	6.10	6.04	6.60	31.2	32.5	31.75	33.5
LSD	0.11	0.05	0.08	0.30	0.95	1.01	0.46	0.98	2.95	1.73	1.50	1.75

Values are means of 5 replicates. Means with the same letter in the column are not significantly different from each other ($p > 0.05$, LSD test)

TABLE.3: LEAF Na^+ AND K^+ OF FOUR RICE CULTIVARS GROWN AT DIFFERENT CONCENTRATIONS OF NaCl AND Na_2SO_4 SOIL SALINITY

	Na^+				K^+			
NaCl (ds/m)	**IR20**	**POKKALI**	**IR29**	**NERICA1**	**IR20**	**POKKALI**	**IR29**	**NERICA1**
0	0.13a	0.36c	0.22b	0.18a	0.57a	0.75a	0.55a	0.64a
5	0.18a	0.38c	0.27a	0.21a	0.56a	0.51b	0.51a	0.63a
10	0.20b	0.43b	0.29a	0.25a	0.48b	0.50b	0.51a	0.49b
15	0.33a	0.50a	0.30a	0.29a	0.47b	0.27c	0.50a	0.47b
Mean	0.21	0.42	0.27	0.23	0.52	0.50	0.52	0.56
LSD	0.08	0.04	0.06	0.08	0.07	0.19	0.06	0.07
Na_2SO_4(ds/m)								
0	0.16d	0.30c	0.18b	0.26a	0.59a	0.54a	0.43b	0.40c
5	0.25c	0.40a	0.27a	0.32b	0.50a	0.44b	0.59a	0.64a
10	0.33b	0.40b	0.29a	0.36a	0.48a	0.42b	0.47a	0.53a
15	0.42a	0.46b	0.30a	0.38a	0.42b	0.59a	0.53a	0.28c
Mean	0.29	0.39	0.26	0.33	0.49	0.50	0.51	0.51
LSD	0.07	0.03	0.04	0.09	0.14	0.10	0.15	0.11

Values are means of 3 replicates. Means with the same letter in the column are not significantly different from each other ($p > 0.05$, LSD test)

TABLE.4: LEAF Mg^{2+} AND Ca^{2+} OF FOUR RICE CULTIVARS GROWN AT DIFFERENT CONCENTRATIONS OF NaCl AND Na_2SO_4 SOIL SALINITY

	Mg^{2+}				Ca^{2+}			
NaCl (ds/m)	**IR20**	**POKKALI**	**IR29**	**NERICA1**	**IR20**	**POKKALI**	**IR29**	**NERICA1**
0	0.36a	0.34a	0.37a	0.24b	0.33a	0.33a	0.47a	0.57a
5	0.34a	0.29a	0.36a	0.29b	0.33a	0.32a	0.32b	0.54a
10	0.26b	0.28a	0.32ab	0.37a	0.26a	0.29a	0.31b	0.52a
15	0.23b	0.24a	0.27b	0.43a	0.23b	0.27a	0.25c	0.50a
Mean	0.29	0.28	0.33	0.34	0.28	0.30	0.34	0.54
LSD	0.06	0.10	0.07	0.07	0.10	0.14	0.12	0.11
Na_2SO_4 (ds/m)								
0	0.55a	0.48a	0.54a	0.60a	0.29ab	0.21a	0.29a	0.19c
5	0.43b	0.51a	0.34b	0.40b	0.31a	0.24a	0.28a	0.35b
10	0.28c	0.54a	0.27b	0.48b	0.28b	0.18a	0.23ab	0.48a
15	0.17d	0.55a	0.60a	0.54b	0.16c	0.18a	0.17b	0.56a
Mean	0.36	0.52	0.44	0.50	0.26	0.20	0.24	0.39
LSD	0.08	0.11	0.11	0.15	0.03	0.07	0.08	0.29

Values are means of 5 replicates. Means with the same letter in the column are not significantly different from each other ($p > 0.05$, LSD test)

4. DISCUSSION

Different physiological and yield components of rice had different sensitivity to salinity [15]. Salinity stress affects tiller formation, panicle formation, photosynthesis rate, metabolic and assimilates processes, nutrient uptake, nutrient transportation between organs and transformation of assimilates and solutes [16]. The drastic reduction in yield and yield components of the cultivars is in agreement with the report of [17] as salinity stress affected grain filling process resulting in poor growth, poor yield attributes and leading finally to low grain yield. Reduction in crop yield as a result of salt stress has also been reported for wheat [18]. This is in agreement with the findings of this study as biomass allocation to the grain was greatly reduced. According to [19], salinity stress can cause a decrease in the photosynthetic mobilization to grains and thereby decreasing grain weight.

Rice has previously being reported to be salt-sensitive at the seedling and reproductive stages, leading to a reduction in crop productivity [20]. The decreased number of spikeletes/panicle recorded in this study might be as a result of assimilate shortage during grain filling, brought about by early senescence as a result of salinity [21]. Many spikelets on lower branches do not produce mature grains and this loss of potential grain may adversely affect the grain number and yield. It is clearly shown that grain weight and grain length was positively related to protein content in the cultivars under both treatments. [22], reported that environmental conditions during grain filling influence the accumulation of protein in the developing rice grain and can alter the functional properties of the resulting flour.

Decrease in number of spikelets per panicle is one of the major factors of reduction in rice yield due to salinity [23]. According to [24], the reduction in the number of spikelets operates through a reduction in the number of primary and secondary branches. The reduction in spikelet development recorded in this study could be attributed to a limitation in carbohydrate supply to the developing panicle. This was substantiated by [25] who reported that sterility and reduction in seed set were primarily due to reduced translocation of soluble carbohydrates to primary and secondary spikelets, accumulation of more sodium and less potassium in all floral parts and inhibition of the specific activity of starch synthetase in developing rice grains. It has earlier been reported that spikelet fertility decreased with increased salinity levels [26]. They observed that grain yield per plant was reduced primarily by a reduction in the number of tillers per plant, number of spikelet per panicle and the grain weight per panicle. They further reported that substantial reduction in filled grains at 6 ds/m was also responsible for sterility. Excessive amount of soluble salts in the root environment causes osmotic stress, which may result in the disturbance of the plant water relations, uptake and utilization of essential nutrients and also in toxic ion accumulation [19], [27].

Crop yield is generally dependent upon various yields contributing components, tillering being the most important one. Generally, higher number of productive tillers will ensure better crop stand and high yield [28]. Salinity stress greatly affected the development and viability of tillers in this study. The decreased level of tiller production with increased salinity was also supported by [26]. However, the reduction in tiller production at high concentrations in this research had a consequent effect on the grain characters recorded in these cultivars. It was reported that the number of tillers in rice decreased progressively with increase in salinity levels [25]. This was attributed to the toxic effect of salt on plant growth. This may indicate that tillers/plant and their behaviour under salt stressed conditions can be used as a simple and non-destructive measurement to evaluate rice cultivars in breeding programmes.

The interaction of salts with mineral nutrients may result in considerable nutrient imbalances and deficiencies [29]. Ionic imbalance occurs in the cells due to excessive accumulation of sodium ion and reduces uptake of other mineral nutrients such as potassium, calcium and manganese [30]. The above findings is in agreement with the result of this study as increased salinity affected the uptake of magnesium, potassium and calcium due to salinity resulting in a drastic reduction of these essential mineral elements. The cation potassium (K^+) is essential for cell expansion, osmoregulation, cellular and whole plant homeostasis [31]. Moreover, the higher content of sodium in leaves suggest that the mechanism to block Na transfer to growing tissues were not effective at higher salt concentrations. The reduction in potassium could be suggestive of direct competition between K^+ and Na^+ at plasma membrane, inhibition of Na^+ on K^+ transport in xylem tissues. The increase in sodium ion concentration in response to salt treatment conforms to the findings on pepper [32], melon [33], tomato [34], okra [35] and groundnut [8]. Many of the deleterious effects of Na^+ seem to be related to the structural and functional integrity of membranes.

Calcium is important during salt stress in preserving membrane integrity and influencing K/Na selectivity [36]. There was a low value of calcium and magnesium content in leaves at increasing salinity levels. There is likelihood of interplay of ionic imbalance in the tissues. Increased Mg^{2+} in POKKALI may strengthen chlorophyll production in this cultivar while the increased Ca^{2+} in NERICA1 as stress increased may be responsible for the strengthening of cell walls against the weakening effects imposed by stress. Excessive Na^+ concentration inhibits Ca^{2+} uptake in many plants [37]. This trend is in line with the result obtained in this study. The decrease in K^+, Ca^{2+} and Mg^{2+} could be due to membrane depolarization by sodium ions (antagonistic effect). It is reported that uptake of calcium ions from the soil solution may decrease because of ion interactions, precipitation and increase in ionic strength that reduce the activity of Ca^{2+} [38]. Low levels of Mg^{2+} in growth media cause defects such as deterioration of the cell membrane, loss of cellular components, and eventually cell and tissue death.

5. CONCLUSION

There is variability in salinity tolerance among the rice varieties depending on the parameter measured, salt type and salt concentration. Salinity caused accumulation of Na^+ in leaf leading to nutrient imbalance in the plant, thus affecting yield.

However, the rice varieties can be categorized as salt-tolerant as they had reasonable yield despite salt stress imposition relative to the control except at high concentration. The traits in the varieties can therefore be a source for developing salt-tolerant variants for improvement in rice production even in saline soils of coastal areas.

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