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INFLUENCE OF SODIUM CHLORIDE (NaCl) SALINITY ON SOME RICE GENOTYPES ADAPTED TO THE CALABAR HUMID ENVIRONMENT

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ABSTRACT

The low lying areas along the creeks in Calabar and its environs are regularly submerged with tidal sea water, particularly during the rainy season. During the dry season, sea water could be used for irrigation purposes. Both of these processes increase soil salinity, making it difficult to cultivate such saline-sensitive crops as rice. Since there is a great variability for salt tolerance among rice genotypes, it is necessary to select suitable varieties for successful cultivation under saline conditions. Six rice genotype adapted to the Calabar humid environment were screened for salinity tolerance during a two year study. Treatments consisted of induced saline water at 0, 2000, 4000, 6000, 8000 and 10,000mgkg^{-1} (Nacl). All genotypes survived to yield grain indicating that there were tolerant to salinity levels up to 10,000mgkg^{-1} (Nacl). There was a highly positive correlation between plant height, panicle length, biomass, and grain yield with salt concentration. In general salinity markedly reduced agronomic attributes in all genotypes, but there were discernible varietal differences. ITA 315 produced the highest yield while FARO 46 and ITA 450 which recorded the least percentage reduction due to salinity stress produced the least. ITA 315 and ITA 305 outperformed the others at both the vegetative and ripening phases and seem to hold promise in this area.

KEYWORDS: Sodium chloride, salinity level, salinity stress, tolerant varieties, swamp rice.

INTRODUCTION

Rice is an important cereal crop in Cross River State and can be cultivated successfully in the low lying areas along the creeks which are regularly submerged wit tidal sea water, particularly during the rainy season.

Although soils in the area are acid sands frequent submergence or irrigation with sea water increases soil salinity which has been observed to be a serious threat to agriculture (Mishra, 1996; Gonzalez et al, 1997). Studies on the sensitivity of rice plant to salt stress suggest that the most susceptible stages are the germination/seedling and reproductive stages. Poor germination and seedling establishment at high salt concentration have been reported in rice (Shannon, 1979; Hansen, 1981), Soyabean (Sharma at al; 1984), Triticale and rye (Francis et al; 1989) and *Trifolium subterraneum* (West and Taylor, 1981). Poor germination was reportedly due to reduced osmotic adjustment which increases the amount of endogenous abscicic acid, specific ion effect exhibited by particular ions in the crop and a general effect due to a rise in osmotic pressure of the solution around the plant roots, altered enzyme activities and toxicity (Russel, 1973).

High salinity reduces vegetative growth. Grist, (1986) reported a more severe effect on tiller number than plant height, with adverse effect on spiklet number per panicle during reproductive growth stages. Gonzalez et al, (1997) observed markedly reduced agronomic attributes (panicle length,, panicle weight, filled grains per panicle, 1000-grain weight, and grain yield) in nine rice mutants obtained from the J-112 variety through gamma radiation and 19 varieties, under saline conditions. Gonzalez and Ramirez (1998) working with 20 rice varieties under laboratory conditions and in the field reported that plant height and panicle weight correlated highly significantly with grain yield under saline conditions, as well as with the saline stress tolerance index. Ashraf and Ali, (1998) observed a reduction in flag leaf area in 5 rice genotypes with increase in salt concentration. The chlorophyll content of rice levels was generally reduced by salinity.

A great variability for salt tolerance among genotypes have been reported (Farooq et al, 1992); Mandal et al, 1993). Suitable rice varieties are needed for successful cultivation under saline conditions. Therefore we urgently need to select or develop salt tolerant rice varieties to increase yield per unit area. The objective of this study was to evaluate salt stress tolerance of some rice genotypes adapted to the Calabar humid environment.

MATERIALS AND METHODS

The study was conduced at the University of Calabar Teaching and, Research farm during the late cropping seasons of 1996 and 1997. Early-to-mid-maturing swamp rice varieties viz. ITA 150, FARO 11, ITA 301, ITA 315, ITA 305, (1996) and ITA 305, ITA 315 and FARO 46 (1997) obtained from the National Cereal Research Institute were sprouted in de-ionized water and salt solution containing 2000, 4000, 6000, 8000 and 10,000mgkg^{-1} sodium chloride. Seeds were sown in polybags filled with topsoil to a depth of 20cm leaving a space of 15cm above the soil surface. Each polybag was 35cm deep and 26.3cm wide and contained 14.9kg of soil. Seeds were sown 2-3cm deep at spacing of 8cm X 6cm giving a plant population of 12 plants per polybag, which were thinned two weeks after emergence to 9 plants per bag. Experimental Units contained 6 polybags arranged in a randomized complete block design in factorial in four replicates.

Treatments consisted of induced saline water at different levels of salt concentration, and de-ionized water as control check. Irrigation was at weekly intervals, and polyags were drained after every rain storm and re-salinized. A single dose of NPK 20:10:10 at the rate of 120kgha-1 was applied two weeks after emergence and 24 hours after draining the polybags, and thereafter irrigating after another 24 hours and elapsed. Recommended practices for weed and insect pest control were adopted.

Agronomic attributes {plant height (at maximum tillering and blossoming stages), dry matter accumulation at blossoming stage, panicle length, 1000-grain weight and grain yield) were collected from 7 plants, selected randomly from each replication. Correlation and regression analysis as well as analysis of variance were obtained for all parameters.

The soil was sandy loam, pH of 4.9, organic carbon 1.37%, total N (Kjeldhal) 0.06 and exchangeable cation (Annomium acetate) of: Ca-1.15, Na-0.06, Mg-0.7, K-0.07-Meq/100g.

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RESULTS AND DISCUSSION

i. Rice Plant Height as Influenced by Salinity of Irrigation Water

The results of the influence of salinity on rice plant height taken at maximum tillering and anthesis are shown in table 1 (a and b). There was a highly positive correlation between salinity and plant height which was generally reduced with increasing salt concentration (r from 0.92-0.97). In both 1996 and 1997 significant differences in height were observed between the check control and the various saline levels, in ITA 150 and ITA 301, these differences increased with salt concentration.

Table 1a: Influence of salinity on plant height at maximum tillering stage (cm)a

Salt level (ppm)	ITA 305		ITA 315		ITA 150	ITA 301	PARO 11	PARO 46
	1996	1997	1996	1997				
0	25.5	25.5.	29.8	29.5	36.8	32.3	28.3	35.1
2000	23.2	24.1 (5.5)	27.0	27.0	33.8	29.1	28.3	32.6
4000	23.1	23.2 (9.0)	26.0	25.5	32.0	27.3	25.8	30.8
6000	22.0	22.4 (12.2)	24.4	24.3	30.1	26.4	25.8	29.7
8000	21.6	21.8 (14.5)	23.6	23.6	27.9	26.0	25.6	27.1
10000	19.5	18.9 (23.9)	23.4	23.0	25.9	25.4	24.8	25.5
LSD (0.05)	NS	0.30	NS	0.30	7.90	7.90	NS	0.30

Data for ITA 150, 301, FARO 11, in 1996 and FARO 46 (1997) not significant.
Figures in ( ) express percent change relative to control.

Table 1b: Influence of salinity on plant height at anthesis (cm)

Salt level (ppm)	ITA 305		ITA 315		ITA 150	ITA 301	PARO 11	PARO 46
	1996	1997	1996	1997				
0	68.3	67.8	94	93.1	76.8	89.5	57	57.4
2000	63.5 (7.0)	63.0 (7.1)	79.8 (15.1)	79.2 (14.9)	76(1.0)	83.8 (6.4)	52.9 (7.2)	74.6 (.0.3)
4000	61.3 (10.2)	61.3 (9.1)	79.5 (15.4)	78.9 (15.3)	69 (10.2)	80 (10.1)	51.8 (9.1)	67.5 (10.5)
6000	61.0 (10.7)	61.1 (9.9)	76.8 (18.3)	76.1 (18.3)	65 (14.1)	76.5 (14.5)	51.4 (9.8)	64.1 (15)
8000	60 (12.2)	59.2 (12.7)	75.5 (19.4)	75 (19.4)	62 (18.2)	72.3 (14.2)	50.1 (12.1)	61.5 (18.4)
10000	58 (15.1)	51.4 (15.3)	68.8 (26.8)	68.6 (26.3)	57.8 (24.7)	63.5 (29.1)	47 (17.5)	56.2 (25.5)

Data for ITA 150, 301, FARO 11, in 1996 and FARO 46 (1997).
Figures in ( ) express percent change relative to control.

However, in FARO 11, ITA 315 and ITA 305 increasing salinity did not considerably reduce plant height. In 1997, all three varieties responded significantly to increase salinity by showing a consistent and progressive decrease in height, percent reduction ranging from 5.5 – 20.5% (ITA 305), 7.1-27.4% (FARO – 46), and 8.4-22 (ITA 315). In all genotypes for both years, reduction in height decreased progressively with increasing salinity levels.

At anthesis average plant height was 51.7, 61.8, 66.6, 77.7 and 78.8cm for FARO 11, ITA 305, FARO 46, ITA 150, ITA 301, and ITA 315 respectively. Generally, induced salinity plant height by approximately 11% in ITA 305 and FARO 11, 14% for ITA 150 and FARO 46 and 16 and 1990 in ITA 301 and ITA 315 respectively. In both years tolerance to salinity seemed to be in the order ITA 305, FARO 46 and ITA 315, FARO 46 and ITA 315.

INFLUENCE OF SALINITY ON PLANT HEIGHT AT ANTHESIS (CM)

ii) Influence of Salinity on Panicle Length and Dry Matter Accumulation

The length of panicle per plant obtained was 19.2, 18.6, 17.1, 16.4 for ITA 315, ITA 301, FARO 11 and ITA 150 respectively while ITA 305 and FARO 46 each had panicles of about 16.2cm. In 1996 salinity did not considerably affect panicle length up to 8000mgkg^{-1} (NaCl) in ITA 305 and ITA 315, but in 1997 length decreased with increasing salinity by 4.7, 7.6, 9.9 and 12.8% at 4000, 6000, 8000 and 10,000mgkg^{-1} (Nacl) respectively for ITA 305. There was no change at 2000mgkg-1 while ITA 315 showed considerable tolerance up to 8000mgkg- (Table 2a)

Table 2a: Influence of salinity on panicle length (cm)*

Salt level (ppm)	ITA 305		ITA 315		ITA 150	ITA 301	PARO 11	PARO 46
	1996	1997	1996	1997				
0	17.3	17.2	20.8	20.7	19.5	21.4	20.3	19.2
2000	17.3	17.2 (0)	20.8 (0)	20.5 (1.0)	17.3 (11.2)	19(11.2)	18.8(7.4)	17.1 (10.9)
4000	16.5	16.4 (4.7)	20.5 (1.4)	20.3 (1.9)	17 (12.8)	19.8(7.5)	16.8(17.2)	16.8(12.5)
6000	16.0	15.9 (7.1)	20.5 (1.4)	20.2 (2.4)	16 (17.9)	18.5(13.6)	15.8(22.2)	15.7(18.2)
8000	15.5	15.5 (9.9)	19.3 (9.9)	19 (8.2)	15.8 (19)	17.3(19.2)	15.8(22.2)	15.4(19.8)
10000	15.1	12.8 (12.8)	14 (32.7)	13.4 (35.3)	13 (33)	15.5(27.6)	15.5 (23.6)	12.8(33.3)
LSD	2.3	0.12	2.3	0.12	2.3	2.3	2.3	0.12

*Data for ITA 150, 301, FARO 11, in 1996n and RARO 46 (1997)
Not significant.
Figures in ( ) express percent change relative to control.

Table 2b: Influence of salinity on dry matter accumulation (g/plant)

Salt level (ppm)	ITA 305		ITA 315		ITA 150	ITA 301	PARO 11	PARO 46
	1996	1997	1996	1997				
0	12.9	12.4	17.9	17.2	15.3	15.6	17.7	14.8
2000	11 (14.7)	10.4 (16.2)	16 (10.6)	15.2 (11.6)	7.6 (50.3)	13(16.7)	16(6.4)	6.9(53.4)
4000	10.5 (18.6)	9.6(22.6)	16.4 (8.4)	14.5 (15.7)	7.5(51)	12.8(19.9)	13.1(23.4)	6.7(54.7)
6000	10.2 (20.9)	9.1(26.6)	13 (27.4)	11(36)	5.8(62.1)	12.6(19.2)	12.9(24.6)	4.9(66.9)
8000	9.3 (27.9)	8.2 (33.9)	12.7 (29.1)	9.7(43.6)	4.9(68)	11(29.5)	12.2(28.7)	4.0(73)
10000	7.3 (43.4)	6.1(50.8)	12.8 (28.5)	9.1 (47.1)	4.7(69.3)	10. (34)	7.8 (54.4)	3.9(73.6)
LSD	0.9	0.17	0.9	0.17	0.9	0.9	0.9	

Data for ITA 150, 301, FARO 11, in 1996n and FARO 46 (1997)
Figures in ( ) express percent change relative to control.

Plant biomass progressively reduced with salinity across varieties and in 1996 there was generally no discernible difference between plants to salinity levels of 2000 and 4000mgkg^{-1} (Nacl). In 1997 however, each rise in salinity correspondingly reduced plant biomass, percent reduction being approximately 60, 32, 28, and 24% respectively in ITA 150, FARO 46, FARO 11and ITA 305, and ITA 301, (Table 2b).

Influence of Salinity on dry matter accumulation (g/plant)

iii) Effect of salinity on Grain Yield

The average grain yield obtained was 6.9, 7.6, 9.8, 12.6, 13.2 and 13.8g/plant in FARO 46, ITA 150, ITA 305, ITA 301, FARO 11 and ITA 315 respectively and average percent reduction in yield due to salinity was 22.5, 26.9, 30.6, 36.7, 41.2 and 48.8% in ITA 150, ITA 305 FARO 11, FARO 46, ITA 315 and ITA 301 respectively. *Yield were marginally* increased over control by 2 and 6% in ITA 305 and ITA 301 respectively at 2000mgkg^{-1} (Nacl) in both years but decreased progressively from 4000mgkg^{-1} at a more or less geometric rate in these and all other varieties. There was no discernible difference in yield at 6000 and 8000mgkg^{-1} but at 10,000mgkg^{-1} yields were consistently lower, (table 3).

GENERAL DISCUSSION

All genotypes were less than 1m tall at anthesis but survived to yield grain indicating that there were tolerant to salinity levels of up to 10,000mgkg^{-1} (NaCl). There was a highly positive correlation between salinity and all agronomic attributes, all of which correlated highly and significantly with grain yield under saline conditions.

In general salinity markedly reduced agronomic attributes in all genotypes, but there were discernible varietal responses. Whereas height at maximum tillering was considerably reduced with increasing salinity in ITA 150 and ITA 301 in 1996, only marginal reductions were observed in other varieties. However, the height of all varieties was significantly reduced in 1997, the least being obtained in ITA 305 and ITA 315, suggesting that these were more tolerant to salt stress at the early stage of growth. At anthesis when plant height had reached its maximum, there was generally no discernible differences between control check and 2000 mgkg^{-1} NaCl), in 1996 but significant differences were obtained in 1997. In both years however, there was no significant effect of salinity across the board at 4000 and 6000 mgkg^{-1}. ITA 305 and FARO 46 were more tolerant to salinity at this stage of development.

Biomass decreased with an increase in salt concentration in all genotypes in both years. The maximum reduction in biomass was under 10,000 mgkg^{-1} (NaCl). Only in ITA 150 was percent reduction greater that 60%, while in all others, it was less than 33%. Reduction in biomass due to high salinity have been reported by Ashraf, (1998).

Table 3: Influence of salinity on grain yield (g//plant)

Salt level (ppm)	ITA 305 1996	1997	ITA 315 1996	1997	ITA 150	ITA 301	FARO 11	PARO 46
0	10.1	9.8	5.3	5.0	81	9.6	9.6	7.9
2000	10.3 (+2)	10.0(+2)	5.6(+5.7)	5.3(+6)	7.4(8.6)	7.1(26)	9.3(3.1)	7.0(11.4)
4000	9.5(5.9)	9.3(5.1)	4.5(15.1)	4.1(18)	6.1(24.7)	5.4(43.8)	8.2(14.6)	5.6(29.1)
6000	8.3(17.8)	7.3(25.5)	3.4(35.8)	2.6(48)	5.5(32.1)	4.6(52.1)	4.7(22.9)	4.9(3.8)
8000	6.4(36.6)	5.9(39.8)	2.7(49.1)	2.3(54)	4.3(46.9)	4.3(55.2)	4.9(49)	4.0(49.3)
10000	5.6(44.6)	5.9(39.8)	2.2(58.5)	2.0(60)	3.8(53.1)	3.2(66.7)	3.5(63.5)	3.5(55.7)
LSD	0.7	0.27	0.7	0.27	0.7	0.7	0.7	

Figures in ( ) express percent change relative to control

Percent decrease in length of panicle was marginal in ITA 315 averaging 0.5, 1.7, 1.9, 7.7 and 34% at 2000, 4000, 6000, 8000 and 10,000 $mgkg^{-1}$ respectively suggesting that this variety is tolerant to salinity up to 8000 $mgkg^{-1}$ (NaCl). The highest grain yield was obtained in ITA 315 and the least in FARO 46 and ITA 150. However, the reduction in yield was highest in ITA 301 and least in ITA 150. Thus, there was a relationship between grain yield and percentage reduced. ITA 150 yielded about ¾ and just over one-half the yields of ITA 305 and ITA 315 respectively. Furthermore, at 2000 $mgkg^{-1}$ (NaCl), yield of 2.0 and 6.0% over control were obtained in ITA 305 and 315 respectively. ITA 315 and to a lesser extent ITA 305 outperformed the others at both the vegetative and ripening phases and seem to be promising in this area.

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