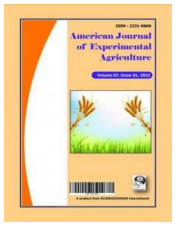

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Phenotypic Response of *Oryza* Species Seedlings to Saline Conditions

R. E. Aliyu[1*], A. K. Adamu[1] and S. K. Sakariyahu[1]

[1]Department of Biological Sciences, Faculty of Science, Ahmadu Bello University, Zaria, Nigeria.

Authors' contributions

This research was conducted in collaboration with all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This investigation was conducted to profile and evaluate the response of *Oryza* species to salt stress at seedling growth stage.

Study Design: Salt tolerance was studied by evaluations, using the Standard Evaluation System of IRRI for salt tolerance under hydroponic systems.

Place and Duration of Study: The investigations for this study were conducted at the International Institute of Tropical Agriculture (IITA), Ibadan (Latitude 3°54 ^{1}N and longitude 7°30 ^{1}W), Nigeria. The seeds of 184 rice genotypes (comprising of 130 *O. sativa* lines; 26 *O. glaberrima*, 16 *O. barthii* lines and 12 interspecific hybrids (NERICA) were obtained from the International Rice Research Institute, Las Boanos, Philippines and Africa Rice, Ibadan station, IITA, Nigeria.

Methodology: A total of 184 rice genotypes (comprising of 130 *Oryza sativa* lines; 26 *Oryza glaberrima*, 16 *Oryza barthi* and 12 interspecific hybrid (NERICA) were subjected to salinization with NaCl at EC 12dSm^{-1} and pH 5.2 for 28 days in a hydroponic system. Plant phenotypic responses were evaluated to ascertain specie response. Among the test entries were Pokkali and IR29 which served as the tolerant and susceptible checks respectively.

Results: Seedlings from the genotypes showed varying levels of salt injury symptoms. The effect of salinity stress on plant growth parameters were genotype and species dependent. Progressive

**Corresponding author: E-mail: s.ramatu@googlemail.com, s.ramatu@gmail.com;*

reductions in most growth parameters were obtained with increasing age of plant. Plasticity due to salinity stress was observed in some growth parameters (increased leaves number, longer root length and improved tillering ability). Susceptible genotypes showed more effect of salt injury than tolerant genotypes. Tolerant genotypes (6.92%) to salinity tress were predominated by *Oryza sativa g*enotypes*.* The interspecific hybrids (NERICA) showed moderate tolerance (73.3%) to salinity stress followed sequentially by *Oryza sativa* (57.9%)*, Oryza glaberrima* (18.5%) *and Oryza barthii* (12.5%)*.* NERICA accumulated more salts in their shoot compared to other species of rice. TOG9047 (*O. glaberrima*) showed tolerance comparable to Pokkali (tolerant check) at seedling stage. Genotypes like OS6, Indiano and WAB 100-B-B-B-2B showed greater salt injury compared to IR29 (negative check) and could serve as an alternative to IR29. Reductions in biomass arising from salinity stress served as a good indicator of susceptible genotypes to salt stress. Reductions in the root/shoot ratio indicated that salinity had more effect on the roots than the shoots of the genotypes and hence, suggests the point of action and damage due to salinity.

Conclusion: *Oryza* species showed varied response to salt stress. These responses were genotype and specie dependent. *Oryza sativa* contained the highest percentage of tolerant genotypes to salinity stress at 12dSm^{-1}. However, NERICA contained the highest percentage of moderately tolerant to salinity stress followed sequentially by *Oryza sativa, Oryza glaberrima* and *Oryza barthii.* Tolerant and moderately tolerant genotypes could further be exploited for breeding purposes geared towards crop advancement.

Keywords: Salt injury; salt tolerance; Oryza sativa; Oryza glaberrima; Oryza barthii; seedling stage.

1. INTRODUCTION

The rice crop grown under extensive irrigation regimes is unusually susceptible to salinity stress [1-3] as soil salinity is a major problem in modern agriculture particularly for irrigated croplands [4]. In Africa, a total of 1,899 million ha of land is salt affected. The proportion of salt-affected irrigated land in various countries ranges from 9% to a maximum of 34%, with a world average of 20%. Total worldwide area of land affected by salinity is about 190 million ha [5]. Irrigated land is only 15 % of total cultivated land, but as irrigated land has at least twice the productivity of rainfed land, it may produce one-third of the world's food [6]. Thus, soil salinity is a major problem in arid and semi-arid region where rainfall is insufficient to leach salts and excessive sodium ion down and out of the root zone. As farmers engage in irrigation schemes, the problem of water logging and soil salinity have reached serious proportions with most of the irrigation systems of the world causing secondary salinity and sodicity [7].

Salinity affects rice growth in varying degrees at all stages due to its differential salinity sensitivity [8,9]. The low success in rice salt tolerance breeding was at least partially due to lack of effective evaluation methods for salt tolerance among genotypes and the complexity of salinity tolerance phenotypes among genotypes [10].

Therefore, there is a great deal of urgency for developing rice genotypes which can sustain and set seed under high salt stress conditions which severely affects global production by altering growth mechanisms and photosynthesis [11]. *Oryza sativa* has acquired a broad range of adaptability and tolerance with good agronomic traits but susceptible to most African stresses [12]. *Oryza glaberrima* is an interesting genetic resource due to its resistance to many rice constraints [13-15]. It harbors a rich reservoir of genes that have allowed the species to survive and prosper in West Africa with minimal human intervention [13].

This research aim to profile and evaluate the phenotypic variability between rice species and their response to salinity stress at seedling growth stage.

2. METHODOLOGY

2.1 Study Area and Plant Material

The investigations for this study were conducted at the International Institute of Tropical Agriculture (IITA), Ibadan (Latitude 3°54^{1}N and longitude 7°30^{1}W), Nigeria. The seeds of 184 rice genotypes (comprising of 130 *O. sativa* lines; 26 *O. glaberrima*, 16 *O. barthii* lines and 12 interspecific hybrid (*O. sativa* × *O. glaberrima*) were obtained from the International Rice Research Institute, Las Boanos, Philippines and

AfricaRice, Ibadan station, IITA, Nigeria. Among the test entries were Pokkali and IR29 which served as the tolerant and susceptible checks respectively.

2.2 Sterilization and Pre-germination

Rice seeds were cleaned and placed in an oven for 3-5 days at 30℃ to break seed dormancy. The seeds were surface sterilized with 1:5 benlate and distilled water solutions. Sterilized seeds were soaked in water in a Petri-dish lined with Whatman's filter paper and incubated for 48 hrs at 30℃. Pre-germinated seeds were sown in a hydroponic system - with two seeds per hole in a Styrofoam sheet of 100 holes with a nylon net bottom. The sheets were floated on a nutrient solution (1.5 gL^{-1} Peters 20-20-20 water soluble fertilizer supplemented with 0.1 gL^{-1} of Ferrous sulphate ($FeSO_4$).

2.3 Screening for Salt Tolerance

The seeded rice genotypes were subjected to salinization with NaCl 72 h after seeding at EC 12 dSm^{-1}. The nutrient solution was maintained daily at a pH of 5.2±0.1 by adding either NaOH or HCl and maintained at 27℃/21℃ day/night temperature with a minimum relative humidity of 70%. The nutrient solution was replaced fortnightly for 28 days. Unsalinized control treatment was also setup and maintained as described for the saline treatment.

2.4 Phenotyping for Salinity Tolerance

The modified standard evaluation score [16] of visualizing injury under salt stress was used to evaluate symptoms of salt damage. Non-saline/saline control was compared for morphological parameters and visual scoring as that of the SES for rice (http://www.knowledgebanking,irri.org/ses/SES.htm). Plant morphological traits characterized were: tiller numbers, plant height (cm), root length (cm), root fresh weight (mg), leaves number, shoot fresh weight (mg), root dry weight (mg), shoot dry Weight (mg), root/shoot (mg), root dry weight/shoot dry weight (mg), shoot fresh weight/root fresh weight (mg) and leaf width (cm).

2.5 Statistical Analysis

Analysis of variance (ANOVA) was performed to determine genotype and specie response to salinization. Significant ($p<0.01$) means were separated with Duncan's Multiple Range Test (DMRT) using the GLM procedure of Statistical Analysis System. The correlations between morphological characters were analyzed simultaneously by stepwise analysis [17].

3. RESULTS AND DISCUSSION

3.1 Screening Genotypes for Salt Tolerance at Seedling Stage

The mean response of the genotypes to salt injury at seedling stage based on the standard evaluation score (IRRI, 1997) are presented in Fig. 1. Forty (40) genotypes cutting across all tolerance levels were evaluated phenotypically and the result presented in Table 1. The genotypes showed varied visual symptoms of salt injury in saline conditions ($p<0.01$) with a ratio of approximately 1:1 for tolerant to moderately tolerant genotypes (49.5%); and for susceptible to highly susceptible genotypes (50.5%). *Oryza sativa* recorded the highest percentage of tolerant genotypes (6.92%) to salinity stress. NERICA had the highest percentage of moderately tolerant genotypes (73.3%) under salt stress followed by *O. sativa* (57.9%); *O. glaberrima* (18.5%) and lastly *O. barthii* (12.5%) (Fig. 2). TOG 9047, an *Oryza glaberrima* with a score of 3 showed tolerance to salt stress. Genotypes with similar salinity score were mostly *O. sativa* of Asian Origin. Three interspecific hybrids (NERICA L-41, NERICA L-50, NERICA L-59) and 7 African *O. sativa* species (AR Burkina, FRK 19, GAMBIAKA CC, GAMBIAKA CL, ITA 302, ITA 306 and WAR 115-1-1-2-3-B-B-H) had salinity index ranging from 3.67 to 5.0 and showed moderate tolerance to the stress factor. *Oryza barthii* genotypes were most susceptible to salinity stress (Fig. 2).

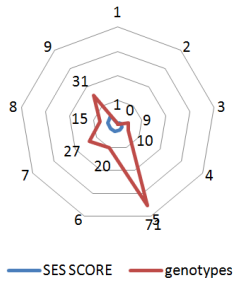

Fig. 1. Salinity evaluation score for 184 genotypes at seedling stage

Key: 1-9 are tolerance levels where 1>2>3>4>5>6>7>8>9

1-3: Tolerant; 4-6: Moderately tolerant; 7-9: Susceptible

Table 1. Growth parameters of tolerant and moderately tolerant rice genotypes at seedling stage

S/N	Genotypes *(O. Sativa)*	PH	LN	TN	LW	RL	SES	SFW	SDW	RFW	RDW	PH_RL	SW_RFW	RDW_SW
1	AR BURKINA	26.67g-k	9.00c-f	2.33a-c	0.47c-f	19.67f-h	4.67ab	3.5g-k	1.27i-m	1.27l-p	0.23r	1.36l-p	2.75g	0.18o
2	ARG 6605	27.33f-j	5.67j-m	1.67ce	0.37d-f	17.67h-m	4.67ab	3.60f-j	1.07k-p	1.60i-m	0.30p-r	1.54h-l	2.20h-j	0.27m-o
3	BG 1370	23.00m-p	6.67h-j	1.00e	0.53b-c	20.00f-g	5.00a	1.97pq	1.13j-o	1.50j-n	1.00d-h	1.17p-t	1.10mn	0.89ab
4	BZ 161 C-MR-57-1-3-1	26.00h-m	8.33d-h	1.67ce	0.53b-c	13.67o-p	4.67ab	2.63l-p	1.10j-p	1.37k-p	0.80g-l	2.01-h	1.93jk	0.72b-f
5	DR 30	27.00f-k	7.67e-i	1.33de	0.48b-e	15.50m-o	4.67ab	4.20df	0.83op	1.00o-q	0.45m-r	1.71-h	4.2c	0.60d-h
6	FKR 19	23.33l-p	4.00m	1.00e	0.57a-c	16.67k-n	5.00a	2.87k-o	1.00l-p	2.00fi	0.97d-i	1.39k-o	1.43lm	0.97a
7	FL 378	17.33q	7.00g-j	2.00b-d	0.43c-f	22.00de	3.33cd	3.73e-j	1.3i-l	1.12n-p	0.63j-o	0.95u-w	3.34de	0.46h-l
8	FL 478	33.00c	9.67b-d	2.33a-c	0.5b-d	24.67bc	3.00de	5.07c	2.90b	2.41ce	1.00d-h	1.34lq	2.13ij	0.34k-o
9	GAMBIAKA CC	40.67b	5.67j-m	1.00e	0.5b-d	15.00no	4.67ab	2.27o-q	1.63f-h	1.00o-q	0.57l-q	2.70a	2.27h-j	0.35j-o
10	GAMBIAKA CL	34.00c	5.67j-m	1.00e	0.5b-d	22.67de	5.00a	3.67e-j	2.13cd	0.68q	0.37o-r	1.50i-l	5.38b	0.17o
11	IR 24	23.00m-p	7.00g-j	2.00b-d	0.43c-f	25.33bc	4.33a-c	1.00r	0.75p	0.97pq	0.27qr	0.88w	0.98n	0.36j-o
12	IR 52	22.67n-p	7.33f-j	2.00b-d	0.5b-d	19.33fi	5.00a	4.20d-f	1.40h-j	2.27d-f	1.20c-f	1.17p-t	3.23d-f	0.86a-c
13	IR 65483-118-25-31-7-1-5	32.67c-d	4.33l-m	1.00e	0.5b-d	13.00p	4.00a-d	4.83cd	1.33h-k	1.97fi	1.10c--g	2.50bc	3.4d	0.82a-c
14	IR 65600-81-5-3-2	31.67c-e	4.67k-m	1.00e	0.5b-d	12.33pq	4.00a-d	3.07j-m	1.00l-p	1.00o-q	0.77g-l	2.57ab	2.03j	0.77b-d
15	IR 75395-2B-B-18-1-1-1-11-2	26.33g-l	7.00g-j	1.67ce	0.5b-d	15.00no	4.67ab	3.03j-n	1.27i-m	1.37k-p	0.93ef-j	1.76fg	2.20h-j	0.74b-e
16	IR 77646-3B-8-1-1-1-B	24.00k-p	5.67j-m	1.00e	0.5b-d	17.33i-m	4.67ab	3.67e-j	2.03ce	1.87f-j	0.97d-i	1.36l-p	2.77fg	0.47h-l
17	IR 77660-3B-29-1-2-2-B	22.33o-p	10.33a-c	2.67ab	0.57a-c	16.67k-n	3.00de	3.50g-k	1.87d-f	2.27d-f	1.28b-d	1.37l-p	2.88e-g	0.68c-g
18	IR 77666-3B-12-3-3-3-1	23.33l-p	7.33f-j	1.67c-e	0.63a-b	19.67f-h	3.33cd	3.9e-h	1.37h-k	2.00fi	1.33bc	1.21o-s	2.95e-g	0.98a
19	IR 77674-3B-21-1-1-1-6-3	25.67h-n	6.0i-l	1.67c-e	0.53bc	23.33cd	4.67ab	4.33de	1.30i-l	1.03o-q	0.60k--p	1.11r-v	2.68gh	0.46h-l
20	IR 77674-3B-8-2-2-4-2	25.67h-n	7.33f-j	2.33a-c	0.63ab	15.67m-o	4.33a-c	3.87e-i	2.20c	1.83g-j	0.97d-i	1.64g-i	2.85f-g	0.44h-m
21	IR 77674-3B-8-2-2-6-1	23.00m-p	7.33f-j	1.67c-e	0.53bc	16.67k-n	3.67b-d	2.57l-p	1.41h-j	1.28l-p	0.63j-o	1.38l-p	1.93jk	0.44h-m
22	IR 77674-3B-8-3-1-1-5	22.00p	8.67c-g	2.00b-d	0.53bc	22.33de	4.67ab	3.33h-k	1.07k-p	1.77h-k	0.90f-k	0.98tw	2.55g-i	0.85a-c
23	IR 77674-B-20-1-2-1-3-11-B	28.33f-h	10.00a-d	2.00b-d	0.43c-f	25.33bc	3.00de	2.83k-o	2.07c-e	1.33lp	1.10c-g	1.14q-u	2.08ij	0.53g-k
24	IR 77674-B-20-3-3-1-3-13-B	28.00f-i	9.67b-d	2.33a-c	0.57a-c	19.00f-j	3.00de	3.20h-l	1.63f-h	1.17np	0.87f-l	1.48i-m	2.18ij	0.53g-k

Table 1. continued….

S/N	Genotypes	PH	LN	TN	LW	RL	SES	SFW	SDW	RFW	RDW	PH_RL	SFW_RFW	RDW_SDW
25	IR 77674-B-20-3-3-1-3-5-5	24.33jp	6.33ik	2.00bd	0.5bd	17.00jn	4.67ab	2.37nq	0.92np	1.23mp	0.63jo	1.43jn	1.80jl	0.69cg
26	IR 77674-B-63-3-3-2-B	27.33fj	7.67ei	2.00bd	0.53bc	17.00jn	4.67ab	2.23oq	0.96mp	1.00oq	0.3pr	1.61gj	1.95jk	0.31lmo
27	IR 7767B-B-20-1-2-3-6-B	27.33fj	8.67cg	2.00bd	0.53bc	22.33de	3.00de	10.33a	7.13a	3.33a	1.67a	1.23ns	6.83a	0.23no
28	IR 80310-12-B-1-3-B	29.33eg	5.67jm	2.00bd	0.47cf	25.67b	4.67ab	3.17im	1.97ce	1.40ko	0.97di	1.17pt	2.28hj	0.50hl
29	ITA 302	25.33ho	6.67hj	2.00bd	0.33f	18.00gl	4.67ab	1.83q	1.18jn	1.22mp	0.83gl	1.40ko	1.53km	0.71bg
30	ITA 306	24.33jp	6.33ik	1.67ce	0.50bd	11.00q	4.67ab	2.53lp	1.53gi	1.90fj	0.65gl	2.22d	2.22hj	0.42hm
31	POKKALI	43.67a	7.67ei	2.33ac	0.51bd	18.67gk	1.00f	7.33b	2.73b	2.87b	1.57ab	2.34cd	5.10b	0.58ei
32	PSB RC 44	27.00fk	5.67jm	1.00e	0.52bc	25.00bc	4.33ac	2.63lp	2.00ce	2.73bc	0.70hn	1.03sw	2.68gh	0.35jo
33	PSB RC 50	27.00fk	11.33a	3.00a	0.53bc	21.00ef	3.00de	3.60fj	0.91np	0.94pq	0.87gl	1.27mr	2.27hj	0.95a
34	PSB RC 60	32.00ce	6.67hj	2.00bd	0.70a	16.33ln	3.67bd	2.33oq	1.30il	2.20dg	1.25ce	1.96e	2.27hj	0.98a
35	PURPLE	22.67np	6.33ik	1.33de	0.63ab	16.67kn	4.33ac	3.42hk	1.11jo	1.00oq	0.44nr	1.36lp	2.21hj	0.39in
36	WAR 115-1-1-2-3-B-B-1	30.00df	6.00il	2.00bd	0.58ac	15.67mo	4.67ab	4.13eg	1.82dg	1.67hl	0.60kp	1.91ef	2.90eg	0.33lmo
	O. glaberrima													
37	TOG 9047	23.00mp	1.90jk	1.00e	0.35ef	12.00pq	2.00e	7.40b	2.90b	3.53a	1.76a	1.93ef	1.90jk	0.61dh
	Interspecifics (NERICA)													
38	NERICA L-41	25.00ip	7.33gk	2.00bd	0.50bd	15.67mo	3.67bd	2.50mq	2.03ce	2.00fi	1.00dh	1.60gk	2.25hj	0.50hl
39	NERICA L-58	24.33jp	9.33be	2.67ab	0.47cf	17.67hm	4.33ac	2.30oq	1.87df	2.03eh	1.00dh	1.37lp	2.17ij	0.54fj
40	NERICA L-59	26.33gl	10.67ab	3.00a	0.5bd	28.00a	4.67ab	3.33hk	1.80gf	2.52bd	1.00dh	0.92vw	2.93eg	0.56ei
	MEAN	26.90	7.29	1.81	0.51	18.68	4.07	3.56	1.68	1.69	0.87	1.52	2.61	0.57
	MIN	15.00	3.00	1.00	0.10	10.00	1.00	1.00	0.65	0.55	0.20	0.84	0.95	0.13
	MAX	45.00	12.00	3.00	0.80	29.00	1.00	1.00	0.65	0.55	0.20	0.84	0.95	0.13
	STDEV	5.09	1.89	0.64	0.09	4.26	1.01	1.67	1.04	0.70	0.39	0.47	1.13	0.24
	$\pm$ S.E	2.94	1.09	0.34	0.05	2.46	0.58	0.97	0.60	0.40	0.23	0.27	0.65	0.14
	R^2	0.93	0.85	0.78	0.59	0.95	0.78	0.97	0.98	0.94	0.88	0.96	0.97	0.90
	CV	6.00	12.23	20.39	14.59	6.00	14.27	10.11	10.10	12.85	19.11	7.23	9.71	16.82
	P value	<.001	<.01	<.001	<.001	<.001	<.01	<.001	<.01	<.001	<.01	<.01	<.001	<.01

PH- plant height, TN- tiller number, LW- leaf width, RL- root length, SES- salinity evaluation score, SFW- shoot fresh weight, SDW- shoot dry weight, RFW-root fresh weight, RDW- root dry weight, PH/RL- plant height/root length, SFW/RFW- shoot fresh weight/root fresh weight, RDW/SDW- root dry weight/shoot dry weight

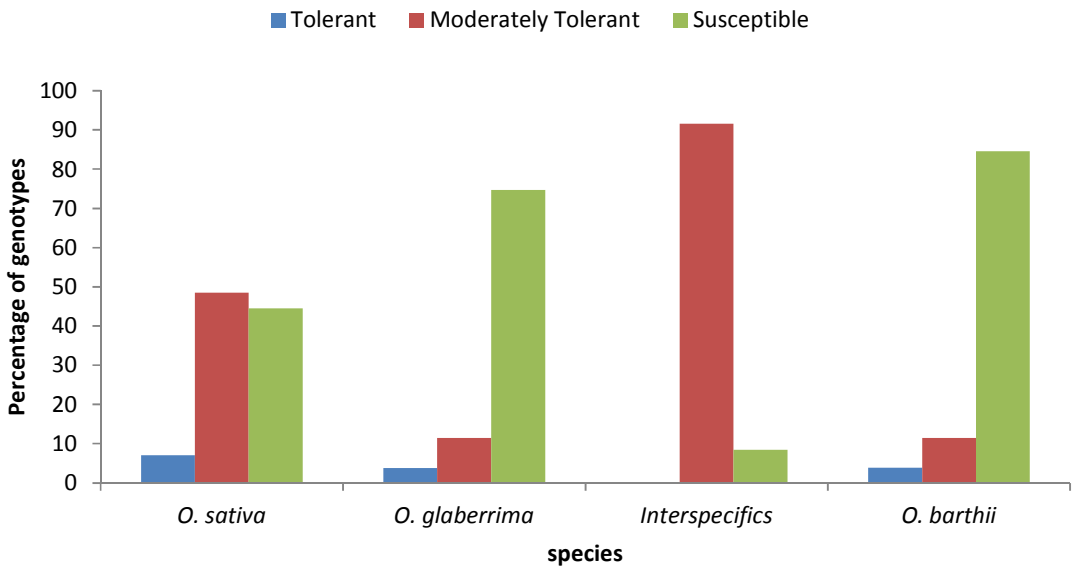

Fig. 2. Reactions of genotypes of rice species to salinity stress

3.2 Plant Heights

Plant heights significantly decreased ($p<0.05$) in salinized conditions compared to plants grown in un-saline conditions (Fig. 3). Plant heights of susceptible genotypes showed higher percentage reductions (70-86%) compared to the tolerant genotypes. Mean reductions in plant height was highest amongst *O. Barthii* (54.8%) genotypes followed by *O. glaberrima* (46.58%), NERICA (44.03%) and *O. sativa* (41.92%) genotypes. (Fig. 4)

3.3 Leaf Number

The number of leaves obtained significantly ($p<0.05$) varied across genotypes and species (Table 1). Seventeen genotypes (9.2%) showed no reduction in leaf number while sixteen genotypes (8.7%) showed increase in leaves numbers. The mean effect of salinity in the reduction of leaves number was 12% (Fig. 3). Tolerant and moderately tolerant genotypes showed lower reductions in leaves number as against susceptible genotypes.

3.4 Tiller Number (TN)

Tiller numbers varied considerably and significantly ($p<0.05$) amongst genotypes and species (Table 1). The effect of salinity on tillering ability was 25%. Nine (4.9%) genotypes produced higher tiller numbers while 38% of the genotypes showed no difference in their tillers in salinized and non-salinized conditions respectively (Fig. 3). Approximately 57.1% of the genotypes showed considerable reduction in tiller numbers ranging from 16 to 66%. Pokkali showed 22% reduction, while IR 29 showed no reduction in tiller number. Tiller reductions (23.20%) in NERICA genotypes were minimal as compared to *O. barthii* with 50% reduction in tillers and presented the highest mean reduction in tillers amongst species (Fig. 4).

3.5 Leaf Width (LW)

All genotypes and species showed significant ($p<0.05$) decreases in leaf width. This decrease ranged from 0%to 64%. A 29% reduction of leaf width was caused due to salinity. POKKALI and IR29 recorded a 10% and 14% decrease in leaf width respectively. *Oryza sativa*, NERICA, *O. glaberrima* and *O. barthii* showed leaf width reductions of 32.47%, 33.01%, 50.63% and 53.14% respectively (Fig. 4).

3.6 Root Length (RL)

Plasticity in root length was pronounced amongst genotypes (Table 1) with mean reductions of 10% in saline conditions amongst tolerant genotypes (Fig. 3). A total of 50 genotypes (27.2%) had increased root lengths in saline conditions. Reductions obtained were apparent in susceptible genotypes. The interspecific hybrids presented a 12.02% mean increase in root length. General reductions of 4.99%, 15.41% and 21.92% were obtained for *O. sativa, O. barthii* and *O. glaberrima* respectively (Fig. 4).

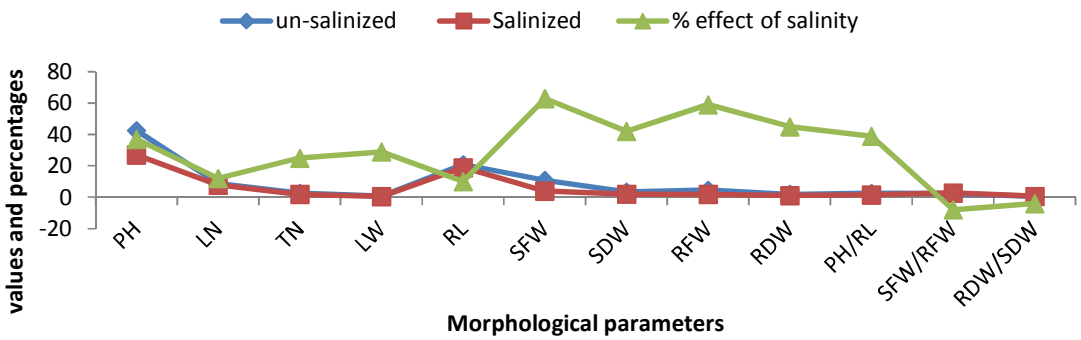

Fig. 3. Comparative effect of tolerant and moderately tolerant rice genotypes to saline and non-saline treatments

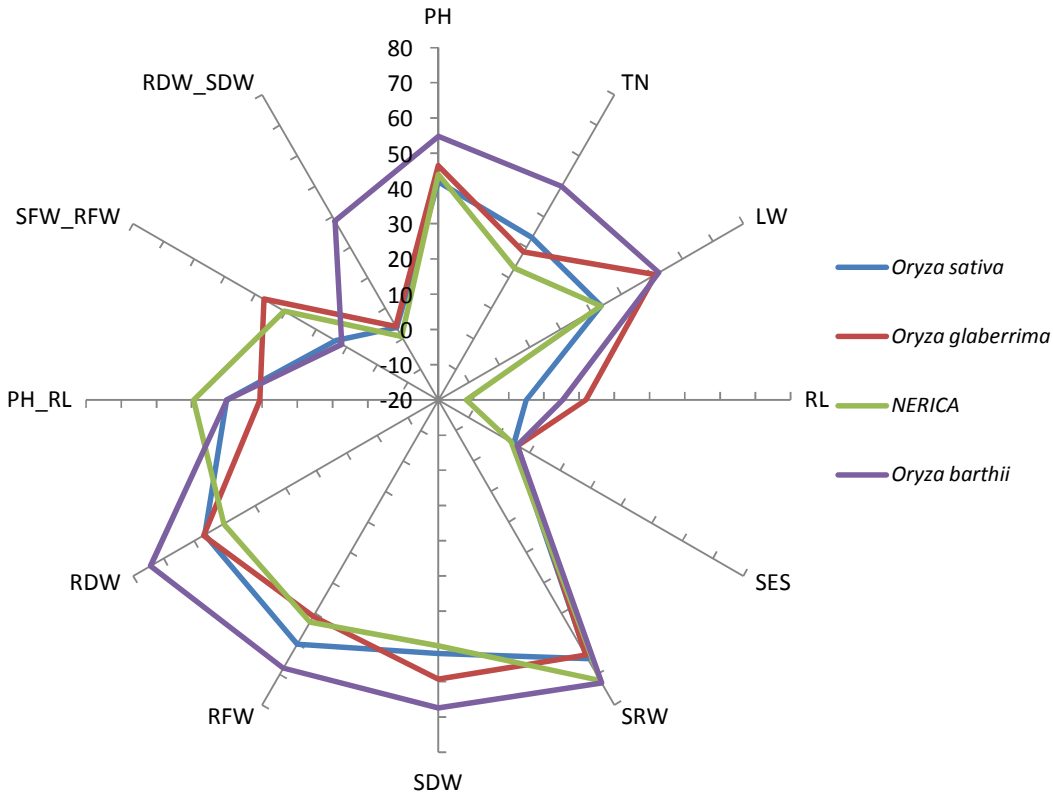

Fig. 4. Response to growth parameters in *Oryza* species in saline conditions

PH- plant height, TN- tillers number, LW- leaf width, RL- root length, SES- salinity evaluation score, SFW- shoot fresh weight, SDW- shoot dry weight, RFW-root fresh weight, RDW- root dry weight, PH/RL- plant height/root length, SFW/RFW- shoot fresh weight/root fresh weight, RDW/SDW- root dry weight/shoot dry weight

3.7 Shoot Fresh Weight (SFW)

Under saline conditions, POKKALI and IR 29 recorded a decrease in shoot fresh weight by 33% and 54% respectively. NERICA L-19 with a percentage reduction of 14.6% had the least reduction rate which was highest in RD 15 (89.1%). All tolerant and moderately tolerant genotypes showed significant ($p<0.05$) reductions in shoot fresh weight up to 63% in saline condition (Fig. 3). The shoot fresh weight in all species decreased greatly ($p<0.05$) with

percentage reductions ranging from 63.31% in *O. sativa* to 73.44% *in O. barthii*. NERICA and *O. glaberrima* showed 72.02% and 63.76% reductions respectively (Fig. 4).

3.8 Shoot Dry Weight (SDW)

The shoot dry weights of 1% of the genotypes in saline conditions were equal to that of the control treatments. The mean reductions observed due to salinity in tolerant genotypes were 42% (Fig. 3). POKKALI had a high reduction in shoot dry weight of 45.4%, with IR29 presenting a reduction of 36.5%. NERICA showed the least percentage reduction in shoot dry weight of 49.91%, while *O. barthii* recorded the highest reductions of 67.54%. *Oryza sativa* and *O. glaberrima* showed 51.95% and 59.16% reductions respectively (Fig. 4).

3.9 Root Fresh Weight (RFW)

The mean percentage reduction in the root fresh weight was 59% in tolerant genotypes (Fig. 3) and ranged from 0% to 87%. The percentage reduction in the root fresh weight was minimal in *O. glaberrima* and optimal in *O. barthii. Oryza sativa* and NERICA recorded a percentage reduction of 60.06% and 52.87% respectively (Fig. 4).

3.10 Root Dry Weight (RDW)

A general reduction in the root dry weight across tolerant genotypes was 45%and ranged from 1% (FL 478) to 94.8% (IRGC 89148). POKKALI showed a higher reduction in root dry weight (60.8%) than IR29 (47.1%). NERICA showed a lower mean reduction in root dry weight of 50.35%. Mean reduction obtained for *O. sativa* and *O. glaberrima* genotypes were 56.62% and 57.04% respectively. *Oryza barthii* recorded the highest mean reduction of 72.49% (Fig. 4).

3.11 Plant Height to Root Length (PH/RL)

The ratio of plant height to root length showed significant ($p<0.01$) decreases in most of the genotypes especially the tolerant ones with a mean of 39%. Generally, plant height to root length ratio reduced from 0.38% to 70%. The control checks both showed reduced PH/ RL ratio of 6% (IR 29) and 22% (Pokkali). *Oryza glaberrima* genotypes showed the lowest plant height to root length ratio (30.58%), followed by *O. barthii* (40%), *O. sativa* (40.08%) and lastly NERICA with a value of 49.40% (Fig. 4).

3.12 Shoot Fresh Weight to Root Fresh Weight Ratio (SFW/RFW)

This value was significantly ($p<0.01$) highest in *O. glaberrima* (37.20%), followed by NERICA (30.46%) and lowest in *O. barthii* (11.59%) (Fig. 3). In most susceptible genotypes, the shoot fresh weight to root fresh weight ratio were higher (25%) in salinized treatments compared to that of moderately tolerant genotypes (8%) (Fig. 4). In non-saline treatment, Pokkali and IR29 revealed increased SFW/RFW ratio of 45.1% and 18.9% respectively.

3.13 Root Dry Weight to Shoot Dry Weight (RDW/SDW)

Approximately 54% of the genotypes showed a reduction in root to shoot dry weight ratio of which most were sensitive genotypes. A 4% rise in the root to shoot dry weight ratio was obtained in tolerant genotypes (Fig. 3). The average effect of salinity on root growth of IR 29 was about 20% this was lower than that of Pokkali (27.3%). This effect varied significantly ($p<0.05$) with genotypes (Table 1).NERICA genotypes had the least value 0.83% in root/shoot dry weight. However 3.70% and 4.08% reductions were obtained with *O. sativa* and *Oryza glaberrima* respectively. A high reduction of 38.67% was obtained for *O. barthii* genotypes.

3.14 Correlation Analysis for Morpho-logical Parameters

Negative correlations between Salinity Evaluation Score and most of the parameters studied were obtained. SES score was positively and significantly ($P<0.01$) correlated to shoot fresh weight ($r=-0.51$) and root dry weight ($r=-0.54$).Shoot fresh weight showed strong positive correlation ($P<0.0001$) with shoot dry weight ($r=0.77$), RFW ($r=0.62$), SFW/RFW ($r=0.74$) and RDW ($r=0.56$). Shoot dry weight was also positively correlated with RFW ($r=0.61$), RDW ($r=0.54$), SFW/RFW ($r=0.64$) and PH ($r=0.77$). Root fresh weight positively correlated with RDW ($r=0.72$) while plant height and leaf number positively correlated with PH/RL ($r=0.62$) and TN ($r=0.77$) respectively. Similarly, strong and negative correlations ($P<0.0001$) was observed between root length and plant height/ root length ratio ($r=-0.76$).

4. DISCUSSION

4.1 Screening of Genotypes at Seedling Stage

Genotypes of *Oryza* species showed variable response to salinity stress at seedling growth stage. Salinity negatively affected the seedling height, leaf width, tillers number and biomass fresh/dry weight at seedling stage. Seedling height and leaf width were shorter in susceptible genotypes compared to tolerant genotypes indicating that salinity stress affected the seedling height and leaf length of the genotypes by interfering with growth mechanisms thereby inhibiting the photosynthesizing abilities of these genotypes. These reductions were more pronounced in un- cultivated genotypes. On the other hand, the leaves and tillers number produced by some tolerant genotypes were higher in saline treatment. It had been reported that salinity caused some morphological changes like reduction of shoot [18], root length [19], and restriction of rooting [20]. It was also reported that, salinity might directly or indirectly inhibit cell division and enlargement in plant's growth phases [21]. Reduced shoot growth caused by salinity originates in growing tissues, not in mature photosynthetic tissues. As a result, plant appears stunted. Increased tillers number and leaves number in saline conditions in some genotypes might be due to the genotypes tillering ability and vigour. Alternatively, it might have been due to unclear morphological determinants which might have triggered some mechanisms that triggered the genotypes to respond more vigorously in the bid to escape long exposure to the stress factor. Increased tillers have also been reported on double haploid and induced mutation in breeding salt tolerance in rice and wheat [22]. This result was not fully in accordance with the report stating that salinity decreased tillering in sensitive rice than in tolerant genotypes [23].

The root/shoot ratio determines where the effect of salinity was most predominant. A reduction in root to shoot ratio suggests that salinity had more effect on the root than the shoot. The ratio of the shoot/root fresh weight biomass in saline conditions represent the total uptake of nutrients by the root and shoot and gives an insight into the total accumulated nutrients in genotypes while serving as an index in determining the ability of these genotypes to take up nutrients in saline conditions. The roots of sensitive genotypes were most affected by salinity than the shoots of the genotypes. Salinity stress have been reported to affect the roots of some genotypes more than the shoot as there exist varietal differences in root capacity to exclude Na^+ and Cl^- negative ions [24]. The increase in biomass in susceptible genotypes could be attributed to salt accumulation in the tissues of these genotypes. However, un-cultivated (wild) genotypes showed greater reductions in plant biomass. The loss of biomass production under salt stress could be attributed to the reduction in photosynthate as salinity significantly has effect on leaves number, length and width thereby resulting in a reduction of these characters in susceptible than tolerant genotypes. The exact physiological mechanism related to the reduction in biomass however is unknown, but it has been reported that the shortage of photosynthate caused reduction and stunting in plant tissues. An increase in chlorophyll content and leaf CO_2 exchange rate at moderate salinity in three rice cultivars have been reported [25]. This reasonably explains increased biomass observed in some genotypes in this study. Alternatively, the inability of these genotypes to exclude salts from their shoot and root thereby accumulating them in their leaf and root tissues might have resulted in increased dry biomass. Genotypes with increased root fresh and dry weight but reduced shoot fresh and dry weight might have also lacked the ability of ionic movement of the salt through the apoplastic pathway from the root to the shoot thereby resulting in higher accumulation of these salt in the root than the shoots.

Seedling height showed significant positive association with plant biomass. This result was in concordance with reports stating that increasing plant height would allow greater biomass production [26]. They reported that under salt stress, increased plant height was responsible for increased biomass.

Species responded differently to salt stress. The root lengths in un-domesticated genotypes and NERICA were longer than in *O. sativa* genotypes. These genotypes were more susceptible to salinity stress at seedling stage except for NERICA that showed greater tolerance at seedling stage than other species. These character exhibited by NERICA may be due to the presence of introgressed genes of *O. sativa* and *O. glaberrima.* NERICA have been reported to possess rare alleles of appreciable traits [27]. The tolerance showed by NERICA could also be due to their high tillering ability [28]

which predisposed them to be more competitive for nutrient uptake [13]. Some wild rice (*O. rufipogon*) from Sri Lanka have been reported to show salinity tolerance at seedling stage comparable to Pokkali [29] as obtained in the result of this present study where TOG 9047, an *O. glaberrima* showed seedling tolerance comparable to Pokkali. The responses between and within species were most likely due to their genetic variability, habitat and domestications of species. Several workers have reported the presence of considerable genetic variation in salinity tolerance among rice varieties [30-32]. Further confirmation on intra-varietal differences in rice tolerance for salt stress has been presented [33]. This intra-varietal difference might also have cut across species of the same genus [34].

5. CONCLUSION

Conclusively, *Oryza* species showed varied response to salt stress. These responses were genotype and specie dependent. *Oryza sativa* contained the highest percentage of tolerant genotypes to salinity stress at $12dsm^{-1}$. However, moderate tolerance to salt stress was highest in NERICA followed sequentially by *Oryza sativa, Oryza glaberrima* and *Oryza barthii.*

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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