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Effect of Salt Stress on Germination and Growth Parameters of Rice (*Oryza sativa* L.)

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Abstract

The response of eight varieties of *Oryza sativa* L.('NERICA 1', 'NERICA 5', 'NERICA 12', 'NERICA 19', 'IR 29', 'IR 20', 'IWA 11', and 'POKKALI', a salt tolerant check) against four salinity levels (0, 5, 10, and 15 ds m^{-1}) were studied at germination and early growth stages. Data were analyzed using Statistical Analytical System (SAS) and means were separated by Duncan Multiple Range Test (DMRT) for Final Germination Percentage (FGP), Speed of Germination (SG), Germination Energy Percentage (GE%), shoot and root length and root and shoot dry weight. Based on dry matter yield reduction, rice varieties were classified as tolerant (T), moderately tolerant (MT), moderately susceptible (MS) or susceptible (S). Germination was not recorded at 20 ds m^{-1} salt concentration in all cultivars. Salinity decreased FGP, SG, GE% and led to reduction in shoot and root length and dry weight in all varieties and the magnitude of reduction increased with increasing salinity stress. Rice varieties 'NERICA 12', 'IR 20', 'IWA 11' and 'NERICA 19' showed greater salt tolerance during germination (germinated at 10 ds m^{-1} salinity). However, 'NERICA 1', 'IR 29', and 'IR 20' performed better based on dry matter yield reduction. The result suggested that 'NERICA 1', 'IR 29', and 'IR 20' might be used for further study of salinity effect on growth processes and physiological consequences at advanced stage of growth. The physiological responses of rice plants to salinity at various developmental stages are therefore critical for identifying salinity tolerance in the cultivars.

Keywords: germination, growth, NaCl, rice, tolerance

Introduction

Soil salinization is a serious problem in the entire world and it has grown substantially causing loss in crop productivity FAO, 2006. It is a major constraint limiting agricultural productivity on nearly 20% of the cultivated and irrigated area worldwide (Zheng *et al.,* 2001). Salinity affects almost every aspect of the physiology and biochemistry of plants and significantly reduces yield. High exogenous salt concentrations affect seed germination, water deficit, ion imbalance of the cellular ions resulting in ion toxicity and osmotic stress (Khan and Panda, 2008). Salt stress has been reported to cause an inhibition of growth and development, reduction in photosynthesis, respiration and protein synthesis in sensitive species (Meloni *et al.,* 2003; Pal *et al.,* 2004). According to the classification of crop tolerance to salinity, the rice crop is within the sensitive division from 0 to 8 ds m^{-1} (Maas *et al.,* 1986) The susceptibility of rice to salinity stress varies with growth stages. Heenan *et al.* (1988) and Lutts *et al.* (1995) reported that rice is extremely sensitive to salinity during germination, young seedling and early developmental stages for most commonly used rice varieties. However, in contrast, Khan *et al.* (1997) observed that rice is relatively salt tolerant at germination and in some cases is not affected significantly up to 16.3 ds m^{-1} of salinity. Seed germination, seedling emergence, and their survival are particularly sensitive to substrate salinity (Mariko et al., 1992; Baldwin *et al.,* 1996). High levels of soil salinity can significantly inhibit seed germination and seedling growth, due to the combined effects of high osmotic potential and specific ion toxicity (Grieve and Suarez, 1997). In general, rice becomes very sensitive at the young seedling stage, which impacts the stand density in salt affected fields (Lutts *et al.,* 1996). It is necessary to identify the sensitivity and tolerance level of a variety at early seedling stages for successful crop production in a saline environment. Therefore, this study was conducted to identify the salt-tolerance rice variety(s) at early seedling establishment and to determine their salt tolerance levels and salinity threshold.

Materials and methods

Plant Material

Seeds of eight different upland rice varieties; 'NERICA 1', 'NERICA 5', 'NERICA 12', 'NERICA 19', 'IR 29', 'IR 20', 'IWA 11' and 'POKKALLI' were utilized in the experiment.

Soil Treatment and Germination of Seedlings

Soil was treated by soaking sand in 1N hydrochloric acid for one hour to eliminate microbes and solubilize mineral elements which might be present in it. The acid was drained off and the sand washed with tap water and then distilled water until the pH of the decantable water was between 6 and 7, which was optimal for the germination and growth of the seedlings. The washed sand was air dried and transferred into seventy-two plastic pots (about 24cm in diameter and 21cm in depth) each with four holes of approximately 4 mm in diameter bored at the bottom to enhance drainage during the course of the experiment. Ten seeds were planted in each pot and after germination thinned to five. The plants were exposed to approximately eight hours of sunlight daily. Each bowl was supplied with 200 ml of distilled water in the morning and evening during the first 6 days after planting. After germination and on the 9^{th} day after planting, the pots were divided into three nutrient regimes each containing twenty-four pots, each pot containing five seedlings. The experiment was arranged in a complete randomized design and carried out in three replicates.

Preliminary Soil Analysis

The soil was analyzed at the Department of Soil Science, Faculty of Agriculture, Obafemi Awolowo University, Ile-Ife, Nigeria. The following physical and chemical properties of the soil was determined; particle size distribution (sand, silt and clay) and textural class, pH, organic carbon, organic matter, total nitrogen, available phosphorus, calcium, magnesium, potassium, sodium, exchangeable acidity and effective cation-exchange capacity.

Screen House Experiment

A shed, surrounded with iron nets was erected to house the pots. This was to protect the plants from direct rainfall contaminations, trampling and to avoid being destroyed by rodents as the plants develop. The average daily temperature, relative humidity and light intensity was also taken and recorded.

Preparation of Salt Solution

Salinity levels using pure salts of NaCl was prepared with the following equation: EC = TDS/640 (Meot-Duros and Magne, 2008); EC = Electrical conductivity; TDS = Concentration of soluble salts in mg/L.

Nutrient Solution Preparation and Salinization: Nutrient solution was prepared following the method described by Yoshida *et al.* (1976) and was salinized by adding NaCl while stirring up to the desired electrical conductivity (EC) levels.

Experimental Design

Factorial experiments under a complete randomized design (CRD) with three replications were conducted at five different levels of salinity (5, 10, 15 and 20 ds m^{-1}) and distilled water (0 ds m^{-1}) served as the control.

Application of Nutrient Solution

Each pot was supplied with 200 ml of appropriate nutrient in the morning and 200 ml of distilled water in the evening until the end of the experiment. Seedlings were grown up to 14 days in normal nutrient solution to allow for sufficient growth before salinization. Sampling was done four weeks after salinity and at one week interval.

Determination of Germination Parameters

After final count (9DAS), speed of germination (SG), final germination percent (FGP) and germination energy percent (GE%) were calculated following by the following formulae (Ellis and Robert, 1981; Ruan *et al.*, 2002).

SG = N1/D1+N2/D2+.....+Ni/Di

FGP = S/T x100

GE% = N/T x 100

where, S is the number of final germinated seeds, T is the total number of seeds, N is the number of germinated seeds at 9 DAS and Ni is the number of germinated seeds per day (Di).

Classification of Varieties

Varieties were classified as tolerant (T=0-20% reduction), moderately tolerant (MT=21-41% reduction), moderately susceptible (MS=41-60% reduction) and susceptible (S≥60% reduction) based on their total dry matter (root and shoot) reduction at different levels of salt impositions (Fageria, 1985). This experiment was repeated twice to determine the consistency of results of various varieties against different levels of salt concentrations.

Measurement of Morphological Parameter

Seedlings shoot and root length of five randomly selected seedlings from each replication was measured at the time of harvest (9 days after treatment application) with a metre rule.

Determination of Root and Shoot Dry Weight

Shoot dry weight and root dry weight of five randomly selected seedlings were recorded after oven drying at 80 °C to constant weight.

Statistical Analysis

Data were analyzed using two way Analysis of Variance method (ANOVA) and means were separated by Duncan Multiple Range Test (DMRT) using Statistical Analysis System (SAS, version 9.1) at 0.05 level of significance

Results and discussion

Final Germination percentage (FGP)

At 15 ds m^{-1} salinity, germination was completely inhibited for varieties. Germination percentages were inversely related to salt concentration level. The percentage of germination significantly decreased in all varieties due to increasing salinity level (Tab. 1). In the control (0 ds m^{-1}), the germination percentages of all varieties were greater than 90%. At the salinity level of 5 ds m^{-1}, a higher germination percentage of more than 90% was observed from the varieties 'NERICA 5' and 'NERICA 12', which were statistically similar with three other varieties, 'NERICA 1', 'IWA 11' and salt tolerant check 'POKKALI'. The other three varieties 'IR 20', 'IR 29' and 'NERICA 19' showed germination efficiency between 80 to 90%.

Similar trend with decreasing germination percentage was also observed for salinity level at 5 ds m^{-1} (Tab. 1).

Tab. 1. Effect of Salinity on germination percentage of different rice varieties

Variety	Salinity levels (ds m-1)			
	0	5	10	15
'IR20'	95.0^{a}	88.75^{bc}	82.50^{abc}	45.8^{d}
'POKKALI'	97.00^{a}	95.64^{ab}	92.77^{bc}	68.42^{bc}
'IR29'	94.64^{ab}	84.38^{cd}	76.84^{c}	55.34^{b}
'NERICA 1'	93.45^{ab}	90.00^{ab}	80.14^{cd}	64.38^{ab}
'NERICA 5'	96.76^{b}	94.88^{a}	78.63^{b}	60.51^{c}
'NERICA 12'	94.34^{a}	91.00^{ab}	58.75^{cd}	37.84^{d}
'NERICA 19'	95.45^{ab}	85.88^{cd}	51.86^{d}	45.16^{cd}
'IWAII'	90.42^{b}	91.25^{ab}	64.23^{c}	40.84^{c}

Means with the same letter in the columns do not differ significantly (p>0.05). Values in parenthesis indicate percent reduction of respective controls

Germination less than 90% mainly occurred at and above 10 ds m^{-1} salt concentrations for all rice varieties except 'POKKALI'. However, variety differences were visible at 10 ds m^{-1} salinity level. Significantly, highest germination percentage was found in 'POKKALI', which was identical to variety 'NERICA 1'.

Among the tested varieties, 'NERICA 1', 'NERICA 19', 'IR 29' and 'IR 20' were the superior in germination under saline condition at 10 ds m^{-1} in comparison to salt tolerant cultivar 'POKKALI'. The variability in salinity tolerance among rice varieties at germination have been reported (Reddy and Vaid, 1983; Mondal *et al.*, 1988; Masood *et al.*, 2006). Salinity results in poor stand due to decrease in the rate of seed germination. Presumably, the osmotic effect due to salinity was the main inhibitory factor that reduced germination as indicated by Akbar and Ponnamperuma (1982). Salinity reduces plant growth due to osmotic and ionic effects on soil solution (Parida and Das, 2005, Khan *et al.*, 2008). High levels of soil salinity can significantly inhibit seed germination and seedling growth, due to the combined effects of high osmotic potential and specific ion toxicity (Grieve and Suarez, 1997). High accumulation of Na^{+} in saline soils causes lowering of water potential and thus makes the plant unable to extract water from soil osmotic stress (Misra *et al.*, 2005).

Speed of Germination (SG)

The mean values of SG of the rice varieties at different levels of salinity are presented in Tab. 2. The speed of germination was decreased as the salinity levels increased. Irrespective of varieties, the highest mean SG was found at the control and the least was at 15 ds m^{-1}. At lower electrical conductivity (EC) level of 5 ds m^{-1}, the variety 'POKKALI', 'NERICA 12', and 'IWA 11' showed better speed of germination (SG) followed by IR 20, and the least SG was observed from the other varieties. At 5 ds m^{-1}, varieties 'IR 20', 'NERICA 12', 'NERICA 19' and 'IWA 11' had higher SG compared to control.

With the increase of salinity to 10 ds m^{-1}, a few

Tab. 2. Effect of Salinity on Speed of Germination (SG) of different rice varieties

Variety	Salinity levels (ds m^{-1})			
	0	5	10	15
'IR20'	19.45^{b}	17.87^{bc}	12.48^{adc}	2.78^{c}
'POKKALI'	24.76^{a}	21.28^{a}	14.64^{ab}	7.14^{b}
'IR29'	21.17^{a}	17.13^{bc}	8.48^{b}	0.25^{e}
'NERICA 1'	21.45^{a}	15.81^{a}	7.39^{a}	0.13^{e}
'NERICA 5'	19.87^{ab}	14.74^{ab}	8.64^{c}	2.63^{c}
'NERICA 12'	26.46^{ab}	23.76^{bc}	17.14^{de}	1.58^{cd}
'NERICA 19'	25.68^{bc}	21.17^{ab}	14.48^{cd}	2.92^{bc}
'IWAII'	24.55^{a}	20.48^{bc}	17.41^{ab}	2.53^{b}

Means with the same letter in the columns do not differ significantly (p>0.05). Values in parenthesis indicate percent reduction of respective controls

number of varieties 'IR 20', 'NERICA 19', 'NERICA 12' and 'IWA 11' showed higher SG value compared to control. At EC level of 15 ds m^{-1}, although 'IR 20' maintained its higher speed of germination compared to other varieties, it reduced 75% of SG compared to control (Tab. 2).

The decreasing tendency of SG due to increasing salinity was in the conformity with the reports of others (Mohammed *et al.*, 1989; Khan *et al.*, 1997; Hakim *et al.*, 2010). The reduction of speed of germination at high salt levels might be mainly due to osmotic stress (Heenan *et al.*, 1988).

Germination Energy (GE %)

Germination energy was observed at 9th day after germination of seed and varietal differences were observed in relation to GE% under saline condition. With the increased in the concentration of NaCl, germination energy was reduced significantly (Tab. 3). At salinity level of 5 ds m^{-1} varieties 'IWA 11', 'NERICA 19', and 'NERICA 12' showed higher or identical GE% compared to check variety 'POKKALI'. While the salinity level increased up to 10 ds m^{-1} only four varieties; 'IWA 11', 'NERICA 19', 'NERICA 12' and 'IR 29' showed better GE% compared to check variety. However, at EC of 15 ds m^{-1} seed germination did not occur for most varieties except 'IR 20', 'POKKALI' and 'IWA 11'. The result agreed with the work of Karim *et al.* (1992), Khan *et al.* (1994) that salinity delays germination processes. Hakim *et al.* (2010) reported that seed germination did not occur at 15 ds^{-1}. Folkard and Wopereis (2001) reported that salinity delayed germination in rice with increasing salt stress. In this study, some of the variety had high FGP but low GE%, which means that most of the seeds from these varieties might be germinated after 4 days. The varieties with high GE% value at specific salinity level obviously would be of higher competitive advantages than the varieties having lower GE% value for capturing

Tab. 3. Effect of salinity on Germination Energy (GE %) of different rice varieties

Variety	Salinity levels (ds m^{-1})			
	0	5	10	15
'IR20'	67.84^{bc}	54.78^{c}	19.8^{c}	7.62^{a}
'POKKALI'	68.01^{c}	53.41^{d}	15.60^{d}	0.0
'IR29'	62.16^{d}	48.64^{e}	23.50^{b}	0.0
'NERICA 1'	60.0^{cd}	37.81^{b}	11.8^{a}	0.0
'NERICA 5'	44.75^{e}	31.89^{ef}	5.64^{e}	0.0
'NERICA 12'	64.36^{cd}	58.61^{bc}	22.5^{b}	0.0
'NERICA 19'	74.75^{a}	68.01^{a}	29.84^{c}	5.4^{c}

Means with the same letter in the columns do not differ significantly (p>0.05). Values in parenthesis indicate percent reduction of respective controls

environmental and edaphic resources. Even though salinity delays germination, higher salt concentrations will eventually reduce the percentage of germinated seeds (Mauromicale and Licandro, 2002).

Shoot and Root Length

Shoot length of all the rice varieties declined in all the salt treatments relative to the control and with increase in salinity (Fig. 1). However, Shoot length reduction was less than 5% at salt concentration of 5 ds m^{-1} except for variety 'NERICA' (25% reduction).

At salinity level of 10 ds m^{-1}, the check variety ('POKKALI') showed better performance followed by 'IR 20' and 'IWAII' and the least performance was observed on 'NERICA 12'. At this salt concentration level, shoot length reduction was around 16-38% for the varieties. With further increase of salinity at 15 ds m^{-1}, the reduction percentage was 29-60%. Although varieties 'IR 20' and 'POKKALI' had produced significantly higher shoot length at this salt concentration level compared to others, it was only 29 and 35% of the control. At 15 ds m^{-1}, the differences of shoot length of varieties were not pronounced due to serious reduction in height including control variety except 'IR 20'. Reduction of seedling height is a common phenomenon of many crop plants grown under saline conditions (Javed and Khan, 1995; Karim *et al*., 1992; Amin *et al*., 1996). Similarly, root length was also decreased with increased salinity (Fig. 2). Root length was more suppressed than shoot by salinity at each specific salt concentration level. At all salinity level, varieties 'POKKALI', 'IR 29' and 'IR 20' produced significantly higher root length compared to other varieties and 'IWAII' produced lowest root length. The gradual decrease in root length with the increase in salinity as observed might be due to more inhibitory effect of NaCl salt to root growth compared to that of shoot growth (Rahman *et al.,* 2001).

Root and Shoot Dry Weight

Shoot dry weight was inversely proportional to salt concentration i.e. it decreased with increase in salt concentration (Tab. 4). It was relatively less sensitive to salt than root dry weight especially at higher salt concentrations. On the average, at the salinity concentration of 5, 10 and 15 ds m^{-1}, shoot dry weight were reduced to about 27, 62 and 80%, respectively, of the control, while root dry weight showed greater reduction of about 34, 70 and 86%, respectively, of the control (Tab. 4 and 5). Cultivars also differed and showed variability in the response of shoot dry weight to salt concentration.

At the lowest salt concentration (5 ds m^{-1}), the greatest reduction in shoot dry weight was observed in' IR 29' (50%), while in other varieties, reduction range was 13-29% relative to the control. At 10 ds m^{-1}, variety differences were pronounced; 'IWA 11', 'NERICA 5', 'NERICA 12' and 'IR 20' had about 52-65% reductions, only three varieties 'IR 29', 'NERICA 1' and 'NERICA 19' had 70-74%. At 10 ds m^{-1} reduction in shoot dry weight ranged from 50-74%. The smallest reduction was observed in 'NERICA 12' (50%) and the greatest was in 'IR 29' (about 75%). At 15 ds m^{-1}, reduction was much higher (67-92%) and all rice varieties were salt susceptible. In this study, at all salinity levels, shoot dry weight of all varieties were significantly affected, while variety 'NERICA 19' showed highest salt sensitivity in all salinity treatments (Tab. 6).

The root dry weight was decreased with increasing salinity levels. Varieties differences were pronounced in this character. At high level of salinity (10 and 15 ds m^{-1}), dry matter reduction in all the variety was serious. At the lowest salt concentration (5 ds m^{-1}), root dry weight of all the varieties were reduced to about 20-57% of the control, whilst 'POKKALI' and 'NERICA 5' reduced with tremendous amount of 50 and 57%, respectively.

However, similar trend were not observed for EC 10 ds m^{-1} but from statistical point of view, 'NERICA 5' showed the highest root dry weight at 5 ds m^{-1} as compared to all other varieties. At 10 ds m^{-1} EC level 'NERICA 19' showed highest root dry weight and lowest was observed by 'IR 20' at that salinity level. Similar trend was also observed for EC 15 ds m^{-1} as 'NERICA 19' was completely reduced (100%) followed by 'NERICA 5' (about 97%) while other varieties were reduced to about 76-88% of the control. Hence, varietal differences and high level of salt sensitivity were much pronounced at this level. Similarly, Jamil and Rha (2007) observed that shoot length, root lengths and dry weight were decreased with increasing salt stress.

This confirms previous reports which suggested that salt stress reduced the biomass of tomato (Kaya *et al.,* 2001), pea (Ahmad and Jhon, 2005) and rice (Masood *et al.,* 2005), although shoot dry weight was more sensitive to salinity than root dry weight (Essa, 2002). The reduction in root and shoot development may be due to toxic effects of the NaCl as well as unbalanced nutrient uptake by the seedlings. This also confirms the findings of Hussain and Rehman (1997). High salinity may inhibit the root and shoot elongation due to slowing down the water uptake by the plant (Jeannette *et al.,* 2002). Neumann (1993) indicated that salinity can rapidly inhibit the root growth and its capacity to water uptake and essential mineral nutrition from soil (Hakim *et al*., 2010).

Classification of Varieties

All varieties showed inconsistency in salt treatment over increasing salt concentrations. At an electrical conductivity of 5 ds m^{-1}, three varieties 'IR 20', 'IR 29' and 'NERICA 1' were salt tolerant (T) and other five varieties were moderately tolerant (MT). However, as salinity level increased to 10, most varieties showed gradual deviation from their previous salt tolerant ranking T to MT, MT to MS and MS to S respectively while sharp deviation were

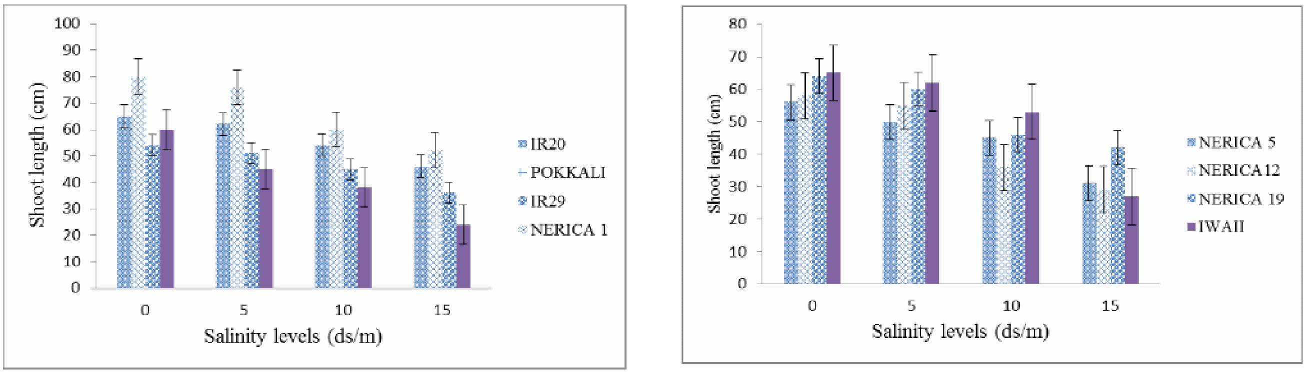

Fig. 1. Effect of salinity on shoot length (cm) of different rice varieties

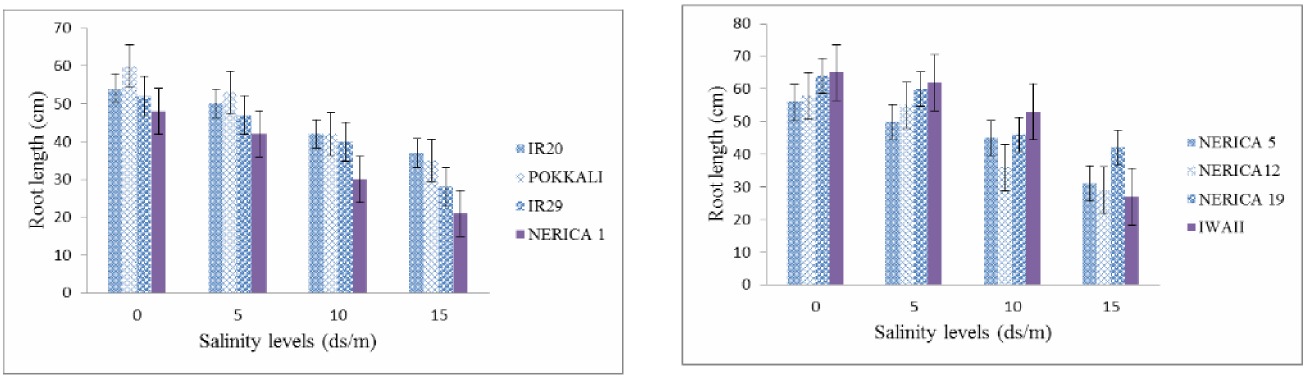

Fig. 2. Effect of salinity on root length (cm) of different rice varieties

Tab. 4. Effect of salinity on shoot dry weight (g/5 plants) of different rice varieties

Variety	Salinity levels (ds m^{-1})			
	0	5	10	15
'IR20'	0.030^{c}	0.025^{de} (16.7)	0.014^{e} (53.33)	0.008^{c} (73.33)
'POKKALI'	0.067^{a}	0.058^{b} (13.43)	0.032^{a} (52.23)	0.022^{b} (67.16)
'IR29'	0.070^{c}	0.035^{bc} (50)	0.018^{g} (74.28)	0.007^{bc} (90)
'NERICA 1'	0.042^{d}	0.032^{cd} (23.81)	0.012^{ef} (71.42)	0.004^{d} (90.48)
'NERICA 5'	0.038^{a}	0.027^{e} (28.95)	0.016^{de} (57.89)	0.010^{b} (73.68)
'NERICA 12'	0.046^{bc}	0.034^{b} (26.08)	0.023^{c} (50)	0.014^{a} (69.56)
'NERICA 19'	0.027^{bc}	0.019^{d} (29.63)	0.007^{a} (74.07)	0.002^{bc} (92.6)
'IWAII'	0.045^{b}	0.034^{c} (24.44)	0.016^{de} (64.44)	0.010^{b} (77.78)

Means with the same letter in the columns do not differ significantly (p>0.05). Values in parenthesis indicate percent reduction of respective controls

Tab. 5. Effect of salinity on root dry weight (g/5 plants) of different rice varieties

Variety	Salinity levels (ds m^{-1})			
	0	5	10	15
'IR20'	0.034^{b}	0.024^{a} (29.41)	0.018^{a} (47.06)	0.008^{c} (76.47)
'POKKALI'	0.076^{a}	0.038^{bc} (50)	0.013^{b} (82.89)	0.009^{b} (88.15)
'IR29'	0.030^{c}	0.024^{c} (20)	0.011^{bc}(63.3)	0.006^{c} (80)
'NERICA 1'	0.027^{b}	0.019^{d} (29.63)	0.009^{d} (66.7)	0.005^{d} (81.5)
'NERICA 5'	0.065^{b}	0.028^{bc} (56.92)	0.008^{b} (87.7)	0.002^{d} (96.9)
'NERICA 12'	0.031^{bc}	0.020^{b} (35.48)	0.012^{bc} (61.29)	0.005^{ab} (83.87)
'NERICA 19'	0.018^{c}	0.014^{bc} (22.22)	0.001^{b} (94.4)	0.00^{d} (100)
'IWAII'	0.034^{b}	0.023^{d} (32.35)	0.014^{bc} (58.83	0.008^{c} (76.47)

Means with the same letter in the columns do not differ significantly (p>0.05). Values in parenthesis indicate percent reduction of respective controls

Tab. 6. Effect of salinity on total dry matter production (g/5 plants) of different rice varieties and their classification to salinity

Variety	Salinity levels (ds m^{-1})						
	0	5	10	15	5	10	15
'IR20'	0.070^{b}	0.054^{a}	0.031^{a}	0.010^{c}	T	S	S
'POKKALI'	0.14^{a}	0.09^{b}	0.043^{b}	0.023^{b}	MT	S	S
'IR29'	0.068^{c}	0.056^{c}	0.028^{bc}	0.038^{d}	T	S	S
'NERICA 1'	0.084^{c}	0.067^{d}	0.052^{d}	0.008^{c}	T	MS	S
'NERICA 5'	0.066^{b}	$0.05b^{c}$	0.027^{b}	0.012^{d}	MT	MT	S
'NERICA 12'	0.106^{bc}	0.057^{b}	0.019^{bc}	0.005^{ab}	MS	MS	S
'NERICA 19'	0.079^{b}	$0.06b^{c}$	0.036^{b}	0.01^{d}	MT	S	S
'IWAII'	0.08^{b}	0.056^{bc}	0.028^{bc}	0.015^{e}	MT	MS	MS

noticed in 'IR 20' and 'IR 29'. At 15 ds m^{-1}, all varieties except 'NERICA 1' were susceptible to salinity. Hakim *et al.* (2010) had earlier reported all varieties to be susceptible at 16ds m^{-1}. Fageria (1985) classified rice cultivars based on their percentage yield reductions, they observed that at salinity level of 5 ds m^{-1}, almost all of eight cultivars were tolerant, while at 15 ds m^{-1}, all the varieties were susceptible and at 10 ds m^{-1}, the cultivars showed intermediate tolerance.

It was concluded that germination and early seedling growth of different rice varieties were inhibited by increasing salt concentration. No seed was germinated at 20 ds m^{-1}. In respect to speed of germination and germination energy, four varieties namely, 'NERICA 12', 'NERICA 19', 'IWA II' and 'IR 29' were found superior at 10 ds m^{-1} salt concentration level compared to check variety 'POKKALI'. Based on final germination percentage, tolerant check ('POKKALI') performed better than all other varieties.

The degree of stress among the varieties increased with salinity. In general, salinity caused a considerable reduction in dry matter among the eight varieties. However, roots appeared to be more sensitive to salt injury than the shoots as manifested by higher percent reduction in root dry weight. This observation suggested that the capacity to produce roots was more severely affected than the shoot. It's also suggestive of more inhibitory effect of NaCl salt to root growth rather than that of the shoot. It might also be due to energy partitioning to the root and this may be used as an indicator of salinity tolerance in determining the salinity threshold of a particular variety. Hence, there appeared to be marked variations in the response of the eight varieties of rice to salinity. The eight varieties showed different ranges of tolerance to salinity. The result suggested that 'NERICA 1', 'IR 29', and 'IR 20' might be used for further study of salinity effect on growth processes and physiological consequences at advanced stage of growth. The physiological responses of rice plants to salinity at various developmental stages are therefore critical for identifying salinity tolerance in the cultivars.

Recommendation

This study should be further conducted in the field to better understand detailed changes in vegetative and reproductive developmental processes of rice.

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