Research article

Evaluation of Salt Tolerance for Improved Rice Lines in terms of Agronomic Parameters

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Received 7 January 2019 Accepted 25 March 2019 (*Corresponding Author)

Abstract Soil salinity has become a serious threat to crop productivity worldwide. Salt tolerance for rice varieties vary with different stages against salinity. This study was to evaluate the effect of three different levels [0.2, 6.0, and 8.0 dS m^{-1}] of salinity on the growth and yield of improved rice lines at different growth stages. This study was conducted as two-factor factorial in a randomized complete block design with three replications at Yezin Agricultural University in 2017 and 2018. After screening at seedling and vegetative stages, the selected rice lines were grown at three different salinity levels [3.3, 6.0, and 7.6 dS m^{-1}] in the field. Among the one hundred improved rice lines, thirteen lines were tolerant to 8.0 dS m^{-1} during three weeks of application at seedling stage. Studies at vegetative stage showed that these thirteen lines were tolerant to 6.0 dS m^{-1} during six weeks of application. However, seven rice lines were moderately tolerant to 8.0 dS m^{-1} during six weeks of application in term of leaf mortality. In the field experiment, all seven rice lines were tolerant to 6.0 dS m^{-1} at all growth stages, whereas death occurred at 7.6 dS m^{-1}. All agronomic parameters such as tiller numbers, panicle numbers and grain numbers per panicle were grown up to maturity under 6.0 dS m^{-1} at field condition. All these parameters were found to be major cause of yield reduction under saline conditions.

Keywords salinity; screening rice lines

INTRODUCTION

Rice (*Oryza sativa*), the staple food of half of the population of the world, is an important target for water use reduction because of its greater input water requirement than other crops. On the other hand, rice crop that resists to climate change is prevalent among farmer's requirements.

Soil salinization has become a serious problem all over the world and around 20% of the world's cultivated land are affected (Sumner, 2000). In Myanmar, soil salinization was found in coastal and inland regions. Coastal salinity was affected by seawater intrusion/ infiltration during flood resulting salt accumulation in the topsoil in the summer season. It was commonly happened in Ayeyarwady, Yangon, Yakhaing and Taninthari regions. Inland salinity is commonly seen in dry zone areas of the central Myanmar such as Mandalay, Magway and Sagaing regions. Swe and Ando (2017) observed that salinity is becoming a prominent abiotic problem declining rice production in central dry zone which little attention was paid in the past. They reviewed that with irrigation for several years continuously, alkali/saline soils have been developed in certain areas. The excessive applications of irrigation water have raised the ground water level sufficiently to increase concentration of salts through evaporation. It is related principally to the presence of sodium carbonate and sodium bicarbonate in these areas. Inland salinity or irrigation salinity is due to over-watering, seepage from irrigation channel, impaired natural drainage and high water table. From the low land rice in these salt affected areas, high rate of evaporation and evapotranspiration of rice crop increase the capillary transport of water and solutes from the groundwater to the root zone. When there is a condition of no or negligible leaching of these salts, the soils will be affected with salinity within a few years. In addition, due to the poor drainage facilities in the irrigation areas not only the agricultural lands have suffered but also agricultural production has suffered from the twin hazard of water logging (hypoxia) and salinity.

Rice productivity is quite low due to the salinization, limitation of water resources, and low soil fertility in inland salinity areas of Myanmar (Oo et al., 2017). To improve crop productivity in these areas, it is needed to investigate the plant responses to conditions with the ultimate goal of improving crop performance in these areas where salinity has a problem. According to further improvement of rice breeding program in national level, it offers doing research and providing rice varieties for farmer needs are recently lined out. The water requirement and salt tolerance for rice genotypes vary with different stages of its establishment processes, and to determine the best tolerance on rice varieties at different stages in our country is one of the advantageous and encouraging rice productions to climate adaptability.

OBJECTIVES

This study was to evaluate the most salt tolerance rice lines at different growth stages among the improved genotypes and to determine the best improved rice lines based on influences of salinity stress on the growth and yield of rice in the central dry zone of Myanmar.

MATERIALS AND METHODS

Evaluation of Improved Rice Lines at Seedling Stage

A population of 100 improved rice genotypes (provided from the Department of Plant Breeding, Physiology and Ecology, Yezin Agricultural University) with Pokkali (tolerant check) and IR29 (susceptible check) were tested at the Department of Soil and Water Science, Yezin Agricultural University, Myanmar.

The first experiment was conducted in a net house with 31/21 °C day/night temperatures and a minimum relative humidity of 75% during the day in 2017. Pre-germinated seeds of 100 rice lines were sown at two seeds per hole and a sheet with 100 holes and a nylon net bottom. The sheets were floated on a plastic tray filled with distilled water for 4 days and then in nutrient solution (Yoshida et al., 1976) for 4 days. All seedlings were then well-established, and the culture medium was salinized with EC 6 dS m^{-1} by adding NaCl. After 4 days, salinity was increased to electrical conductivity (EC) 8.0 dS m^{-1} by adding NaCl. The experimental design was set up with both non-saline and salinized nutrient solutions in a randomized complete block (RCB) design with three replications. The pH was maintained daily at 5.5.

Table 1 Modified SES of visual salt injury at seedling and vegetative stages

Score	Observation	Tolerance
1	Normal growth, no leaf symptoms	Highly tolerant
3	Nearly normal growth, but leaf tips of few leaves whitish and rolled	Tolerant
5	Growth severely retarded, most leave rolled	Moderately tolerant
7	Complete cessation of growth, most leaves dry, some plant dying	Susceptible
9	Almost all plant dead or dying	Highly susceptible

Source; Gregorio et al., 1997

Salinity tolerance was rated using a modified standard evaluation system (SES) in rating the visual symptoms of salt toxicity (Gregorio et al., 1997) as shown in Table 1. This scoring discriminates the susceptible from the tolerant and the moderately tolerant genotypes. Scoring was started at 10 days after salinization and final scoring at 16 days after salinization.

Evaluation of Selected Improved Rice Lines at Vegetative Stage

This experiment was conducted as two-factor factorial in a randomized complete block design with three replications at vegetative stage in 2018. The selected seven rice lines, after screening at seedling stage, with Pokkali (tolerant check) and IR29 (susceptible check) were grown at three different levels (0.2, 6.0, and 8.0 dS m^{-1}) in the net house.

According to Gregorio et al. (1997) who modified the method for the screening of rice genotypes at vegetative stage, the wall of plastic pot was drilled with 3-4 mm diameter holes 2 cm apart with the topmost circle of holes at least 3 cm below the rim of plastic pot. Cotton cloth was used and fit well inside the plastic pot. The pots were filled with fertilized soil. These pots were placed in the plastic tray filled with ordinary tap water which served as water bath. Four to five pre-germinated seeds of test entries are placed on soil surface of each pot. Two weeks after seeding, seedlings were thinned to one per pot and the water level was raised to about 1 cm above soil. When the seedlings were 25 days old, all water in the water bath was siphon out. And then, salinized water was filled up to the desired EC level by dissolving NaCl in water. Maintain water level daily and protect the plants from any pests and diseases were performed.

Scoring was started at two weeks after salinization by using a modified standard evaluation system in rating the visual symptoms of salt toxicity (Gregorio et al., 1997) as presented in Table 1. Test entries was scored from then onwards based on visual symptoms. Plant height (cm) and the number of tillers per hill were recorded at 6 weeks after salinization.

Evaluation of Selected Improved Rice Lines at Vegetative Stage in the Field Condition

In order to determine the best improved rice lines based on influences of salinity stress on the growth and yield of rice, the experiment was conducted in the salinity area at Htein Kan Gyi Village in Myittha Township, Mandalay Division where is situated in the dry zone area of Myanmar during the rainy season of 2018. The experiment was laid out in a randomized complete block design (RCBD) with four replications. The selected seven rice lines, after screening in the net house at vegetative stages, with Pokkali (tolerant check) and IR29 (susceptible check) were grown with a spacing of 20 cm x 20 cm under three different salinity levels (3.3, 6.0 and 7.6 dS m^{-1}) which were set up according to the salinity survey measurement in the study area. Scoring was started at two weeks after transplanting by using a modified standard evaluation system in rating the visual symptoms of salt toxicity (Gregorio et al., 1997) as shown in Table 1. Test entries was scored from then onwards based on visual symptoms. Plant height (cm) and the number of tillers per hill were recorded at 42 days after transplanting (DAT) (i.e at vegetative stage) and the number of panicles per hill and yield were measured at harvesting.

Data Analysis

The data collected were analyzed statistically using Analysis of Variance (ANOVA) Techniques, and rice lines means were compared by least significant different (LSD) method at 5% probability level. All statistical analyses were done using Statistix 8.0 software and Excel program (2010).

RESULTS AND DISCUSSION

Evaluation of Improved Rice Lines at Seedling Stage

All one hundred improved rice lines at seedling stage were grown strongly and showed uniform green colour in the non-salinized condition (0.2 dS m^{-1}). In salinized condition (8.0 dS m^{-1}), the rice lines differed significantly for salt tolerance at seedling stage among the rice lines ranging from score 1 (highly tolerant) and score 9 (highly susceptible) (data not show).

The one hundred improved rice lines were classified into five groups from highly tolerant (score 1) to highly sensitive (score 9) as 0 (highly tolerant), 13 (tolerant), 12 (moderate tolerant), 28 (sensitive) and 51 (highly sensitive) at 16 days after salinization. Among the one hundred improved rice lines, thirteen lines were tolerant to 8.0 dS m^{-1} during three weeks of application at seedling stage. The effects of salinity stress on plants are complex and it is difficult to interpret the results if experiments are not designed carefully and if appropriate measurements are not made (Negrao et al., 2017). Hence, the selected seven rice lines from thirteen tolerant lines were evaluated at vegetation stage in the net house and field condition.

Evaluation of Selected Improved Rice Lines at Vegetative Stage

The visual evaluation scores, SES showed a variation in response to salt stress among the rice lines. SES increased with the increase in stress level, indicating greater susceptibility at higher stress level (Table 2). All seven improved rice lines at vegetative stage were grown strongly and showed uniform green colour in the non-salinized condition (0.2 dS m^{-1}). In salinized condition (6.0 and 8.0 dS m^{-1}), the rice lines differed significantly for salt tolerance at vegetative stage among the rice lines ranging from score 1 (highly tolerant) and score 9 (highly susceptible) (Table 2). The seven rice lines showed a higher degree of tolerant and moderately tolerant under two different salinity levels (6.0 and 8.0 dS m^{-1}, respectively).

Table 2 Salinity reactions of improved rice lines in terms of Standard Evaluation Score (SES) under three different salinity levels at vegetative stage in the net house

Improved rice lines	Reaction to salinity at 6 weeks after salinization		
	0.2 dS m^{-1}	6.0 dS m^{-1}	8.0 dS m^{-1}
YAU-1211-14-1-1	Highly tolerant	Tolerant	Moderately tolerant
YAU-1201-90-2-4	Highly tolerant	Tolerant	Moderately tolerant
YAU-1211-118-1-1	Highly tolerant	Tolerant	Moderately tolerant
YAU-1211-195-1-1	Highly tolerant	Tolerant	Moderately tolerant
YAU-1201-26-1-1	Highly tolerant	Tolerant	Moderately tolerant
YAU-1201-26-1-3	Highly tolerant	Tolerant	Moderately tolerant
YAU-1211-82-1-1	Highly tolerant	Tolerant	Moderately tolerant
Pokkali	Highly tolerant	Tolerant	Tolerant
IR29	Highly tolerant	Highly susceptible	Highly susceptible

Table 3 Salinity reactions of selected improved rice lines in terms of plant height and number of tillers per hill under three different salinity levels at vegetative stage

Improved rice lines	Plant height (cm)			Number of tillers per hill		
	0.2 dS m^{-1}	6.0 dS m^{-1}	8.0 dS m^{-1}	0.2 dS m^{-1}	6.0 dS m^{-1}	8.0 dS m^{-1}
YAU-1211-14-1-1	39.0 bcd	32.7	26.3	4.7	4.0	3.0
YAU-1201-90-2-4	37.3 de	32.3	25.7	4.3	4.0	3.3
YAU-1211-118-1-1	42.0 ab	32.7	23.7	4.3	3.7	3.3
YAU-1211-195-1-1	39.7 bcd	33.3	24.0	4.0	3.7	3.3
YAU-1201-26-1-1	44.7 a	32.0	26.7	5.0	4.3	4.0
YAU-1201-26-1-3	38.0 cde	35.7	22.7	4.0	3.3	3.3
YAU-1211-82-1-1	40.7 bc	34.0	27.3	4.3	3.7	4.0
Pokkali	35.3 ef	36.3	25.0	4.3	3.3	3.3
IR29	33.0 f	31.7	24.0	3.7	3.7	3.3
F-test	**	ns	ns	ns	ns	ns
C.V %	4.6	5.5	9.2	15.2	18.6	19.4

Values in the same column followed by the same letter are not significantly different at the 5% level by the LSD test, (**) significantly different at $P \leq 0.01$, ns − not significant

Salinity reactions of selected improved rice lines in terms of plant height and number of tillers per hill under three different salinity levels at vegetative stage are showed in Table 3. The plant heights were significantly different among the rice lines in the non-salinized condition (0.2 dS m^{-1}). In contrast, these parameters were not significantly different among the rice lines in both salinized conditions. Similarly, the number of tillers per hill was not significantly different among the rice lines in all salinized conditions.

Evaluation of Selected Improved Rice Lines at Vegetative Stage in the Field Condition

According to the visual evaluation scores, the selected rice lines were tolerant to 3.3 and 6.0 dS m^{-1} salinity levels, whereas all rice lines were susceptible at 7.6 dS m^{-1} (Table 4). In high salinity level (7.6 dS m^{-1}), visual damage was serious; chlorosis and leaf rolling were observed on all plants of selected rice genotypes in the field condition.

Table 4 Salinity reactions of improved rice lines in terms of Standard Evaluation Score (SES) under three different salinity levels at vegetative stage in field experiment

Improved rice lines	Reaction to salinity		
	3.3 dS m^{-1}	6.0 dS m^{-1}	7.6 dS m^{-1}
YAU-1211-14-1-1	Tolerant	Tolerant	Susceptible
YAU-1201-90-2-4	Tolerant	Tolerant	Susceptible
YAU-1211-118-1-1	Tolerant	Tolerant	Susceptible
YAU-1211-195-1-1	Tolerant	Tolerant	Susceptible
YAU-1201-26-1-1	Tolerant	Tolerant	Susceptible
YAU-1201-26-1-3	Tolerant	Tolerant	Susceptible
YAU-1211-82-1-1	Tolerant	Tolerant	Susceptible
Pokkali	Tolerant	Tolerant	Susceptible
IR29	Moderate Tolerant	Susceptible	Susceptible

Table 5 Salinity reactions of improved rice lines in terms of plant height and number of tillers per hill under three different salinity stress levels at vegetative stage (42 DAT) in field experiment

Improved rice lines	Plant height (cm)			Number of tillers per hill		
	3.3 dS m^{-1}	6.0 dS m^{-1}	7.6 dS m^{-1}	3.3 dS m^{-1}	6.0 dS m^{-1}	7.6 dS m^{-1}
YAU-1211-14-1-1	50.0 cd	38.8 e	27.6	12.6 abc	7.8 de	3.4
YAU-1201-90-2-4	59.8 ab	39.0 e	28.9	14.7 a	6.3 e	3.1
YAU-1211-118-1-1	54.6 bcd	50.3 bc	24.6	10.8 bc	9.4 bcd	3.8
YAU-1211-195-1-1	56.0 bc	45.8 bcde	26.7	15.1 a	9.5 bcd	4.1
YAU-1201-26-1-1	54.7 bcd	46.7 bcd	29.5	12.9 abc	12.6 a	4.8
YAU-1201-26-1-3	57.5 bc	42.9 de	25.4	13.3 ab	8.5 cd	4.9
YAU-1211-82-1-1	58.8 bc	53.8 b	29.2	10.9 bc	10.4 b	4.3
Pokkali	67.9 a	67.7 a	29.4	10.8 bc	9.1 bcd	4.0
IR29	46.3 c	43.0 c	25.4	10.0 c	9.7 bc	2.6
F-test	**	**	ns	**	**	ns
C.V %	10.8	10.7	12.8	17.4	12.5	35.7

Values in the same column followed by the same letter are not significantly different at the 5% level by the LSD test, (**) significantly different at $P \leq 0.01$, ns − not significant

Comparing between seven improved rice lines, the result showed that effects of salinity on all measured traits were significantly different (Table 5 and 6). The selected improved rice lines were highly significant different in both 3.3 and 6.0 dS m^{-1} salinity levels in terms of plant height and number of tillers per hill at vegetative stage. At this growth stage, YAU-1201-26-1-1 line significantly produced maximum number of tillers per hill 6.0 dS m^{-1}. In the field experiment, salinity stress reduced the growth of the selected improved rice lines in 7.6 dS m^{-1} when compare with 3.3 and 6.0 dS m^{-1} salinity levels. In this study, Pokkali (tolerant check) was not tolerant to 7.6 dS m^{-1} in the field condition and it produced a smaller number of tillers per hill, when compare to other improved rice lines. The selected improved rice lines were highly significant different in both 3.3 and 6.0 dS m^{-1} salinity levels in terms of number of panicles per hill and grain yield at harvesting (Table 6). YAU-1201-195-1-1 gave the highest values of grain yield among the rice lines in 6.0 dS m^{-1}. Mass and Grattan (1999) indicated that the rice yield decreased with increasing in soil salinity.

Table 6 Salinity reactions of improved rice lines in terms of number of panicles per hill and yield under three different salinity levels at harvesting in field experiment

Improved rice lines	Number of panicles per hill			Yield (g m^{-2})		
	3.3 dS m^{-1}	6.0 dS m^{-1}	7.6 dS m^{-1}	3.3 dS m^{-1}	6.0 dS m^{-1}	7.6 dS m^{-1}
YAU-1211-14-1-1	14.8 b	13.0 cde	n.a	671 bc	438 b	n.a
YAU-1201-90-2-4	13.8 bc	12.5 de	n.a	488 d	437 b	n.a
YAU-1211-118-1-1	17.7 a	16.3 ab	n.a	829 a	505 ab	n.a
YAU-1211-195-1-1	13.0 bc	15.5 abc	n.a	701 abc	573 a	n.a
YAU-1201-26-1-1	13.5 bc	17.3 a	n.a	644 bc	447 ab	n.a
YAU-1201-26-1-3	12.3 c	14.5 bcd	n.a	573 cd	292 c	n.a
YAU-1211-82-1-1	13.3 bc	16.5 ab	n.a	734 ab	529 ab	n.a
Pokkali	12.7 bc	12.8 de	n.a	499 d	473 ab	n.a
IR29	12.4 c	11.3 e	n.a	458 d	444 c	n.a
F-test	*	*		**	**	
C.V %	8.9	12.1		14.2	19.6	

Values in the same column followed by the same letter are not significantly different at the 5% level by the LSD test, (**) significantly different at P ≤ 0.01, (*) significantly different at P ≤ 0.05, na – not available

CONCLUSION

In conclusion, differences of 100 improved rice lines were observed for relative salt tolerance in terms of agronomic parameters such as tiller numbers, panicle numbers and grain yield. From this study, seven tolerant rice lines had good performance in the areas where salinity has a problem. This study will be useful for developing salinity tolerant varieties. Therefore, this performance would be valuable information for plant breeding program.

ACKNOWLEDGEMENTS

The authors would like to thank the JICA (Japan International Cooperation Agency) for the project for capacity development of Yezin Agricultural University, for financial support.

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