Research article

Evaluation of Drought Tolerance for Improved Rice Lines in terms of Yield, Chlorophyll content and Water Use Efficiency

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Abstract Rice (*Oryza sativa* L.) is an important target crop for water use reduction because of its greater input water requirement than other crops. The pot experiment was conducted to evaluate the effect of two different levels [full irrigation and deficit irrigation (50% Plant Available Moisture)] on the growth, yield, chlorophyll content and water use efficiency of improved rice lines. Preliminary test for drought tolerance for the one hundred improved rice lines was conducted and screened under pot experiments in the dry season of 2018. After screening this test, the selected rice lines were grown at two different water levels in the screen house during the rainy season of 2019. Each experiment was assigned as a randomized complete block design with three replications at Yezin Agricultural University. The result of the preliminary test in 2018 found that among the one hundred YAU improved rice lines, seven lines were tolerant to deficit irrigation. In 2019, all selected rice lines were also tolerant to deficit irrigation. These lines also produced the best performance of the plant growth, the grain yield and yield component characters when compared with the checked variety. However, deficit irrigation for all selected lines reduced these characters when compared with full irrigation. The five rice lines under deficit irrigation produced the high chlorophyll content and water use efficiency when compared with full irrigation. Thus, it can be concluded that the highest drought- tolerant rice lines would be useful for plant breeding program.

Keywords deficit irrigation, screening rice lines, water use efficiency

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop for more than half of the population of the world. It is cultivated over 167 million hectares with the production of 780 million tonnes (FAO STAT, 2017). It is grown under various environmental conditions in both upland and lowland rainfed ecosystem. Crop productions are affected by many climatic and environmental factors, which can be abiotic and biotic factors. Among them, drought is the most significant environmental factor to impact on the growth and yield of crop in accordance with the global climate change in the world's agricultural lands. In Myanmar, especially in the central dry zone areas, rice yield is quite low due to the salinization, drought, and low soil fertility (Oo et al., 2017). Among them, drought is an increasingly severe problem in rainfed rice production. To increase crop yield in these areas, it is needed to study the plant responses to conditions with the ultimate goal of improving crop performance in areas where water scarcity 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 for rice genotypes vary with different stages of its establishment processes, and to determine the best tolerance on rice varieties in our country is one of the advantages and encouraging rice production to climate adaptability.

OBJECTIVES

This study was to evaluate the most drought tolerance rice lines based on the effects of water stress on the growth, yield, chlorophyll content and water use efficiency of improved rice lines.

MATERIALS AND METHODS

Evaluation of Improved Rice Lines at Vegetative Stage

A population of 100 improved rice genotypes (provided from the Department of Plant Breeding, Physiology and Ecology, Yezin Agricultural University) with Yar-8 (tolerant check) were tested at the Department of Soil and Water Science, Yezin Agricultural University, Myanmar.

Preliminary test for drought tolerance screening trial was conducted in a net house with 41/23°C day/night temperatures and a minimum relative humidity of 75% during the day in the dry season of 2018. This trial was laid out in a randomized complete block design with three replications. Two water levels were used as full irrigation and deficit irrigation (50% Plant Available Moisture). Five kilograms of 2-mm-sieved air-dried soil was filled in each black plastic pot of 15-cm height and 20-cm diameter. Pre-germinated seeds of 100 rice lines were sown at two-three seeds on soil surface of each pot. Each plot was well-watered (soil moisture close to the field capacity) before starting the deficit irrigation which was started at 35 days after sowing. Daily soil water status was monitored by using soil moisture meter. Fertilizer was applied as the recommended rate of urea, triple superphosphate and muriate of potash (Buresh and Witt, 2006). Hand weeding and insecticide spraying were done whenever necessary. Drought tolerance was rated using a modified standard evaluation system (SES) in rating the visual symptoms of water stress (IRRI, 2013). This scoring discriminates the susceptible from the tolerant and the moderately tolerant genotypes. Leaf rolling and dry scores were started at 10 days after starting the deficit irrigation.

Evaluation of Selected Improved Rice Lines at Various Stages

This experiment was conducted in a randomized complete block design with three replications in the rainy season of 2019. The selected seven rice lines, after screening at vegetative stage, with Yar-8 (tolerant check) were grown at two different water levels (full irrigation and deficit irrigation (50% PAM)) in the net house. The black plastic pots (30-cm height and 30-cm diameter) were filled with twelve kilograms of 2-mm-sieved air-dried fertilized soil. Three to four pre-germinated seeds of test entries were placed on soil surface of each pot. Two weeks after seeding, seedlings were thinned to one per pot. Maintain soil water status daily and protect the plants from any pests and diseases were performed. Fertilizer was applied as the recommended rate. Plant height (cm), the number of tillers per hill, the number of panicles per hill, the number of spikelets per panicle, filled grain percent, 1000-grain weight, dry matter and grain yield were recorded at harvesting. Chlorophyll content was measured by using chlorophyll meter (SPAD-502, Minolta, Japan) at vegetative and panicle initiation stages. Water use efficiency was calculated as grain yield (usually the economic yield) divided by water used to produce yield consumed by the crop during the growing season (Boutraa, 2010). In order to identify the drought tolerant rice lines, drought susceptibility index (DSI) (Fischer and Maurer, 1978), stress tolerance (TOL) (Rosielle and Hamblin, 1981), mean productivity (MP) (Hosssain et al., 1990), stress tolerance index (STI) (Fernandez, 1992), yield index (YI) (Lin et al., 1986) were also taken into consideration.

Data Analysis

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

RESULTS AND DISCUSSION

Evaluation of Improved Rice Lines to Drought Stress at Vegetative Stage

All one hundred improved rice lines were grown strongly and showed uniform green colour under both soil water levels. According to the leaf rolling and dry scores, the rice lines differed significantly for drought tolerance at vegetative stage among the rice lines ranging from score 0 (highly tolerant) and score 9 (highly susceptible) under deficit irrigation (data not shown).

The one hundred improved rice lines were classified into five groups from highly tolerant (score 0) to highly sensitive (score 9) as 0 (highly tolerant), 10 (tolerant), 20 (moderately tolerant), 16 (sensitive) and 54 (highly sensitive) at vegetative stage. The effects of water stress on rice plants were complex and it was difficult to interpret the results. Hence, the selected seven rice lines from ten tolerant lines were evaluated for all stages in the net house.

Evaluation of Selected Improved Rice Lines to Drought Stress

Mean comparisons of selected improved rice lines in terms of plant height and number of tillers per hill under two different irrigation levels at harvesting are shown in (Table 1). The plant height was significantly different among the rice lines under deficit irrigation, whereas it was not different in full irrigation. The number of tillers per hill was not significantly different among the rice lines under full irrigation, while it was significantly different under deficit irrigation at 5% level. Similarly, the number of panicles per hill was not significantly different among the rice lines under full irrigation, whereas it was significantly different under deficit irrigation (Table 2). YAU-1211-82-1-1 and YAU-1211-118-1-1 had the highest (16.7 and 15.7) values, respectively. The number of spikelets per panicle was significantly different among the rice lines under full irrigation at 1 % level. In contrast, it was not significantly different under deficit irrigation (Table 2).

Table 1 Mean comparison of plant height and number of tillers per hill in different improved rice lines at harvesting

Improved rice lines	Plant height (cm)		D (%)	Number of tillers per hill		D (%)
	FI	DI		FI	DI	
YAU-1211-14-1-1	118.5	105.0 b	8.8	20.0	11.3 d	30.0
YAU-1201-90-2-4	128.5	97.1 bc	24.5	20.3	13.3 bcd	34.4
YAU-1211-118-1-1	125.3	90.5 c	27.7	17.7	16.3 ab	7.5
YAU-1211-195-1-1	121.5	100.5 bc	17.3	17.0	15.0 abc	11.8
YAU-1201-26-1-1	126.7	101.6 bc	21.9	13.7	13.3 cd	2.4
YAU-1201-26-1-3	124.2	104.7 b	15.7	17.0	13.0 bcd	23.5
YAU-1211-82-1-1	117.5	106.7 b	11.7	19.0	17.0 a	10.5
Yar-8 (Tolerance check)	127.6	119.3 a	8.2	17.7	15.3 abc	13.2
F-test	ns	**		ns	*	
C.V %	5.2	6.2		21.6	13.7	

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≤0.01, (*) significantly different at P≤0.05, ns − not significant,
FI: Full Irrigation, DI: Deficit Irrigation, D (%): Percentage decrease down

The data regarding filled grain percent and 1000-grain weight of selected improved rice lines under two different irrigation levels at harvesting are presented in Table (3). There was significant difference in filled grain percent under full and deficit irrigation at 5 % and 1 % level, respectively. YAU-1211-195-1-1 had the highest filled grain percent (79.1) among the rice lines. The filled grain percent of this rice line under full irrigation was lower than that under deficit irrigation. 1000-grain weight was significantly different among the rice lines under full irrigation at 1 % level, while it was not different under deficit irrigation.

Table 2 Mean comparisons of number of panicles per hill and number of spikelets per panicle in different improved rice lines at harvesting

Improved rice lines	Number of panicles per hill		D (%)	Number of spikelets per panicle		D (%)
	FI	DI		FI	DI	
YAU-1211-14-1-1	17.0	10.7 cd	29.4	169 ab	124	23.9
YAU-1201-90-2-4	19.3	9.7 d	50.0	123 d	121	1.1
YAU-1211-118-1-1	17.3	15.7 a	9.6	161 bc	111	31.3
YAU-1211-195-1-1	16.0	14.0 abc	12.5	149 bc	131	12.7
YAU-1201-26-1-1	12.3	12.0 bcd	2.7	142 cd	106	25.7
YAU-1201-26-1-3	15.7	10.7 cd	31.9	189 a	125	33.8
YAU-1211-82-1-1	17.0	16.7 a	2.0	154 bc	118	24.1
Yar-8 (Tolerance check)	16.3	15.0 ab	24.0	186 abc	122	21.2
F-test	ns	*		**	ns	
C.V %	19.8	15.0		8.9	10.8	

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, ns − not significant
FI: Full Irrigation, DI: Deficit Irrigation, D (%): Percentage decrease down

Table 3 Mean comparisons of filled grain percentage and 1000-grain weight in different improved rice lines at harvesting

Improved rice lines	Filled grain (%)		D (%)	1000-grain weight (g)		D (%)
	FI	DI		FI	DI	
YAU-1211-14-1-1	80.9 ab	68.5 bc	15.4	25.5 d	24.4	4.1
YAU-1201-90-2-4	85.7 a	72.5 abc	15.4	31.7 a	28.9	9.0
YAU-1211-118-1-1	79.5 ab	76.4 ab	4.0	28.2 bc	25.7	8.7
YAU-1211-195-1-1	77.2 b	79.1 a	-2.4	24.7 d	24.7	0.2
YAU-1201-26-1-1	85.6 a	75.3 abc	12.0	28.8 b	28.6	0.6
YAU-1201-26-1-3	69.7 c	58.0 d	16.8	26.5 cd	25.8	2.5
YAU-1211-82-1-1	85.1 a	64.9 cd	23.6	29.2 b	25.2	13.9
Yar-8 (Tolerance check)	73.7 ab	76.6 ab	5.4	29.5 b	25.5	13.7
F-test	*	**		**	ns	
C.V %	5.2	8.4		4.4	7.4	

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≤0.01, (*) significantly different at P≤0.05, ns − not significant
FI: Full Irrigation, DI: Deficit Irrigation, D (%): Percentage decrease down

In comparing the seven improved rice lines, the effect of drought stress on grain yield was significantly different under deficit irrigation, whereas it was not different under full irrigation (Table 4). Yar-8 (Tolerance check) had the highest grain yield (38.8 g) than the rice lines and followed by YAU-1211-195-1-1 which had the highest grain yield (35.4 g) among the rice lines. In contrast, YAU-1201-26-1-3 had the lowest yield (19.9 g).

The evaluation of drought tolerant promising rice lines based on a single criterion index was incongruous (Table 4). Lower DSI and TOL values indicated the more resistant to drought (Winter et al., 1988; Rosielle and Hamblin, 1981). In this study, regarding to DSI and TOL values, YAU-1211-195-1-1 and YAU-1201-26-1-1 were the most drought tolerant rice lines, while YAU-1201-

90-2-4 and YAU-1211-82-1-1 were the least relative tolerant lines. According to MP, YAU-1211-118-1-1 was the most tolerant rice lines, while YAU-1201-26-1-1 was the least rice lines. Concerning to STI, YAU-1211-118-1-1 was the best tolerant rice lines, whereas YAU-1201-26-1-3 was the worst relatively tolerant lines. Regarding to YI, YAU-1211-195-1-1 was the greatest tolerant rice lines, while YAU-1201-26-1-3 was the poorest relatively drought tolerant lines.

Table 4 Evaluation of improved rice lines based on drought tolerance indices

Improved rice lines	Grain Yield (g per hill)		D (%)	DSI	TOL	MP	STI	YI
	FI	DI						
YAU-1211-14-1-1	58.9	25.3 de	57.1	1.17	33.60	42.09	0.46	0.44
YAU-1201-90-2-4	63.9	24.5 de	59.7	1.27	36.21	42.59	0.45	0.43
YAU-1211-118-1-1	63.4	33.2 abc	47.7	0.98	30.26	48.28	0.64	0.58
YAU-1211-195-1-1	45.3	35.4 ab	22.0	0.45	9.99	40.35	0.49	0.62
YAU-1201-26-1-1	41.7	29.3 bcd	29.7	0.61	12.40	35.49	0.37	0.51
YAU-1201-26-1-3	54.4	19.9 e	63.5	1.29	34.57	37.13	0.33	0.35
YAU-1211-82-1-1	66.2	27.2 cd	58.9	1.20	38.99	46.74	0.55	0.48
Yar-8 (Tolerance check)	66.6	38.8 a	41.7	0.85	27.72	52.69	0.79	0.68
F-test	ns	**						
C.V %	22.8	10.4						

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≤0.01, ns − not significant,
FI: Full Irrigation, DI: Deficit Irrigation, D (%): Percentage decrease down

Table 5 Mean comparisons of chlorophyll content (SPAD reading) in different improved rice lines at vegetative and panicle initiation stage

Improved rice lines	Chlorophyll content at vegetative stage		D (%)	Chlorophyll content at panicle initiation		D (%)
	FI	DI		FI	DI	
YAU-1211-14-1-1	39.8	47.2	-18.6	38.9	39.6	-1.6
YAU-1201-90-2-4	41.1	44.1	-7.2	33.3	40.6	-21.9
YAU-1211-118-1-1	46.1	46.7	-1.3	42.5	39.7	6.6
YAU-1211-195-1-1	40.0	47.0	-17.4	34.8	41.8	-15.0
YAU-1201-26-1-1	35.5	44.0	-24.0	30.7	37.2	-21.3
YAU-1201-26-1-3	39.9	43.2	-8.1	31.4	39.6	-26.1
YAU-1211-82-1-1	42.8	45.3	-5.8	37.9	39.3	-3.6
Yar-8 (Tolerance check)	42.2	44.4	-5.1	36.1	39.7	-10.0
F-test	**	ns		**	ns	
C.V %	5.1	5.5		6.2	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≤0.01, ns − not significant
FI: Full Irrigation, DI: Deficit Irrigation, D (%): Percentage decrease down

The effect of drought stress on chlorophyll content was significantly different under full irrigation among the improved rice lines, while it was not different under deficit irrigation for both vegetative and panicle initiation stages. In comparing between two irrigations, chlorophyll content of the most rice lines resulted from deficit irrigation was higher than that from full irrigation, indicating that drought tolerant lines had a high chlorophyll concentration. Kalaji et al. (2016) stated that chlorophyll content was increased in abiotic stress tolerant crops, although it was reduced in stress susceptible crops. YAU-1211-195-1-1 had the highest chlorophyll content among the rice lines under deficit irrigation and followed by YAU-1201-90-2-4 rice line.

Mean comparisons of selected improved rice lines in terms of dry matter production and water use efficiency under two different irrigation levels at harvesting are presented in (Table 6). The result showed that there were significant differences in dry matter production among the rice lines under both irrigations. In comparing the seven improved rice lines, there was significant difference in WUE under deficit irrigation, whereas it was not different under full irrigation. WUE ranged from 0.42 kg m^{-3} to 0.75 kg m^{-3}. The maximum WUE value (0.75 kg m^{-3}) was found from Yar-8 (Tolerance check) and it was followed by YAU-1201-26-1-1 and YAU-1211-195-1-1, (0.69 kg m^{-3} and 0.68 kg m^{-3}, respectively) under deficit irrigation.

Table 6 Mean comparisons of dry matter production and water use efficiency (WUE) in different improved rice lines at harvesting

Improved rice lines	Dry matter (g)		D (%)	WUE (kg m^{-3})		D (%)
	FI	DI		FI	DI	
YAU-1211-14-1-1	125.7 abc	70.2 d	26.3	0.62	0.42 d	32.5
YAU-1201-90-2-4	160.6 a	72.9 cd	25.7	0.67	0.59 abcd	12.6
YAU-1211-118-1-1	139.4 ab	78.9 bcd	23.7	0.67	0.63 abc	6.2
YAU-1211-195-1-1	110.3 bc	80.0 abcd	24.0	0.48	0.68 ab	-42.6
YAU-1201-26-1-1	91.0 c	85.3 abc	26.7	0.44	0.69 ab	-57.3
YAU-1201-26-1-3	128.7 abc	84.8 abc	22.7	0.57	0.45 cd	21.8
YAU-1211-82-1-1	171.7 a	87.1 ab	27.3	0.69	0.53 bcd	23.9
Yar-8 (Tolerance check)	146.1 ab	92.4 a	24.0	0.70	0.75 a	-6.1
F-test	*	*		ns	*	
C.V %	20.3	9.2		22.2	19.2	

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≤0.05, ns − not significant, FI: Full Irrigation, DI: Deficit Irrigation, D (%): decrease down

CONCLUSIONS

In conclusion, differences of the selected improved rice lines were observed for relative drought tolerance in terms of growth, grain yield, chlorophyll content and water use efficiency. From this study, five tolerant rice lines would be useful in the areas where drought has a problem.

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REFERENCES

Boutraa, T. 2010. Improvement of water use efficiency in irrigated agriculture, A review. Journal of Agronomy, 9 (1), 1-8.

Buresh, R. and C. Witt. 2006. Productivity and sustainability in irrigated rice, Myanmar (MY-Rice). MYANMAR- 02. Interpretive Summaries.

Food and Agricultural Organization (FAO). 2017. FAO STAT. FAO, Rome, Retrived from http://faostat3. fao.org/faostatgateway/go/to/down load/ Q/QC/E

Fernandez, J.C. 1992. Effective selection criteria for assessing stress tolerance. Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress, Taiwan, 13-18 August 1992, 257-270.

Fischer, R.A. and Maurer, R. 1978. Drought resistance in spring wheat cultivars, I. Grain yield responses. Australian Journal of Agriculture Research, 29, 897-912.

Hossain, A.B.S., Sears, R.G., Cox, T.S. and Paulsen, G.M. 1990. Desiccation tolerance and its relationship to assimilate partitioning in winter wheat. Crop Science, 30, 622-627.

IRRI, 2013. Standard evaluation system (SES) for rice. 5th Edition, International Rice Research Institute, Los Baños, Philippines.

Kalaji, H.M., Jajoo, A., Oukarroum, A., Brestic, M., Zivcak, M., Samborska, I.A., Cetner, M. D., Łukasik, I., Goltsev, V. and Ladle, R.J. 2016. Chlorophyll a fluorescence as a tool to monitor physiological status of plants under abiotic stress conditions. Acta Physiol Plant, 38, 102.

Lin, C.S., Binns, M.R. and Lefkovitch, L.P. 1986. Stability analysis: Where do we stand? Crop Science, 26, 894.

Oo, A.N., Ando, K., Khaung, T. and Khaing, M.T. 2017. Food security and socio-economic impacts of soil salinization in the central dry zone of Myanmar, A case study. Journal of Agroforestry and Environment, 11 (1&2), 149-154.

Rosielle, A.A. and Hamblin, J. 1981. Theoretical aspects of selection for yield in stress and non-stress environment. Crop Science, 21, 943-946.

Winter, S.R., Musick, J.T. and Porter, K.B. 1988. Evaluation of screening techniques for breeding drought resistance winter wheat. Crop Science, 28, 512-516.