Evaluation of drought tolerance indices for selection of high yielding drought tolerant rice genotypes in Lamjung, Nepal

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Article Info

Accepted:
5 June 2020

Keywords:

Correlation, Cultivar,
Mean Production,
Stress, Yield stability

ABSTRACT

The performance of eleven rice genotypes along with local check variety was studied at the field of IAAS Lamjung campus. The experiment was conducted under two field conditions i.e., drought stress and non-stress conditions. Grain yield was recorded in both experiments stress (Ys) and non-stress (Yns) at maturity. From grain yield data, some drought tolerance indices such as Stress Tolerance Index (STI), Stress Susceptibility Index (SSI), Drought Tolerance Efficiency (DTE%), Yield Stability Index (YSI), Mean Productivity index (MPI), Geometric Mean Productivity (GMP) were calculated. A genotypic correlation was also calculated for grain yield and all indices. Grain yield under stress conditions (Yns) was positively and significantly correlated with MRP, MPI, GMP and STL. Similarly, a positive and significant association has also been observed between grain yield under stress condition and MPI, MRP, STL and GMP. So, they were the best predictor of potential yield Yns and Ys than SSI, DTE, YSI. Among the eleven rice genotypes Khumal-8, Khumal-7 and IR87760-15-2-3-4 were selected as the superior genotypes for the development of drought-tolerant cultivar in the future breeding programs.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the important staple cereal crops which is the predominant staple food feeding more than 3.5 billion global population (IRRI, 2017). In terms of productivity and production, it ranks in first position and hence contributed significantly to majority of people livelihood (Tiwari et al. 2018). It is grown in 1.36 million hectares, producing 4.3 million tons with productivity of 3.15 t ha⁻¹ (MoAD 2017) in Nepal. Nepal is known as one of the centers of rice diversity (Joshi 2005). Studies reported that about 2000 rice landraces exist in Nepal that are assumed to be grown from 60 to

3050 m altitude (MoAD 2015). It contributes to about 16.33 % in Agriculture Development Project (AGDP) (MoAD 2015/16).

Rice growing areas are highly prone to different biotic and abiotic stresses. In Terai, hills and mountains majority of people depend upon stress agriculture system producing rice which are highly prone to abiotic stresses (Kumar et al. 2014). Among different stresses, drought is the major limiting abiotic stress that reduces productivity by 13– 35% (Rosegrant et al. 2002). Even under moderate drought stress, rice is particularly sensitive to drought stress during reproductive growth (Hsiao and O'Toole 1982). In rice, as compared with non-stress conditions moderate stress can be broadly characterized by a 31 to 64% loss in grain yield whereas under severe stress, yield reduction in rice is 65-85% (Kumar et al. 2008). Most of the rice in mid –hills including Lamjung is cultivated in terraced, banded fields without supplement irrigation. As rice is cultivated in rainfed, water recipient of rice is mostly irregular which leads lower grain yield average of 2.34 t ha⁻¹. Which is below the national average of about 2.71 t ha⁻¹ (Pandey et al. 2007). High yearly and seasonal fluctuations of rainfall cause concurrent

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fluctuations of total rice production as large portion of total rice area in Nepal is rainfed (about 65%). Drought can cause severe damage at any stage of rice growth and development as rice is quite susceptible to water stress and this situation may lead to partial or complete yield loss (Adhikari et al. 2015)

To overcome yield reduction under stress and upland conditions, breeding objective should be targeted for development of drought tolerant cultivars suitable to stress agriculture. For characterizing genotypic performance under varying degrees of water stress, the combination of high yield stability and high relative yield under drought has been proposed as useful selection criteria (Pinter et al. 1990). There are some indices on the basis of a mathematical relationship between yield under drought conditions and non-stressed conditions to determine drought tolerance i.e. Stress Tolerance index (STI), Stress Susceptibility Index (SSI), Drought Tolerance Efficiency (DTE%), Yield Stability Index (YSI), Mean Productivity index (MPI) and Geometric Mean Productivity (GMP). These indices are based on either drought susceptibility or drought resistance of genotypes (Raman et al. 2012) which may be useful as an indicator to identify drought tolerant genotypes that perform well in stress environments. These indices are yield stability parameters, based on how much reduction are realized under drought stress condition. In this context, the main objective of our research was to screen rice genotypes having high and stable yield potential under stressed conditions by analyzing drought tolerant indices.

MATERIALS AND METHODS

Ten pipeline rice genotypes (KHUMAL-13, NR-B-B-31-3, IR87760-15-2-3-4, NR-11032-B-B-53, NR-11130-B-B-B-12, NR-11289-B-16-1, NR-11137-B-B-10, KHUMAL-7, KHUMAL-4, KHUMAL-8, (obtained from NARC Khumaltar, Kathmandu) and one local check variety were applied in study (Anadi obtained from local farmers). The experiment was carried out in Randomized Complete Block Design (RCBD) with 3 replications each for stress and non-stress condition in a field of Institute of Agriculture and Animal Science (IAAS, TU), Lamjung Campus during 25th July rainy season 2018. The size of each plot was 2 m *1 m and spacing between rows and plants was 20 cm x 20 cm. The distance between two plots were 50 cm and distance between two replications were 1 m. 25 days old seedlings raised under dry seed bed condition were transplanted in both condition in same day. Each hill consists of 2-3 seedlings. Chemical fertilizers @ (60:20:20 kg NPK ha⁻¹) and 100:30:30 kg NPK ha⁻¹ were applied for stress condition and non-stress conditions respectively. Half dose of Nitrogen and full dose of phosphorous and potash was applied as a basal

dose at transplanting time and remaining half dose nitrogen was applied as split doses at 30 DAT and 45 DAT. FYM (Farm yard manure) 6 mt ha⁻¹ were applied at the time of field preparation in both conditions. Various intercultural operations like weeding, pest control, harvesting, threshing etc. were applied manually. In non- stress condition, standing water of minimum 5 cm depth was maintained at each plot from transplanting to 10 days before maturity by supplementary irrigation. The grain yield data were recorded for each genotype at both environment (non-stress and stress) and were subjected to calculate and analyze different drought selection indices using following formulas using MS Excel and R package. Mean data is used to calculate correlation for drought indices.

We had calculated different drought tolerant indices like Mean Relative Performance (MRP) = $[(Y_i)_s / (Y_s)] + [(Y_i)_{ns} / (Y_{ns})]$ (Hossain et al. 1999), Stress tolerance index $STI = (Y_i)_{ns} * (Y_i)_s / (Y_{ns})^2$ (Fernandez 1992), which can be used to identify genotype that produce high yield under both stress and non-stress conditions. A high value of STI implies higher tolerance to drought stress, Stress Susceptibility Index (SSI) $SSI = 1 - (Y_s / Y_p) / SI$, while $SI = 1 - (Y_s / Y_p)$, (Fisher & Maurer 1978), (Raman et al. 2012) revealed least yield reduction in rice genotypes, resulting the lowest SSI. Lower SSI values indicate, more tolerance to drought. Often SSI has been applied for identifying genotypes with yield stability in moisture restricted environment often uses SSI (Puri et al. 2010; Raman et al. 2012), Drought Tolerance Efficiency (DTE%) = $(\text{Yield under stress} / \text{yield under non-stress}) * 100$ (Fischer and wood, 1981). Higher drought tolerance ability of genotypes is indicated by higher values of DTE as successfully demonstrated by many groups (Ouk et al. 2006; Talebi et al. 2009; Singh et al. 2011; Raman et al. 2012). Yield Stability Index (YSI) = Y_s / Y_{ns} (Bouslama and Schapaugh 1984), Yield Stability Index (yield of an individual genotype under drought relative to that of the highest yielding genotype in the population) performance could be used to assess the yield potential of a genotype under water stressed conditions. Higher relative yield shows that the genotype performed relatively well under drought stress condition, Mean Productivity index (MPI) = $(Y_s + Y_{ns}) / 2$ (Rosielle & Hamblin 1981). MPI for genotype is the average of yield under stress and non- stress condition (Hossain et al. 1990) and Geometric Mean Productivity (GMP) = $(Y_s * Y_{ns})^{(1/2)}$, (Ramirez and Kelly 1998).

Table 1. Grain yield and drought tolerance indices of rice genotypes in response to drought stress and non-stress condition.

Genotypes	Grain yield (t ha ⁻¹)		MRP	STI	SSI	DTE	YSI	MPI	GMP
	Ys	Yns							
KHUMAL-8	5.276	7.149	3.056	2.432	-3.295	73.790	0.738	6.213	6.141
KHUMAL-7	5.207	6.956	2.991	2.335	-3.161	74.854	0.749	6.082	6.018
IR87760-15-2-3-4	5.292	5.408	2.618	1.845	-0.270	97.853	0.979	5.350	5.349
NR11115-B-B-31-3	4.181	5.833	2.464	1.572	-3.562	71.667	0.717	5.007	4.938
KHUMAL-4	4.523	5.331	2.417	1.555	-1.905	84.848	0.848	4.927	4.911
NR-11032-B-B-5-3	4.463	5.116	2.349	1.472	-1.606	87.222	0.872	4.789	4.778
NR11289-B-16-1	4.069	5.231	2.285	1.372	-2.792	77.796	0.778	4.650	4.613
NR11137-B-B-10	4.111	4.712	2.163	1.249	-1.603	87.254	0.873	4.411	4.401
ANADI	3.809	4.119	1.942	1.011	-0.945	92.487	0.925	3.964	3.961
KHUMAL-13	2.783	4.286	1.743	0.769	-4.408	64.938	0.649	3.535	3.454
NR-11130-B-B-B-12	3.056	3.623	1.639	0.714	-1.969	84.336	0.843	3.339	3.327

RESULTS AND DISCUSSION

Drought tolerance indices

On the basis of grain yield of the genotypes under non-stress (Yns) and stressed (Ys) conditions different drought tolerant indices were calculated. It is depicted from Table 1, that greater the value of STI, DTE, GMP, MRP lesser the yield reduction under stress conditions and higher the drought tolerance. Also, lower the SSI showed more yield under stressed conditions. Based on the ranking of SSI indices, whose low value show tolerant lines, NR11115-B-B-31-3, Khumal-8 and khumal-7 were more tolerant genotypes. Based on the ranking of GMP and STI indices Khumal-8, Khumal-7 and IR87760-15-2-3-4 represent highest values and present more tolerant genotypes. The genotypes with higher values of MPI and MRP index, have a higher tolerance to drought. Based on MPI index, Khumal-8, Khumal-7 and IR87760-15-2-3-4 showed the highest values and were more tolerant lines and cultivars. The genotypes with higher values of YSI index, have a higher tolerance to drought. Based on the YSI index, Anadi, IR87760-15-2-3-4 and NR11137-B-B-10 showed the highest values and were more tolerant lines.

Correlation of among drought tolerance indices and yield

Correlation among drought tolerance indices and yield in both condition (stress and non-stress) is calculated and presented in Table 2. Results of correlation analysis showed that grain yield under water stress conditions had a highly significant and positive correlation with grain yield under non-stress conditions ($r=0.831^{**}$). This result showed that genotypes that demonstrates high yield under non-stressed conditions also demonstrate high yield under stressed conditions. Therefore, indirect selection for stressed environment based on the performance of non-stress conditions would be effective. A positive correlation between yield under stressed and non- stressed condition has also been reported in earlier studies (Moosavi et al. 2008; Dadbakhsh et al. 2011; Naghavi et al. 2013; Bennani et al. 2017). In contrast to our findings,

(Aminpanah et al. 2018) showed that there was not a correlation between Yns and Ys.

There was a significant positive correlation between Ys and MRP ($r=0.954^{**}$), MPI ($r=0.944^{**}$), GMP ($r=0.954^{**}$), STL($r=.936^{**}$). Whereas negative correlation was observed between Ys and SSI. Also significant correlation between Yns and MRP ($r=0.959^{**}$), MPI ($r=0.968^{**}$), GMP($r=0.960^{**}$), STL ($r=0.968^{**}$) and negative correlation between Yns and DTE and YSI.

In our experiment MRP, STL, MPI and GMP were identified as appropriate indices to select drought tolerance genotypes as these indices show high correlation with grain yield under both drought stress and nonstress. Similar results were obtained in the study of (Rahimi et al. 2013) and they reported that there was a positive and significant correlation between Ys and Yns. There were positive and significant correlations between Yield and MRP, STL, MPI and GMP under both stress and non- stress conditions suggesting that drought indices are able to identify high yielding genotypes under both conditions. Therefore, MRP, STL, MPI and GMP were identified in functional rice breeding programs as suitable indices to select the high yielding lines. Abbasian et al. (2014) observed similar results and grain yield under normal irrigations showed a positive significant correlation with yield under drought condition. Marcelo et al. (2017) observed similar results, as well and they reported that there was a significant and positive correlation between MRP, STL, MPI and GMP with yield and these indices were effective in identifying high yield and stable genotypes across environments. Positive and significant correlation between STI, GMP and MPI with Yns and YS have also been previously reported by other workers (Golabadi et al. 2006; Jafari et al. 2009; İlker et al. 2011; Toorchi et al. 2012). The high correlations between YP, YS and drought indices may serve as good indicators for selection of best cultivar under drought condition. Drought indices having a significant correlation with grain yield in both non-stressed and stressed conditions are reported to be

suitable for selecting drought tolerant genotypes (Mitra 2001). Under stress conditions, grain yield

and IR87760-15-2-3-4 were selected as superior upland rice genotypes based on the chosen indices.

Table 2. Estimates of correlation coefficients between different drought tolerance indices

	Ys	Yns	MRP	STI	SSI	DTE	YSI	MPI	GMP
Ys	1								
Yns	.831**	1							
MRP	.954**	.959**	1						
STI	.936**	.968**	.995**	1					
SSI	-.262	.313	.036	.077	1				
DTE	.262	-.313	-.036	-.077	-1.000**	1			
YSI	.262	-.313	-.036	-.077	-1.000**	1.000**	1		
MPI	.944**	.968**	.999**	.996**	.067	-.067	-.067	1	
GMP	.954**	.960**	1.000**	.995**	.036	-.036	-.036	.999**	1

showed negative correlation with SSI and similar results were obtained by Gholipouri et al. (2009). Therefore, SSI is suitable and important factor to identify rice genotypes with low yield and tolerant to drought because under stress conditions, yield decreased with increasing SSI.

Mean Relative Performance (MRP) was significantly and positively correlated with STI, MPI and GMP. The indices MRP, STI, MPI and GMP are dependent upon high yielding genotypes in both stress and nonstress condition so they are positively correlated. Similar results were obtained by (Link et al. 1999). STI was significantly and positively correlated with MPI and GMP. Similarly, SSI showed significant and negative association with DTE and YSI. But showed positive association with MPI and GMP. DTE showed significant and positive correlation with YSI. Similarly, GMP showed significant and positive correlation with MPI. DTE.

In our experiment, normal irrigated conditions genotypes bared long panicle whereas in drought conditions all genotypes except Khumal-8, Khumal-7 and IR87760-15-2-3-4 bared short panicle which is due to decrease in translocation of assimilates towards reproductive part which ultimately leads decreased flower organ formation. Also, higher grain and straw yield reduction was found in drought stress than normal irrigated conditions. Similarly, all genotypes except Khumal-8, Khumal-7 and IR87760-15-2-3-4 were susceptible to water stress which is due to reduction of cell water content, diminished leaf water potential and reduce in cell enlargement and growth. So, Khumal-8, Khumal-7 and IR87760-15-2-3-4 were regarded as drought tolerant genotypes as these are not highly susceptible to water stress. Similar results were obtained in the study of (Tripathi et al. 2019)

CONCLUSIONS

Among seven drought-tolerance indices evaluated, STI, GMP, MRP, MPI were considered to be the most effective for selection of drought tolerant rice genotypes. The genotypes Khumal-8, Khumal-7

The selected genotypes are recommended to use as parents in a breeding program for improvement of drought tolerance and high grain yield of rice variety.

ACKNOWLEDGMENTS

I would like to thank to National Agricultural Research Council (NARC), Khumaltar for providing research materials and RD-TEC for providing technical support to carry out this research work.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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