Evaluation of drought tolerance in rice (*Oryza sativa* L.) cultivars and recombinant inbred lines

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Abstract

In order to study the adaptation of rice lines to drought stress and to identify the tolerant and sensitive lines, 150 pure lines in RIL population each derived from a cross between two Iranian rice varieties Gharib and Sepidroud were investigated. Augment design based on the randomized complete block design (RCBD) was used with 6 check cultivars and 4 replications in 2013-2014 growing season. In this study, based on correlation analysis geometric mean productivity (GMP), stress tolerance index (STI), mean harmonic (HM) and mean productivity (MP) were the most suitable indices for the selection of cultivars and lines under stress and non-stress conditions. The result of PCA showed that the first two PCs explained 98% of the total variance. Cluster analysis showed five distinct groups. In addition, according to results three-dimensional scatter plot and cluster analysis, Alikazemi, Gharib, Hashemi, Tarommahali, 1, 3, 7, 14, 22, 26, 27, 40, 49, 64, 65, 67, 68, 75, 98, 99, 120, 124, 126, 127, 133, 134, 138, 139, 141, 146, 147, 153, 157, 159, 162 and 163 were determined as the high yielding and the most tolerant cultivars and lines under drought stress condition which could be used in breeding programs.

Key words: Cluster analysis, Drought stress, Rice, Three-dimensional scatter plot, Tolerance indices, Yield.

INTRODUCTION

Water is the main factor in agricultural and food production that is extremely restricted (Wang *et al.,* 2012). Drought stress is an intensive threat to sustainable agriculture and causes large losses to global agricultural production. Reduction in water supply along with the growing population enforce us to find or develop genotypes tolerant to drought stress (Foley *et al.,* 2011). Rice is a main food for more than three billion people which provids 50% to 80% of their daily calory (Khush, 2005). Rice production is strongly affected by drought stress. Global, drought affects nearly 23 million hectares of rainfed rice (Serraj *et al.,* 2011).

The water resources are strongly affected by climate variability and the increase in the frequency of droughts and floods could be revealed in future. Crop yield is strongly affected by climate variations and depends on special climate conditions. Nearly 32 and 53% of rice yield variability and harvested regions were affected by climate variability, respectively (Ray *et al.,* 2015).

Abarshahr *et al.* (2011) reported that mean harmonic (HM), geometric mean productivity (GMP), stress tolerance index (STI) and mean productivity (MP) indices can be used as the best indices to introduce high grain yielding genotypes and drought tolerant cultivars in rice breeding programs. Hosseini *et al.* (2012) concluded that low SSI and high STI, MP for both rice root dry weight and shoot length were the potential indices for tolerance to salt stress. Furthermore, Rahimi *et al.* (2013) indicated that rice grain yield under drought stress and normal environments had the highest significant correlations with MP, GMP, HM and STI indices and these indices as suitable indices were identified in functional rice breeding programs to select the high yielding genotypes. Abbasian *et al.* (2014) indicated that GMP, MP, STI and YI (yield index) indices were more effective in identifying rice cultivars with high yield in different water deficiency. Kumar *et al.* (2014) showed that selection based on stress tolerance indices such as TOL, SSI and STI will result in recognition of drought tolerant rice genotypes for the rainfed environments. Sriramachandrasekharan *et al.* (2014) showed that MP and GMP indices were more effective in identifying high yielding rice cultivars both under sulfur stress and non-stress conditions. Marcelo *et al.* (2017) showed that GMP, HM and STI indices were effective in identifying stable and high yielding recombinant inbred lines across environments. Aminpanah *et al.* (2018) showed that MP, GMP, YI and STI were the best indices for selecting and specifying rice tolerant genotypes in arid areas. The use of mutation caused drought resistance in the progenies. These tolerant lines could be used in a project of the introduction of drought tolerant rice varieties. Singh *et al.* (2018) showed that advanced breeding lines of rice with high YSI and STI and low SSI and TOL were drought tolerant lines.

This research was carried out using the drought tolerance criteria for identifying sensitive and drought tolerant rice lines in non-stress and drought stress field conditions and lastly select the best suitable lines for improving tolerant and high-yielding rice lines.

MATERIALS AND METHODS

Plant material

A set of 150 pure lines in an RIL population was derived from the cross between two rice cultivars Sepidroud (drought susceptible variety, male parent) and Gharib (drought tolerant variety, female parent) (Indica/Indica) were evaluated in this research. The experiment was conducted under normal irrigation and drought stress conditions using augment design based on randomized complete block design (RCBD) with 6 check cultivars and 4 replications. Check cultivars were composed of Alikazemi, Gharib, Hashemi, Tarommahali (drought tolerant cultivars) and Sepidroud and Shahpasand (drought susceptible cultivars). Sepidroud is an improved rice cultivar and other are local cultivars.

Experimental procedures

The experiment was conducted in the research farm, at the Faculty of Agricultural Sciences, University of Guilan, Guilan, Iran (49º36´ E longitude, 37º16´ N latitude and 7 m altitude) during 2013-2014 growing season. Despite the above-average annual rainfall in Guilan, rainfall distribution does not coincide with the growing stages of rice, particularly with the reproductive stages (from April to September) and there is a very low amount of rainfall at this period. Therefore, drought stress commonly affects rice plants.

Each line was transplanted in one row consisting of 25 plants per plot. Single plants were transplanted 30 days after sowing with a 25×25 cm distance. When rice lines were firmly settled, drought stress (30 days after transplantation in other word at stage of maximum tiller number per plant) was induced by irrigation prevention, whereas under normal conditions rice lines were irrigated entirely until harvesting. To increase rice lines growth, 150 kg per hectare nitrogen fertilizer from urea source was applied (two-thirds of urea was utilized during transplantation and one-third during tillering stage). Furthermore, 120 kg per hectare phosphorus fertilizer from ammonium phosphate source was utilized during transplantation.

Calculation of drought tolerance indices

Eight drought tolerance indices containing tolerance index (TOL), stress susceptibility index (SSI), stress tolerance index (STI), yield stability index (YSI), geometric mean productivity (GMP), harmonic mean (HM), yield index (YI) and mean productivity (MP) were estimated on the basis of grain yield in irrigated (Y_p) and drought (Y_s) conditions. Drought tolerance indices were estimated using the equations referenced by Marcelo *et al.* (2017). The variance analysis was performed using the SAS software ver. 9.2 (SAS Institute, 2010), correlation coefficients, Principal component analysis and three dimensional scatter plots were estimated using the SPSS software version 19.0 (SPSS Inc, 2010).

RESULTS AND DISCUSSION

Yield performance of lines and cultivars

Mean comparison of lines and cultivars indicated that the highest yield belonged to 67, 139, Sepidroud, 70, 184, 62, 185, 107, 8, 141 and Hashemi in non-stress and 40, 127, 147, 139, 75, Hashemi, 124, 22 and141 in stress conditions (data not shown). Range of mean comparison of yield and drought tolerance indices in rice cultivars and lines under non-stress conditions and stress conditions are shown in Table 1.

Comparing lines and cultivars based on the resistance/tolerance indices

Based on the ranking of TOL and SSI indices, whose low values show tolerant lines, 74, 84, 131, 179, 79, 81, 52, 166 and 135 were more tolerant lines. Higher GMP and STI indices indicate that genotypes have a higher

Table 1. Comparison of range of the grain yield under stress and non stress conditions and drought tolerance indices in rice cultivars and lines.

Tolerance indices	RIL	Checks					
		Alikazemi	Gharib	Hashemi	Sepidroud	Shahpasand	Tarommahali
Y_S (kg.ha^{-1})	120.40-1378.20	706-1108	344.72-454	903-1196	650-842	385-545	545-896
Y_P (kg.ha^{-1})	442-3233	1435-1628	1060-1425	1547-1898	1921-2297	1517-1769	1242-1520
TOL	2.50-2526.17	520.00-800.00	702.61-970.44	553.32-701.60	1270.79-1454.88	1071.24-1224.00	614.40-814.40
SSI	0.01-1.99	0.69-1.09	1.39-1.47	0.74-0.90	1.36-1.43	1.47-1.61	0.88-1.22
STI	0.08-2.22	0.78-1.39	0.28-0.50	1.08-1.75	0.96-1.49	0.45-0.74	0.52-1.05
MP	398.27-1969.97	1070.50-1367.60	702.16-939.70	1224.80-1546.80	1285.11-1569.76	950.80-1157.28	893.44-1207.98
GMP	321.50-1693.50	1006.48-1342.66	604.37-804.73	181.72-1506.50	1117.05-1391.03	763.98-982.22	822.81-1167.07
HM	223.84-1575.19	946.28-1318.17	520.20-689.15	1140.15-1467.24	970.96-1232.66	613.87-833.64	757.77-1127.55
YSI	0.08-1.00	0.49-0.68	0.32-0.35	0.58-0.66	0.34-0.37	0.25-0.32	0.43-0.59
YI	0.20-2.26	1.16-1.82	0.57-0.75	1.48-1.96	1.07-1.38	0.63-0.89	0.89-1.47

RIL: Recombinant Inbred Lines.

tolerance to drought. Based on the ranking of GMP and STI indices 139, 67, 40, 147, Hashemi, 141, 127 and 22 showed the highest values and present more tolerant lines and cultivars.

The genotypes with higher values of HM index, have a higher tolerance to drought Based on HM index 139, 40, 147, 127, Hashemi, 141, 22 and 75 indicated the highest values and were more tolerant lines and cultivars. The genotypes with higher values of MP index, have a higher tolerance to drought Based on MP index, 67, 139, 147, 40, Sepidroud, Hashemi, 70, 141 and 127 showed the highest values and were more tolerant lines and cultivars. The genotypes with higher values of YSI index, have a higher tolerance to droughtBased on the YSI index, 74, 84, 131, 179, 79, 166, 52, 81 and 127 showed the highest values and were more tolerant lines. The genotypes with higher values of YI index, have a higher tolerance to droughtBased on YI index, 40, 127, 147, 139, 75, Hashemi, 124, 22 and 141 showed the highest values and were more tolerant lines and cultivars.

In the previous generation of 150 F_5 lines of this population, derived from the cross between two rice cultivars Sepidroud and Gharib based on tolerance indices and biplot Rahimi *et al.* (2013) showed that lines 3, 7, 11, 30, 37, 39, 47, 49, 50, 60, 69, 92, 93, 123 and 124 were drought tolerant lines. In our study also lines 3, 7, 49 and 124 were shown to be tolerant lines. The presence of environment and line×environment interaction on grain yield suggest difficulties in identification of tolerant lines in different years.

Correlation analysis

The correlation coefficients between Y_s, Y_p and other quantitative indices of drought tolerance were calculated to estimate the most desirable drought tolerant criteria. In other words, a good criterion for screening the best genotypes and indices can be correlation analysis between drought tolerance indices and grain yield (Table 2). Under both conditions, a desirable index must have a considerable correlation with grain yield (Mitra, 2001).

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 ($r=0.33^{**}$). This result showed that high grain yield efficiency under optimum conditions certainly results in enhanced yield under water shortage conditions.

Correlation analysis showed a correlation between grain yield in the stress (Y_s) and non-stress (Y_p) conditions with stress tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), harmonic mean (HM) and yield index (YI). Stress tolerance criteria discriminated high grain yield genotypes with drought tolerance under non-stress and stress environments (Fernandez, 1992) (Table 2). There was a positive and significant correlation between Y_p and MP ($r=0.91^{**}$), TOL ($r=0.84^{**}$), STI ($r=0.78^{**}$), GMP ($r=0.77^{**}$), HM ($r=0.60^{**}$), SSI

Table 2. Correlation coefficients between drought tolerance and susceptibility indices and yield for rice cultivars and lines under non-stress and stress conditions.

Index	Y_S	Y_P	TOL	SSI	STI	MP	GMP	HM	YSI
Y_S									
Y_P	0.33**								
TOL	-0.24**	0.84**							
SSI	-0.58**	0.50**	0.85**						
STI	0.81**	0.78**	0.33**	-0.06ns					
MP	0.68**	0.91**	0.54**	0.13ns	0.95**				
GMP	0.85**	0.77**	0.30**	-0.10ns	0.98**	0.96**			
HM	0.94**	0.60**	0.08ns	-0.29**	0.94**	0.87**	0.97**		
YSI	0.58**	-0.50**	-0.85**	-1.00**	0.06ns	-0.13ns	0.10ns	0.29**	
YI	1**	0.33**	-0.24**	-0.58**	0.81**	0.68**	0.85**	0.94**	0.58**

**: Significant at 1% probability level; ns: non-significant.

(r=0.50**) and YI (r=0.33**). By contrast, a significant and negative correlation was observed between Y_p with YSI (r=-0.50**). There was also a significant and positive correlation between Y_s and HM (r=0.94**), GMP (r=0.85**), STI (r=0.81**), MP (r=0.68**) and YSI (r=0.58**). Also a significant and negative correlation was observed between Y_s with SSI (r=-0.58**) and TOL (r=-0.24**).

The results of this experiment showed that an index which has a high correlation with grain yield under both non-stress and stress conditions is the most suitable index to select drought tolerant genotypes. So, GMP, STI, HM and MP were identified as appropriate indices to select drought tolerance genotypes. Similar results were obtained in the study of Rahimi *et al.* (2013) and they reported that there was a positive and significant correlation between Y_p and Y_s. There were positive and significant correlations among Y_p and MP, GMP, STI, HM, YI and YSI. There was also a significant and positive correlation between Y_s and YI, HM, GMP, STI, MP and YSI. Therefore, MP, GMP, HM and STI were identified in functional rice breeding programs as suitable indices to select the high yielding lines. Abbasian *et al.* (2014) observed similar results. They reported that grain yield under normal irrigation showed a positive significant correlation with yield under drought condition. The correlation between yield and SSI index was negative under drought and normal irrigation conditions. Whereas, MP, GMP, STI and YI indices had a positive significant correlation with each other and grain yield in both conditions. Marcelo *et al.* (2017) observed similar results, as well. They reported that there was a significant and positive correlation between GMP, STI and HM with yield and these indices were effective in identifying high yield and stable genotypes across environments. Aminpanah *et al.* (2018) showed that there was not a correlation between Y_p and Y_s. This result disagreed with our findings. They reported positive and significant correlations among Y_p and MP, GMP, STI and HM. There were also a significant and positive correlation between Y_s and YI, HM, GMP, YSI, STI and MP which is in agreement with our findings.

Principal component and biplot analysis

Plant breeders apply PCA as a "pattern of finding procedure to supplement cluster analysis" (Sajjad *et al.,* 2011). The principal advantage of using PCA over cluster analysis is that each statistics can be given to one group only (Khodadadi *et al.,* 2011). The aim of PCA is to earn a small number of linear combinations of the 10 variables which are descriptive for most of the variation in the data. If so, 2 components have been obtained, because 2 components had eigenvalues greater than or equal to 1.0. (Table 3).

The PCA results indicated that the first two components explained 60.2 and 37.8% of the total variation (Table 3). Actually, ten indices were decreased to two independent components by PCA. Eigenvectors in every component is applied to the correlation between the indices and the component. In each component, a high correlation between an index and the component showing that the index is related to the direction of the maximum measure of variation in the dataset. The first component had high positive coefficients for indices Y_p, Y_s, STI, MP, GMP, HM, and YI. Therefore, the first component can be nominated as potentialy stable yield component.

In this regard, selection of lines and cultivars with a high and positive value of the first PCA on biplot, should lead to high yield under non-stress and stress conditions (Figure 1). The second component had a high negative coefficient for index YSI and high positive coefficients for Y_p, TOL and SSI. Thus, the second component can be nominated as sensitive to stress component.

Hosseini *et al.* (2012) and Rahimi *et al.* (2013) showed that selection of lines and cultivars that have high PCA1 and low PCA2 are suitable for both non-stress and stress conditions and had high yields (stable genotypes), and lines and cultivars with lower PCA1 and larger PCA2 scores gave low yields (unstable genotypes) that agreed with our findings (Figure 1). Marcelo *et al.* (2017) reported PCA1 as the yield potential and drought tolerance dimension and showed high yielding genotypes under drought environment. Aminpanah *et al.* (2018) showed that the first two components explained 82.8% and 17% of the total variation, respectively. The relationship between principal components and studied indices showed that

Table 3. Principal component analysis for drought tolerance and susceptibility indices.

Trait	Principal component	
	1	2
Y_S	0.89	-0.45
Y_P	0.72	0.67
TOL	0.24	0.95
SSI	-0.18	0.97
STI	0.98	0.12
MP	0.94	0.33
GMP	0.99	0.07
HM	0.98	-0.14
YSI	0.18	-0.97
YI	0.89	-0.45
Eigenvalue	6.02	3.78
Proportion variance	60.21	37.84
Cumulative variance	60.21	98.05

Extraction method: Principal component analysis. Rotation method: Varimax with Kaiser Normalization.

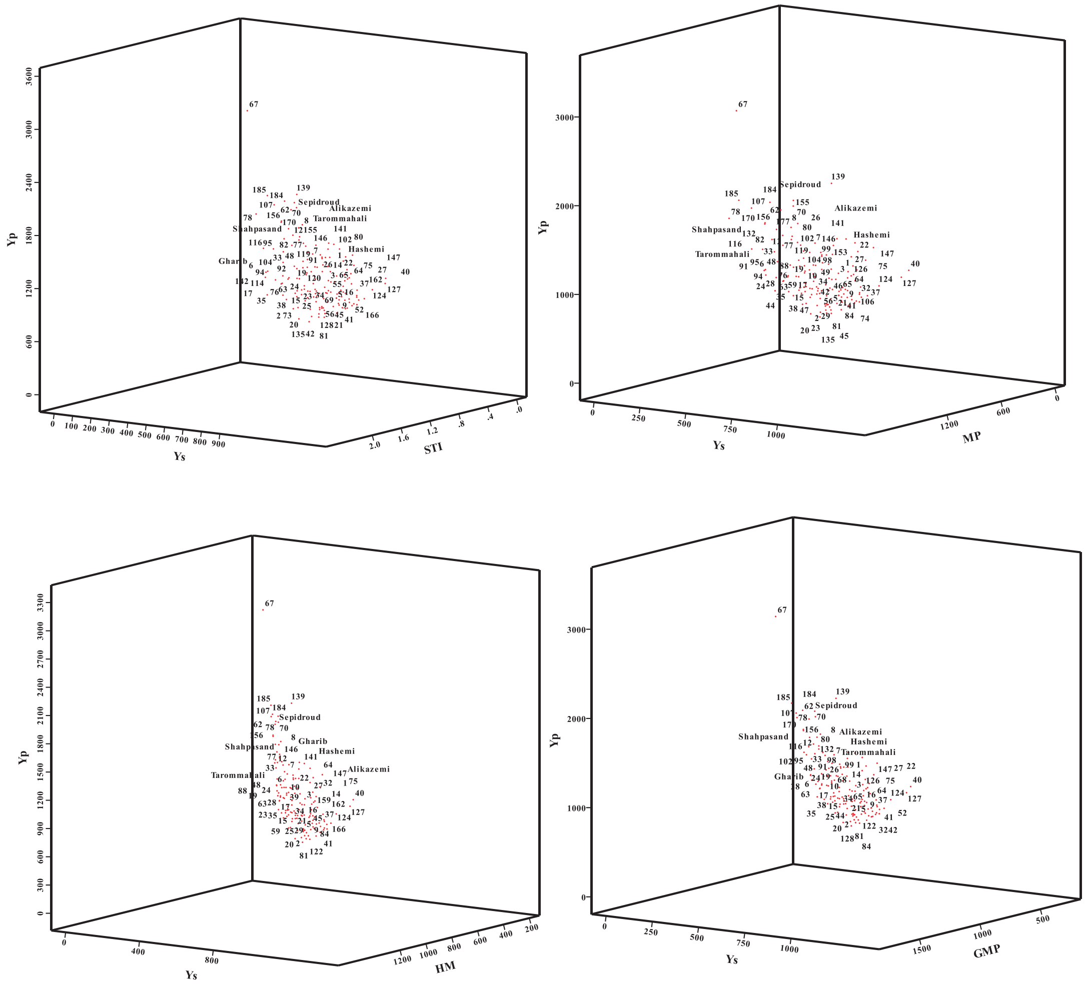

Figure 1. Three dimensional scatter to determine drought tolerant cultivars and lines on the basis of drought tolerance indices. X-axis: Yield under drought stress environment (Ys); Y-axis: Yield under non-stress environment (Yp); Z-axis: Drought tolerance indicators including STI, MP, HM and GMP.

the larger values of PCA1 and the lower values of PCA2 were related to drought tolerance and sensitivity to stress, respectively.

Three dimensional scatter plots on the basis of STI, MP, GMP and HM were drawn to place the 156 cultivars and lines according to their yield performance (Figure 1). According to the findings of Fernández (1992), these plots on the basis of STI, MP, GMP divided the cultivars and lines into four groups each showing one combination of the cultivars and lines with high yields under both environments (Group A), high yield under non-stress environment (Group B), high yield under drought stress environment (Group C), and low yield under both environments (Group D). Three dimensional scatter plots showed that cultivars and lines Alikazemi, Hashemi, 1, 22, 40, 67, 75, 127, 139, 141, 146 and 147 were placed on group A. These lines showed firstly superior yield in stressed and non-stressed environments and were secondly superior for quantitative tolerance indices than others. Therefore, they were recommended as candidate cultivars and lines for tolerance to drought. In spite to having high yield in stressed environment, 67, 139, 70, 184, 62, 185, 107, 8, 141 and Hashemi yield (yield potential) were low under non-stress environment. Therefore, they were divided in group C. The plot based on STI showed that lines 2, 5, 6, 9, 10, 15, 17, 19, 20, 21, 23, 24, 25, 28, 29, 33, 35, 38, 39, 42, 44, 45, 46, 47, 48, 50, 53, 54, 56, 57, 59, 60, 61, 63, 69, 73, 76, 78, 79, 81, 84, 85, 87, 89, 90, 91, 92, 93, 94, 95, 96, 100, 103, 105, 110, 111, 114, 116, 117, 118, 121, 122, 123, 125, 128, 130, 131, 135, 137, 140, 142, 144, 145, 148, 151, 152, 160, 167, 172, 175, 181 and 186 had low yield under both environments. Therefore, they were divided in group D. The Plot based on GMP showed that lines 5, 9, 10, 19, 21, 23, 25, 34, 39, 42, 45, 46, 53, 54, 57, 60, 79, 84, 85, 87, 90, 91, 93, 103, 104, 105, 110, 111, 117, 118, 121, 123, 125, 130, 131, 148, 151, 152, 160, 167, 172, 175, 181 and 186 had low yield under both environments, therefore, they were divided in group D. The Plot based on MP showed that lines 5, 9, 16, 21, 32, 41, 45, 46, 49, 52, 53, 55, 60, 72, 74, 79, 84, 85, 90, 93, 103, 106, 108, 118, 121, 123, 131, 133, 138, 143, 148, 166, 172, 175, 178 and 179 had low yield under both environments, therefore, they were divided in group D. The Plot based on HM showed that lines 2, 6, 10, 15, 17, 19, 20, 23, 24, 25, 28, 29, 33, 34, 35, 38, 39, 42, 44, 47, 48, 50, 54, 56, 57, 59, 61, 63, 69, 73, 76, 78, 81, 87, 88, 89, 91, 92, 94, 95, 96, 100, 104, 105, 110, 111, 114, 116, 117, 122, 125, 128, 130, 135, 137, 140, 142, 144, 145, 151, 152, 160, 173, 181 and 186 had low yield under both environments, therefore, they were divided in group D. Conversely, yield potential in genotypes 77, 78, 82, 107 and 185 were high but their yields in stressed environment were poor. Therefore, these lines were classified as drought susceptible genotypes and they are only suggested for environments with sufficient water. Three dimensional scatter plots on the basis of HM showed that cultivars and lines Alikazemi, Hashemi, Tarommahali, 1, 3, 7, 14, 22, 26, 27, 37, 55, 64, 65, 40, 55, 64, 65, 67, 68, 75, 98, 99, 124 and 126 were placed in group A. Aminpanah *et al.* (2018) used the three-dimensional diagram on the basis of HM to place the 18 rice genotypes according to their yield performance.

Cluster analysis

To determine the diversity among different genotypes and appoint the genotypes nearness or farness, the cluster analysis was used to put the similar genotypes in one cluster. The cluster analysis based on Euclidean distance and with minimum variance method (Ward's Method) was carried out to classify the genotypes on the basis of drought tolerance indices. Cluster analysis classified cultivars and lines into five groups each of which had 20, 36, 57, 28 and 15 genotypes, respectively (Figure 2, Table 4).

The first group included a high value of Y_p and TOL. This group included cultivars and lines with good performance under non-stress conditions and sensitive to drought as Shahpasand, Sepidroud, 8, 12, 62, 70, 77, 80, 82, 102, 107, 119, 132, 155, 156, 170, 176, 177, 184 and 185. The second group included cultivars and lines with high Y_s, STI, MP, GMP, HM, and YI indices. This group included cultivars and lines with good performance under stress condition and tolerant to drought as Alikazemi, Gharib, Hashemi, Tarommahali, 1, 3, 7, 14, 22, 26, 27, 40, 49, 64, 65, 67, 68, 75, 98, 99, 120, 124, 126, 127, 133, 134, 138, 139, 141, 146, 147, 153, 157, 159, 162 and 163. The third group contained lines with a low value of Y_s and rather low values of STI, MP, GMP, HM and YI indices. This group included lines with a low yield in stress condition (a rather low yield in non-stress condition) and sensitive to drought. This group included lines 2, 10, 15, 17, 19, 20, 23, 25, 29, 34, 38, 39, 42, 44, 47, 50, 54, 56, 57, 59, 61, 69, 73, 81, 87, 88, 90, 91, 92, 96, 100, 104, 105, 110, 111, 117, 121, 122, 123, 125, 128, 130, 135, 137, 140, 144, 145, 148, 151, 152, 160, 167, 172, 173, 175, 181 and 186. The fourth group included cultivars and lines with a low value of TOL and SSI and high value of YSI. This group included lines with rather high yield in stress condition and tolerant to drought as lines 5, 9, 16, 21, 32, 37, 41, 45, 46, 52, 53, 55, 60, 72, 74, 79, 84, 85, 93, 103, 106, 108, 118, 131, 143, 166, 178 and 179.

Table 4. Mean values of groups and standard error of mean in cluster analysis for tolerance indices of 156 rice cultivars and lines under non-stress and stress conditions.

Indices	Mean±Standard Error of mean					Total mean
	Group 1	Group 2	Group 3	Group 4	Group 5	
Y_S	529.53±27.77	867.27±31.85	478.90±11.15	742.20±14.77	237.40±19.87	599.05±18.48
Y_P	1655.21±51.34	1416.92±68.74	811.87±26.35	847.28±19.38	1015.50±59.15	1085.55±33.15
TOL	1125.68±53.05	549.66±68.88	332.96±25.07	105.09±14.27	778.10±64.30	486.50±32.21
SSI	1.47±0.04	0.79±0.05	0.83±0.05	0.26±0.02	1.64±0.05	0.88±0.04
STI	0.68±0.05	0.96±0.06	0.30±0.01	0.49±0.02	0.18±0.02	0.53±0.03
MP	1092.37±31.62	1142.10±41.03	645.39±15.88	794.74±15.68	626.45±30.21	842.30±21.47
GMP	928.75±31.98	1097.52±34.38	618.65±14.26	792.21±15.54	481.12±23.77	786.84±20.05
HM	793.63±34.96	1057.28±31.71	593.66±13.22	789.70±15.41	376.57±26.76	740.60±19.90
YSI	0.32±0.02	0.63±0.02	0.62±0.02	0.88±0.01	0.24±0.02	0.60±0.02
YI	0.86±0.05	1.41±0.05	0.78±0.02	1.21±0.02	0.39±0.03	0.98±0.03

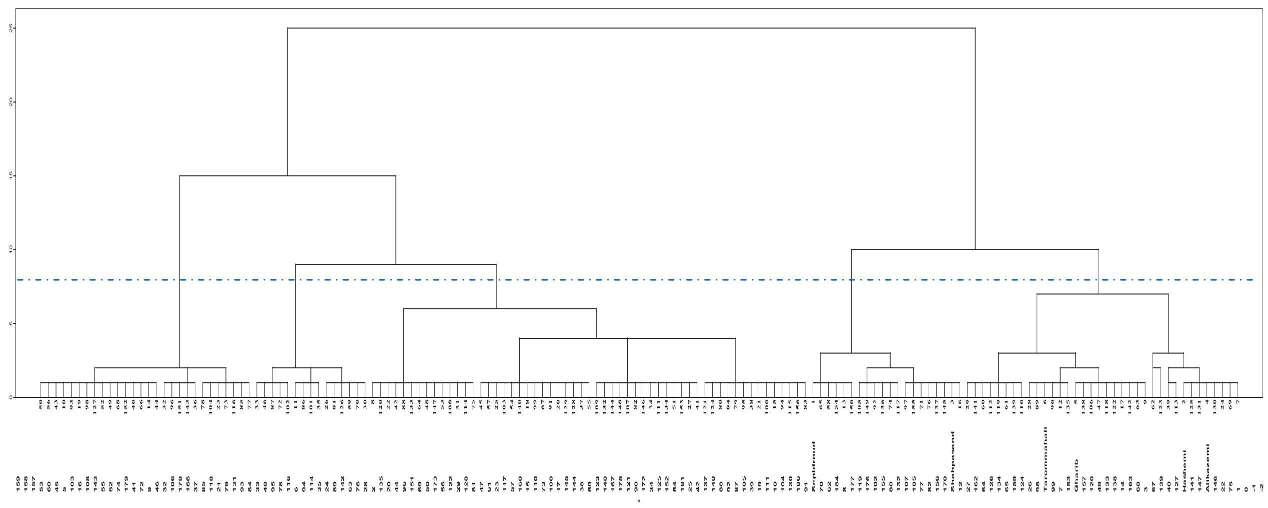

Figure 2. Dendrogram of 156 rice cultivars and lines based on evaluated indices by Ward method (5 distinct groups).

The fifth group included cultivars and lines with low values of Y_s, STI, MP, GMP, HM, YSI and YI and a high value of SSI. This group included lines with a low yield in stress condition and sensitive to drought lines 6, 24, 28, 33, 35, 48, 63, 76, 78, 89, 94, 95, 114, 116 and 142. Hosseini *et al.* (2012) divided 65 genotypes into five groups by the cluster analysis. Each group showed high values of some indices that have been in conjunction with our results.

CONCLUSIONS

Based on the results of these experiments, MP, GMP, STI and HM indices had positive significant correlations with Y_p and Y_s and are suggested as suitable indices to determine tolerant cultivars and lines. Three dimensional scatter plots and cluster analysis confirmed these results and identified the same tolerant and high-yielding cultivars and lines. According to these results, cultivars and lines Alikazemi, Gharib, Hashemi, Tarommahali, 1, 3, 7, 14, 22, 26, 27, 40, 49, 64, 65, 67, 68, 75, 98, 99, 120, 124, 126, 127, 133, 134, 138, 139, 141, 146, 147, 153, 157, 159, 162 and 163 were determined as the high yielding and the most tolerant cultivars and lines. In conclusion, these lines and cultivars are suggested as suitable material for drought stress conditions and are suitable for hybridization with the purpose of increasing drought tolerance while 6, 24, 28, 33, 35, 48, 63, 76, 78, 89, 94, 95, 114, 116 and 142 being the low yielding and most sensitive to drought stress.

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