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Full Length Research Paper

Evaluation of sorghum genotypes under drought stress conditions using some stress tolerance indices

Mohammad Ali Shirazi Kharrazi[1] and Mohammad Reza Naroui Rad[2]*

[1]Scientific Member Board of University of Payam-e-Noor, Khash Branch, Khash, Iran.
[2]Scientific Member Board of Agriculture and Natural Resources Research Center of Sistan, Iran.

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Seven genotypes of sorghum (*Sorghum bicolour* (L.) Moench) were studied in both drought and normal conditions. In each condition, the genotypes were evaluated using a split plot based randomized complete block design with three replications. Drought tolerance indices including stability tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), stress susceptibility index (SSI), tolerance index (TOL) were calculated for each genotype. The maximum value of STI (0.687), MP (658.95) and GMP (624.94) were recorded for genotype KGS 3. Correlation coefficients revealed that MP index had the highest value in two conditions with grain yield. Thus, tolerance index including MP is suitable for screening of tolerant genotypes in drought stress condition. Cluster analysis by method Ward classified seven genotypes in two groups in drought stress condition.

Key words: Sorghum, drought indices, grain yield, cluster analysis.

INTRODUCTION

Sorghum is one of the important dry land crop of semi arid tropics. Plant moisture conditions are crucial to growth and development of plants. Under these stress conditions, the uptake of water by roots may be insufficient to meet the transpiration in such dry air and soil environments. Drought response in sorghum has been classified into two distinct stages, pre-flowering and post-flowering (Rosenow and clark, 1981). Resistance to water deficit stress at both of these stages has been reported to occur in the existing germplasm. However, many genotypes with a high level of resistance at one stage are susceptible at the other stage (Walulu, 1994). Most sorghum cultivars used for grain production have pre-flowering drought resistance but do not have any significant post-flowering drought resistance (Subudhi et al., 1999). Pre flowering drought stress during grain development often leads to premature leaf senescence (Rosenow and Clark, 1981). Post-flowering drought resistance allows plants to retain their leaves in an active photosynthetic state when stressed during the grain filling stage and has been referred to as stay-green response (Walulu et al., 1994). Fisher and Maurer (1978) noted that quantification of drought tolerance should be based on seed yield under limited moisture conditions even in the absence of an understanding of specific mechanisms of tolerance. Drought is an important factor limiting crop production in arid and semi-arid conditions (Blum, 1988; Fisher and Maurer, 1978). Several drought stress indices or selection criteria, such as stress tolerance (TOL; Rosielle and Hambling, 1981), mean productivity (MP), (geometric mean productivity (GMP; Ramirez and Kelley, 1998), stress susceptibility index (SSI; Fisher and Maurer, 1978), stress tolerance index (STI; Fernandez, 1992), have been proposed as ways to identify genotypes with better stress tolerance. A larger value of TOL and SSI show relatively more sensitivity to stress (Golabadi et al., 2006). Identifying groups of individuals or objects that are similar to each other but different from individuals in other groups can be intellectually satisfying, profitable, or sometimes both and that is why scientist with using of cluster analysis could divide individuals to subgroup with specific traits .The aim of this study was to compare the usefulness of several drought stress indices for the identification of genotypes with better performance at different levels of water stress. Innovation of this study is the developing of cultivars with appropriate

*Corresponding author. E-mail: narouirad@gmail.com.

Table 1. Genotypes and origins.

Number	Genotype	Origin
1	Kimia	Karaj-Iran
2	Payam	Karaj-Iran
3	Sepideh	Karaj-Iran
4	KGS 2	Karaj-Iran
5	KGS 3	Karaj-Iran
6	KGS 4	Karaj-Iran
7	Native genotype	Zabol-Iran

performance in dry and warm zone like Sistan.

MATERIALS AND METHODS

Seven genotypes of sorghum (Table 1) were conducted during 2004 at agriculture research stations, Zahak-Zabol, in Sistan and Baluchistan Province , South East of Iran (483 m above sea level, 30°54´ N, 61°41´ E), experimental site have warm and dry summers. Genotypes were chosen for this study based on their reputed differences in yield performance under irrigated and non-irrigated conditions. Experimental design was split plot based on randomized complete block design and each plot consisted of four rows with 4 m in length and row to row space was 0.3 m apart. Grain yield was measured from central two lines after removing of 0.5 m margin from each line. Irrigation treatment for normal and drought stress condition was done with continuation and interrupting of irrigation after panicle appearance respectively. Six selection indices including stress susceptibility index, SSI (Fischer and Maurer, 1978), stress tolerance index, STI (Fernandez, 1992), tolerance, TOL, (Hossain et al., 1990), mean productivity, MP (Hossain et al., 1990), geometric mean productivity, and GMP (Fernandez, 1992) were calculated based on grain yield under drought-stressed and irrigated conditions. Stress tolerance attributes were calculated by the formula: SSI = [1- (Ys) /(Yp)] / SI . SI is the stress intensity and calculated as: SI = [1- (Ys) /(Yp)], STI = [(Yp) × (Ys)/(Yp)2], GMP = $\sqrt{(YP \times YS)}$, TOL = (Yp - Ys) and MP = (Yp + Ys) / 2 where Ys and Yp are the yields of genotypes evaluated under stress and non-stress conditions and Ys and Yp are the mean yields over all genotypes evaluated under stress and non-stress conditions. Cluster analysis or clustering is the assignment of a set of observations into subsets (called clusters) so that observations in the same cluster are similar in some sense. The aim in Ward's method is to join cases into clusters such that the variance within a cluster is minimised. To do this, each case begins as its own cluster. Clusters are then merged in such a way as to reduce the variability within a cluster. Analysis of data was performed using (SAS Institute, Inc. 1995) and SPSS.16 computer software packages.

RESULTS AND DISCUSSION

From the stress tolerance point of view (TOL), the lowest values were recorded for genotype zabol (Table 2). Obviously, this index only pointed out the genotypes with the lowest yield in normal conditions. The highest average yield (MP) and geometric mean productivity yield (GMP) were recorded in genotypes KGS3 (MP = 658.9 kgh^{-1} and GMP =624.9 kgh^{-1}). Based on GMP and STI values in this group, the cultivar KGS3 could be considered relatively drought tolerant. An analysis of correlations between the various stress tolerance parameters used in this study provides interesting observations about the information reflected by each of them (Table 3). MP indices had the significant and positive relation with yields in the normal irrigation (Yp) and stress (Ys) respectively (r = 0.793) and (r = 0.939). Stress tolerance (TOL) was strongly correlated with two indices SSI and STI (r = 0.920 and -0.917, respectively). Having in mind the fact that a small value of TOL is desirable, selection for this parameter would tend to favour low yielding genotypes. Cengiz and ilhan (1998) reported that the mean productivity was positively and significantly ($p< 0.01$) correlated with seed yield (r = 0.885) and tolerance to drought index, (STI) (r = -0.426) under drought stress and non-drought stress conditions for Chickpea. some researchers (Golabadi et al., 2006; Naroui Rad et al., 2004) believes that the valid indices for screening have a good relation with yield in normal and stress condition and based on this research so Naroui Rad et al. (2010) reported three indices STI, GMP and MP had the highest positive correlation coefficient with yields in normal and drought stress condition and they introduced these three indices for post anthesis water stress in sorghum collection of national plant gene bank of Iran. The stress susceptibility index (SSI) introduced by Fisher and Maurer (1978) was significant and negatively correlated with yield under stress and presented a positive correlation with TOL index. Having in mind the fact that a small value of SSI is desirable and on the bases of this index genotypes, native genotype and KGS3 had the least index among genotypes. From this point of view, STI and GMP seem to be more useful. Fernandez (1992) proposed STI index which discriminates genotypes with high yield and stress tolerance potentials. The optimal selection criterion should distinguish genotypes that express uniform superiority in both stress and non stress environments from the genotypes. Clarke et al. (1992) used SSI for evaluation of drought tolerance in wheat genotypes and found a year-to-year variation in SSI for genotypes and their ranking pattern. Ramirez and Kelly (1998) reported that GM and SSI as the mathematical derivations of the same yield data; selection based on a combination of both indices

Table 2. Drought stress indices and yield in drought stress and normal conditions.

Genotype	YP	YS	TOL	MP	GMP	SSI	STI
Kimia	688.4	397.7	517.6	534.05	511.258	0.789	0.460
Payam	668	210.8	456.2	438.9	374.971	1.204	0.247
Sepideh	831.4	237	594.4	534.2	443.893	1.258	0.346
KGS 2	720.8	436	677.2	382.2	177.276	0.695	0.553
KGS 3	867.9	450	417.9	658.95	624.93	0.847	0.687
KGS 4	815	395.9	419.1	605.45	56.83	0.905	0.568
Native genotype	683.8	166.2	308.7	425	337.116	1.332	0.200

YP, Yield of genotype evaluated under non stress condition; YS, yield of genotype evaluated under stress condition; TOL, tolerance index; MP, mean productivity; GMP, geometric mean productivity; SSI, susceptibility index; STI, stability tolerance index.

Table 3. Correlation coefficients of drought stress indices and yield (normal and drought).

Index	YP	YS	TOL	MP	GMP	SSI	STI
YP	1						
YS	0.535	1					
TOL	0.036	-0.825**	1				
MP	0.793*	0.939**	-0.58	1			
GMP	0.153	0.391	-0.36	0.334	1		
SSI	-0.332	-0.973**	0.920**	-0.836**	-0.404	1	
STI	0.335	0.973**	-0.917**	0.838**	0.405	-0.989**	1

*, ** significant at 5 and 1% level. YP, Yield of genotype evaluated under non stress condition; YS, yield of genotype evaluated under stress condition; TOL, tolerance index; MP, mean productivity; GMP, geometric mean productivity; SSI, susceptibility index; STI, stability tolerance index.

may provide a more desirable criterion for improving drought resistance in common bean. Guttieri et al. (2001) used SSI criterion and suggested that SSI more than 1 indicates above-average susceptibility to drought stress. Golabadi et al. (2006), Sio-Se Mardeh et al. (2006) and Naroui Rad et al. (2004) suggested that selection for drought tolerance in wheat could be conducted for high MP, GMP and STI under rainfed and supplementary irrigation environments. Cluster analysis by ward method in drought stress condition showed the genotypes distributed in two groups, first group include Kimia, KGS3 and KGS4 and for second group Payam, Sepideh, KGS2 and Native genotype were inserted. The genotypes that are placed in first cluster had a good performance in drought stress condition while second cluster introduces sensitive genotypes to stress condition.

Conclusion

The findings of this study showed that the breeders should choose the indices on the basis of stress severity in the target environment; MP and STI are suggested as useful indicators to selection of tolerant genotypes, based on of this indices, the genotype KGS3 was introduced as a tolerant genotype.

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