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Drought tolerance screening of Maize Inbred Lines using tolerance Indices

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Maize (*Zea mays* L.) is the third most important cereal in Pakistan. Drought tolerance improvement in maize has become most important objective of breeding programs because maize is highly drought sensitive. Maize productivity drastically reduces under water shortage. For this purpose identification of genotypes with improved drought tolerance is very important. 30 maize inbred lines were evaluated under two moisture levels at Barani Agricultural Research Institute, Chakwal, Pakistan. Nine drought tolerance indices including stress tolerance index (STI), stress susceptibility index (SSI), tolerance index (TOL), mean production (MP), yield index (YI), yield stability index (YSI), drought resistance index (DI), relative drought index (RDI) and modified stress tolerance indices (K_1STI and K_2STI) were calculated based on grain yield under stress and non-stress conditions. Results suggested genetic variability present among the inbred lines. Highly positive correlation was observed between TOL, DI, YI, STI, MP, K1STI and K2STI indices and grain yield under stress and non-stress conditions. SSI exhibited negative correlation with grain yield under both conditions. In this study, Modified stress tolerance indices (K_1STI and K_2STI) were identified as best criteria for drought tolerance screening. Based on these indices, six inbred lines UAF-35, UAF-38, UAF-43, UAF-48, UAF-49 and UAF-54 were screened to be highly drought tolerant.

Keywords: Drought, Inbred lines, Indices, Maize, Tolerance

INTRODUCTION

Maize (Zea mays L.) is most important crop in world's agriculture. In Pakistan maize is third important cereal crop after wheat and rice. It is being grown on an area of 1.117 million hectares with annual production of 4.527 million tons and average grain yield of 4053 kg ha-1 (Rehman et al. 2015). It contributes 62% in the total cereal production (Farhad et al. 2011). Maize is one of the major world food crops. Under limited water availability maize may lose its grain yield. In Pakistan, water stress is also a major obstacle for maize production. Approximately, 35% of the maize in Pakistan strictly depends on natural rain (Arora et al. 2002). Maize is physiologically more efficient, has higher grain yield potential and wider adaptation over a range of environmental conditions. It is a principal source of carbohydrates and proteins and is on par with other cereals in its other nutritional qualities. It has diversified uses as food, feed and as raw material for various industrial products. It has also become a key resource for industrial applications and bio energy production. Maize is highly productive under optimal environmental and crop management conditions. However, maize plants are also very susceptible to abiotic stresses particularly, drought and heat. Each year, an average of 15 to 20 per cent of the potential world maize production is lost due to these stresses (Lobell et al. 2011). Maize is efficient user of moisture for dry matter production and requires 500-800 mm of water during life cycle of 80-110 days (Aslam et al. 2006). At the time of tasseling maize requires 135 mm / month and this may increase up to 195 mm / month during hot windy conditions. Climatic changes adversely affect distribution pattern of rainfall that will result in poor and scanty rainfall in one area and heavy rainfall in other area causing severe water deficit. Occurrence of drought is unpredictable, it can occur at any stage of the crop. Drought occurring between two weeks before and after the silking stage can cause significant yield loss to an extent of 20 to 50 per cent (Shadakshari and Shanthakumar, 2015).

To avoid the harmful effects of drought stress, development of stress tolerant plant varieties will play more important role. Identification and characterization of variations for drought tolerance in maize germplasm is a first and foremost step in developing drought tolerant maize hybrids (Chen et al. 2012). Loss of yield is the main concern of plant breeders and they hence emphasize on yield performance under stress conditions. Thus, drought indices

rought which provide a measure of drought based on loss of yield under drought conditions in comparison to normal conditions have been used for screening drought tolerant genotypes (Naghavi et al. 2013). The best measure for selection in drought condition could be able to separate genotypes which have desirable and similar yield in stress and non-stress condition from other groups and also, the best indices are those which have high correlation with kernel yield in both conditions. Several selection criteria have been proposed to select genotypes based on their performance in stress and non-stress environments.

In order to avoid the drought problem, plant breeders use various statistical tools and methods to improve crop plant yield and production under varying environmental conditions. There is a need for the development of such crop varieties by genetic improvement and successful breeding practices which can thrive well under drought stress and produce acceptable yields. The only option is to increase the maize productivity per unit area of land and time, which can be achieved through selection of best genotype improved in breeding program and application of proper production management techniques. For this purpose, the present research was conducted with an aim to screen the drought tolerant inbred lines based upon their productivity under stress and non-stress conditions and to identify suitable inbred lines that can be used in future breeding programs..

MATERIALS AND METHODS

The current study was conducted at Barani Agricultural Research Institute, Chakwal, Pakistan during spring 2015. Chakwal is situated at 72º longitude, 32º latitude and 575 ams altitude. The average summer temperature of Chakwal is 32.5 °C. Climate of Chakwal is semi-arid, sub-tropical and annual rainfall ranges from 500-1000 mm most of which falls during monsoon in the form of high intensity showers. Soil is silty loam to loam with pH 7-9.

The experimental material comprised of 30 inbred lines which were obtained from University of Agriculture, Faisalabad (Table 1).

Table1: Maize inbred lines used for drought tolerance screening

No	Line	No	Line
1	UAF-31	16	UAF-46
2	UAF-32	17	UAF-47
3	UAF-33	18	UAF-48
4	UAF-34	19	UAF-49
5	UAF-35	20	UAF-50
6	UAF-36	21	UAF-51
7	UAF-37	22	UAF-52
8	UAF-38	23	UAF-53
9	UAF-39	24	UAF-54
10	UAF-40	25	UAF-55
11	UAF-41	26	UAF-56
12	UAF-42	27	UAF-57
13	UAF-43	28	UAF-58
14	UAF-44	29	UAF-59
15	UAF-45	30	UAF-60

These lines were planted following Randomized Complete Block Design (RCBD) with two replications under two different irrigations (stress and non-stress). Seeds were sown (10 per line) at a plant to plant distance of 0.8 inches and row to row distance of 2 feet. Crop under the non-stress condition was given weekly irrigation till cob maturity while in stress condition irrigation was withheld 60 days after sowing till harvest so that crop should experience maximum drought at crucial stages. Same cultural practices were done in both plots. Three potential plants were randomly selected from each line for both stress and non-stress conditions and their potential yield (Yp) and Stress yield (Ys) were measured.

Tolerance Indices Calculation

Following nine dtolerance indices were calculated using the relationships given by Naghavi*et al* (2013):

STI= $(Ys \times Yp)/(\bar{Y}^2 p)$

TOL= $Yp-Ys$

DI= $\{Ys \times (YsYp)\}/ \bar{Y}s$

YI= $Ys/ \bar{Y}s$

MP= $(Ys+Yp)/2$

RDI= $(YsYp)/(\bar{Y}s/\bar{Y}p)$

SSI= $1-(Ys/Yp)/SI$: SI= $1-(\bar{Y}s/\bar{Y}p)$

In the above formulae, Ys, Yp, $\bar{Y}$ *s* and $\bar{Y}$ p represent yield under stress, yield non-stress for each cultivar, yield mean in stress and non-stress conditions for all cultivars, respectively.

Statistical Analysis

Analysis of variance for all tolerance indices and correlation among the indices and grain yield under two conditions were performed by the Statistix 8.1 software.

RESULTS AND DISCUSSION

Analysis of Variance

The analysis of variance (Table 2) for different drought tolerance indices exhibited highly significant variation for all the indices except for RDI. The results suggested the presence of genetic variation among the inbred lines for drought tolerance. This creates a possibility for the selection of drought tolerant lines based on Yp, Ys, TOL, SSI, STI, DI, YI, MP, K1STI and K2STI.

Kiani (2013) studied various drought tolerance indices for pure lines of maize and found highly significant variations for Ys, Yp, TOL and STI.

Table 2: Genotypes mean squares and co-efficient of variation values for different drought tolerance indices in maize inbred lines

Indices	MSr	MSg	CV%
Ys	3.03	660.14**	5.86
Yp	0.07	397**	8.31
TOL	4.05	158.15**	8.08
SSI	0.005	0.06**	7.39
DI	0.0003	0.08**	12.11
YI	0.0001	0.13**	8.33
STI	0.0003	0.13**	13.65
MP	0.54	489.03**	6.45
RDI	0.04	0.09	25.52
K1STI	0.01	0.58**	30.13
K2STI	6.67	1.22**	22.86

** Significant at the 1% probability level

Estimation of Drought Tolerance Indices

In order to screen the inbred lines for drought tolerance, grain yield under stress and non- stress conditions was measured for estimating different tolerance indices (Table 3). The lines UAf-33, UAF-34, UAF-35, UAF-37, UAF-38, UAF-42, UAF-43, UAF-44, UAF-48, UAF-49 and UAF-54 showed highest estimates of STI and grain yield under stress and non-stress conditions. According to the estimates of MP, YI and DI these lines were found to be relatively drought tolerant. But the RDI estimates ranked UAF-36, UAF-38, UAF-39, UAF-46, UAF-48, UAF-57 and UAF-58 as the most relatively drought tolerant lines. Based on TOL estimates inbred lines UAF-31, UAF-32, UAF-36, UAF 38, UAF-49 and UAF 60 were found to be most relatively tolerant lines. Inbred lines UAF-38, UAF-39, UAF-42, UAF-46 and UAF-48 showed the least stress susceptibility values.

Naghavi et al. (2013) studied 8 maize cultivars and observed variation among cultivars for tolerance indices. Farshadfar et al. (2012a) also used stress tolerance indices for screening bread wheat landraces.

Correlation Analysis

The results showed that the screening of inbred lines based on a single criteria is difficult.To determine the most desirable drought tolerance criteria, the correlation coefficient between Yp, Ys and quantitative indices of drought tolerance were calculated (Table 4). Correlation analysis between grain yield and drought tolerance indices can be a good criterion for screening the best cultivars and indices used (Table 4). A suitable index must have a significant correlation with grain yield under both the conditions (Mitra, 2001). The results of correlation analysis depicted highest positive correlation between MP and Yp. High positive correlation between YI and Ys was also observed. SSI showed a highly significant negative correlation with the yield under stress condition. These results are supported by the study of Naghavi et al. (2013). Yields under both (stress and non-stress conditions) were highly significantly and positively correlated with TOL, DI, YI, STI, MP, K1STI and K2STI while a negative correlation was observed between SSI and yield under both conditions. RDI exhibited a negative correlation with yield under non-stress condition. Khalili et al. (2012) reported a significant positive correlation between MP, STI and yield under drought condition. Mehrabi et al (2011) also found STI as the best index to screen high yielding maize hybrids. Ilker et al. (2011) concluded that MP and STI are effective indices to select high yielding wheat genotypes. Jafari et al. (2009) found that STI showed the highest correlation with grain yield under both optimal and stress conditions and can be used as the best index for maize breeding programs to introduce drought tolerant hybrids. Consequently Stress Tolerant Index (STI) is most useful index in order to select favorable maize cultivars under stress and non-stress conditions.

To improve the efficiency of STI, modified stress tolerance indices (K1STI and K2STI) were calculated. K1STI and K2STI are the optimal selection indices for stress and non-stress conditions respectively. Khalili et al. (2012) also suggested that K1STI and K2STI can be used as the most suitable indicators for screening drought tolerant cultivars. Results of correlation analysis suggested a significant positive correlation between K1STI, K2STI and yield under both conditions. These results are in accordance with the findings of Farshadfar and Elyasi (2012) and Farshadfar et al. (2012a,b). They also reported a positive correlation between MSTI (K1STI and K2STI) and grain yield under stress and non-stress conditions.

Considering STI, K1STI and K2STI as the best indices for drought tolerance screening 6 inbred lines were found to be most relatively tolerant. These inbred lines include UAF-35, UAF-38, UAF-43, UAF-48, UAF-49 and UAF-54. Among these lines UAF-49 ranked best showing highest estimates of STI (1.21), K1STI (2.48) and K2STI (0.03).

Table 3: Estimates of tolerance indices of maize inbred lines under stress and non-stress conditions

Line	Ys	Yp	TOL	SSI	DI	YI	STI	MP	RDI	K1STI	K2STI
UAF-31	43.4	93.3	49.9	1.28	0.37	0.81	0.46	68.35	0.79	0.46	0.006
UAF-32	38.95	89.8	50.85	1.35	0.31	0.72	0.4	64.37	0.73	0.37	0.004
UAF-33	57.6	105	47.4	1.08	0.58	1.07	0.69	81.3	0.93	0.88	0.012
UAF-34	58.65	104.65	46	1.04	0.61	1.09	0.69	81.65	0.96	0.88	0.013
UAF-35	69.85	110.15	40.3	0.88	0.82	1.3	0.86	90	1.08	1.19	0.019
UAF-36	56.25	99	42.75	1.03	0.59	1.05	0.62	77.62	1.47	0.69	0.011
UAF37	65.15	104.8	39.65	0.9	0.75	1.21	0.77	84.97	1.06	0.96	0.016
UAF-38	74.1	112.65	38.55	0.81	0.9	1.38	0.94	93.37	1.12	1.35	0.022
UAF-39	59.55	89.85	30.3	0.79	0.73	1.11	0.6	74.7	1.14	0.54	0.011
UAF-40	51.55	81.65	30.1	0.88	0.6	0.95	0.47	66.6	1.08	0.36	0.007
UAF-41	36.25	68.85	32.6	1.13	0.35	0.67	0.28	52.55	0.9	0.14	0.003
UAF-42	66.3	105.15	38.85	0.83	0.8	1.23	0.79	85.72	1.11	0.99	0.016
UAF-43	71.5	113.5	42	0.88	0.84	1.33	0.91	92.5	1.08	1.33	0.022
UAF-44	64.05	100.2	36.15	0.87	0.75	1.19	0.72	82.12	1.09	0.82	0.014
UAF-45	59.2	96.5	37.3	0.91	0.68	1.1	0.64	77.85	1.05	0.68	0.012
UAF-46	49.65	74	24.35	0.8	0.62	0.92	0.41	61.82	1.14	0.25	0.006
UAF-47	43.45	74.65	31.2	0.98	0.47	0.81	0.36	59.05	1	0.22	0.004
UAF-48	75.95	113	37.05	0.78	0.95	1.41	0.97	94.47	1.15	1.41	0.023
UAF-49	80.3	133.35	53.05	0.95	0.9	1.5	1.21	106.82	1.03	2.48	0.032
UAF-50	44.65	81.35	36.7	1.06	0.46	0.83	0.41	63	0.94	0.3	0.005
UAF-51	42.75	81.3	38.55	1.13	0.41	0.79	0.39	62.02	0.9	0.29	0.005
UAF-52	42.5	81.3	38.8	1.14	0.41	0.79	0.38	61.9	0.89	0.28	0.005
UAF-53	40.9	74.35	33.45	1.08	0.41	0.76	0.34	57.62	0.93	0.21	0.004
UAF-54	69.65	115.2	45.55	0.94	0.78	1.3	0.91	92.42	1.04	1.37	0.02
UAF-55	57.2	95.5	38.3	0.95	0.63	1.06	0.62	76.35	1.03	0.64	0.011
UAF-56	31.15	55.5	24.35	1.04	0.32	0.57	0.19	43.32	1.46	0.06	0.001
UAF-57	37.5	64	26.5	0.97	0.41	0.69	0.26	50.75	1.51	0.12	0.002
UAF-58	45.6	77.7	32.1	0.97	0.5	0.85	0.39	61.65	1.51	0.27	0.005
UAF-59	37.05	68.2	31.15	1.09	0.37	0.69	0.28	52.62	0.92	0.14	0.003
UAF-60	33	97.5	64.5	1.57	0.2	0.61	0.36	65.25	0.58	0.38	0.003

Table 4: Correlation coefficients between Yp, Ys and resistance indices

Indices	Ys	Yp	TOL	SSI	DI	YI	STI	MP	RDI	K_1STI	K_2STI
Ys	1										
Yp	0.87**	1									
TOL	0.19	0.64**	1								
SSI	-0.67**	-0.23	0.57**	1							
DI	0.97**	0.74**	-0.01	-0.81**	1						
YI	0.99**	0.87**	0.19	-0.67**	0.97**	1					
STI	0.97**	0.94**	0.38**	-0.5**	0.9**	0.97**	1				
MP	0.95**	0.97**	0.46**	-0.44**	0.87**	0.95**	0.98**	1			
RDI	0.13	-0.11	-0.46**	0.46**	0.23	0.13	0.04	-0.006	1		
K1STI	0.89**	0.92**	0.45**	-0.37**	0.8**	0.89**	0.96	0.94	0.01	1	
K2STI	0.96**	0.9**	0.32*	-0.52**	0.9**	0.96**	0.98**	0.96**	0.07	0.97**	1

**** Significant at the 1% probability level**

CONCLUSION

Inbred lines of maize showed highly significant variations for all the indices and grain yield under stress and non-stress conditions. This suggests the presence of genetic variability among these lines. All the drought tolerance and resistance indices exhibited highly significant positive correlation with the grain yields in the stress and non-stress conditions except SSI and RDI. The study revealed that the modified Stress Tolerance Indices i.e., K_1STI and K_2STI are the most suitable indicators for drought tolerance screening. Using these indices as criteria 6 inbred lines UAF-35, UAF-38, UAF-43, UAF-48, UAF-49 and UAF-54 were screened to be most drought tolerant. Therefore, these lines are suggested to be incorporated in future breeding programs to develop drought tolerant hybrids.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

All the authors contributed equally in this manuscript.

REFERENCES

Arora, A., R. K. Sairam and G.C. Srivastava. 2002. Oxidative stress and anti-oxidative systems in plants. Curr. Sci., 82: 1227-1238.

Aslam, M., I. A. Khan, M. Saleem and Z. Ali. 2006. Assessment of water stress tolerance in different maize accessions at germination and early growth stage. Pak. J. Bot., 38(5): 1571-1579.

Chen, J., Xu., W. Velten, J. Xin, Z and J. Stout. 2012. Characterization of maize inbred lines for drought and heat tolerance. J. Soil Water Cons., 67(5): 354-364.

Farhad, W., M. A. Cheema, M. F. Saleem and M. Saqib, 2011.Evaluation of drought tolerance in maize hybrids.Int. J. Agric. Biol., 4: 523-528

Farshadfar, E. and P. Elyasi. 2012. Screening quantitative indicators of drought tolerance in bread wheat (*TriticumaestivumL.*) landraces. Eur. J. Exp. Biol., 2 (3): 577-584.

Farshadfar, E., M. Farshadfar and S. Dabiri.2012a. Comparison between effective selection criteria of drought tolerance in bread wheat landraces of Iran. Ann. Biol. Res., 3 (7): 3381-3389.

Farshadfar, E., M. M. P. Siahbidi and A. R. P. Aboughadareh.2012b. Repeatability of drought tolerance indices in bread wheat genotypes. Int. J. Agri. Crop Sci., 4 (13): 891-903.

İlker, E., O. Tatar, F. T. Aykut, M. Tosun and J. Turk. 2011. Determination of tolerance level of some wheat genotypes to post-anthesis drought. Turk. J. Field Crops, 16 (1): 59-63.

Jafari, A., F. Paknejad and M. Jami Al-Ahmadi. 2009. Evaluation of selection indices for drought tolerance of corn (*Zea mays* L.) hybrids. Inter. J. Plant Prod., 3 (4): 33-38.

Khalili, M., M. R. Naghavi, A. R. P. Aboughadareh and J. Talebzadeh. 2012. Evaluating of drought stress tolerance based on selection indices in spring canola cultivars (*Brassica napus*L.). J. Agri. Sci., 4 (11): 78-85.

Kiani, M. 2013. Screening drought tolerance criteria in maize. Asian J. Agric. Rural Develop., 3 (5): 290-295.

Lobell, D.B., M. Bänziger, C. Magorokosho and B. Vivek. 2011. Non-linear heat effects on African maize as evidenced by historical yield trials. Nat. Climate Chang., 1:42-45

Mehrabi.P., H. Homayoun and M. S. Daliri. 2011. Study of drought tolerance of corn genotypes using STI index. Middle-East J. Sci. Res., 9 (1): 68-70.

Mitra, J. 2001. Genetics and genetic improvement of drought resistance in crop plants.Curr. Sci. India, 80: 758-762.

Naghavi, M. R., A. P. Aboughadareh, and M. Khalili. 2013. Evaluation of drought tolerance indices for screening some of corn (Zea mays L.) cultivars under environmental conditions. Not. Sci. Biol., 5 (3): 388-393.

Rahman, S. U., M. Arif, K. Hussain, M. Arshad, S. Hussain, T. Mukhtar and A. Razaq. 2015. Breeding for heat stress tolerance of maize in Pakistan. J. Env. Agri. Sci., 5: 27-33.

Shadakshari, T. V. and G. Shanthakumar. 2015. Evaluation of maize inbred lines for drought tolerance under contrasting soil moisture regimes. Karnataka J. Agric. Sci., 28 (2): 142-146.