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Original article

Assessment of drought tolerance indices in durum wheat (*Triticum durum* L.) genotypes

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Extended abstract

Introduction

Durum wheat (*Triticum durum* L.) is grown on 10% of the world's wheat area. In spite of its low acreage, durum wheat is an economically important crop because of its unique characteristics and end products. Drought stress is one of the most devastating environmental stresses that depresses wheat yield productivity in many parts of the world. Breeding for drought tolerance is critical for sustainable wheat production in these areas. Different indices, including tolerance (TOL), mean productivity (MP), geometric mean productivity (GMP), stress tolerance index (STI), stress susceptibility index (SSI), harmonic mean (HAM), yield index (YI), and yield stability index (YSI) have been employed for screening the stress tolerant genotypes. The objectives of the study were to assess durum wheat genotypes under stress and non-stress conditions and to evaluate drought resistance indices in identifying genotypes adapted to the conditions.

Materials and Methods

The experiment was carried out at the research farm of Faculty of Agriculture, Razi University, Kermanshah, during 2015-2016 cropping season. In this study, 23 durum wheat genotypes originally from Iran and ICARDA were evaluated using a randomized complete block design with three replications under stress (rain-fed) and non-stress (irrigated) conditions. Irrigated plots were watered three times at flowering and grain filling stages. Rain-fed plots received no water other than rainfall. Grain yield (g/m2) was measured. Tolerance indices were calculated for genotypes based on the grain yield. Combined analysis of variance appropriate to RCBD was carried out using SAS. Environments (rain-fed and irrigated) were considered as fixed effects. Least significant difference (LSD) test was used for the mean comparisons. Orthogonal comparisons and correlation analysis were performed by SAS software. Principal component analysis (PCA) and biplot diagram were carried out by MINITAB 17 and Stat graphics 18.1.01, respectively.

Results and discussion

The results of combined analysis of variance showed significant differences between environments (rain-fed and irrigated) and genotypes for grain yield. Orthogonal comparisons showed that there was a

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significant difference between Iranian genotypes (contrast 1) in both conditions. Also, there were significant differences between ICARDA genotypes (contrast 2) and Iranian and ICARDA genotypes (contrast 3). Results showed that water stress reduced the grain yield of all genotypes and mean grain yield in rain-fed conditions was 32% lower than that in irrigated conditions (the stress intensity was 0.32). Based on all calculated drought indices, in most cases genotypes 15, 10, 18, 12 and 19 were tolerant and genotypes 2, 9, 17, 4 and 7 were susceptible to drought stress. The results of correlation analysis showed that TOL, MP, GMP, STI, YI and HAM had significant ($P \leq 0.01$) and positive correlations with grain yield under non-stressed condition. The MP, GMP, STI, YI and HAM revealed a significant ($P \leq 0.01$) and positive correlations with yield under stressed condition. Positive and significant correlation were observed between Ys and Yp and also with MP, GMP, STI, YI and HAM indicated that these indices are the most suitable indices to screen genotypes in drought stress conditions. Principal component analysis showed that the first component explained 71% of the variation with Ys, Yp, MP, YI, GMP, STI and HAM. First dimension can be considered as the yield in both environments and drought tolerance. Second component explained 28% of the total obtained variation and can be named drought susceptible dimension. Hence, selection of genotypes with high PCA1 and low PCA2 are suitable for both stress and non-stress environments. Thus, Genotypes 18, 22 and 23 with rather higher PCA1 and lower PCA2 are superior genotypes under both stressed and non-stressed conditions (Group A). Genotypes 19, 14, 3, 16, 21 and 20 could be known as Group B. These genotypes are suitable for non-stressed conditions. Genotypes 4, 7, 17 and 13 are drought susceptible and had low yield in both conditions (Group D). Genotypes 15, 10, 12, 11 and 6 with high amount of yield stability index (YSI) had a relatively low yield in both conditions, but they were more stable genotypes than the others (Group C).

Conclusion

What can be concluded from these results are:

1) Identifying the genotypes with high and stable yield in both conditions which are 18, 22 and 23 originated from ICARDA.

2) Identifying genotypes with low yield in both conditions and susceptible to drought which are 4, 7, 17 and 13.

3) Suggesting genotypes 19, 14, 3, 16, 21 and 20 for non-stress conditions.

Keywords**:** Drought tolerance indices, Durum wheat, Principal component analysis, Cluster analysis, Orthogonal comparisons

, pedigrees and origins of durum wheat genotypes used in the experiment

Code	Pedigree	Origin
1	Saji	Iran
2	Zardak	Iran
3	65-12-3-3	Iran
4	25-25-1-5	Iran
5	75-5-3-5	Iran
6	409	Iran
7	259	Iran
8	15-15-1-3	Iran
9	240	Iran
10	37-24-2-3	Iran
11	249	Iran
12	Heider/Mt/Ho	ICARDA
13	Arthar 71/Bcr//ch5	ICARDA
14	Stj3/4/stn//Hvi/Somo/3/yav/fg/Roh	ICARDA
15	Grdara-2	ICARDA
16	Lgt3/4/Bcr/3/chl//Gta/stk	ICARDA
17	Aghrass-2	ICARDA
18	Quadalete//Erp/mol/3/unk/4/Mrb3/Mnal	ICARDA
19	MRB/MRA-1	ICARDA
20	BCR/GRO1/MGN/1	ICARDA
21	ADNON-2	ICARDA
22	WAHA	ICARDA
23	STG3/BCR/LK54/3N ER-5	ICARDA

Table 2. Combined analysis of variance of 23 durum wheat genotypes for grain yield

Sources of Variations	df	Mean of squares
Environment	1	1291345.5**
Error	4	27722
Genotype	22	130585.97**
Environment×Genotype	22	9292.02^{ns}
Error	88	17624.2
CV%		*26.16*

^{ns} and **: Not significant and significant at 1% level respectively.

Table 3. Analysis of variance and orthogonal comparison of 23 durum wheat genotypes for grain yield

Sources of Variations	df	Irrigated	Rain-fed
Replication	2	29200.45^{ns}	26243.56^{ns}
Genotype	22	81211.75**	58666.24**
contrast 1	10	529444.64*	23934.03*
contrast 2	11	82047.48**	58473.98**
contrast 3	1	354689.71**	408103.11**
Error	44	24504.78	10743.62
CV%		*25.91*	*25.24*

^{ns}, * and **: Not significant and significant at 5% and 1% level, respectively.

Table 4. Average values of drought tolerance indices in genotypes of durum wheat

ژنوتیپ‌ها Genotypes	Y_p	Y_s	TOL	MP	GMP	HAM	STI	SSI	YI	YSI
1	609.18	346.71	262.47	477.95	459.57	441.91	0.58	1.35	0.84	0.57
2	590.74	290.71	300.03	440.73	414.41	389.66	0.47	1.59	0.71	0.49
3	774.88	513.81	261.07	644.34	630.98	617.90	1.09	1.05	1.25	0.66
4	356.06	201.58	154.48	278.82	267.91	257.42	0.20	1.35	0.49	0.57
5	592.3	402.4	189.9	497.35	488.20	479.22	0.65	1.00	0.98	0.68
6	490.97	348.21	142.76	419.59	413.48	407.45	0.47	0.91	0.85	0.71
7	364.16	204.23	159.93	284.20	272.72	261.70	0.20	1.37	0.50	0.56
8	593.99	365.32	228.67	479.65	465.83	452.40	0.59	1.20	0.89	0.62
9	630.42	322.37	308.05	476.40	450.81	426.60	0.56	1.53	0.78	0.51
10	422.99	368.33	54.66	395.66	394.72	393.78	0.43	0.40	0.90	0.87
11	396.69	270.7	125.99	333.70	327.70	321.80	0.29	0.99	0.66	0.68
12	507.44	428.35	79.09	467.90	466.22	464.55	0.60	0.49	1.04	0.84
13	516.68	319.65	197.03	418.16	406.39	394.95	0.45	1.19	0.78	0.62
14	797.01	518.25	278.77	657.63	642.69	628.09	1.13	1.09	1.26	0.65
15	359.54	329.01	30.53	344.27	343.93	343.60	0.32	0.27	0.80	0.92
16	735.99	489.43	246.57	612.71	600.18	587.90	0.99	1.05	1.19	0.66
17	516.61	282.59	234.02	399.60	382.09	365.34	0.40	1.41	0.69	0.55
18	938.37	804.11	134.27	871.24	868.65	866.07	2.07	0.45	1.96	0.86
19	838.62	558.5	280.12	698.56	684.38	670.48	1.28	1.04	1.36	0.67
20	720.91	478.24	242.67	599.58	587.17	575.02	0.94	1.05	1.16	0.66
21	729.88	492.2	237.68	611.04	599.37	587.93	0.98	1.02	1.20	0.67
22	732.04	552.24	179.8	642.14	635.81	629.55	1.11	0.77	1.34	0.75
23	680.94	559.71	121.23	620.33	617.36	614.41	1.04	0.56	1.36	0.82
Mean	604.19	410.72	193.47	507.46	496.55	485.99	0.73	1.01	1.00	0.68
LSD 0.05	*257.59*	*170.56*								

Table 5. Correlation coefficients between grain yield and utilized indices

	Yp	Ys	TOL	MP	GMP	HAM	STI	SSI	YI
Ys	0.878^{**}								
TOL	0.529^{**}	0.060^{ns}							
MP	0.974^{**}	0.963^{**}	0.323^{ns}						
GMP	0.962^{**}	0.975^{**}	0.279^{ns}	0.998^{**}					
HAM	0.949^{**}	0.983^{**}	0.237^{ns}	0.995^{**}	0.998^{**}				
STI	0.931^{**}	0.975^{**}	0.213^{ns}	0.981^{**}	0.985^{**}	0.986^{**}			
SSI	-0.52^{ns}	-0.503^{*}	0.784^{**}	-0.268^{ns}	-0.310^{ns}	-0.350^{ns}	-0.331^{ns}		
YI	0.877^{**}	1.000^{**}	0.058^{ns}	0.963^{**}	0.974^{**}	0.983^{**}	0.975^{**}	-0.504^{*}	
YSI	0.049^{ns}	0.500^{*}	-0.786^{**}	0.246^{ns}	0.307^{ns}	0.346^{ns}	0.329^{ns}	-1.000^{**}	0.501^{*}

^{ns}, * and **: Not significant, significant at 5% and 1% levels respectively.

Table 6. The results of principal components analysis for drought tolerance indices in durum wheat genotypes

Component	Eigenvalue	Percentage of variance	Cumulative variance	Component coefficients for yield under normal conditions (Yp), stress (Ys) and stress indices				
				Y_s	Y_p	TOL	MP	YSI
1	7.135	0.71	0.71	0.37	0.34	0.06	0.37	0.16
2	2.775	0.28	0.99	-0.06	0.23	0.58	0.10	-0.54

Table 6. Continued

Component	Eigenvalue	Percentage of variance	Cumulative variance	Component coefficients for yield under normal conditions (Yp), stress (Ys) and stress indices				
				YI	GMP	STI	HAM	SSI
1	7.135	0.71	0.71	0.37	0.37	0.37	0.37	-0.16
2	2.775	0.28	0.99	-0.06	0.07	0.05	0.05	0.54

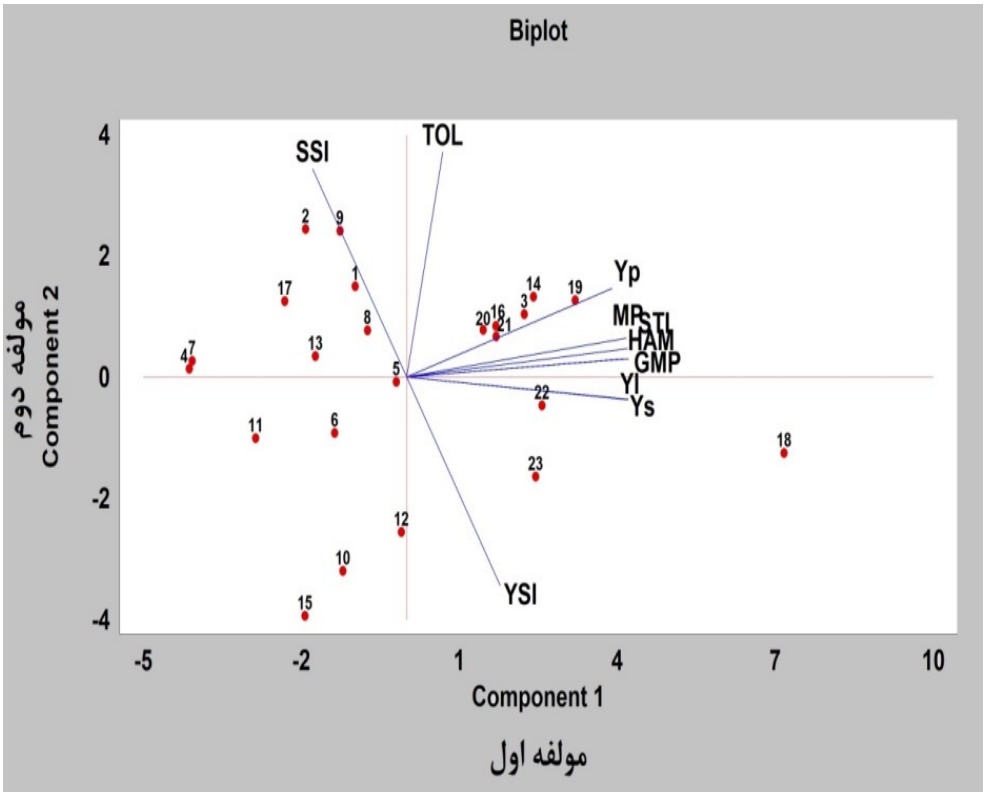

Fig. 1. Biplot graph of durum wheat genotypes based on first and second components

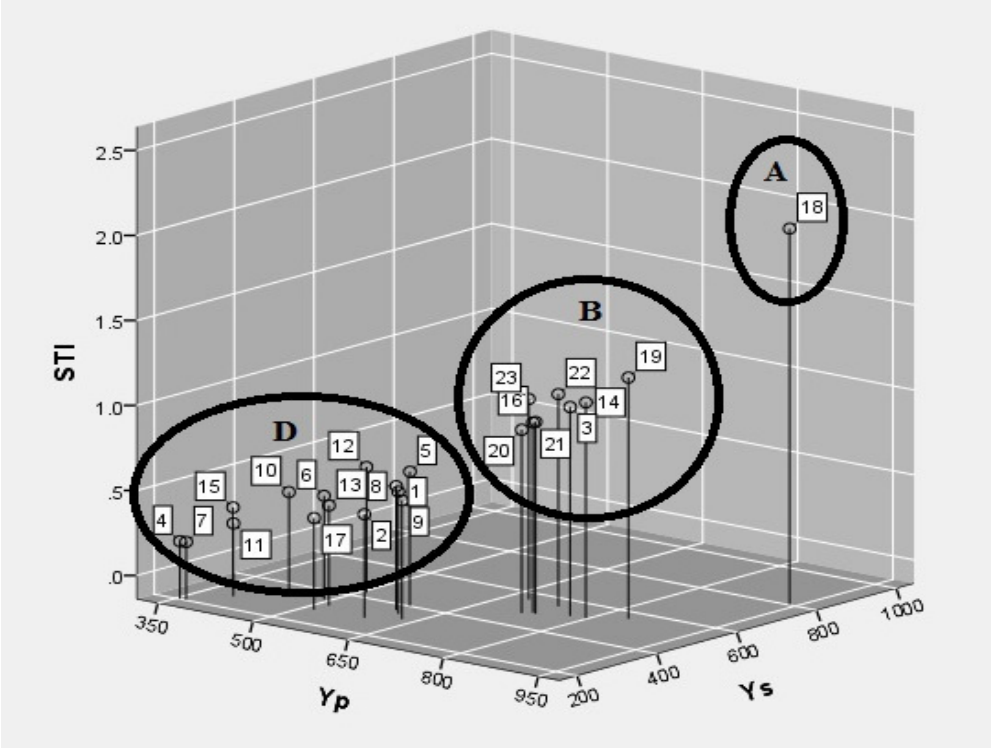

Fig. 2. Three dimensional plot based on STI, Y_p and Y_s indices.

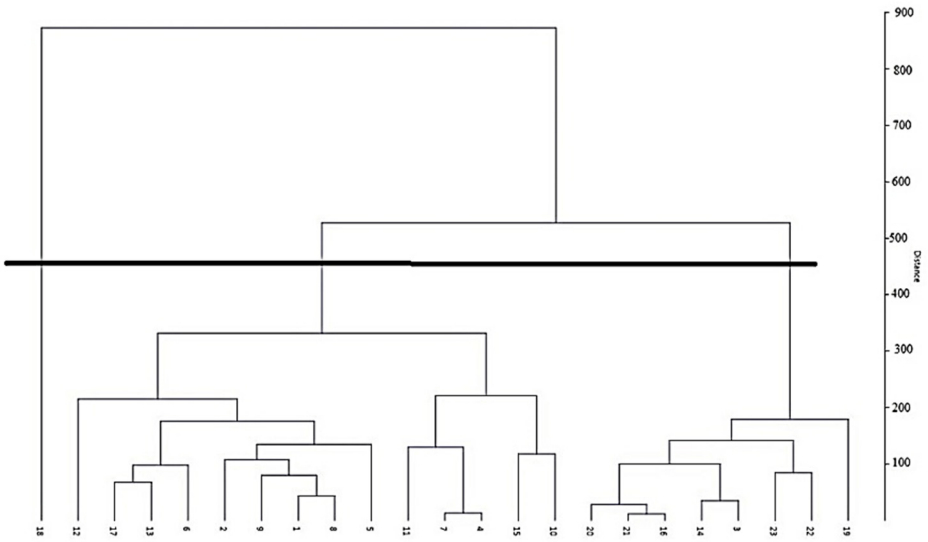

Fig. 3. Dendrogram of cluster analysis based on drought tolerance indices in 23 durum wheat genotypes by UPGMA method