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RESEARCH ARTICLE

Evaluation of drought tolerance indices in corn genotypes (*Zea mays* L.)

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ABSTRACT

In order to evaluate of six corn genotypes for drought stress tolerance an experiment was conducted under field conditions at Satloo station of agricultural research center of west Azerbaijan province in 2010-11 seasons. A strip plot experiment with the based on complete blocks design was carried out at four replications. Three drought stress levels including control, water held at flowering stage and ear emergence arranged as main plots and six genotypes single crosses of 704, 700, 640, 540, 500, and 260 were at subplots. Results analysis of variance showed that for traits of plant height, leaf area, ear length and diameter, grain per row, grain per ear, wood ear weight, 100-kernel weight, harvest index, total dry matter, grain yield and shoot weight under drought stress, genotypes and interaction between them were significantly differences ($p \leq 0.05$). Single crosses of 640 and 704 with 3458 and 3442g/m^2 grain yield at well-watered had the highest amounts and single crosses of 500 and 700 with 1430 and 1406g/m^2 at drought stress of flowering stage were the lowest values. Indices of STI, GMP, MP, and HAR identified genotypes of 640, 540 with 1917 and 2162g/m^2 grain yield as tolerant, and single cross 700 with 1512g/m^2 as a sensitive genotype. HAR index had significant positive correlation with grain yield under drought stress ($r=0.91^{**}$) and it was the best index for identifying drought tolerance genotypes. Principal component analysis showed that two first components explained more than 95% of variations. Also MP and TOL indices with 82% and 77% had the highest coefficients at the first and second components, respectively.

INTRODUCTION

Corn cultivation areas in Iran and west Azerbaijan province were respectively 276 and 31 thousand hectors, in 2011 season (Kaboli, 2012). Water deficit is a serious problem at the growing season in west Azerbaijan province. Therefore, water use efficiency through field management, crop rotation, appropriate density, and drought tolerance genotypes were the best strategies (Kaboli, 2012). Water consumption in agricultural part was 90% in Iran. Therefore, any providence is considered to save water (Tadayyoun and Emam, 2009). Drought stress is one of the main limiting factors of grain crops such as corn (Emam and Niknejad, 2004). Corn cultivation has increased at recent years and used in livestock, poultry feed and raw industrial materials. However, water supply requirement is important in the stages of specific vegetative and generative growth of corn (Sharma and Makherjee, 2005). Adverse effects of water stress on growth and grain yield of corn depend on the time of tension, intensity stress, developmental stage, and type of genotype (Paolo *et al*., 2008). At the developmental stage water deficit has less impact on the final growth, but effective in leaf and shoot expansion and reduced assimilate (Emam, 2007). Water deficit may delay tassel emergence (Alizadeh *et al*., 2007). Drought stress at different growth stages such as flowering stage and ear emergence reduced dramatically of grain yield (Cakir, 2004). Severity stress at final season of growth may be resulted to escape from harmful effects of water deficit at earlier genotypes (Kaman *et al*., 2011; Tadayyoun and Emam, 2009). Larson and Clegg, (1999) in evaluation the effects of drought stress at three stages including before and during flowering and grain filling period of corn concluded that drought stress in each step decreased significantly grain yield. In another experiment concluded that corn at flowering and pollination stages are more sensitive to drought stress (Campose *et al*., 2004). Researchers observed positive significant correlations between grain yield and its components such as grain per ear, number of grain rows and wood ear diameter under drought stress conditions (Ghahfarrokhi *et al*., 2004). Aim of experiment was to investigate the effects of drought stress at different growth stages on grain yield and its components of corn genotypes under Urmia region and identification of tolerant and sensitive genotypes.

MATERIALS AND METHODS

In order to evaluate of six corn genotypes under drought stress tolerance an experiment was conducted under field conditions at Satloo station of agricultural research center of west Azerbaijan province in 2010-11 seasons. A strip plot experiment with the based on complete blocks design was carried out at four replications. Three stress levels including, well-watered, water held at flowering stage and ear emergence arranged as main plots and six single crosses of 704, 700, 640, 540, 500, and 260 were at the subplots. Experiment located in latitude 37°, 44′, 18″ north, longitude 45°, 10′, 53″ east and 1338m altitude. Soil physico-chemical properties were analyzed before sowing (Table 1). Each plot had six rows with length of three meters and between rows 75cm. Spacing plants were 20cm. After sowing plots were irrigated. Irrigation treatments were held at flowering stage and ear emergence. At maturity stage plants per plot harvested and traits of leaf area, number of rows per ear, number of kernel per row, ear length, wood ear weight, 100-kernel weight, grain yield, total dry matter, harvest index was measured. Statistical analysis was used with MSTAT-C, SPSS software. Comparison means was done with Duncan's Multiple Range test. Tolerance indices were calculated as below formulas:

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GMP =√(Ys)(Yp), Fernandez *et al*., (1992)
SSI =1-[Ys-Yp]/SI and SI=1-[Ys/Yp], Fischer *et al*., (1978)
STI =(Ys)(Yp)/$(Yp)^2$, Fernandez *et al*., (1992)
TOL =Yp-Ys, Rosiele and Hamblin, (1981)
HAR=2(Yp.Ys)/(Ys+Yp), Farshadfar, (2002)
MP =(Yp+Ys)/2, Rosiele and Hamblin, (1981)

RESULTS AND DISCUSSION

Analysis of variance showed that between genotypes, drought stress levels and interactions between them for traits of leaf area, grain per row, wood ear weight, 100-kernel weight, harvest index, total dry matter, and grain yield were significantly differences ($p \leq 0.05$). Significant differences between combined treatments showed different behavior of genotypes at different stages of drought stress (Table 2).

Grain Yield and its components

Drought stresses at flowering and ear emergence stages reduced grain yield 12% and 11%, respectively (Table 3). The main reasons reduction of grain yield was due to reducing number of grain per ear, and 100-kernel weight. Held irrigation at final growth stage with reducing leaf longevity decreased assimilates in photosynthetic organs and consequently crop production (Earl *et al*., 2003). The highest grain at rows per ear obtained for 704 and 640 with 53, 49 in well-watered conditions, respectively (Table 3).

Drought stress at flowering stage for single cross 640 had less effect than others. Reducing of grain due to drought stress was resulted non fertilized eggs and consequently kernels decreased. Different irrigation regimes on late maturity genotypes had significantly effects on grain per ear (Ouattar *et al*., 2006). Researchers reported that reduction of grains were due to sterility florets under drought stress conditions (Schussler and Westgate, 2006). Single crosses of 540 and 640 with 155 and 295g had the lowest and highest 100-kernel weight, respectively. Also, at well-watered 100-kernel weight had the highest value with 279g. With closing stomata reduced Calvin cycle enzyme activities under drought stress. It could reduce assimilate production and consequently grain weight (Seilsepoor *et al*., 2006; Cross *et al*., 1991; Lauer, 2003). The highest wood ear weight was allocated for single cross 540 with 742g/m^2 in well-watered conditions and the lowest value was in single cross 700 with 243g/m^2 at flowering stage (Table 3). Mirhadi and Kobayashi, (1999) reported that reduction of wood ear weight under drought stress done at beginning grain filling stage. Researchers showed that drought stress reduced wood ear weight (Mossavat *et al*., 2002; Valad-Abadi *et al*., 2002). The highest leaf area was related to flowering drought stress at single cross 640 with 539cm^2 and single crosses of 704 and 640 had similar values. This increasing may be due to finish vegetative growth at the beginning drought stress. Also the lowest leaf area was allocated to single cross 260 at flowering stress with 294cm^2 (Table 3). Reducing leaf area during different growth stages under drought stress was reported by Stone *et al*. (2001). Single cross of 704, with 18kg/m^2 in the well-watered had the highest total dry

Table 1. Soil physic-chemical characteristics of experiment location from 0-50cm depth

Salinity (%)	pH	Soil saturation (%)	lime (%)	clay (%)	silt (%)	sand (%)	Soil texture	Organic Carbon (%)	Total nitrogen (%)	phosphor (ppm)	Potassium (ppm)
0.8	8	47	16	43	43	16	Clay	1.2	12	12	425

Table 2. Mean square traits of corn cultivars under drought stress conditions

SOV	df	Mean squares						
		Grain yield	100-kernel weight	Grain per row	Wood ear weight	Leaf area	Harvest index	Total dry matter
Replication	3	218796	2638	5	1785	2929	3	8
Stress	2	11532589**	35822**	400**	313350**	1078^{ns}	1098**	63*
Error	6	146755	850	2	5746	7703	7	10
Genotype	5	667507^{ns}	43695**	233**	71528**	43128**	798**	86**
Error	15	284713	3746	6	4473	6620	29	5
Genotype×Stress	15	262483*	3582^{ns}	15**	13279**	5074*	90**	9**
Error	30	110989	1787	5	2309	2336	20	3
Coefficient of variation (%)		14	18	5	11	11	15	12

Ns,*,**: was not significant and significant at 0.05 and 0.01 probability levels, respectively.

Table 3. Mean comparisons of different drought stress levels and genotypes under field conditions

Stress level	Genotype	Leaf area (cm^2)	Grain per row	Wood ear weight (g/m^2)	Grain yield (g/m^2)	Harvest index (%)	Total dry matter (kg/m^2)
Well- watered	704	241be	53a	530bc	3442a	35cd	18a
	700	458bd	41df	444df	2694bc	24eh	14bd
	640	460bd	49b	597b	3458a	35cd	17ab
	540	438be	45c	742a	3073ab	52cd	17ab
	500	400ce	44cd	472cd	2818bc	41bc	11df
	260	367eg	38fg	475cd	2625bc	56a	10f
Flowering	704	467ac	41df	298ij	1914ef	31de	14cd
	700	471ac	31i	243j	1617ef	16ij	12df
	640	539a	4cd	459cd	1785ef	22gi	14cd
	540	393ce	39ef	375eh	1825ef	23fh	12df
	500	380df	33i	298hj	1430f	20hj	11ef
	260	294g	34hi	323gi	1894ef	45b	7g
Ear emergence	704	490ab	43cd	460cd	1809ef	28dg	17a
	700	427be	37fh	285ij	1406f	15j	15ac
	640	496ab	43cd	376fg	2049de	24eh	13ce
	540	471ac	42ce	450de	2500cd	26eh	16ac
	500	418be	39ef	309gj	1836ef	27eh	10f
	260	314fg	34gi	278ij	1850ef	30df	12df

matter. Also, single crosses of 640 and 540 with 17kg/m^2 in well-watered were the same group. Single crosses of 260 in well-watered and 500 under ear emergence stress with 10kg/m^2 had the lowest values (Table 3). The highest harvest index was related to single cross 260 with 43% in the well-watered and lowest value was to single cross 700 with 18% at three conditions (Table 3). Regardless of genotypes, the lowest harvest index obtained with 25% under ear emergence stress which was 12% lower than well-watered. Decreasing of harvest index at flowing stage was due to critical sensitivity at this stage (Cakir, 2004; Farlay, 1999; Schussler *et al*., 2006).

Drought tolerance indices

High values of MP, GMP, HAR and STI indices show tolerant genotypes. Hence, single crosses of 640, 540 and 704 were tolerant (Table 4). In opposite single cross 700 was sensitive.

Correlation coefficients

Indices of STI, MP and GMP were significantly correlated with grain yield under well-watered (Yp) conditions r=0.86*, r=0.84* and r=0.85*, respectively (Table 5). In contrast, indices of STI, MP, and HAR were significantly correlated with grain yield under drought stress (Ys) r=0.84*, r=0.85* and r=0.91**, respectively. Therefore, Based on these indices single crosses of 640, 540 and 704 with 1917, 2162 and 1861g/m^2 grain yield under drought stress conditions identified tolerant genotypes and single cross 700 with 1512g/m^2 grain yield was susceptible. HAR index with the highest positive correlation coefficient with grain yield under stress was the best index for identifying drought tolerance genotypes. Similar results were reported by Yahoueian *et al*. (2008).

Principal component analysis

Under drought stress conditions 95% of cumulative variations were justified by two first components (Table 6). The first and second components had variations 83% and 12%, respectively. First component had high positive coefficients such as grain yield at well-watered (Yp) and indices of SSI, MP. Therefore, it was detached genotypes with high grain yield at well-watered conditions. Second component had high positive coefficients including grain yield under drought stress (Ys) and TOL index. Therefore, this component was named as grain yield under drought stress conditions and identified sensitive genotypes. Genotypes located in the first district of bi-plot had the highest grain yield under well-watered and drought stress conditions (Figure 1). In contrast, genotypes at fourth district had the lowest grain yield in both conditions and were sensitive. Single crosses of 704, 640, 540 and 700 had high values for indices of SSI, Yp and were tolerant. Single crosses of 500 and 260 have been lower values for these indices and introduced as sensitive.

Table 4. values of drought tolerance indices of corn genotypes

Genotype	Yp	Ys	TOL	MP	GMP	SSI	STI	HAR
704	3442	1861	1580	2652	2531	1.00	0.70	2416
260	2625	1872	752	1312	2216	0.72	0.53	2185
700	2694	1512	1182	903	2018	1.00	0.44	1937
500	2818	1633	1185	2225	2145	1.00	0.50	2067
640	3458	1917	1541	2688	2575	1.00	0.72	2467
540	3073	2162	911	2618	2578	0.75	0.72	2538

Table 5. Correlation coefficients of drought tolerance indices in corn genotypes

Index	SSI	STI	TOL	MP	GMP	HAR	Yp
STI	-0.05						
TOL	0.09	0.38					
MP	0.14	0.86*	0.49				
GMP	-0.07	0.99**	0.36	0.86*			
HAR	-0.21	0.98**	0.23	0.83*	0.99**		
Yp	0.44	0.86*	0.79	0.84*	0.85*	0.77	
Ys	-0.57	0.84*	-0.17	0.63	0.85*	0.91**	0.46

Table 6. Principal component analysis for drought tolerance indices in corn genotypes

Component	Variance (%)	Cumulative variance (%)	Yp	Ys	TOL	SSI	MP	GMP	STI	HAR
1	83.56	83.56	0.36	0.16	0.02	0.82	0.24	0	0	0.22
2	12.22	95.78	0.32	-0.44	0.77	-0.13	-0.15	0	0	-0.23

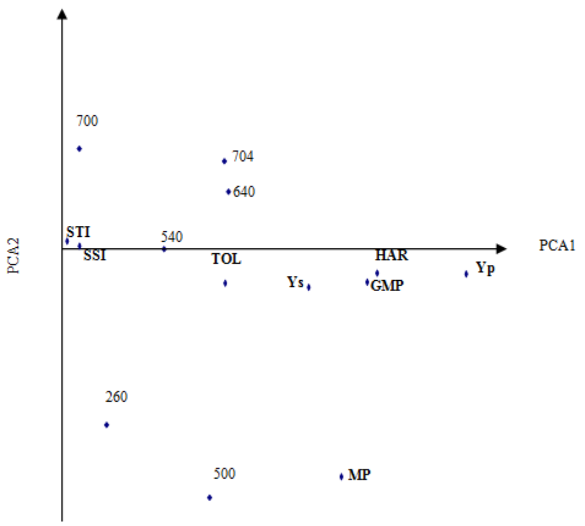

Figure 1- Bi-plot principal component analysis for drought tolerance indices in corn genotypes

Conclusion

Drought stress at both stages reduced grain yield and its components. The highest reduction in grain yield was related at flowering stage. Single crosses of 540 and 704 had the highest grain yield 3458 and 3442g/m^2 under well-watered conditions, respectively. Also, single crosses of 704 with 1914g/m^2 and 540 with 2500g/m^2 had the highest grain yield at flowering and ear emergence stresses. In opposite, single crosses of 700 and 500 were sensitive genotypes at both drought stress conditions. Correlation coefficients between indices and grain yield could be used as an indirect criterion for selecting tolerant genotypes and the best indices. Indices of STI, GMP, MP and HAR were appropriate to identifying tolerant genotypes. Therefore, single crosses of 640, 540 and 704 with 1917, 2162 and 1861g/m^2 had highest grain yield under drought stress conditions. In contrast single cross 700 with 1512g/m^2 grain yield was susceptible. Grain yield at both drought stress (Ys) with indices of STI, MP and HAR with r=0.84*, r=0.85* and r=0.91** was significant positive correlations. Within indices, HAR was the highest value therefore it was the best index for identifying drought tolerance genotypes. Under drought stress conditions 95% of cumulative variations were justified by two first components. First component had high positive coefficients with grain yield (Yp) and indices of SSI, MP and was named grain yield under well-watered conditions. At this component characterized genotypes with high grain yield. The second component had high positive coefficients with grain yield (Ys) and TOL index and it was named component with high grain yield at drought stress conditions.

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