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Assessment of yield and yield components and drought tolerance at end-of season drought condition on corn hybrids (*Zea mays* L.)

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Abstract

In order to study the reaction of ten hybrids of corn to end-of season drought stress, an experiment was conducted following a randomized complete blocks design with four replications. Five indices of dry endurance were calculated for attribute. In normal condition and tension, Bc678 with 7.45 and 5.48 tons per hectare was in the highest rate of performance. The results showed that GMP (Geometric mean productivity), MP (Mean productivity), STI (Stress tolerance index,) indices were introduced better or superior indices because they could separate group A from other groups. After drawing by plot figure of Bc 404, Bc 678, Golden west genotypes by having the most performances or returns in tension and without tension conditions were placed in group A and identified as endurable genotypes. Also ZP, single cross 704, BC 582, 434 genotypes by having the least performance rate in both tension and without tension conditions were placed in group D and identified as sensitive genotypes. Cluster analysis showed that the genotypes, based on TOL (Tolerance Index), GMP, MP, SSI (Stress susceptibility index), YI (yield index), STI and YSI (Yield stability index), tended to group into three groups with 6, 3 and 1 genotypes, respectively. In this analysis, the third group had the highest MP, GMP, YI and STI, and was thus considered to be the most desirable cluster for both growth conditions. The second group had lower Yield in stress condition values. Therefore, the genotype of this group was considered to be stable in rainfed conditions. In the first group, all of the genotypes had high SSI and TOL, thus they were susceptible to drought and only suitable for irrigated conditions.

Keywords: Ardabil, Corn, End season drought, drought tolerance, Yield.
Abbreviation: TOL – Tolerance Index, GMP – Geometric Mean Productivity, MP – Mean Productivity, SSI – Stress Susceptibility Index, YI – Yield index, STI – Stress Tolerance Index, YSI – Yield stability index.

Introduction

Maize (*Zea mays L.*) crop plays an important role in the world and is valuable ingredient in manufactured items that affect a large proportion of the world population (AOQP, 2006). Understanding plant responses to drought is of great importance and also a fundamental part of making the crops tolerant to stress (Reddy et al., 2004; Zhao et al., 2008). The corn crop requires adequate water in all stages of its physiological development to attain optimum productivity. But like other cereal crops, there are some critical growth stages where soil moisture deficiencies greatly affect the productivity. Growers especially those in rainfed farms should know this by heart. Precautions must be taken to prevent loss of crop productivity due to avoidable circumstances (Khayatnezhad et al., 2010). The relative yield performance of genotypes in drought-stressed and favorable environments seems to be a common starting point for the identification of desirable genotypes for unpredictable rainfed conditions (Mohammadi et al., 2010). Some researchers believe in selection under favorable conditions (Betran et al., 2003), others in a target stress condition (Rathjen, 1994) while others yet have chosen a mid-point and believe in selection under both favorable and stress conditions (Byrne et al., 1995; Rajaram and van Ginkel, 2001). Drought resistance is defined by Hall (1993) as the relative yield of a genotype compared to other genotypes subjected to the same drought stress. Drought susceptibility of a genotype is often measured as a function of the reduction in yield under drought stress (Blum, 1988), while the values are confounded with differential yield potential of genotypes (Ramirez and Kelly, 1998). Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between the stress and irrigated environments and mean productivity (MP) as the average yield of yield of genotypes under irrigated (Yi) and rainfed (Yr) conditions. Fischer and Maurer (1978) suggested the stress susceptibility index (SSI) for measurement of yield stability that apprehended the changes in both potential and actual yields in variable environments. Fernandez (1992) defined a new advanced index, the stress tolerance index (STI), which can be used to identify genotypes that produce high yield under both stressed and non-stressed conditions .Other yield-based estimates of drought resistance are mean productivity (MP) and TOL. Clark et al. (1992) applied SSI to evaluate drought tolerance in wheat genotypes and found year-to-year variation in SSI for genotypes and could rank their pattern. In spring wheat cultivars, Guttieri et al. (2001), using SSI, suggested that an SSI > 1 indicated above-average susceptibility to drought stress. Golabadi et al. (2006), Sio-Se Mardeh et al. (2006) and Talebi et al. (2009) suggested that selection for drought tolerance in wheat could be conducted for high MP, GMP and STI under stressed and non-stressed environments. Selection of different genotypes under environmental stress conditions is one of the main tasks of plant breeders for exploiting genetic variations to improve stress-tolerant cultivars (Clarke et al., 1992). The present study was undertaken to assess the selection criteria for identifying drought tolerance in durum wheat genotypes, so that suitable genotypes can be recommended for cultivation in drought-prone areas of Iran.

Among various abiotic stress factors, drought is an important cause of genotype by environmental interactions in maize across years, locations (Löffler et al., 2005; Setimela et al., 2005) and most likely within individual fields (Bruce et al., 2002). Drought is one of the most important abiotic stress factor (Bruce et al., 2002), which affects almost every aspect of plant growth (Aslam et al., 2006). Drought, or more generally, limited water availability is the main factor limiting crop production (Seghatoleslami et al., 2008; Golbashy et al., 2010). However, low heritability of drought tolerance and lack of effective selection approaches limit development of resistant crop cultivars to environmental stresses (Kirigwi et al., 2004). A wide variety of physiological, morphological and molecular traits have been suggested for improving the drought and salinity tolerance of crops since most of them are potentially applicable to maize. Several recent reviews are available (Munns, 2002; Flowers, 2004; Barker et al., 2005; Hasanuzzaman et al. 2009; Hasanuzzaman and Fujita 2011). Moghaddam and Hadi-Zadeh (2002) observed that stress tolerant index (STI) was more useful in order to select favourable corn cultivars under stressful and stress-free conditions. Khalili et al. (2004) showed that based on GMP and STI indices, corn hybrids with high yield in both stress and non-stress environments could be selected. To improve corn yield and stability in stress environments, there is a necessity to identify selection indices able to distinguish high yielding corn cultivars in these situations. Thus, our purpose of the study was evaluation of efficiency and profitability of different selection indices in identification of tolerant cultivars which are compatible with stressful and optimal conditions in Ardabil region, Iran.

Results

Results of ANOVA showed significant differences among hybrids for all of traits in both condition (P<0.01) (Table 2), which demonstrated existence of high diversity among hybrids studied for drought tolerance. Among all hybrids, BC678 (7.45 t ha^{-1}) and BC404 (7.35 t ha^{-1}) had the highest yield under optimal condition and BC678 (5.48 ha^{-1}) and BC404 (5.49 t ha^{-1}) produced the highest yields under stress conditions (Table 3). Results of this experiment also indicated that yield component such as row per ear, kernel per row, kernel per ear, ear length, cob diameter, 1000-kernel weight, plant height, chlorophyll and relative water content were adversely affected in water deficit condition (Table 2) . Endurance indices to tension based on average of performances of genotypes in both calculation conditions are given in Table 3. BC-678 and BC-404 genotypes had the highest performance in complete irrigation condition. These genotypes had also the highest performance rate in tension condition which indicates high potential. Generally, the less sensitivity index of genotype to tension and tolerance, (that is sensitivity of genotype to tension is less, its resistance is more) based on this matter single cross 704 , single cross 647 had the least rate of these indices and identified as endurable or tolerable to tension. Based on YI, MP, STI, GMP indices, high rates of these indices indicate endurance or tolerance of genotypes to tension. Based on this matter BC 404 and BC 678 genotypes were identified as the most endurable or tolerable genotypes. Selected genotypes based on mentioned indices are given in Table 4. Sio-Se et al. (2006) stated, it seems these indices are reliable indices being able to identify high-yielding, drought tolerant genotypes under both environmental conditions (Table 2). Correlation between endurance or tolerable indices to tension has been calculated and given in Table 5. Based on this matter, except SSI and YSI indices, the rest of indices had positive and meaningful correlation in irrigation conditions. Also, except YSI, SSI, TOL indices, the rest of indices indicated positive and high correlation and this means that by increasing performance, above indices increased and caused resistance to tension. Positive and meaningful correlation was observed between STI with YI, MP, GMP and MP with YI, GMP, GMP wit YI and TOL with SSI which by increasing each of these indices, the other index increases. Also negative correlation was observed between YSI with SSI, TOL which by increasing of above indices the rate of this index will be decreased. There were high and significant correlations between GMPand STI (Table 4). Therefore, the results showed that different indices will produce similar results (Table 3). Correlation analysis between endurance or tolerance indices and amount of measured attributes in two separate conditions (Table 6) showed that except cob diameter, row per ear, plant height, the rest of attributes had positive correlation with all of indices except YSI index and this means that which mentioned attributes play a good role according to positive and meaningful correlation with indices in tolerance or resistance to tension and can be used in modification programs for increasing performance and tolerance to tension. Result of this study showed that, kernel number per row could be used as an important trait for prediction of total yield under drought stress. The first two PCAs accounted for about 89.6% of total variation. PCA indicated that the indices could discriminate the corn genotypes. Analyzing to main components for attribute performance by using tolerance or endurance indices to drying in moderate tension condition was calculated or moderate tension condition was calculated or measured (96%). Since three variations were interpretable and deleting other components had very little effect among variations, drawing by plot was done based on these two components. In moderate tension, the first component explained 5.70% of variations and had high correlation with performance in normal conditions and MP, GMP, Harm, SII indices. As a result the first component can be called performance potential which was able to separate hybrids with high performance in tension conditions. The second component explained 82% of variations in moderate tension which had high correlation with performance in tension condition and sensitivity to tension and endurance or tolerance to tension. Thus the second component was called sensitivity to tension. According to these two components, the hybrids were placed inside separated groups based on performance rate and endurance or tolerance to tension and thereby plots were drawn. According to by plot figure, Golden west, BC678, BC-404 genotypes were placed in group A having the highest performance rate in tension

Table 1. List of genotypes studied in this experiment

No.	Genotype	No.	Genotype
1	Single cross 704	6	Single cross 647
2	ZP677	7	Golden west
3	BC582	8	BC678
4	BC666	9	ZP434
5	OS499	10	BC404

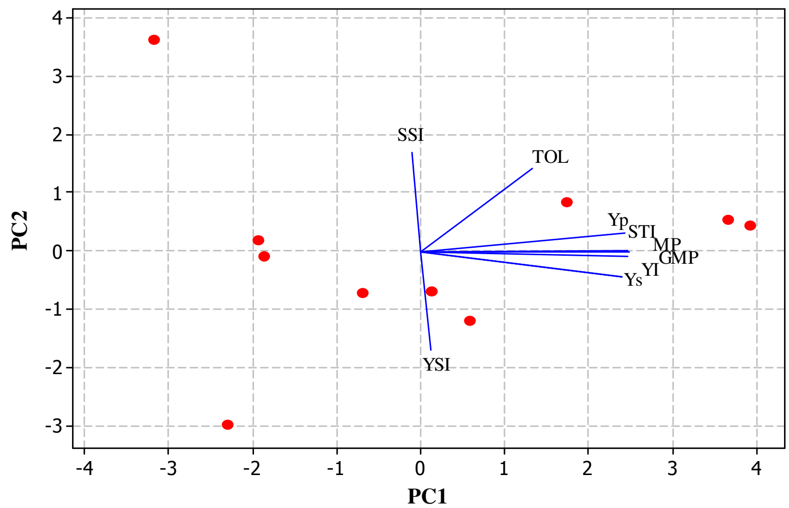

Fig 1. Principal component analysis of drought resistance indices

condition and without tension condition and identified as endurable or tolerant genotypes. Also BC582, single cross 704, ZP43.4 hybrids were placed in group D by having the least performance rate in both tension condition and without tension condition and identified as sensitive genotypes. According to Fernandez (1992) the yield of genotypes in two environments and without drought stress than plants in two environments in this study appears to be divided into four groups:

Group A: The genotypes that have high yield in stress and non stress environments

Group B: The genotypes that have high yield only in non stress environments

Group C: The genotypes that have high yield in stress environments

Group D: The genotypes that have weak yield in stress and non stress environments. Fernandez's (1992) opinion appropriate selection criterion for stress group A criterion that can recognize from other groups. How much higher STI value represents higher drought tolerance of specific genotypes that cause this rise in yield potential is higher than its genotype. These index genotypes of group A group B and C are separated. Selected based on selection index SSI caused some genotypes with low yield but high yield under normal environmental conditions are stressful. The major drawback of this index is able to identify group A, but not the group C. Any differences between the YP and YS is more TOL value increases and this represents the most susceptible to drought and whatever values of this index is lower, will be more favorable. Selection index based on these selected causes some genotypes with low yield potential under stress and high yield under stress is. The index also able to isolate the group A of C is not. GMP less sensitive to the values of YS and YP is very different, whereas the MP index is based on an arithmetic average, when the relative difference between YS and YP is great with unbiasedness will be upwards. Therefore, GMP index compared with the MP index higher separation power than other groups, Group A and on this basis that Fernandez STI index to put on the GMP. Cluster analysis showed that the genotypes, based on TOL, MP, GMP, SSI, YI, STI and YSI, tended to group into three groups with 6, 3 and 1 genotypes, respectively (Fig. 2). In this analysis, the third group had the highest MP, GMP, YI and STI, and was thus considered to be the most desirable cluster for both growth conditions. The second group had lower Yield in stress condition values. Therefore, the genotype of this group was considered to be stable in rainfed conditions. In the first group, all genotypes had high SSI and TOL, thus they were susceptible to drought and only suitable for irrigated conditions.

Discussion

Variation due to genotypes was significant for all characters in two conditions (rainfed and poorly irrigated). This suggested that the magnitude of differences in genotypes was sufficient to provide some scope for selecting genotypes to improve drought tolerance. The mean comparison of traits which was observed in this study in an irrigated site showed that BC678 had the highest grain yield value. This genotype also had the highest Chlorophyll and RWC. This result confirms a previous finding on corn (Khayatnezhad et al., 2010) and durum wheat and bread wheat (Mekliche et al., 1992) that showed the effect of water stress on RWC in

Table 2. Results of Analysis of variance for studied traits

			MS									
	SOV	df	RPE	KPR	KPE	EL	CD	KW	PL	Y	CH	RWC
Irrigated condition	Rep	3	0.09	0.04	6.28	3.5	0.02	2.82	13.12	0.14*	4.09	2.4
	Genotypes	9	0.63**	6.71**	1049.04**	30.74**	0.46**	790.39**	281.88**	4.91**	460.28**	307.02**
	Error	27	0.073	0.23	37.33	1.51	0.046	3.36	11.007	0.045	6.77	2.12
	CV (%)		2.20	2.74	2.89	8.14	7.25	1.09	11.7	3.72	4.61	1.75
stress condition	Rep	3	0.092	0.227	35.46	9.91	5.84	2.82	15.37	0.06	8.7	0.62
	Genotypes	9	0.63**	6.405**	1000.76**	24.33**	45.34**	790.39**	272.35**	2.91**	393.71**	307.78**
	Error	27	0.073	0.185	28.9	5.58	4.809	3.36	10.29	0.094	23.64	3.92
	CV (%)		2.21	10.9	12.58	8.67	11.25	1.17	14.2	7.21	11.04	9.57

* and ** indicates significant at the 5%and 1% levels of probability, respectively
RPE—Row per ear , KPR —(Kernel per row, KPE—Kernel per ear, EL—Ear length, CD—Cob diameter, KW—1000-Kernel weight, PL—Plant height, Y—Yield, CH—Chlorophyll, RWC—Relative water content

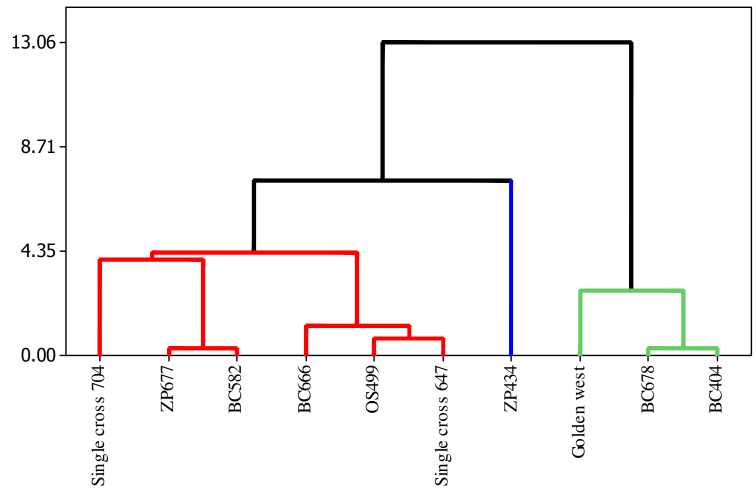

Fig 2. Cluster based on all drought stress tolerance indices

wheat plants. The highest value for GY, TKW, NS, PH and RWC was also found for G14 followed by G13 under rainfed condition. Similar results were reported by del Blanco et al. (2001) and Ozturk and Aydin (2004), who showed positive correlations between TKW and GY in hexaploid wheat.Yield and yield-related traits under stress were independent of yield and yield-related traits under non-stress conditions, but this was not the case in less severe stress conditions. Our results concur partly with observations made by Khayatnwzhad et al. (2010), who reported that the total yield decreased with increasing water deficit. The measurement of total yield components showed that in drought stress condition total yield decline was mainly due to reduction of kernel no. per row and total kernel number per ear (Shoa et al., 2007). Seed weight reduction under drought stress condition might be a result of kernel depth reduction. As STI, GMP and MP were able to identify cultivars producing high yield in both conditions. When the stress was severe, TOL, YSI and SSI were found to be more useful indices discriminating resistant cultivars, although none of the indicators could clearly identify cultivars with high yield under both stress and non-stress conditions (group A cultivars). It is concluded that the effectiveness of selection indices depends on the stress severity supporting the idea that only under moderate stress conditions, potential yield greatly influences yield under stress (Blum, 1996; Panthuwan et al., 2002; Shirinzade et al. 2009) Two primary schools of thought have influenced plant breeders who target their germless to drought-prone areas. The first of these philosophies states that high input responsiveness and inherently high yielding potential, combined with stress-adaptive traits will improve performance in drought-affected environments (Richards, 1996; Rajaram and Van Ginkle, 2001; Betran et al., 2003). The breeders who advocate selection in favorable environments follow this philosophy. Producers, therefore, prefer cultivars that produce high yields when water is not so limiting, but suffer a minimum loss during drought seasons (Nasir et al., 1992). The second is the belief that progress in yield and adaptation in drought-affected environments can be achieved only by selection under the prevailing conditions found in target environments (Rathjen, 1994). Over all, drought stress reduced significantly the yield of some genotypes, which suggested the genetic variability for drought tolerance in this material. Therefore, based on this limited sample and environments, testing and selection under non-stress and stress conditions alone may not be the most effective for increasing yield under drought stress. On the other hand, MP, GMP and STI indices which highly correlated with grain yield in both environments are introduced as the best indices. The significant and positive correlation of Yp and MP, GMP and STI showed that these criteria indices were more effective in identifying high yielding cultivars under different moisture conditions. Similar results were reported by several researchers (Fernandez,

Table 3. Resistance indices of 10 corn genotypes under stress and non-stress environment

Genotype	YSI	YI	GMP	MP	TOL	STI	SSI	Yp	Ys
Single cross 704	0.89	0.9	4.07	4.08	0.49	0.51	0.45	4.32	3.83
ZP677	0.75	0.86	4.2	4.25	1.19	0.55	0.98	4.84	3.65
BC582	0.74	0.84	4.17	4.22	1.27	0.54	1.04	4.85	3.58
BC666	0.78	0.97	4.67	4.71	1.15	0.68	0.87	5.28	4.13
OS499	0.78	1.04	4.99	5.03	1.24	0.77	0.87	5.65	4.41
Single cross 647	0.80	1.09	5.18	5.22	1.13	0.83	0.78	5.78	4.65
Golden west	0.72	1.11	5.57	5.65	1.87	0.96	1.13	6.58	4.71
BC678	0.74	1.29	6.39	6.47	1.97	1.27	1.05	7.45	5.48
ZP434	0.58	0.64	3.59	3.72	1.99	0.4	1.67	4.72	2.73
BC404	0.73	1.27	6.29	6.37	1.96	1.23	1.06	7.35	5.39

Yp – grain yield under irrigated conditions; Ys – Grain yield under rainfed condition, MP – mean productivity , TOL –tolerance, GMP – geometric mean productivity, STI – stress tolerance index, YI – yield index, YSI – yield stability index, SSI – stress susceptibility index

Table 4. The genotypes selected by indices

Selected hybrids	Different indices
BC404,BC678	Select based on YP
BC404,BC678	Select based on YS
Single cross 704, Single cross 647	Select based on TOL
Single cross 704, Single cross 647	Select based on SSI
BC404,BC678	Select based on MP
BC404,BC678	Select based on GMP
BC404,BC678	Select based on STI

1992; Zeynali et al., 2004; Sio Se- Mardeh, 2006; Talebi et al., 2009; Jafari et al. 2009; Mohammadi et al., 2011). Selection based on a combination of indices may provide a more useful criterion for improving drought resistance of wheat although correlation coefficients are useful to find the degree of overall linear association between any two attributes (Golabadi et al., 2006; Talebi et al., 2009). Thus, a better approach than a correlation analysis such as a biplot is needed to identify superior genotypes for both stressed and non-stressed environments. The results of calculated gain from indirect selection in moisture stress environment would improve yield in moisture stress environment better than selection from non-moisture stress environment.

Material and methods

Plant material and drought treatments

Ten corns Genotype were evaluated in a randomized complete block design with four replications in two separate experiments under dryland and supplemental irrigation in 2009–2010 years (Table 1). Each hybrid was hand-seeded in hills, separated 20 cm from each other. There were three rows in each plot, with 7 m in length and 0.6 m row distance. The final plant population was 8.3pl.m-2. Irrigation depth was calculated based on average of soil moisture gravimetric percent in rooting zone (maximum to 60 cm) using Eq. 1 Poor Midani and Ahmad Pour (2006):

$$I = \frac{FC - \theta}{100} \times D \times BD \qquad \text{Eq. 1}$$

at the harvest time, to prevent border effect, 50 cm of each row from both sides were eliminated to harvest and following traits were measured: Row per ear , Kernel per row, Kernel per ear, Ear length, cob diameter, 1000-kernel weight, Plant height, Yield, Chlorophyll, relative water content.

Stress intensity

Stress intensity was (SI=0.2).

Drought indices

Drought tolerance/susceptibility indices were calculated for each genotype using the following relationships:

1. Stress Susceptibility Index (SSI)= $\left[1-\left(Ysi-Ypi\right)\right]/SI$ (Fischer and Maurer, 1978);
2. Stress Tolerance Index (STI) = $\left[Ypi \times Ysi\right]/\left(Yp\right)^2$ (Fernandez, 1992)
3. Tolerance Index (TOL)= $Ypi - Ysi$ (Hossain et al., 1990)
4. Geometric Mean Productivity (GMP)= $\sqrt{\left(Ypi \times Ysi\right)}$ (Fernandez, 1992)
5. Mean Productivity (MP)= $\left(Ypi + Ysi\right)/2$ (Hossain et al., 1990)
6. Yield index (YI)= Ysi/Ys (Gavuzzi et al., 1997)
7. Yield stability index (YSI)= Ysi/Ypi (Bouslama and Schapaugh, 1984)

where, Ysi, is the yield of cultivar in stress condition, Ypi, the yield of cultivar in normal condition, SI that is stress intensity, where:

Table 5. Correlation coefficients between Yp, Ys and drought tolerance indices

	Y_{Pi}	Y_S	SSI	STI	TOL	MP	GMP	YSI	YI
Y_{Pi}	1	0.903**	0.138	0.982**	0.681*	0.982**	0.974**	–0.138	0.903**
Y_S		1	–0.300	0.964**	–0.300	0.968**	0.977**	0.300	1**
SSI			1	–0.045	0.815**	–0.054	–0.090	–1**	–0.300
STI				1	0.537	0.998**	0.997**	0.045	0.964**
TOL					1	0.528	0.497	–0.815**	0.300
MP						1	0.999**	0.054	0.968**
GMP							1	0.090	0.977**
YSI								1	0.300
YI									1

Ypi – grain yield under irrigated conditions; Ys – grain yield under rainfed condition, SSI – stress susceptibility index, STI – stress tolerance index, TOL –tolerance, MP – mean productivity , GMP – geometric mean productivity, , YSI – yield stability index, YI – yield index

Table 6. Correlation coefficients between Stress tolerance indices and measured traits

	YSI	YI	GMP	MP	TOL	STI	SSI	Yp	Ys
Row per ear (i)	–0.15	0.45	0.51	0.51	0.44	0.52	0.15	0.54	0.44
Row per ear (s)	–0.15	0.45	0.50	0.51	0.44	0.50	0.15	0.54	0.44
Kernel per row (i)	–0.15	0.83**	0.91**	0.92**	0.67**	0.92**	0.15	0.94**	0.83**
Kernel per row (s)	–0.22	0.78**	0.87**	0.88**	0.69**	0.85**	0.22	0.91**	0.78**
Kernel per ear (i)	–0.17	0.81**	0.89**	0.87**	0.62**	0.76**	0.21	0.86**	0.79**
Kernel per ear (s)	–0.32	0.68**	0.80**	0.88**	0.69**	0.78**	0.32	0.89**	0.69**
Ear length (i)	0.029	0.74**	0.86**	0.84**	0.46	0.85**	–0.024	0.84**	0.89**
Ear length (s)	–0.05	0.77**	0.82**	0.83**	0.55	0.83**	0.07	0.84**	0.77*
Cob diameter (i)	–0.18	0.40	0.46	0.47	0.43	0.45	0.20	0.51	0.40
Cob diameter (s)	–0.012	–0.29	–0.33	–0.34	–0.28	–0.33	–0.106	–0.35	–0.30
500 kernel weight (i)	–0.04	0.907**	0.95**	0.96**	0.60	0.97**	0.05	0.96**	0.906**
500 kernel weight(s)	–0.04	0.90**	0.95**	0.96**	0.60	0.97**	0.05	0.96**	0.90**
Plant height (i)	–0.36	0.47	0.58	0.59	0.66*	0.61	0.35	0.66	0.47
Plant height (s)	–0.32	0.48	0.57	0.58	0.63	0.60	0.31	0.65*	0.47
Yield(i)	–0.13	0.90**	0.97**	0.98**	0.68**	0.98**	0.13	1**	0.90**
Yield(s)	0.30	1**	0.97**	0.96**	0.3	0.96**	–0.29	0.90**	1**
Chlorophyll (i)	–0.12	0.99**	0.96**	0.97**	0.66*	0.97**	0.12	0.98**	0.89**
Chlorophyll (s)	0.18	0.91**	0.90**	0.90**	0.35	0.88**	–0.18	0.85**	0.91**
RWC(i)	–0.004	0.93**	0.97**	0.98**	0.57	0.97**	0.1	0.97**	0.93**
RWC(s)	0.21	0.85**	0.88**	0.81**	0.47	0.85**	–0.21	0.86**	0.85**

SI= $1-(Ys/Yp)$; Ys, is total yield mean in stress condition, Yp, the total yield mean in normal condition. Among the stress tolerance indices, a larger value of TOL and SSI represent relatively more sensitivity to stress, thus a smaller value of TOL and SSI are favorable. Selection based on these two criteria favors genotypes with low yield potential under non-stress conditions and high yield under stress conditions. On the other hand, selection based on STI and GMP will be resulted in genotypes with higher stress tolerance and yield potential will be selected (Fernandez, 1992).

Statistical analysis

Analysis of variance, mean comparison, correlation between different treatments and cluster analysis of genotypes based on Euclidean distance was computed by MStatC and SPSS16 package. The biplot display was also used to identify tolerant and high yielding genotypes using Minitab16 software, based on principal component analysis.

Conclusion

In this experiment, drought stress had significant effects on maize hybrids yield and its components. BC678 (7.45 t ha^{-1}) and BC404 (7.35 t ha^{-1}) hybrids were the best genotypes under normal condition and BC678 (5.48 t ha^{-1}) and BC404 (5.39 ha^{-1}) showed the best reaction under drought stress condition. In summary, it seems MP, STI and GMP indices have a similar ability to separate drought sensitive and tolerant genotypes. Thus, they can be used to detect the studied genotypes which have low water requirements and/or suffer less yield reduction by water deficits during their growth period, and can be cultivated in regions with limited water resources in order to increase cultivated area and production efficiency. In conclusion, it can be suggested that BC678 and BC404 hybrids should be grown in Ardabil Plains, Iran.

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