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Relationships of Morphological Characters and Yield Components in Corn Hybrids under Water Deficit Stress

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ABSTRACT: A split plot experiment (using RCB design) with four replications was conducted, in order to evaluate the response of some corn hybrids to water stress at field during 2010. Main plots included three different irrigation treatments (Non-water stress, Middle-water stress and Severe-water stress) and sub plots included 14 corn hybrids. In this study correlation, regression, path and principal components analysis were carried out to decide correlations among the agronomic traits and their contributions to seed yield per plant in some new corn hybrids. Correlation analysis indicated that there was the most significant and positive correlation between grain yield and row number per ear, grain number per row, ear height and plant height at the average of irrigation treatments. The results of stepwise regression and path analysis for grain yield revealed that row number per ear, 300 grain weight, grain number per row and number of leaves made 78 percent of the grain yield variation. The row number per ear had the greatest direct and positive effect on grain yield per plant. It is concluded that selection for high grain yield corn hybrids in water deficit stress conditions can be improved through this traits. Factor analysis showed that the first two factors would explain 78 percent of the total variation. This experiment showed that the hybrids K3647 × K18, SC400 and SC500 are more tolerant hybrids to water stress than that of other hybrids.

Keywords: Corn, Factor analysis, Path analysis, Water deficit stress.

INTRODUCTION

Plants are constantly challenged with numerous environmental stresses, both biotic and abiotic. To survive under such conditions, plants have evolved a variety of mechanisms to perceive external stimuli and to transduce the stress signal for activation of the optimal response to each type of stress. A coordinated regulation of plant response requires crosstalk between pathways that are initiated by external cues and orchestrated through a complex network of signaling pathways. There is compelling evidence that stress-responsive genes such as transcription factors or kinases might function in multiple pathways and also facilitate crosstalk between different stress signaling pathways (Quilis et al., 2008; Saibo et al., 2009). Limited water availability impairs plant growth and is one of the main issues of future climate changes (Ciais et al., 2005; Loreto and Centritto, 2008). Because drought is a common occurrence in many environments, many perennial plant species have developed mechanisms to cope with an inadequate water supply (Arndt *et al.* 2001). Thus, adaptation and survival strategies are demanded from plants to persist in their current habitats. As drought stress mainly affects the plant carbon balance, in particular, photosynthesis and respiration, adjustments at the leaf level are of primary importance, while long-term adjustments at the whole plant level may then follow (Chaves et al., 2003; Flexas et al., 2006). Water scarcity, typically accompanied by increasing salinity, is the one of the major causes of poor plant performance and limited crop yields worldwide (Boyer, 1982) and is the single most common cause of severe food shortage in developing countries. Even in most of the agriculturally productive regions, short periods of water deficiency are responsible for considerable reductions in seed and biomass yields each year (Eckardt, *et al.* 2009.

Global climate change, which is increasing temperatures worldwide and changing rainfall patterns, is expected to exacerbate the negative effects of water deficiency in agriculture (Battisti and Naylor 2009).

Maize is the third most important cereal after wheat and rice all over the world serving as staple food for many countries (Frova *et al.,* 1999). Maize crop plays an important role in the world economy and is valuable ingredient in manufactured items that affect a large proportion of the world population. The most serious non-alive stress factor is that limits the growth and crop production (Terzi and Asim Kadioglu, 2006). The pigments can be destroyed by drought, thus causing damage by water shortage to the photosynthetic device (Hendry *et al.,* 1987).

Iran lies in a dry and semi-arid area on the earth, its average annual rain fall is about 230 mm and its falling dispersion in this area (dry and half dry) doesn't satisfy the farming needs, and consequently production is always faced with temporary and constant drought stress, therefore a suitable management is needed to get optimum output in half dry areas and increase the efficiency of land under cultivation (Haydari Sharifabad, 2005).

Maize grown under semi-arid climate of Iran requires supplementary irrigation application to maximize the grain yield. The crop is adapted to tropical, sub-tropical and temperate areas, but little is known about drought stress response within tropical maize cultivars. Reports showed that in semi-arid regions of Iran, drought declines season length (Magorocosho *et al.,* 2003), disturb photosynthesis and assimilate remobilization which finally reduces grain weight (Vaezi and Ahmadikhah, 2010). It has been shown that water shortage declines corn canopy height, leaf area index and root growth (Hirich *et al.,* 2012; Payero *et al.,* 2006). Corn yield components are controlled by many genes which react to the lack of water with different flexibility (Esmailiyan *et al.,* 2008) but it is affected by the environmental condition, either (Farre *et al.,* 2000). Grain yield reduction of maize due to the drought pressure is varied between 1 to 76% depending on the severity, timing and stage of occurrence (Mostafavi *et al.,* 2011; Zarabi *et al.,* 2011; Song *et al.,* 2010). Oktem (2008) found that under water pressure, grain yield was reduced to 37 percent because of 18 percent grain weight reduction and 1 percent reduction in the number of seeds.

Several reports of physiological, morphological and molecular traits have been suggested for improving the drought and salinity tolerance of crops that many of them potentially applicable to maize. Several recent reviews are available (Barker *et al.,* 2005; Flowers, 2004, Munns, 2002 and Hasan uzzaman and Fujita, 2011). No exact figures on yield and economic losses in maize due to drought are available. Heisey and Edmeades (1999) estimated that 20 to 25% of the global maize planting area is affected by drought in any given year. In maize, grain yield reduction caused by drought ranges from 10 to 76% depending on the severity and stage of occurrence. Drought stress coinciding with flowering delays silking and results in an increase of anthesis-silking interval (Bolaòos *et al.,* 1993); this usually associates with reduction in grain number and yield (Edmeades *et al.,* 1993).

Productivity is a complex character, and influenced by many characters and controlled by multiple factors that interact with genotypes and environmental conditions (Kashiani *et al.,* 2010; Zilio *et al.,* 2011). For expression of high levels of production, the corn crop depends, in addition to proper management techniques, the interaction of genetic material, with the soil and climatic conditions (Duvick, 2005). In corn, variations in the choice of cultivar and the interactions with the environment may represent half of the productivity (Cruz, *et al.,* 2005). For the purpose of crop production and yield improvement, development of drought tolerant varieties is the best option (Siddique *et al.,* 2000). Water availability mostly affects growth of leaves and roots, photosynthesis and dry mater accumulation (Blum, 1996).

Corn is very susceptible to drought damage due to the plants requirement for water for cell elongation and its inability to delay vegetative growth (Heinigre, 2000). Yield is reduced when evapotranspiration demand exceeds water supply from the soil at any time during the corn life cycle. Corn yield is most sensitive to water stress during flowering and pollination, followed by grain filling and finally vegetative growth stages (Lauer, 2003).

Correlation studies are also very useful to plant breeders for improving drought tolerance in the sense that, any physiological or yield trait having high heritability could be used as indirect selection criteria to improve yield in water-deficit environments. Path Analysis is a multivariate technique to explain direct and indirect impacts between variables. Path coefficient analysis has been being used successfully to illustrate interrelation between yield and other traits for many crops such as maize, soybean, field bean and rapeseed (Khazaei *et al.,* 2010). Different researches have been conducted for determining the phenotypic and genotypic correlation between important agronomic traits and corn yield. However association between these features and grain yield is vital but computing of correlation coefficient does not specify the essence of relationship between features (Vaezi *et al.,* 2000).

Rosielle and Hamblin (1981) believed that selection based on yield under stress condition led to selection of genotypes with low yield in non-stress condition. Blum *et al.,* (1980) stated that drought stress caused reduction of genetic variance and yield heritability which restricts efficiency of selection for yield under stress situation. Some researchers claimed that selection for higher yield under non-stress condition caused improvement of this feature under stress situation and vice versa, selection for drought tolerance led to yield reduction at sowing in non-stress condition (Vaezi and Ahmadikhah, 2010).

The main goal of the present research is to recognize and present the hybrids of maize which withstand the water deficit situations by having the suitable efficiency and suitable resistant under the different normal and stress environments.

MATERIALS AND METHODS

A split plot experiment (using RCB design) with four replications was conducted in 2010 at the Research Farm of the Faculty of Agriculture, University of Tabriz, Iran, in order to determine response of some corn hybrids to water stress. Irrigation treatments (NWS: non-water stress, MWS: middle water stress and SWS: severe water stress) were located in main plots and 14 corn hybrids were allocated to sub plots. Hybrids have been listed in the Table 1.

Table 1: Names of maize hybrids studied at different levels of irrigation.

Hybrid No.	Name of Hybrids	Hybrid No.	Name of Hybrids	Hybrid No.	Name of Hybrids
1	SC700	6	SC670	11	K48xK19
2	SC704	7	SC647	12	SC500
3	KSC705	8	SC604	13	K3647xK18
4	SC706	9	K166 x K18	14	SC400
5	SC702	10	DC370		

Seeds of corn hybrids were sown by hand on 6 June 2010. Different water stress treatments (I1, I2 and I3; 40, 70 and 120 mm evaporation from class A pan, respectively) applied after completing the pollination. Several morphological traits were measured under control and water stress conditions. Data were recorded on 10 competitive plants of each plot and grain yield (kg ha^{-1}) and yield component was calculated for the entire plot. Some of the studied traits were: Number of leaves per plant (NLP), 300-grain weight (W300), number of rows per ear (NRE), number of seeds per row (NSR), ear length (EL), flag leaf area (FLE), ear diameter (ED), cob diameter (CD), plant height (PH), plant dry weight (PDW) and grain yield (GY).

For statistical analysis of each characteristic, Excel, SPSS and Minitab soft wares were used. Duncan multiple range test was applied to compare means of each trait at 5% probability.

RESULTS AND DISCUSSION

Plant breeders work with some yield components related to yield in the selection programs and it is very important to determine relative importance of such characters contributing to yield directly or indirectly. Correlation and path coefficient analyses can assist to determine certain characters to be used in the improvement of the complex character such as yield (Joshi, 2005).

In the present study, grain yield had a positive-significant correlation with number of rows per ear (0.85), number of seeds per row (0.69), number of leaves per plant (0.68), ear length (0.64) and plant height (0.58) (Table 2). It was reported that there was a correlation between grain yield and ear dimension, ear weight, number of seeds per ear and 1000-grain weight (Palta *et al.,* 2011; Khazaei *et al.,* 2010). Alvi *et al.* (2003) and Najeeb *et al.* (2009), also found strong association between grain yield and number of seeds per row. Results of a number of researches and studies show that there is a significant positive correlation between grain yield and the plant height, ear height, ear diameter, ear cob diameter, number of rows per grain, number of grain per ear, 1000-grain weight (Nemati *et al.,* 2009 and Viola *et al.,* 2003). Therefore, these traits have considerable importance for the increase in grain yield on maize hybrids (Nemati *et al.,* 2009).

Stepwise regression and path analysis indicated that number of row per ear (X1), 300-grain weight (X2), number of seeds per row (X3) and Number of leaves per plant (X4) explained 83% of the variance in yield standard deviation (Table 3).

Shoae Hosseini *et al.* (2008) in a study using simple correlations and stepwise regression reported under water stress, ear diameter, number of seeds per row and ear length and in normal condition grain depth, number of seeds per row and plant height were useful for the determination of an increase in grain yield. Khayatnezhad *et al.* (2010) reported that 500-grain weight had the most positive correlation (r=0.98**) with grain yield. After this trait, number of seeds per row and ear length show the most significant correlation with grain yield (r=0.94** and r=0.89**). Similar results were also reported for number of seeds per row (Mohan *et al.*, 2002) and for 100-seed weight (Venugopal *et al.*, 2003).

Table 2: Correlation coefficients between the traits of maize hybrids in moderate levels of water stress.

Traits	W300 (gr)	PH (cm)	EL (cm)	ED (cm)	CD (cm)	PDW (gr)	FLA (cm)	NSR	NLP	NRE
PH (cm)	0.75^{**}									
LE (cm)	0.77^{**}	0.88**								
ED (cm)	0.75**	0.77**	0.76**							
CD (cm)	-0.59*	-0.36^{ns}	-0.55*	-0.51^{ns}						
PDW (gr)	-0.33^{ns}	-0.42^{ns}	-0.24^{ns}	-0.31^{ns}	-0.22^{ns}					
FLA (cm)	0.77**	0.71**	0.90**	0.69**	-0.54*	-0.26^{ns}				
NSR	0.18^{ns}	0.26^{ns}	0.35^{ns}	0.11^{ns}	-0.27^{ns}	0.33*	0.36^{ns}			
NLP	-0.53*	-0.87**	-0.58*	-0.48^{ns}	0.29^{ns}	0.40^{ns}	-0.58*	0.38^{ns}		
NRE	0.12^{ns}	-0.59*	-0.35^{ns}	-0.19^{ns}	0.07^{ns}	0.29^{ns}	-0.32^{ns}	0.34^{ns}	0.86**	
GY (gr)	0.43^{ns}	0.58*	0.64*	0.11^{ns}	-0.21^{ns}	0.24^{ns}	0.10^{ns}	0.69**	0.68**	0.85**

ns . *,** : non-Significant, Significant at 0.05 and 0.01 probability level, respectively.

Table 3: Multiple regression analysis for grain yield as dependent variable and the other studied traits as an independent variable y in maize hybrids on the average stress levels.

Model	Regression	Adjusted R^2	Durbin-Watson
1	$Y= -55.57+14.56 X_1$	0.623	
2	$Y= -224.08+13.51 X_1+2.43 X_2$	0.750	
3	$Y= -274.51+11.236 X_1+2.15 X_2+2.483 X_3$	0.810	
4	$Y= -2.862+8.43 X_1+2.32 X_2+2.34 X_3+3.642 X_4$	0.835	2.42

Y= yield, X1= number of row per ear, X2= 300-grain weight, X3= number of seeds per row and X4= number of leaves per plant.

Path coefficients under water stress revealed that number of row per ear had the highest effect (0.458) on total yield followed by 300-grain weight (0.345), number of seeds per row (0.286) and number of leaves per plant (0.182), respectively. These traits had high correlation with yield. Thus, number of row per ear, 300-grain weight, number of seeds per row and number of leaves per plant may significantly influence grain yield of corn hybrids (Table 4). Khazaei *et al.* (2010) reported that 100-grain weight and number of grains had the highest direct effective on grain yield. However, Selvaraj and Nagarajan (2011) on interrelationship and path coefficient analysis in corn revealed that direct selection for ear length and number of rows per ear are effective for yield improvement. Mohan *et al.* (2002) studied path analysis on corn cultivars for grain yield and oil content and reported that 100-grain weight and ear length had direct effect on grain yield, in contrast the effect of plant height had the lowest effect on grain yield.

Table 4: Direct and indirect effects of different characters on grain yield per plant in drought stress condition.

Grain yield per plant	Direct effect	Indirect effect through				Correlation with Yield
		NRE	300W	NSR	NLP	
Number of Row per Ear (NRE)	0.458	-	0.054	0.122	0.155	0.790
300-Grain Weight (300W)	0.345	0.071	-	0.057	0.003	0.477
Number of Seeds per Row (NSR)	0.286	0.196	0.069	-	0.077	0.629
Number of Leaves per Plant (NLP)	0.182	0.390	0.005	0.121	-	0.699

Table 5 shows the mean and standard deviation of the total mean for each group based on all the studied traits. In the first group, hybrids had the highest 300-grain weight, plant height, ear length, flag leaf area and ear diameter but, these hybrids had minimum plant dry weight, cob diameter, number of seeds per row, number of leaves per plant, number of rows per ear and grain yield.

Table 5: The mean and standard deviation of the total mean on some of the studied traits.

Group		W300 (gr)	PH (cm)	EL (cm)	PDW (gr)	ED (cm)	CD (cm)	NLP	NRE	NSR	FLA (cm^2)	GY (gr)
1	Mean	77.78	197.67	20.31	110.16	4.92	2.71	11.72	14.02	41.68	237.99	153.18
	Deviation of the Mean	3.21	2.72	3.30	-4.04	1.64	-1.35	-6.51	-3.09	-0.85	8.87	-1.26
2	Mean	71.00	182.99	18.49	123.16	4.69	2.81	14.02	15.28	42.69	183.65	158.70
	Deviation of the Mean	-5.78	-4.90	-5.94	7.27	-2.96	2.43	11.71	5.57	1.54	-15.98	2.28
Total Mean		75.36	192.43	19.66	114.80	4.841	2.747	12.52	14.47	42.04	218.58	155.15

In further evaluation of relations between genotypes and all studied traits, principal components analysis was performed (Table 6). Table 7 shows eigenvectors of studied hybrids for two first components which justified 78% of the variations between data expressed by two components. The results showed that the first factor had the great coefficient on 300-grain weight, plant height, length of ear, flag leaf area, ear diameter and cob diameter. The second factor had the great coefficient on plant dry weight, number of seeds per row, number of leaves per plant, number of rows per ear and grain yield. By attention to identity of justified traits by each one of the factors, the first factor was called as the morphological-growth characteristics and the second factor was called as the application factor.

The principal components analysis was drawn to reviewing relationships between variables based on biplot first and second components (Fig. 1).

Table 6: Principal component analysis on the different traits of maize hybrids.

Component	Cumulative percentage of the eigenvalues	Component share (percent)	Eigen value
The first Component	50.8	50.8	10.154
The second Component	78.00	27.2	5.441

Table 7: Eigenvector of the first and second components with measured variables in the principal components analysis.

Component	W300 (Y1)	PH (Y2)	EL (Y3)	PDW (Y4)	ED (Y5)	CD (Y6)	NLP (Y7)	NRE (Y8)	NSR (Y9)	FLA (Y10)	GY (Y11)
The first Component	0.276	0.268	0.294	-0.090	0.266	-0.203	-0.218	-0.114	0.046	0.292	0.006
The second Component	0.052	-0.175	0.039	0.169	0.025	-0.106	0.295	0.362	0.308	0.036	0.419

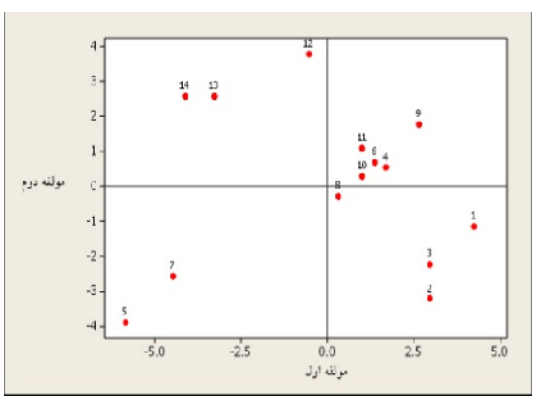

Fig. 1. Bi-plot of the first component in front of second component for evaluated hybrids.

The horizontal axis was related to first component and the vertical axis was related to the second component. Based on component values, the location of genotypes and their grouping were determined in top of bi-plot. Hybrids SC706, SC670, K166 × K18, DC370 and K48 × K19 were placed in area A and had high growth and yield, while the hybrids SC702 and SC647 were in area D, and from both factors had the less value and less application and growth. Hybrid SC500 had the most value from the yield point of view and was presented as the most efficient hybrid. Hybrids K3647 × K18 and SC400 were near the area D and faced with less reduction in yield. Hybrids SC700, SC704, KSC705 and SC604 were in area C; that is, they were in high level with growth factors but in low level with the yield.

CONCLUSION

In the present study, grain yield had a positive-significant correlation with plant height, ear length, number of rows per ear, number of seeds per row and number of leaves per plant. Number of rows per ear had the highest correlation with grain yield. Multiple regression analyses determined that number of row per ear, 300-grain weight, number of grain per row and Number of leaves per plant explained 83% of the variance in yield standard deviation. Path coefficients in water stress condition revealed that number of row per ear had highest direct effect (0.458) on total yield. Based on principal components analysis two first components justified 78% of the variations between data expressed by two components. By attention to identity of justified traits by each one of the factors, the first factor was called as the morphological-growth characteristics and the second factor was called as the application factor. Hybrids SC706, SC670, K166 × K18, DC370 and K48 × K19 had high growth and yield, while the hybrids SC702 and SC647 were had the less value and less application and growth. Hybrid SC500 had the most value from the yield point of view and was presented as the most efficient hybrid.

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