Genetic evaluation of maize (*Zea mays* L.) accessions under drought stress

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The present study pertaining to the estimation of genetic parameters and characters association in eighty maize genotypes was conducted in the glasshouse of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, during the crop season in Fabruary 2011. The highest genotypic coefficient of variance was found for fresh root length, the highest value of heritability was found for chlorophyll contents and path coefficient analysis showed that fresh root length had maximum direct effect on fresh shoot length followed by dry root weight, root density, leaf temperature and dry shoot weight under drought stress. It was concluded that fresh root length, dry root weight, root density, leaf temperature and dry shoot weight are the characters which contribute largely to fresh shoot length of maize seedlings and selection can be made on the basis of these characters.

Keywords: *Zea mays,* path coefficient, correlation, heritability, genotypic, phenotypic, Pakistan

INTRODUCTION

Maize ranks third among the cereal crops worldwide after wheat and rice. In Pakistan, maize is grown on an area of 950 thousand hectares with total production of 3487 thousand tons (Anonymous, 2009-10) with an average yield of 2892 kg ha^{-1}.It is consumed as food by human and feed for the livestock and poultry. It also fulfills the requirement of raw material in food, medicine and textile industries, which finally manufacture corn oil, corn flakes, dextrose, textile dyes etc. A plant may experience biotic and abiotic stresses in the field like diseases attack, water scarcity, water logging, salinity, high and low temperature extremes, etc., either continuously or with some breaks at different times during the growing season (Tester and Bacic, 2005). Abiotic stresses limit crop productivity (Araus et al., 2002: Boyer, 1970). Among various abiotic stresses drought is undoubtedly one of the worst natural enemy of life. It can occur in any region of the world, and can affect life from very basic personal inconvenience to nationwide. Drought can reduce crop yield, pasture deterioration and death of livestock. It strongly affects the production of cereals, and poses a serious threat to the food security of households. World food security is dependent on continuous crop improvement in particular; the development of crops with increased tolerance to abiotic stresses especially drought and salinity (Denby and Gehring, 2005). The maize was grown at three levels of water availability (100, 75, or 60% of daily transpiration) during a period bracketing silking and at two plant densities (6 and 10 plants m^{-2}) without nutrient limitations to generate a range of levels of resource availability of water (Echarte and Tollenaar, 2006). A study for water stress at 3 growth stages before silking, at silking and during grain filling growth stages caused a significant reduction in the different growth parameters studied at 90 days after planting as compared with the normal irrigation regime (Ghooshch, *et al*., 2008). Chlorophyll content measurements were performed on each leaf of several plants along the crop cycle (Moulin, *et al*., 2009). Those measurements, as well as the surface measurements and the leaf insertion height measurements gave the vertical distribution of

Table 1. Estimates of genetic components for maize genotypes

Traits	Genotypic Coefficient Variation %	Phenotypic Coefficient Variation %	Standard Deviation	Genotypic Variance	Phenotypic variance	Broad sense Heritability $h^2_{BS\%}$
Leaf temperature	2.991	4.451	0.546	0.932	2.341	65.10
Chlorophyll contents	125.491	134.41	0.017	0.321	0.326	99.22
Fresh Shoot length	17.521	17.145	3.012	78.45	83.441	91.98
Root density	233.45	48.54	0.635	4.211	4.345	81.41
Fresh root length	231.41	49.63	0.632	4.32	5.352	81.19
Root-shoot length ratio	14.32	24.51	0.059	0.012	7.574	60.95
Dry shoot weight	15.39	27.213	0.158	0.056	6.140	63.40
Dry root weight	36.34	35.456	0.115	0.033	0.058	68.20
Root-shoot weight ratio	8.945	23.964	0.19	0.0018	0.096	66.20

chlorophyll pigments within the canopy.

MATERIALS AND METHODS

The proposed study was carried out in the glasshouse of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad to evaluate the maize genotypes for drought tolerance. The experimental material was consisting of 80 accessions including ten check varieties namely: F-121, F-128, F-150, F-142, F-151, F-118, F-117, F-130, F-140, F-143, F-113, F-111, F-114, F-136, F-122, F-134, F-147, F-105, F-148, F-146, B-303, B-316, B-306, B-303, B-313, B-314, B-305, B-321, B-326, B-308, B-304, B-312, EV-344, EV-343, EV-310, POP/209, EV-342, EV-347, F-96, EV-324, EV-335, EV-323, EV-334, EV-330, EV-329, EV-338, EV-340, E-349, E-352, E-341, E-351, E-322, E-346, E-336, BF-337 BF-248, BF-212, BF-236, BF-238, F-98, B-96, F-135, VB-06, B-121, B-15, B-11, Sh-213, Sh-139, SWL-2002, Sawan-3, Pak-Afgoee, Gold Isalamabad, Islamabad W, VB-51, EV-1097, EV-7004Q, Raka-Poshi, BS-2 and POP/2007. These accessions were sown in polythene bags (18 × 9 cm) filled with sandy loam soil (pH 7.8 and EC 1.7 dS m^{-1}) in the glasshouse of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. Field capacity of the soil was determined before sowing. Two seeds per polythene bag were sown and thinned up one healthy seedling after emergence. All the recommended agronomic and cultural practices were carried out. The moisture level was maintained in order to create water stress by volume on alternate days by using moisture meter (∆T-NH2, Cambridge, England). The data was analyzed statistically using analysis of variance technique (Steel *et al.* 1997) and Duncan Multiple Range (DMR) test at 1% significance level was used to compare the treatments means. The data was recorded for fresh shoot length, fresh root length, root density, leaf temperature, chlorophyll contents, dry shoot weight, dry root weight, root/shoot length ratio and root/shoot dry weight ratio. Genotypic and phenotypic correlations were calculated to observe the association between different traits (Kwon and Torrie, 1964). Path coefficient analysis were performed (Dewey and Lu, 1959) to assess the direct and indirect effects on fresh shoot length using genotypic correlations where association of all the above traits were calculated by keeping one at a time as response variable and other contributing traits as causal variables.

RESULTS AND DISCUSSION

The genetic parameters as indicated in Tables 1, it is clear that the higher genotypic variance for FSL, RD and FRL as 78.45, 4.211 and 4.32 but lowest for RSLR and RSWR 0.012, 0.0018 while higher phenotypic variances were for FSL, RSLR and DSW as 83.441, 7.245 and 6.211 respectively, while lowest for RSWR and Chl.C was 0.059 and 0.311 respectively. The highest genotypic coefficients of variability was for FRL, RD and Chl.C as 231.41%, 233.45% and 125.491% while lowest for LT and RSWR as 1.871% and 8.945%. The highest phenotypic coefficient of variability was for Chl.C and FRL as 134.41 and 17.145% respectively, while lowest for LT (4.451%). The highest value for standard deviation was for FSL as 3.012 and lowest for Chl.C as 0.017. The higher values of genotypic variance and genotypic coefficient variance indicated that these traits can be use for selecting higher yielding maize genotypes. The same results were by Ojo *et al.* (2006). The highest heritability values were found for Chl.C, FSL, FRL and RD as 99.22%, 91.98%, 81.41% and 81.19% respectively while RSLR showed lowest heritability value as 660.45%. The higher values of heritabilities indicated that selection can be made on the bases of these traits.

Table 2a. Genotypic correlation for different traits of maize genotypes

Variables	Chl.C	DRW	DSW	FRL	LT	RD	RSLR	RSWR
DRW	-0.0652							
DSW	0.0282	0.2985**						
FRL	0.0332	0.0450	0.1917					
LT	-0.6586**	-0.492**	-0.2842**	-.4560**				
RD	0.8135**	-0.2427 **	-0.4916**	-.3843**	-0.7127**			
RSLR	-0.0813	-0.1443	-0.1104	0.6543**	0.7914**	-0.4607*		
RSWR	-0.1602	-0.6246**	0.5633**	0.6211**	0.4312*	-0.4512*	0.6779**	
FSL	0.1224	0.4549*	0.7214*	0.5916*	0.4525*	0.7014*	-0.3356*	0.8145*

DRW = Dry root weight, DSW = Dry shoot weight, FRL = Fresh root length, LT = Leaf temperature, Chl.C = Chlorophyll contents, RD = Root density, RSLR = Root-shoot length ratio, RSWR = Root-shoot weight ratio, FSL = Fresh shoot length, * = Significant, ** = Highly Significant.

Table 2b. Phenotypic correlation for different traits of maize genotypes

Variables	Chl.C	DRW	DSW	FRL	LT	RD	RSLR	RSWR
DRW	-0.0471							
DSW	0.0212	0.5748**						
FRL	0.0341	0.2121	0.2014					
LT	-0.5886**	-.0436 **	-0.4528**	-0.7134**				
RD	0.6862 **	-0.4796**	0.7118 **	-0.5586**	-0.4978**			
RSLR	-0.064	-0.0187	-0.1414	0.5868 **	0.7546**	-0.8012**		
RSWR	-0.0614	0.4854 **	-0.4753**	-0.5535**	-0.7455**	-0.6161**	-.0312	
FSL	0.1442	0.5684 **	0.5775 **	0.4367 **	-0.5017**	0.6541 **	-0.3425*	-.2108*

DRW = Dry root weight, DSW = Dry shoot weight, FRL = Fresh root length, LT = Leaf temperature, Chl.C = Chlorophyll contents, RD = Root density, RSLR = Root-shoot length ratio, RSWR = Root-shoot weight ratio, FSL = Fresh shoot length
* = Significant, ** = Highly Significant.

Correlations

Correlation is the measure of the extent of relationship occurring between two or more independent variables. Correlation analysis in plant breeding reveals the relative importance of different plant traits, which can be of value in a crop breeding programme.

Negative and significant correlation coefficient of leaf temperature with root density and fresh shoot length at genotypic and phenotypic levels but negative and significant with root-shoot weight ratio at phenotypic level (Table II a, b). A positive and significant correlation coefficient of chlorophyll contents with root density at genotypic and phenotypic levels. There was found a negative but significant correlation coefficient of chlorophyll contents with leaf temperature both at genotypic and phenotypic levels. Correlation coefficient of fresh shoot length (FSL) with dry SW, dry RW, Fresh RL, RSW ratio, LT, root density at genotypic and phenotypic levels was positive and significant. RD showed positive and significant correlation coefficient with fresh shoot length

Table 3. Direct (In Parenthesis) and indirect effect of various traits on FSL

Variables	Chl.C	DRW	DSW	FRL	LT	RD	RSLR	RSWR
Chl.C	(-0.4874)	-0.2413	0.0247	0.0345	-0.1344	0.6121	0.0234	0.0254
DRW	0.045	(0.2143)	0.6242	0.3411	-0.0445	-0.1112	0.1147	-0.3455
DSW	-0.0743	0.1237	(0.5746)	0.5434	-0.0354	-0.0241	0.0234	-0.3354
FRL	-0.0421	0.0724	0.3234	(0.7848)	-0.0412	-0.0242	-0.4447	-0.0254
LT	0.3425	-0.0423	-0.0234	-0.0341	(0.4543)	-0.5411	-0.0435	-0.0425
RD	-0.2420	-0.0752	-0.0752	-0.0347	-0.2421	(0.7304)	0.1364	0.0525
RSLR	0.0234	-0.0224	-0.0524	0.2354	0.0121	-0.1241	(-0.7141)	-0.0561
RSWR	0.0534	0.1742	0.3721	0.0374	0.0231	-0.1124	-0.0434	(-0.6432)

DRW = Dry root weight, DSW = Dry shoot weight, FRL = Fresh root length, LT = Leaf temperature, Chl.C = Chlorophyll contents, RD = Root density, RSLR = Root-shoot length ratio, RSWR = Root-shoot weight ratio, FSL = Fresh shoot length

(FSL) at genotypic and phenotypic levels. Fresh root length (FRL) indicated a positive and significant correlation coefficient with dry SW, dry RW and Fresh SL at genotypic and phenotypic levels. The same results were by Ojo *et al.* (2006). Dry shoot weight (DSW) was positively and significantly correlated with RSW ratio, FSL and Fresh RL at genotypic and phenotypic levels. There was a positive and significant correlation coefficient of dry root weight (DRW) with DSW, FSL and Fresh RL at genotypic and phenotypic levels. There was found a negative but significant correlation coefficient of dry root weight (DRW) with RD and LT both at genotypic and phenotypic levels. The same results were by Ojo *et al.* (2006) and Yousuf and Saleem (2001). The Table (Table II a, b) indicated that a positive and significant correlation coefficient of root-shoot weight ratio (RSW ratio) with all traits except RD at genotypic but negative at phenotypic levels. A positive and significant association occurred between RSW ratio and DRW at both phenotypic levels. The same results were by Ojo *et al.* (2006) and Malik *et al.* (2005).

Path coefficient

When several variables are mutually correlated in some complicated means like crop yield and its components, simple correlation coefficients provide incomplete information about the nature of the association. Thus by simple correlation coefficients a breeder, searching for high degree components of yield, upon which his entire success for a certain programme depends, may be misled. From Table III, which indicates that the direct effect of leaf temperature on fresh shoot length was positive (0.4543) whereas FSL has negative indirect effects through FRL, RD, RSL ratio DRW, DSW and RSWR while Chl.C have positive indirect effects on FSL. The positive direct effects indicated that selection can be made on the basis of leaf temperature for fresh shoot length. The direct effect of Chl.C on fresh shoot length was negative (-0.4874) whereas Chl.C has negative indirect effects through LT and DRW while all others have positive indirect effects on FSL. The negative direct effects indicated that selection may mislead made on the basis of chlorophyll contents for fresh shoot length. The similar results were found by Asrar-ur-Rehman *et al*. (2007), Gresiak *et al*. (2007) and Veronica *et al.* (2009). The direct effect of root density on fresh shoot length was positive (0.7304) whereas root density has negative indirect effects through all traits except RSW ratio and RSL ratio have positive indirect effects on FSL. The negative direct effects indicated that selection may mislead made on the basis of root density for fresh shoot length. The similar results were found by Asrar-ur-Rehman *et al*. (2007).

The direct effect of fresh root length on fresh shoot length was positive (0.7848), whereas fresh root length has negative indirect effects through all traits except, RSW ratio and RDW have positive indirect effects on FSL. The higher direct effects indicated that selection may be useful to be made on the basis of fresh root length for fresh shoot length. The similar results were found by Boyer and Westgate (2004) and Asrar-ur-Rehman *et al*. (2007). The direct effect root-shoot length ratio on fresh shoot length was higher but negative (-0.7141) whereas root-shoot length ratio has negative indirect effects through DRW, SDW, RD and RSW ratio while others have positive indirect effects through root-shoot length ratio on FSL. The higher negative direct effects indicated that selection may be causes the loss of yield which will be made on the basis of root-shoot length ratio for fresh shoot length. The similar results were found by Aslam and Tahir (2003) and Xu *et al*. (2007). The direct effect of root dry weight on fresh shoot length was positive (0.2143), whereas root dry weight has negative indirect effects through all traits except LT, RD and RSW ratio, while others have positive indirect effects on FSL. The direct effects indicated that selection may be useful to be made on the basis of root dry weight for fresh shoot length. The similar results were found by Aslam and Tahir (2003) and Hugh and Richard (2003). The direct effect of shoot dry weight on fresh shoot length was positive (0.5746) whereas shoot dry weight has negative indirect effects through all traits except Chl.C, LT, RD and RSL ratio, while others have positive indirect effects through shoot dry weight on FSL. The direct effects indicated that selection may or may not be useful to be made on the basis of shoot dry weight for fresh shoot length. The similar results were found by Dai et *al*., (1990), O' Regan *et al*. (1992), Hugh and Richard (2003) and Camacho and Caraballo (1994). The direct effect of root-shoot weight ratio on fresh shoot length was negative (-0.6432), whereas root-shoot weight ratio has negative indirect effects through all traits except RD and RSL ratio, while others have positive indirect effects through shoot dry weight on FSL. The direct effects indicated that selection may or may not be useful to be made on the basis of root-shoot weight ratio for fresh shoot length. The similar results were found by Aslam and Tahir (2003) and Hugh and Richard (2003).

CONCLUSIONS

The fresh root length, dry root weight, root density, leaf temperature and dry shoot weight are the characters which contribute largely to fresh shoot length of maize seedlings, and selection can be made on the basis of these characters. So is suggested that the selection under the discussed traits for batter yielding genotypes for drought conditions may be fruitful.

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