African Journal of Agricultural Research Vol. 7(24), pp. 3594-3604, 26 June, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.1475
ISSN 1991-637X © 2012 Academic Journals

Full Length Research Paper

Screening for drought tolerance in maize (*Zea mays* L.) hybrids at an early seedling stage

Abdul Qayyum*, Shahzad Ahmad, Shoaib Liaqat, Waqas Malik, Etrat Noor, Hafiz Muhammad Saeed and Memoona Hanif

Department of Plant Breeding and Genetics, University College of Agriculture, Bahauddin Zakariya University, Multan, Pakistan.

Accepted 3 April, 2012

Drought stress is an abiotic factor affecting growth badly and ultimately, yields of crop plants. The current study was planned to explore the variations and determine the performance of target traits under drought conditions. Six seedling characters; that is, number of crown roots, number of seminal roots, primary root length, number of lateral roots, fresh root weight and dry root weight were evaluated under three moisture levels. On the basis of mean values, hybrids of tropical yellow H_3, H_4, H_8, H_{11}, H_{15}, H_{19} and highland yellow H_{27}, H_{29} showed best performance under the drought conditions. Principal component analysis was also used to assess the contribution of major traits which were attributing maximum variations among maize hybrids. The first two components with eigen values greater $>$ 1 contributed 76.94% of the variability among the hybrids. The PC-1 was related to the number of seminal roots while the PC-2 was related to the number of crown roots and number of seminal roots. The magnitude of broad sense heritability was high for all the traits. It suggested that all traits were genetically determined and there is an ample scope for the improvement of these traits by selection and breeding.

Key words: Drought stress, heritability, genetic diversity, principal components analysis.

INTRODUCTION

Maize is the third most important cereal crop after wheat and rice. It is necessary for global food security (Cassman, 1999). But abiotic stresses including water stress, salinity and temperature in which drought and salinity are major limiting factors for crop yield (Tester and Basic, 2005), badly affect the plant growth and ultimately yield (Araus et al., 2002). Drought affects the plant from seedling to maturity. Crop performance under drought condition is highly a complex phenomenon and badly affected because of unpredictable factors in the environments and the interaction with other abiotic and biotic factors (Reynold et al., 2006). The effect of drought on crop yield is environmentally dependant; the traits or the genes improving yield under severe drought may not act under drought conditions, and might even have negative effects under well water conditions (Verhoeven et al., 2008). Global climate is changing rapidly (Hillel and Rosenzweig, 2002) and is expected that its temperatures and evapotranspirations are going to be higher resulting in increased incidence of drought in specific regions (Campos et al., 2004). To fulfill needs of the crops, surface water included precipitation and river water is used but maximum rainfall is received during July to September and hardly utilized by crop production due to rapid runoff. Therefore, water becomes short during the growing season of crop (Ahmad et al., 2009a). To meet the requirements of crop, ground water is an alternate source but cost of electricity to pump ground water has raised. Thus, additional maize production from the drought-prone “marginal” areas of Pakistan is the need of the day, which requires breeding for drought tolerant maize varieties producing relatively better yield under drought conditions.

Since farmers usually have trend to grow a single cultivar in a field, this trend needs development of good

*Corresponding author. E-mail: raoqayyim@bzu.edu.pk. Tel: 92619210073-75 (4040). Fax: 92619210068.

level of drought tolerance through breeding in majority of hybrids and varieties grown under drought conditions (Edmeades, 2008). A lot of work has been done to develop drought tolerance in maize and many other crops, that is, Campos et al. (2004) studied that kernels per plant under drought conditions can be increased by exploiting native genetic variation among elite breeding lines but improvements in root distribution and function may need additional genetic variation from other species. While, Moreno et al. (2005) studied several strategies to develop transgenic maize lines with improved drought tolerance. Whereas, Ahmad et al. (2009b) studied that all three kinds of gene effects (additive, dominance and interactions) were involved in the inheritance of the traits that is, plant height, number of monopodial branches per plant, number of sympodial branches per plant, number of bolls per plant, boll weight, ginning out-turn, staple length, fiber strength, fiber fineness, relative water content and excised leaf water loss under drought tolerance. Assessment of drought tolerance at seedling stage is necessary to predict a good crop stand at maturity (Mock and McNeill, 1979; Koscielniak and Dubert, 1985). Maize plants with more roots at seedling stage subsequently developed stronger root system, producing more green matter and high seed yield (Bocev, 1963).

Significant genotypic differences in root growth and development under both normal as well as drought exist among various crop plants including maize (Nour and Weibal, 1978; Maiti et al., 1996; Mehdi et al., 2001) and therefore, could be used as selection criteria for improved drought tolerance in various crops (Clarke, 1987; Gregory, 1989). Genetic improvement in crop for drought tolerance helps in yield stability. Genetics solution covers more than 30% of the gap between potential and realized yield under water stress (Edmeades et al., 2004). However, root growth in cultivars intrinsically capable of avoiding drought through enhanced water uptake (Aggarwal and Sinha, 1983; Dai et al., 1990; Kondo et al., 2000).

Nevertheless, reduction in root growth and development in response to drought has also been reported in literature (Shiralipour and West, 1984; Thakur and Rai, 1984; Ramadan et al., 1985). Therefore, it is necessary to screen breeding lines for rooting traits under drought conditions. Under drought stress, increase in root weight could be attributed to the fact that roots are enlarged in search of water, and may also be attributed to increased weight due to accumulation of different solutes (Aggarwal and Sinha, 1983; Nour and Weibal, 1978; Thakur and Rai, 1984). For the development of elite line having drought tolerance, the existence of variability in the available germplasm of maize is a key to success for the maize breeders.

This current study was planned to explore the variation and to determine the target traits conferring drought tolerance in maize.

MATERIALS AND METHODS

The current study was conducted at the Department of Plant Breeding and Genetics, University College of Agriculture, Bahaudddin Zakariya University Multan, Pakistan which is situated at longitude: 71° 30.79' E; latitude: 31° 16.4' and altitude 128 m with day temperature of about 25°C and average night temperature of 14°C (Ahmad et al., 2009a). The experimental material was comprised of 38 hybrids of maize among which 20 were tropical yellow and 18 were highland yellow (Table 1). These 38 hybrids were evaluated at early seedling stage under three moisture levels that is, 1st, normal that was set at 100% of the field capacity; 2nd, application at 40% water of the normal; and 3rd, application at 60% water of the normal. Three seeds of each genotype per bag were sown and set in a complete randomized design two factors factorial with three replications. The soil was a mixture of clay and sand (3:7). Hybrid seeds were planted on 3 March, 2010. Recording of data regarding various seedling traits was started after 50% of the mortality within the replications that is, after 24 days of planting, the plants from each of the bags were carefully uprooted, washed free of sand, and divided at the cotyledonary node into their respective root and shoot portions. The data on the number of crown roots, number of seminal roots, primary root length (cm), number of lateral roots, fresh root weight (g) and dry root weight (g) were recorded.

The collected data were subjected to analysis of variance technique (steel et al., 1997) using MSTAT C statistical software and numerical taxonomic techniques following the procedure of principal component analysis (Sneath and Sokal, 1973). Phenotypic and genotypic correlations among traits were calculated from mean values and genetic variance was obtained from the combined analysis of variance of each replication (Dewy and Lu, 1959). Broad sense heritability was calculated using the formula given by Falconer (1981).

RESULTS AND DISCUSSION

The genotypes were highly significant (Table 2) with respect to all the measured parameters (Brugnoli and Lauteri, 1991; Muneir et al., 1995; Ray et al., 1987). Water levels were also highly significant ($P<0.01$) except number of lateral roots and dry root weight ($P>0.05$). Drought tolerance of crop plants is also a genetically controlled trait but expression of the plant traits are determined by genotype and environment interaction (Moaveni, 2011). Negative and highly significant correlation was observed between the pairs of traits that is, number of crown roots with number of seminal roots, primary root length, number of lateral roots, fresh root weight, dry root weight and also among number of seminal roots with primary root length at genotypic level (Table 3). Dhanda et al. (2004) reported negative association among the physiological characters in wheat under water stress. While positive and highly significant correlation was observed between the pairs of traits that is, number of seminal roots with number of lateral roots and primary root length with number of lateral roots, fresh root weight, dry root weight and number of lateral roots with, fresh root weight and dry root weight, and fresh root weight with dry root weight at genotypic level. Ali et al. (2008) reported significant positive association among different morpho-physiological traits in chickpea (*Cicer*

Table 1. Tropical yellow hybrids.

Hybrid	Parentage
H_1	Tropical yellow
H_2	Tropical yellow
H_3	Tropical yellow
H_4	Tropical yellow
H_5	Tropical yellow
H_6	Tropical yellow
H_7	Tropical yellow
H_8	Tropical yellow
H_9	Tropical yellow
H_{10}	Tropical yellow
H_{11}	Tropical yellow
H_{12}	Tropical yellow
H_{13}	Tropical yellow
H_{14}	Tropical yellow
H_{15}	Tropical yellow
H_{16}	Tropical yellow
H_{17}	Tropical yellow
H_{18}	Tropical yellow
H_{19}	Tropical yellow
H_{20}	Tropical yellow
High land yellow hybrids	
H_{21}	High land yellow
H_{22}	High land yellow
H_{23}	High land yellow
H_{24}	High land yellow
H_{25}	High land yellow
H_{26}	High land yellow
H_{27}	High land yellow
H_{28}	High land yellow
H_{29}	High land yellow
H_{30}	High land yellow
H_{31}	High land yellow
H_{32}	High land yellow
H_{33}	High land yellow
H_{34}	High land yellow
H_{35}	High land yellow
H_{36}	High land yellow
H_{37}	High land yellow
H_{38}	High land yellow

arietinum). While, negative but significant correlation was observed between number of seminal roots with fresh root weight and dry root weight at genotypic level.

Clarke et al. (1991) reported significant negative correlation between residual transpiration and grain yield among winter wheat genotypes. At phenotypic level, positive and highly significant correlation was observed between pairs of traits that is, primary root length with number of lateral roots, fresh root weight, dry root weight and between number of lateral roots with fresh root weight, dry root weight, and also among fresh root weight and dry root weight, and then also among number of crown roots with number of seminal roots. Negative and non significant correlation was observed between the pairs of traits that is, number of crown roots with primary root length, fresh root weight, dry root weight and between number of seminal roots with fresh root weight and dry root weight at phenotypic level, while positive but

Table 2. Mean squares and F values for analysis of variance of six seedling traits in (Zea mays L.) 38 hybrids.

SOV	df	F-value					
		No. of crown roots	No. of seminal roots	Primary root length	No. of lateral roots	Fresh root weight	Dry root weight
Genotype	37	2.82**	4.48**	33.68**	34.97**	13.90**	14.95**
Water level	2	16.11**	52.01**	23.18**	2.47^{NS}	48.97**	0.64^{NS}
Genotype × treatment	74	2.42**	5.50**	1.29^{NS}	1.17^{NS}	2.40**	1.22^{NS}
Error	228	MS = 0.39	MS = 0.52	MS = 60.7	MS=105.3	MS = 8.13	MS = 1.13
Total	341						

MS, Mean squares; *, significant (p ≤ 0.05); **, highly significant (p ≤ 0.01); NS, non-significant; SOV, source of variability; and df, degree of freedom.

Table 3. Genotypic and phenotypic co-relation among 38 maize hybrids.

Trait	No. of C.R	No. of S.R	P.R.L	No. of L.R	F.R.Wt	D.R.Wt
No. of C.R	1					
	1					
No. of S.R	-1.69**	1				
	0.44**	1				
P.R.L	-1.09**	-0.67**	1			
	-0.05	0.08	1			
No. of L.R	-0.91**	0.53**	0.98**	1		
	0.07	0.12	0.84**	1		
F.R.Wt	-0.58**	-0.34*	0.94**	0.96**	1	
	-0.09	-0.05	0.69**	0.71**	1	
D.R.Wt	-0.52**	-0.35*	0.94**	0.98**	0.98**	1
	-0.10	-7.2	0.64**	0.68**	0.96**	1

No. of C.R, no. of crown roots; no. of S.R, No. of seminal roots; P.R.L, primary root length; no. of L.R, No. of lateral roots; F.R.Wt, fresh root weight and D.R.Wt, dry root weight.

non-significant correlation was observed among pairs of traits; that is, number of crown roots with number of lateral roots, and between number of seminal roots with primary root length and number of lateral roots at phenotypic level. The oldest crown root originates deepest roots (Araki and Iijima, 1998). Araki et al. (2000) reported that crown roots supply water to the plant when water availability is scared to deeper layers of soil. Positive direct effect of number of seminal roots with number of lateral roots and also positive direct effect of primary root length with number of lateral roots, fresh root weight, dry root weight, and number of lateral roots have also shown again positive direct effect with that of fresh root weight and dry root weight and fresh root weight with dry root weight.

These are positively correlated that if one increases the other will also increase and vice versa. These results are in agreement with the results of Khan et al. (2004a) who reported positive direct effect of dry shoot weight on fresh seedling weight. Negative effect was also shown by number of crown roots with number of seminal roots, primary root length, number of lateral roots, fresh root weight and dry root weight that is, if number of crown roots increases then all the other traits will decrease and if number of crown roots decrease then all the other traits will increase (Table 3). Negative effect of shoot length was observed by Khan et al. (2004b).

Principal component analysis

The first two components with eigen values contributed 76.94% of variability among hybrids evaluated for drought tolerance at seedling stage (Table 4). Other PCs (3 to

Table 4. PC's for six quantitative characters in 38 hybrids of maize.

	PC1	PC2
Eigen-values	4.319884	1.066498
Percent of total variance	61.71	15.23
Cumulative %	61.71	76.94
Eigen vector		
Variable		
No. of C.R	-0.013063	0.829824
No. of S.R	0.217966	0.597530
P.R.L	-0.906991	-0.061311
No. of L.R	-0.928910	0.071792
F.R.Wt	-0.975183	0.004346
D.R.Wt	-0.972726	0.014663

No. of C.R, no. of crown roots; no. of S.R, no. of seminal roots; P.R.L, primary root length; No. of L.R, no. of lateral roots; F.R.Wt, fresh root weight; and D.R.Wt, dry root weight.

6) had very less eigen values (<1). The first PC was only related to number of seminal roots (Table 4) whereas second PC was related to the number of crown roots and the number of seminal roots. The variation for number of seminal roots was distributed among both the PCs (1 and 2). Among the second PC, number of lateral roots, dry root weight and fresh root weight also showed very little positive effects along with strong positive effects shown by number of crown roots and number of seminal roots. In second PC, number of crown roots showed the greatest positive weightage. The character with positive weightage on PC_1 was only the number of seminal roots. These findings suggest that positive performance of number of seminal roots along with number of crown roots is very important to tolerate the drought conditions. As PC_1 exhibited positive effects only for number of seminal roots which suggests that hybrids emphasized only on number of seminal roots for the development of tolerance against drought.

As PCA based on mean values (Table 5), hence from mean values of the data hybrids H_{33} followed by H_{26} under normal condition of water application regarding number of seminal roots showed the best performance while under drought condition 1 that was set at 40% of the normal water application hybrids (H_4, H_{11}) followed by H_3 and H_{16} regarding number of seminal roots showed the best performance and under condition 2 that was set at 60% of the normal water application hybrids H_{19} and H_{27} followed by H_4, H_6, H_{36} showed the best performance regarding number of seminal roots. These results are similar to the results of Rashid et al. (2008) who identified the major characters that is, days to 50% flowering, plant height (cm), productive tillers/plant, panicle length (cm), panicle fertility %, 1000-seed weight (g) and yield (kg/ha) accounting variation among Basmati rice mutants. Drought drastically affected all the root traits except primary root length which was affected very little and number of lateral roots also were less affected under drought condition 1 (Table 5). Comparing with the controlled conditions (which was set at 100% of water application), the values of all traits decreased under drought conditions 1 and 2 except the primary root length and number of lateral roots in drought condition 1. Primary root length increases under both drought conditions T_1 and T_2 in search of water. The highest negative impact under drought condition T_1 was shown by fresh root weight followed by dry root weight, number of crown roots and number of seminal roots. While in drought condition T_2, it drastically affected the fresh root weight followed by the number of crown roots, number of seminal roots, dry root weight and very less effect was also shown on number of lateral roots. These results are similar to the results of Khan et al. (2004a) in which highest negative impact under drought conditions was observed in emergence rate index followed by emergence percentage, dry shoot weight and fresh shoot weight whereas, shoot length was least effected by drought.

The only root trait which acts positively under both drought conditions (Table 5) is primary root length because primary root length increases while other traits during water stress decreases. This result is in accordance with the results of Khan et al. (2004b) in which he observed highest increase in dry root weight under drought.

Comparative evaluation of various hybrids of maize

Number of crown roots

Under normal conditions, highest number of crown roots was shown by H_{22}, H_{23} followed by H_{33}. Under drought condition 1 that was set at 40% of the normal water, the

Table 5. Mean performance of 38 maize hybrids for various plant root traits under normal and drought conditions.

Hybrid	No. of C.R			No. of S.R			P.R.L			No. of L.R			F.R.Wt			D.R.Wt		
	T_0	T_1	T_2	T_0	T_1	T_2	T_0	T_1	T_2	T_0	T_1	T_2	T_0	T_1	T_2	T_0	T_1	T_2
H_1	4.00	3.56	3.78	5.67	5.89	5.89	16.17	37.56	33.67	39.33	66.67	58.56	7.24	9.38	6.04	2.83	3.24	2.91
H_2	4.67	3.44	3.67	7.33	5.89	5.56	28.33	52.11	42.78	61.33	81.44	72.00	11.27	6.87	4.98	3.22	2.47	3.22
H_3	4.00	4.00	3.67	5.00	6.33	6.56	38.00	52.33	44.22	72.00	77.56	78.44	9.99	6.17	6.63	3.33	2.61	4.82
H_4	3.33	4.33	4.11	6.00	6.78	6.67	35.67	52.44	42.67	61.67	77.67	72.00	10.12	5.18	5.33	2.98	2.36	3.80
H_5	3.33	3.67	3.44	6.67	5.78	5.44	36.33	47.56	42.78	63.33	69.67	69.00	12.84	6.86	5.54	2.90	3.00	3.31
H_6	4.00	3.67	4.00	7.00	6.11	6.67	45.33	51.22	46.56	82.00	86.00	77.33	13.36	7.24	4.85	4.13	3.23	2.79
H_7	4.33	3.11	3.78	6.00	5.67	6.11	43.00	47.22	46.56	71.00	72.78	68.56	17.06	5.60	4.61	4.41	2.52	2.14
H_8	4.00	3.11	3.44	7.00	5.78	5.89	37.00	49.44	45.33	66.33	73.89	66.22	12.82	8.49	4.80	3.04	3.80	2.78
H_9	3.67	4.33	3.78	7.33	5.89	6.22	42.33	47.89	38.11	64.33	69.78	62.00	10.88	8.31	5.81	2.44	3.52	2.89
H_{10}	4.67	4.00	3.89	7.33	6.00	5.44	39.67	47.67	42.44	75.00	67.67	68.22	15.44	7.19	5.45	4.10	2.96	2.18
H_{11}	4.33	4.56	4.11	6.67	6.78	6.56	54.00	49.67	41.11	67.00	78.22	71.00	13.70	8.04	5.46	3.31	3.15	2.71
H_{12}	3.33	3.33	3.22	6.33	5.89	4.89	48.67	50.89	45.22	72.33	70.44	76.22	14.61	7.51	5.13	3.82	3.29	2.62
H_{13}	4.33	4.00	4.22	7.00	6.00	6.56	31.67	54.00	53.89	62.33	81.67	78.33	13.14	6.83	5.29	4.08	2.96	2.27
H_{14}	4.00	3.78	3.67	5.00	6.22	6.22	28.33	57.78	49.78	59.33	83.11	79.67	14.09	6.84	4.89	4.15	3.05	2.97
H_{15}	4.67	3.56	4.11	7.33	6.11	6.44	44.00	61.00	48.00	72.33	86.89	76.44	6.02	4.53	6.21	1.86	2.35	3.73
H_{16}	3.67	3.89	4.11	7.00	6.33	6.56	53.33	56.22	45.00	86.00	80.89	71.78	12.88	5.53	6.65	4.00	2.77	3.99
H_{17}	4.33	3.56	3.89	6.67	5.78	6.11	56.00	55.89	43.67	84.33	83.11	73.22	12.83	5.46	5.92	3.79	2.65	3.43
H_{18}	4.00	3.67	3.78	5.67	6.22	6.11	46.67	54.67	57.89	80.00	78.78	81.78	14.12	5.16	4.68	3.48	2.44	2.79
H_{19}	3.33	4.00	4.33	6.00	6.22	6.78	51.67	53.44	60.00	74.67	77.89	93.89	11.62	5.29	5.21	3.09	2.61	3.17
H_{20}	3.33	3.67	3.44	7.00	6.44	6.22	39.67	57.00	49.56	66.33	79.00	77.56	7.42	5.78	5.38	2.79	2.77	3.34
H_{21}	3.33	4.33	3.89	3.67	6.11	6.22	16.33	17.44	16.56	34.00	31.67	32.44	1.39	0.55	0.69	0.53	0.27	0.35
H_{22}	5.33	3.67	3.33	7.67	6.56	5.78	18.67	18.11	15.67	39.67	35.67	30.67	1.08	0.85	0.75	0.71	0.42	0.37
H_{23}	5.33	3.33	3.11	6.67	5.22	5.11	15.33	18.44	15.33	40.67	33.33	28.22	1.37	0.81	0.68	0.70	0.41	0.33
H_{24}	3.67	3.56	3.67	7.00	6.11	6.00	18.33	19.22	16.11	36.67	37.78	29.56	0.70	0.93	0.67	0.30	0.46	5.61
H_{25}	4.33	3.67	4.11	8.00	5.89	6.22	17.00	20.67	15.11	38.67	33.89	32.67	1.67	1.02	0.80	0.91	3.80	0.38
H_{26}	4.33	3.33	3.44	8.33	5.00	5.78	21.67	19.44	14.44	36.67	35.44	29.22	1.07	0.72	0.71	0.37	0.35	0.30
H_{27}	4.33	3.11	4.56	6.67	5.22	6.78	12.00	21.33	17.11	26.00	35.89	33.00	0.72	0.54	0.89	0.26	0.28	0.46
H_{28}	4.67	2.89	3.44	7.00	5.56	6.33	15.00	19.44	15.33	42.67	32.00	31.56	1.23	0.48	0.72	0.50	0.24	0.38
H_{29}	4.67	3.00	3.56	5.67	5.11	5.78	13.00	22.22	14.89	30.00	34.11	28.67	1.12	10.51	0.76	0.49	0.24	0.38
H_{30}	4.67	3.67	3.44	7.67	5.11	6.00	16.67	20.33	16.44	49.33	33.89	30.33	0.83	0.41	0.99	0.38	0.22	0.54
H_{31}	3.00	3.11	3.56	6.33	5.67	5.89	17.00	17.89	14.44	45.67	33.11	33.33	0.83	0.42	1.23	0.36	0.22	0.47
H_{32}	4.00	2.89	3.78	4.33	4.56	6.33	19.00	16.33	16.44	27.00	30.00	32.44	1.11	0.38	1.09	0.54	0.19	0.55
H_{33}	5.00	3.00	3.56	9.33	5.56	6.00	17.00	19.89	17.00	52.67	35.00	36.56	1.15	8.38	1.24	0.53	0.16	0.65
H_{34}	4.33	3.44	3.56	6.00	5.78	5.89	13.67	19.33	16.78	27.33	35.44	34.11	1.50	5.14	1.00	0.70	0.26	0.58

Table 5. contd.

H_{35}	4.67	3.78	3.78	7.00	6.11	6.44	19.33	23.56	15.78	40.33	38.44	34.67	1.37	0.43	1.09	0.55	0.23	0.59
H_{36}	3.67	2.78	4.00	7.00	4.67	6.67	15.33	18.89	14.33	32.00	31.56	35.22	1.28	0.36	1.01	0.47	0.19	0.56
H_{37}	2.67	3.44	3.67	5.67	6.00	5.89	20.00	18.11	14.33	32.67	30.56	31.78	1.75	0.41	0.95	0.71	0.18	0.46
H_{38}	4.33	3.33	3.89	4.67	6.11	6.33	28.00	21.00	15.11	46.67	33.22	33.56	1.63	0.41	1.06	0.63	0.20	0.55

T_0, Control; T_1, 40% of control, T_2, 60% of control; no. of C.R, no. of crown roots; no. of S.R, no of seminal roots; P.R.L, primary root length; no. of L.R, no. of lateral roots; F.R.Wt, fresh root weight; and D.R.Wt, dry root weight.

Table 6. Mean performances of maize hybrids under different levels of moisture stress for different root traits.

Trait	Control	T_1	T_2
		40% of control	60% of control
No. of crown roots	4.10	3.57	3.76
No. of seminal roots	6.54	5.85	6.11
Primary root length	29.71	36.52	31.59
No. of lateral roots	54.20	56.69	53.95
Fresh roots weight	6.93	4.34	3.29
Dry roots weight	2.04	1.74	1.98

best performance regarding number of crown roots was showed by H_{11}, followed by H_4, H_9 and H_{21}. While under drought condition 2 that was set at 60% of the normal water application best performance regarding number of crown roots was shown by H_{27}, followed by H_{19} (Table 6) but the performances under both the drought conditions by hybrids regarding this trait are less than the performances by hybrids under normal conditions. These results are similar to the results of Khan et al. (2004a).

Number of seminal roots

Under normal conditions, highest number of seminal roots was shown by H_{33} followed by H_{26}. Under drought condition 1 that was set at 40% of the normal water, the best performance regarding number of seminal roots were showed by H_4, H_{11} followed by H_3 and H_{16}; while under drought condition 2 that was set at 60% of the normal water application best performance regarding number of seminal roots were shown by H_{19}, H_{27} followed by H_4, H_6 and H_{36} (Table 6) but the performances under both the drought conditions by hybrids regarding this trait are less than the performances by hybrids under normal conditions. These results are similar to the results of Khan et al. (2004b).

Primary root length

Under normal conditions, highest primary root length was shown by H_{17} followed by H_{11}. Under drought condition 1 that was set at 40% of the normal water, the best performance regarding primary root length was shown by H_{15}, followed by H_{14}; while under drought condition 2 that was set at 60% of the normal water application, best performance regarding primary root length was shown by H_{19} followed by H_{18} (Table 6). The performances under both the drought conditions by hybrids regarding this trait are almost higher than the performances by hybrids under normal conditions. So we may select this trait as selection criteria for the evaluation of hybrids against drought. These results are similar to the results of Khan et al. (2004a).

Number of lateral roots

Under normal conditions, highest number of

Table 7. Heritability for different root traits of maize hybrids under normal and drought conditions.

Trait	Control $H^2_{B.S}$	T_1 $H^2_{B.S}$	T_2 $H^2_{B.S}$
		40% of control	60% of control
No. of crown roots	80.14	62.32	63.84
No. of seminal roots	87.25	79.07	74.54
Primary root length	87.82	94.37	93.91
No. of lateral roots	87.38	94.65	94.34
Fresh root weight	95.30	63.79	95.59
Dry root weight	91.71	97.89	70.50

lateral roots was shown by H_{16} followed by H_{17}. Under drought condition 1 that was set at 40% of the normal water, the best performance regarding number of lateral roots was showed by H_{15}, followed by H_6 (Table 6); while under drought condition 2 that was set at 60% of the normal water application, best performance regarding number of lateral roots was shown by H_{19} followed by H_{18} (Table 6). The performances under both the drought conditions by hybrids regarding this trait are almost higher than the performances by hybrids under normal conditions. Thus, we may select this trait as selection criteria for the evaluation of hybrids against drought. These results are similar to the results of Khan et al. (2004b).

Fresh root weight

Under normal conditions, highest fresh root weight was shown by H_7 followed by H_{10}. Under drought condition 1 that was set at 40% of the normal water, the best performance regarding highest fresh root weight was showed by H_{29} followed by H_1; while under drought condition 2 that was set at 60% of the normal water application, best performance regarding highest fresh root weight was shown by H_{16} followed by H_3 (Table 6) but the performances under both the drought conditions by hybrids regarding this trait are less than the performances by hybrids under normal conditions. These results are similar to the results of Khan et al. (2004a).

Dry root weight

Under normal conditions, highest dry root weight was shown by H_7 followed by H_{14}. Under drought condition 1 that was set at 40% of the normal water, the best performance regarding highest dry root weight was showed by H_8 followed by H_9. While under drought condition 2 that was set at 60% of the normal water application, best performance regarding highest dry root weight was shown by H_3 followed by H_{16} (Table 6) but the performances under both the drought conditions by hybrids regarding this trait are less than the performances by hybrids under normal conditions. These results are similar to the results of Khan et al. (2004b). In controlled conditions which was set at 100% of water application, $H^2_{B.S}$ for all the traits (number of crown roots, number of seminal roots, primary root length, number of lateral roots, fresh root weight and dry root weight) was above 80% (Table 7) which showed the strong genetic effect for the development of these traits. These results are in agreement with the findings of Waldia et al. (1991) who reported high heritability estimates for seed mass, shoot length, root length and seedling biomass; while in T_1 that was 40% of the controlled $H^2_{B.S}$ was above 90% for primary root length, number of lateral roots and dry root weight indicating that genetic material played an important role for the development of these traits. These results are similar to the results of Ali et al. (2010) who reported high heritability for seedling length, root length, root to shoot ratio, seedling biomass, primary leaf area, primary leaf length and primary leaf width in chickpea (*C. arietinum* L.).

While in T_1 $H^2_{B.S}$ was above 60% for number of crown roots and fresh roots weight which means environment also played the role for the development of these traits and for number of seminal roots was 79.07% which means a very little role has been played by the environment along with strong genetic role for the development of this trait; while in T_2 that was set at 60% of the controlled, $H^2_{B.S}$ was above 90% for primary root length, number of lateral roots and fresh root weight which also means that genetic material role was too strong for the development of these traits, while for dry root weight and number of seminal roots, $H^2_{B.S}$ was above 70%, that means a very little role was also played by the environment along with genetic material for the development of this trait, while for number of crown roots $H^2_{B.S}$ was only 63% that means environment has also played an important role for the development of this trait.

Kashiwagi et al. (2006) investigated genetic variability of root traits and found moderate heritability.

Conclusion

Accordingly to the PCA and mean values data, best performance under drought conditions were observed by H_3, H_4, H_8, H_{11}, H_{15}, H_{19}, H_{27} and H_{29}. Among these, H_3,

H_4, H_8, H_{11}, H_{15}, H_{19} were tropical yellow and H_{27}, H_{29} were highland yellow hybrids. Overall, according to the current study, hybrids belonging to the group tropical yellow showed best performances against drought conditions. Our results further validate that screening isan effective tool to exploit genetic variation among maize hybrids. To develop high yielding drought tolerant/ resistant maize genotypes through selection and conventional breeding approaches, these genetic variations can be used. This criterion can also be utilized for other agricultural crops to establish high yielding drought tolerant genotypes.

REFERENCES

Aggarwal PK, Sinha SK (1983). Relationship between mother shoot and tillers as a criterion of selection for wide or specific adaptability to drought in wheat. Zacker–Planzenb, 152: 310-20.

Ahmad N, Abid M, Ahmad F (2009a). Boron toxicity in irrigated cotton (*Gossypium hissutum* L.) Pakistan J. Bot., 40: 2443-2452.

Ahmad RT, Malik TA, Khan IA, Jaskani MJ (2009b). Genetic analysis of some morpho-physiological traits related to drought stress. Int. J. Agric. Biol., 11: 235-240.

Ali MA, Nawab NN, Rasool G, Saleem M (2008). Estimates of variability and correlations for quantative traits in (*Cicer arietinum* L). J. Agric. Soc. Sci., 4: 177-179.

Ali Q, Ahsan M, Farooq J (2010). Genetic variability and trait assertion in Chickpea (*Cicer ariehnum* L.) genotypes at seedling stage. Elect. J. Plant Bleeding 1(3): 334 - 341.

Araki H, Hirayama M, Hirasawa H, Iijima M (2000). Which roots penetrate the deepest in rice and maize root systems? Plant Prod. Sci., 3: 281-288.

Araki H, Iijima M (1998). Rooting nodes of deep roots in rice and maize grown in a long tube. Plant Prod. Sci., 1: 242-247.

Araus JI, Slafer GA, Reynolds MP, Toyo C (2002). Plant breeding and drought in C3 cereals,what should we breed for? Ann. Bot., 89: 925-940.

Bocev BV (1963). Maize selection at an initial phase of development. Kukuruzu, pp. 1: 54.

Brugnoli E, Lauteri M (1991). Carbon isotope discrimination and salt tolerant (*Gossypium hirsutum* L.) and salt sensitive (*Phaseolus vulgaris* L.) C3 non helophytes. Pl. Phy., 95(2): 628-635.

Campos H, Cooper M, Habben JE, Edmeades GO, Schussler JR (2004). Improving drought tolerance in maize: a view from industry. Field Crops Res., 90: 19-34.

Cassman KG (1999). Ecological intensification of cereal production systems: yield potential, soil quality, and precision agriculture. Proc. Natl. Acad. Sci. U.S.A., 96: 5952-5959.

Clarke JM (1987). Use of physiological and morphological traits in breeding programme to improve drought resistance of cereals. In: Srivastava, J.P., E. Preeddu, E. Acevedo and S. Verma (eds.) Drought Tolerance Resistance in Winter Cereals. John Wiley and John Wiley and Sons, New York.

Clarke JM, Richards RA, Condon AG (1991). Effect of drought on residual transpiration and relationship with water use of wheat. Canadian J. Plant Sci., 71: 695-702.

Dai JY, Gu WL, Shen XY, Zheng B, Qi H, Cai SF (1990). Effect of drought on the development and yield of maize at different growth stages. J. Shery Agric. Univ., 21: 18-5.

Dewey OK, Lu KH (1959). A correlation and path co-efficient analysis of components of crested wheat grass and seed production. Agron. J., 51: 515-517.

Dhanda SS, Sethi GS, Behl RK (2004). Indices of drought tolerance in wheat genotypes at early stages of plant growth. J. Agron. Crop Sci., 190: 6-12.

Edmeades GO (2008). Drought Tolerance in Maize: An Emerging Reality. Companion Document to Executive Summary ISAAA Briefs, pp. 39-2008.

Edmeades GO, Banziger M, Schussler JR, Campos H (2004). Improving abiotic stress tolerance in Maize: a random or planned process? In: proceeding of the Arnel R. Hllauer International symposium on plant Breeding. Mexico city, 17 - 22 August 2003 Lowa state university press, in press.

Falconer DS (1981). Introduction to Quantitative Genetics, P: 127. Longman press, New Yark, USA.

Gregory PJ (1989). The role of root characteristics moderating the effects of drought. Irrigation and Drainage Abst. 17: 1439; 1991.

Hillel D, Rosenzweig C (2002). Desertification in relation to climate variability and change. Adv. Agron., 77: 1-38.

Kashiwagi J, Krishnamurthy L, Upadhyaya DH, Krishna H, Chandea S, Vadez V, Serraj R (2006). Genetic variability of drought avoidance root traits in the mini core germplasm collection of Chickpea (*Cicer arietinum* L.) Euphytica, 146: 213-222.

Khan IA, Habib S, Sadaqat HA, Tabir MHN (2004a). Comparative evaluation and analysis of seedling traits for drought tolerance in Maize. IJ. Agric Bot., 2: 246-251.

Khan IA, Habib S, Sadaqat HA, Tabir MHN (2004b). Selection criteria based on seedling growth parameters in Maize varies under normal and water stress conditions. I. J. Agric. Bot., 2: 252-256.

Kondo M, Murty MVR, Araqones DV (2000). Characteristics of root growth and water uptake from soil in upland rice and maize under water stress. Soil Sci. Pl. Nutr., 46: 721 - 32.

Koscielniak J, Dubert F (1985). Biological indices of productivity of various breeding lines of maize. III. Correlation between simple and final yield of grain and dry matter under natural conditions of vegetative growth. Acta. Agra. Silvestria Ser. Agra., 24: 35–48.

Maiti RK, Amaya LED, Cardana SI, Oimas AMO, De La Rosa– Ibarra M, De Leoncastillo H (1996). Genotypic variability in maize cultivars for resistance to drought and salinity at seedling stage. J. Pl. Physiol., 148: 741-4.

Mehdi SS, Ahmad N, Ahsan M (2001). Evaluation of S1 maize (*Zea mays* L.) families at seedling stage under drought conditions. On line J. Biol. Sci., 1: 4-6.

Moaveni P (2011). Effect of water deficit stress on some physiological traits of wheat (*triticum aestivum*). Agric. Sci. Res. J., 1(1): 64-68.

Mock JJ, McNeill MJ (1979). Cold tolerance of maize inbred lines adapted to various latitude in North America. Crop Sci., 19: 239-41.

Moreno A, Lumbreras V, Pagès M (2005). Drought tolerance in maize. Maydica, 50: 549-558.

Munir A, Abdul R, Mukhdum MI (1995). Study on salt tolerance of cotton 9 (*Gossypium hirsutum* L.). Ind. J. Agric. Res., 29(1/2): 64-68.

Nour MA, Weibal DE (1978). Evaluation of root characteristics in grain sorghum. Agron. J., 70: 217-8.

Ramadan HA, Al–Niemi SN, Hamdan TT (1985). Water stress, soil type and phosphorus effects on corn and soybean, I. Effect on growth. Iraqi J. Agric. Sci., 3: 137-44.

Rashid M, Cheema AA, Ashraf M (2008). Numerical analysis of variation among Basmati rice mutants. Pak. J. Bot., 40(6): 2413-2417.

Ray M, Jadhav SB, Khaddar VK (1987). Effect of graded salinilty levels on the lint quality of *hirsutum* cotton cultivars. Ind. J. Agric. Res., 21(3): 127-132.

Reynolds MP, Rebetzke G, Pellegrinesci A, Trethowan R (2006). Chapter 11, Drought adaptation in wheat. In drought tolerance in cereals (ed.J.M.Ribaut), pp. 402 - 436. Hawaorth,s Food Products press, New York.

Shiralipour A, West SH (1984). Inhibition of specific protein synthesis in maize seedlings during water stress. Proc. Soil Crop Sci. Soc. Florida, 43: 102 - 6.

Sneath PHA, Sokal RR (1973). Numerical Taxonomy: The principles and practices of Numerical Classification. W.F. Freeman and Co., San Francisco, pp. 573. Sons, New York.

Steel RGD, Torrie JH, Dickey DA (1997). Principles and procedures of statistics. A Biometric Approach. Mc Graw Hill Book Co. New Yerk, USA.

Tester M, Basic A (2005). Abiotic stress tolerance in grasses. From model plants to crop plants. Plant physiol.,137: 791-793.

Thakur PS, Rai VK (1984). Water stress effect on maize cultivars during early stage of growth. Indian J. Ecol., 11: 92-8.

Verhoeven KJF, Poorter H, Nevo E, Biere A (2008). Habitat – specific natural selection at a flowering time QTL is a main driver of local adaptation in two wild barley populations. Mol. Ecol., 17: 3416-3424.

Waldia RS, Ram CS, Sood DR, Puna RC, Chobea AK (1991). Variation for seed mass, seedling vigorand quality attributes in desi and kubuli Chickpea (*Cicer arietinum* L.) genotypes. International Chickpea Newsletter 24: 15-27.