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PHYSIO-GENETIC BEHAVIOR OF MAIZE SEEDLINGS AT WATER DEFICIT CONDITIONS

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ABSTRACT. Drought stress is limiting global crop production more seriously than ever because of rapid change in global climate. Present investigations were made with a view to understand the traits which can be used as selection criteria for drought tolerance in maize at seedling stage. For this purpose twenty-five maize inbred lines were evaluated under water deficit conditions for traits like fresh shoot weight, fresh shoot length, fresh root length, fresh root weight, leaf venation, stomatal frequency and epidermal cell size. Significant differences were found among the genotypes for various physio-genetic traits. The genotypes 20P2-1, L5-1, 150P2-1, 70NO2-2, 150P1 and L7-2 were found good performer and may be exploited for developing drought tolerant synthetics and hybrids. Fresh shoot length and fresh root weight found overall direct and indirect contributor in fresh shoot weight and they were positive and significantly correlated with fresh shoot weight. Stomatal frequency and epidermal cell size had significantly decreasing direct and indirect effects on fresh shoot weight and significant genetic correlation with it. These results suggested that fresh shoot length and fresh root weight (Increased) stomatal frequency and epidermal cell size (decreased) might be used as selection criterion while selection for high fresh shoot yield under drought conditions.

Key words: Maize, Selection criteria, Genetic effects, Correlation coefficients.

INTRODUCTION

Water stress is one of the most serious constraints limiting crop production. One-third of the world's potentially arable lands yield low crop production by drought (Kramer, 1980; Ashraf, 1989). Maize (*Zea mays* L.) is the third most important cereal after wheat and rice all over the world as well as in Pakistan. During 2006-07 world area under maize crop was 147.6 million hectare with a grain production of 701.3 million metric tones and overall yield of 4752 kg per hectare. In Pakistan its area was

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1016.9 thousand hectares with annual production of 3088.4 thousand tones and average yield of 3037 kg per hectare. Grain yield per unit area in Pakistan is 1.59 times less as compared to the world yield. Among cereals it is highly profitable crop due to higher yield per unit area per unit time (Anonymous, 2007).

In addition to grain crop, maize is also extensively grown as fodder crop for livestock consumption. Very little attention has been paid to the development of maize varieties, which are good both for grain and fodder purposes. Under such circumstances evolution of high yielding maize varieties under drought conditions is the cheapest option to cope with the menace of water shortage. To attain the desired goal the physiological parameters to be used as selection criteria that must be simple and rapidly measurable, heritable, responsive to selection and related to crop growth and yield (Richards, 1978).

Keeping in view the need of the above said information the present study would be conducted to observe the variability among various physio-genetical characters under different water stress conditions at different sampling dates. Such information is of great value to formulate future maize breeding strategies under drought conditions. The present study was also planned to estimate the degree to which various characters of maize plants are associated with economic productivity and also to determine the precise contribution of each component towards the yield.

MATERIALS AND METHODS

The present study was carried out in the glasshouse of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The material consisted of 25 maize inbred lines such as A495, PB77, A556, PB7-1, OH8, 52B4, W64SP, 53AP1, WF-9, 53P4, B34, 82P1, B34-2B, 20P2-1, B42, L5-1, Q66, L7-2, Q67, 70NO2-2, Q97, 150P1, N18, 150P2-1 and N48-1. The inbred lines were sown at 100 percent water deficit conditions in randomized complete block design with two replications. Sowing was done in plastic bags (16×6 cm), filled up to 12×6 cm with sand. One seed per bag was sown. The number of plants in each replication of each genotype was ten. 150 ml water was given at sowing and no further irrigation was applied till harvesting. Harvesting was done after 15 days of sowing. Average temperature throughout the experimental period was 35°C. Five plants were selected from each genotype of each replicated level at random and data was recorded for different physio-genetic traits at seedling stage, such as fresh shoot length (cm), fresh root length (cm), fresh root weight (g), leaf venation, stomatal frequency, stomata size, epidermal cell size and fresh shoot weight.

Statistical analysis. Analysis of variance and covariance for all the characters studied using the method given by Steel et al. (1997). The individual comparisons for genotypic means were accomplished by using Duncan,s New Multiple Range Test (DMR-test). The means, standard error, phenotypic and genotypic coefficients of variability for each character were calculated. The variance was partitioned into phenotypic and genotypic components. Correlation analysis was performed according to the statistical technique outlined by Kown and Torrie (1964) as follow. The method for path coefficient analysis was used as given by Wright (1934) and described by Dewey and Lu (1959). Fresh shoot weight was kept as resultant variable and other contributing characters as causal variables.

RESULTS AND DISCUSSION

Comparative evaluation of genotypes. There were significant differences found among the genotypes for all traits in this study *(Table 1)*. Mehdi *et al.* (2001) reported highly significant differences among S_1 maize families for various traits except dry root weight which was non significant among treatments at drought conditions. Mehdi and Ahsan (1999) evaluated 500 S_1 maize families at seedling stage. They reported the high values of coefficients of variation for fresh shoot and root weight. Maximum performance *(Table 1)* was shown by B34-2B followed by WF-9 and lowest performance was shown by W64SP for fresh shoot weight. Highest performance was shown by Q67 followed by WF-9 and lowest performance was shown by W64SP for fresh shoot length. Overall shoot length was reduced during water stress (Alam, 1985; Ehlig and Lemert, 1976). Thakur and Rai (1984) and Ramadan *et al.* (1985) also reported that drought stress reduced the plant height. The genotype N18 followed by Q66 had highest root length and that of WF-9 had minimum root length. Highest root weight was gained by 150P1 followed by 150P2-1 and that of OH8 gave the lowest weight. These results are in agreement with the results of Aggarwal and Sinha (1983) and Nour and Weibal (1978).

Maximum performance was given by 53P4 followed by 82P1 for leaf venation *(Table 1)*. The lowest performance was shown by N48-1. The genotype 150P2-1 performed well followed by 52B4 and the performance of OH8 was lowest performance for stomatal frequency. The results are similar with Kazemi *et al.* (1978). Maximum performance was shown by Q66 followed by B34-2B and the lowest performance was shown by Q97 for stomata size. Jones (1979) reported similar findings in maize under drought. The genotype WF-9 gave highest performance followed by Q66 for epidermal cell size, but 52B4 genotype showed the lowest performance. Overall drought has drastically affected fresh shoot weight in some lines whereas some genotypes showed increase in shoot weight that may be attributed to the accumulation of organic and inorganic solutes, and that due to higher growth because of osmotic adjustment. Genotypes 20P2-1, L5-1, 150P2-1, 70NO2-2, 150P1 and L7-2 had more fresh shoot length, fresh root weight, leaf venation and stomata size under water deficit conditions.

Table 1 - Means and statistical significance for various maize physio-genetic maize traits under water deficit conditions

Genotypes	Fresh shoot length (cm)	Fresh root length (cm)	Fresh shoot weight (g)	Fresh root weight (g)	Leaf venation (µ)	Stomatal frequency	Stomata size	Epidermal cell size
Q67	33.15 ^{a}	48.03^{abc}	5.10fghi	3.10g	4.5defg	9.8c	906.0efghi	4194bcd
WF-9	28.99 ^{b}	35.35^{g}	4.20hi	5.29ef	4.5defg	7.0jk	962.6ef	4880a
L5-1	28.38 ^{bc}	40.22^{defg}	7.00def	9.73b	4.5defg	9.8c	766.3hij	3699efgh
B34-2B	28.14 ^{bc}	43.68^{abcdef}	8.35bcd	9.75b	6.0abcd	8.0fghi	1404.0ab	4087bcde
150P1	27.86 ^{bcd}	42.94^{abcdefg}	12.55a	10.99a	5.0cdef	11.8b	868.2fghij	3884cdef
B42	27.73 ^{bcde}	47.89^{abcd}	8.00bcd	5.92ef	6.5abc	6.9k	1173.0cd	4285bc
B34	27.01 ^{cdef}	39.10^{efg}	9.35bc	5.52ef	3.0gh	7.7hij	1269.0bc	3514fghij
N18	26.94 ^{cdef}	49.32^{a}	5.75efgh	6.34e	4.0efgh	11.3b	834.9fghij	3370ghijk
70NO2-2	26.33 ^{defg}	46.56^{abcde}	9.50b	8.34cd	5.5bcde	8.4efgh	944.8efgh	3204ijkl
Q66	26.25 ^{efg}	48.77^{ab}	7.20cdef	5.34ef	3.5fgh	5.3l	1463.0a	4406b
L7-2	25.70 ^{fgh}	37.78^{fg}	8.10bcd	9.18bc	6.50abc	8.5fghi	798.3ghij	2768lmn
OH8	25.67 ^{fgh}	36.29^{fg}	7.55bcde	2.67g	2.5h	7.9ghi	1232.0bcd	3673efghi
150P2-1	25.62 ^{fgh}	41.23^{bcdefg}	8.75bcd	10.10ab	6.0abcd	13.2a	794.5hij	2919klm
A495	25.31 ^{ghi}	39.03^{efg}	6.60defg	3.48g	3.0gh	5.5l	1189.0cd	3417fghij
Q97	25.30 ^{ghi}	42.58^{abcdefg}	5.65efghi	5.04f	6.5abc	8.6defg	702.2j	3229hijk
20P2-1	24.76 ^{ghi}	39.24^{efg}	8.50bcd	8.01d	6.0abcd	8.8def	894.7fghi	4320bc
53AP1	24.16 ^{hij}	40.64^{cdefg}	3.55i	5.26ef	3.5fgh	7.3ijk	985.3efg	2512mn
N48-1	23.88 ^{ij}	42.26^{abcdefg}	5.15fghi	7.97d	2.5h	9.8c	924.8efgh	3657efghi
PB77	23.14 ^{jk}	39.71^{efg}	4.50ghi	3.61g	3.5fgh	9.3cd	794.5hij	3107jkl
PB7-1	22.98 ^{jk}	40.48^{cdefg}	5.25fghi	5.88ef	4.0efgh	8.1fghi	902.6efghi	3440fghij
A556	22.24 ^{kl}	39.55^{efg}	7.95bcd	2.70g	5.5bcde	9.1cde	725.5ij	2627mn
53P4	21.94 ^{klm}	42.27^{abcdefg}	7.15def	6.01ef	7.5a	7.8ghi	985.5efg	3597fghi
52B4	21.65 ^{klm}	39.41^{efg}	4.15hi	6.05ef	5.5bcde	11.9b	1081.0de	2409n
82P1	21.21 ^{lm}	40.75^{cdefg}	8.1bcd	6.19e	7.0ab	8.2fgh	889.3fghi	3221ijkl
W64SP	20.48 ^{m}	35.40^{g}	8.15bcd	2.70g	5.0cdef	5.8l	1318.0abc	3819defg

Mean sharing the same letters are not significantly different at 5% probability level.

Table 2 - Genotypic (in parenthesis) and phenotypic (P) correlation coefficients among various maize physio-genetic traits under water deficit conditions

Traits	Fresh shoot weight	Fresh Shoot length	Fresh root length	Fresh root weight	Leaf venation	Stomatal frequency	Stomata size
Fresh shoot length	(0.499*)						
	0.455**						
Fresh root length	(0.576*)	(0.521*)					
	0.403*	0.427**					
Fresh root weight	(0.560*)	(0.229*)	(0.230*)				
	0.483**	0.227^{NS}	0.185^{NS}				
Leaf venation	(0.107^{NS})	(-0.186^{NS})	(0.092^{NS})	(0.334*)			
	0.117	-0.160^{NS}	0.100^{NS}	0.330*			
Stomatal frequency	(0.419*)	(0.112^{NS})	(0.393*)	(0.539*)	(0.180*)		
	0.356^{NS}	0.108^{NS}	0.333*	0.530**	0.175^{NS}		
Stomata size	(0.008^{NS})	(0.040^{NS})	(0.090^{NS})	(-0.219^{NS})	(-0.281*)	(-0.538*)	
	-0.008^{NS}	0.042^{NS}	0.031^{NS}	-0.216^{NS}	-0.272*	-0.518*	
Epidermal cell size	(0.257*)	(0.542*)	(0.195*)	(0.012^{NS})	(-0.126)	(-0.292*)	(0.443*)
	0.210^{NS}	0.529**	0.179^{NS}	0.022^{NS}	-0.081^{NS}	-0.284*	0.408**

N.S = non significant, * = significant at 5% probability level, ** = highly significant

Genetic and phenotypic associations. Fresh shoot length had significantly positive genetic correlation with fresh root length, fresh root weight, stomata size, epidermal cell size and fresh shoot weight *(Table 2)*. It had positive significant correlation with fresh root length, fresh shoot weight and epidermal cell size at phenotypic level. Fresh root length has significantly positive genetic correlation with fresh shoot length, fresh root weight, stomatal frequency, stomata size, epidermal cell size and fresh shoot weight. It had positive significant correlation with stomatal frequency and fresh shoot weight at phenotypic level. Fresh root weight was significantly and positively correlated with fresh shoot length, leaf venation, stomatal frequency, epidermal cell size at genetic level. It had significant and positive correlation with fresh shoot weight, leaf venation and stomatal frequency at phenotypic level. Mehdi and Ahsan (1999) also reported positive correlation between root weight and shoot weight under stress conditions.

Leaf venation had positive and significant genetic correlation with stomatal frequency but negative with stomata size. Stomatal frequency had negative significant correlation with stomata size and epidermal cell size but positive with fresh shoot weight at genetic level. It was negatively and significantly correlated with stomata size and epidermal cell size at phenotypic level. Stomata size had negative significant correlation with epidermal cell size at both genetic and phenotypic level. There was positive and significant genetic and non-significant phenotypic correlation between epidermal cell size and fresh shoot weight. Bocev (1963) reported that the seedlings showing well developed root system also showed well developed rooting system at final stage, thus providing evidence that the plant types showing drought tolerant at seedling stage will also show tolerance at later growth stages. The present study agreed with the result of Sen and Misra (1981) they reported positive correlation between stomatal frequency and yield in wheat.

Direct and indirect effects. Direct and indirect effects *(Table 3)* were rated as described by Lenka and Mishra (1973). Direct effect of fresh shoot length on fresh shoot weight was found positive and very high. But its indirect effects on fresh shoot weight through fresh root length and epidermal cell size were negative and very high and high respectively. Although its effect through fresh root weight was positive moderate and negligible through leaf venation and stomata size. It was found negatively low through stomatal frequency. The direct effect of fresh root length on fresh shoot weight was negative and very high. Its indirect on fresh shoot weight effects through fresh shoot length and fresh root weight was found very high and positive but negligible through leaf venation and stomata size. Indirect effects of stomatal size and epidermal cell size were negatively high and moderate on fresh shoot weight respectively.

Leaf venation had positively moderate direct effect on fresh shoot weight. It had negatively very high indirect effects through fresh shoot length and fresh root length on fresh shoot weight respectively. But it had positive and high indirect effect through fresh root weight and negatively moderate indirect effects through stomatal frequency. The effects were low but positive through epidermal cell size but negligible in case of stomata size on fresh shoot weight. Stomatal frequency had very high negative indirect effect on fresh shoot weight. Stomatal frequency had negatively very high indirect effects on fresh shoot weight through fresh root length. It had positive and high through fresh shoot and root weight and epidermal cell size. The indirect effects of leaf venation and stomata were found negligible on fresh shoot weight. The direct effect of stomata size was found negligible on fresh shoot weight. But its indirect effects through fresh shoot length and stomatal frequency were found high and positive on fresh shoot weight but negative and high through fresh root length and epidermal cell size. But negative and moderate through fresh root weight on fresh shoot weight and negligible via leaf venation. Epidermal cell size had negative and very high direct effect on fresh shoot weight but leaf venation, stomata size and fresh root weight had negligible indirect effects. It had very high and negative indirect effects through fresh root length but very high and positive through fresh shoot length on fresh shoot weight. High and positive indirect effects were found through stomatal frequency on fresh shoot weight.

Table 3 - Direct (bold) and indirect effects of various physio-genetic traits on fresh shoot weight in maize at water deficit conditions

Fresh shoot length	Fresh root length	Fresh root weight	Leaf venation	Stomatal frequency	Stomata size	Epidermal cell size
8.287	-4.269	0.223	-0.044	-0.140	0.003	-0.655
4.321	**-8.187**	1.131	0.022	-0.491	0.008	-0.235
1.898	-1.884	**0.973**	0.079	-0.674	-0.018	-0.015
-1.542	-0.753	0.325	**0.235**	-0.225	-0.023	0.153
0.932	-3.225	0.525	0.043	**-1.248**	-0.045	0.353
0.333	-0.743	-0.213	-0.066	0.672	**0.083**	-0.536
4.499	-1.596	0.012	-0.030	0.365	0.0368	**-1.207**

Direct and indirect effects found significant and positive for fresh shoot length and fresh root weight on fresh shoot weight and their positive correlation with it suggested that both fresh shoot length and fresh root weight with deceased stomatal frequency and epidermal cell size were good contributor for high fresh shoot yield under drought conditions.

Different research workers reported drought effects on crop plants and suggested selection criterion such as stomatal frequency by Khaliq *et al.* (2000) in wheat, fresh shoot weight and dry root weight by Mehdi and Ahsan (2000) and Mehdi *et al.* (2001) in maize, leaf venation and stomatal frequency by Mahmood *et al.* (2003) in wheat. However more precisely it was suggested from the results of this study that overall physio-genetic performance of the genotypes rather than single trait might be more useful selection criteria while selection for tolerance against drought.

REFERENCES

Aggarwal, P.K., S.K. Sinha, 1983 - Relationship between mother shoot and tillers as criterion of selection for wide or specific adaptability to drought in wheat. Zacker-Planzenb 152:310-320

Alam A.N., 1985 - Evapo-transpiration and yield of corn as related to irrigation timing during silking. Dissertation Abst. International 46: 1749-1750

Anonymous, 2007 - Agriculture Statistic of Pakistan, Govt. of Pakistan. Ministry of Food, Agriculture and Livestock, Economic Wing, Islamabad, Pakistan.

Ashraf M., 1989 - Effect of water stress on maize cultivars during the vegetative stage. Ann. Arid Zone 28: 47-55

Bocev B.V., 1963 - Maize selection at an initial phase of development. Kukuruzu (Maize). Pl. Br. Abat 1:54

Dewey O.R., K.H. Lu, 1959 - A correlation and path coefficient analysis of components of crested wheatgrass seed production. J. Agron 57: 515-518

Ehlig C.F., R.D. Lemert, 1976 - Water use and productivity of wheat under five irrigation treatments. Soil Sci. Soc. Am. J 40: 750-755

Jones H.G., 1979 - Stomatal behavior and breeding for drought resistance. Stress physiology in crop plant. Wiley Interscience, New York.

Kazemi H., S.R. Chapman, F.M. Mc Neal, 1978 - Variation in stomatal number in spring wheat cultivars. Cereal Res. Comm 6: 259-365

Khaliq, I., S.A.H. Shah, M. Ahsan, M. Khalid, 2000 - Evaluation of spring wheat (*Triticum aestivum* L.) for drought field condition: A Morphological study. Pak. J. Bio. Sci 2: 1006-1009

Kramer P.J., 1980 - Drought stress and the origin of adaptation. In: N.C. Turner, and P.J. Kramer (ed.) Adaptation of Plants to water and High Temperature Stress. John Wiley and Sons, New York. P. 7-19

Kwon S.H., J.H. Torrie, 1964 - Heritability and interrelationship of trait of two soybean populations. Crop Sci 4:196-198

Lenka D., B. Mishra, 1973 - *Path coefficient analysis of yield in rice varieties. Indian J. Agric. Sci 43:376-379*

Mahmood N., M.A. Chowdhry, M. Kashif, 2003 - Genetic analysis of some physio-morphic traits of wheat under drought condition. J. Genet. Breed 57*: 385–391*

Mehdi S.S., M. Ahsan, 1999 - Evaluation of S_1 maize (*Zea mays* L.) families at seedling stage for fodder purposes. Pak. J. Bio. Sci 2:404-405.

Mehdi S.S., M. Ahsan, 2000 - Genetic coefficient of variation, relative expected genetic advance and inter-relationship in maize (*Zea mays* L.) for green fodder purposes at seedling stage. Pak J. Bio. Sci., 3:1890-1891

Mehdi S.S., M. Ahmad, M. Ahsan, 2001 - Evaluation of S_1 maize (*Zea mays* L.) families at seedling stage under drought conditions. On-Line J. Bio. Sci 1:4-6

Nour M.A. D.E. Weibal, 1978 - Evaluation of root characteristics in grain sorghum. Agron. J 70: 217-218

Ramadan H.A., S.N. Al-Niemi, T.T. Hamdan, 1985 - Water stress, soil type and phosphorus effects on corn and soybean, I. Effect on growth. Iraqi J. Agric. Sci. Sanco 3: 137-144

Richards R.A., 1978 - Variation between and within species of rape seed (*B. Campestris* and *B. napus*) in response to drought stress. III. Physiological and physiochemical characters. Aust. J. Agric. Res 29: 491-501

Sen A., N.M. Misra, 1981 - Correlation coefficient between yield and some drought tolerance capacity parameters in kalian Sona Wheat. Food farming and Agri 14:1-2

Steel R.G.D., J.H. Torrie, D.A. Dickey, 1997 - Principals and Procedure of Statistics. A biometric approach. Mc Graw Hill Book Co., New York, USA.

Thakur P.S., V.K. Rai, 1984 - Water stress effect on maize cultivars during early stage of growth. Ind. J. Ecol 11: 92-98

Wright S., 1934 - The method of path coefficients. Annals of Mathematical Statistics 5:161-215