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EFFECT OF WATER STRESS ON SEEDLING GROWTH OF MAIZE CULTIVARS IN MANNITOL PLUS CULTURE SOLUTION

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ABSTRACT

A Laboratory experiment was conducted to evaluate the effect of four level of water potential (ψ) viz., 0.00; -4.09; -8.18 and -12.28 bars on the seedling growth of six cultivar of maize (*Zea mays* L.). Mannitol was used as an osmoticum alongwith half strength Hoagland culture solution. Results depicted that in response to different levels of water stress all mentioned entries of seedling growth (except root dry weight) as well as different cultivars of maize in general responded significantly ($P<0.05$). Results also depicted that as water stress level increased seedling growth decreased. Generally a maximum reduction in root length (4.75 cm $plant^{-1}$), shoot length (5.46 cm $plant^{-1}$), root moist weight (224.3 mg $plant^{-1}$), shoot moist weight (354.5 mg $plant^{-1}$) and shoot dry weight (234.8 mg $plant^{-1}$) are recorded in highest water stress level (viz., -12.28 bars). Results further deciphered that based on cumulative drought tolerance index; maize cv. Yousafwala E.V. 1081 could be rated as drought tolerant and cv. Synthetic-551 as drought sensitive. While remaining cultivars viz., Agaithi-72, Composite-15, Azam and Ehsan could be rated as drought intermediate in response, respectively. Results also showed there is a total of 72.71% improvement in seedling growth when compared with the results of the same study using no Hoagland culture media. Present study also changed the drought tolerance arrangement of maize cultivars.

Key words: Maize, water stress, root-shoot length, root-shoot weight

INTRODUCTION

Maize (*Zea mays* L.) is an important multipurpose crop used as food, fodder, fuel and in the manufacturing industries. In Pakistan it is grown over 871 thousand hectare with a total production of 1259 thousand tons (Anon., 1997). This crop having high potentiality to cultivate in the country, but its average grain yield is low i.e., 1.42 t ha^{-1} at farmer's field in comparison with research farms and other competing countries i.e., 8.93 t ha^{-1} (Anon., 1993; Mahmood, 1994). Although improved crop genotypes and fertilizer use have increased the crop yield but the full potential of crop has not been obtained. Among various constraints responsible for low grain yield, inadequate supply of water at its critical developmental stages and high sensitivity of different maize cultivars to water stress are of immense importance (Link *et al.,* 1999; Shakhatreh *et al.,* 2001).

Sustainable agriculture in Pakistan not only implies the management and conservation of natural resources but also a steady and substantial increase in crop yield (Ahmed *et al.,* 1996). To find out drought tolerance of a species basic study on the effect of water stress on germination, growth and nutrient uptake a species are of prime importance. Research revealed that any degree of water stress may produce detrimental effects on growth potentials (El-Monayeri *et al.,* 1984). Under drought condition there was a sharp decline in the values of all growth parameters (Del Rosario *et al.,* 1991; Otegui *et al.,* 1995; Ali *et al.,* 1999).

Ashraf and Mehmood (1990) studied the response of four *Brassica* species to drought stress. Saeed *et al.,* (1997) found significantly decreased growth rate of two maize cultivars due to drought. Some post graduate students of this University also studied the effect of water stress on germination of four varieties of maize (Jabbar, 1985), Mungbean (Akhtar, 1985), eight species of Agropyron (Batool, 1988) and six exotic species (Ali, 1988). The present study was therefore mainly designed to evaluate the drought tolerance of six maize cultivars during its early stages of growth response to varying osmotica with and without culture solution.

MATERIALS AND METHODS

The work presented here deals with the effect of four different level or treatment of water potential (Ψ) i.e., 0.00; -4.09; -8.18 and -12.28 bars on the seedling growth of six cultivar of maize (*Zea mays L.)* viz., Agaithi-72; Azam; Composite-15; Ehsan; Synthetic-551 and Yousafwala E.V. 1081. The water potential treatments (S) were prepared by dissolving calculated amount of mannitol ($C_6H_{14}O_6$) in deionized water, using the formula as described by Ting (1980). Half strength of Hoagland culture nutrients was also dissolved separately in each treatment. The treatments were then designated as S_1, S_2, S_3, and S_4.

$$\Psi \text{ (bars)} = \frac{-21.8 \times M \times T}{273}$$

After treating with 1.0% mercuric chloride solution, the seeds of each cultivar were soaked in respective water stress treatments. This study was carried out in Petri-dishes of 9 cm in diameter. Each treatment was replicated thrice and they were then placed in an Incubator at 30 ^{0}C by arranging them in a Completely Randomized Design (CRD). The detail of the procedure has been already explained by Achakzai (2006a). After 15 days of germination, a set of plant from each Petri-dish was taken out and the following growth measurements were made:- (i) Root and shoot length, cm. (ii) Root and shoot fresh weight, g. (iii) Root and shoot oven dry weight (g) at 80 ^{0}C. Individual and cumulative Drought Tolerance Index (DTI) was calculated following the formulae described by Achakzai (2006a). While seedling growth obtained in the highest water stress treatment (-12.28 bars) prepared in culture media was also compared with the same level of water stress in non culture media (prepared in mannitol only) using the formula given below:-

$$\text{Increase in seedling growth (\%)} = \frac{\text{Growth in culture media} - \text{Growth in non culture media x 100}}{\text{Growth in culture media}}$$

Data obtained for seedling growth were also statistically analyzed, following the procedure as described by Steel & Torrie, (1980). MSTAT-C computer software package was used for the purpose.

RESULTS AND DISCUSSION

Results presented in Table 1 depicted that in relation to different levels of water stress (A) all entioned entries of maize seedling growth (except root dry weight) as well as their cultivars (B) responded significantly ($P<0.05$). Whereas interactions between A x B was also found significant (except root dry weight). Similar results are also obtained by Achakzai (2006a) for maize seedlings grown in mannitol solution only.

Data presented in Table 2 & 3 deciphered that water stress levels significantly and linearly decreased both the root and shoot length. This reduction was much marked in shoot as compared with root. Statistically maximum reduction in root length (4.76 cm plant^{-1}) and shoot length (5.46 cm plant^{-1}) is obtained in highest dose of water stress levels (-12.28 bars). However, on comparison basis shoot was much affected than root. Research revealed that water stress affects critically every aspect of plant growth and life, by modifying the anatomy, agronomy, physiology and biochemistry (Kramar, 1969; Saeed *et al.,* 1997). The present decrease in growth was expected because the rate of growth of plant cells and the efficiency of their physiological processes are highest when the cells are at maximum turgor. Plants subjected to water stress (S_2 to S_4) have turgor pressure of the cell lower than the maximum value. Cell and leaf growth are highly sensitive to water stress, because cell expansion is caused by the action of turgor pressure upon cell walls (Greacen & Oh, 1972; Burstrom, 1975). They further revealed that even mild water stress conditions, when turgor pressure is reduced by only few bars would result a significant decrease in growth. The reduction in growth is a primary effect of every stress which may be due to different metabolic disturbances. Similar results have been reported in maize cultivars (Del Rosario *et al.,* 1991; Ali *et al.,* 1999; Achakzai, 2006a) and wheat genotypes (Ashraf & Naqvi, 1995; Ashraf *et al.,* 1995 & 1996). This decrease depends upon the sensitivity of crops and even cultivars/lines to stress. Therefore, based on cultivars response in respect of both of their root and shoot length subjected to various water stress treatments, maize cv. Yousafwala could be rated as drought tolerant and cv. Agaithi-72 as drought sensitive. Whereas remaining cultivars could be ranked as drought intermediate in response. Drought tolerant cultivar might maintain their turgor by decreasing osmotic potential at lower seedling water potential and they showed higher osmotic adjustment. Similar trend of variable response was also recorded by Achakzai (2006ab) in maize and sorghum cultivars, respectively. While contrasting results are obtained by Mahmood *et al.,* (2004) in the field grown crops. It was also noted that the drought tolerance arrangement of cultivars are not same as those described by Achakzai (2006a). Results further enumerates that by comparing the present study with those of Achakzai (2006a) there was a sharp increase in seedling length (36.23 – 79.84%) of maize cultivars grown in culture media over in non culture media (mannitol only). This might be owed to fulfilment of macro and micronutrients by maize seedlings. A maximum increase in root and shoot length was recorded for cv. Agaithi-72 and Composite-15 followed by a minimum in cv. Ehsan and cv. Yousafwala (Table 8).

Data presented in Table 4 & 5 deciphered that water stress conditions significantly ($P<0.05$) and linearly decreased the root and shoot fresh weight. A maximum reduction (i.e., 224.3 and 345.5 mg plant^{-1}) in both attributes is recorded in highest level of imposed water stress (i.e., -12.28 bars), respectively. Similarly, cultivars response was also statistically found significant. These findings are also in line with those described by Achakzai (2006abc). Therefore, based on cultivars response in respect of their root and shoot fresh weight, maize cv. Yousafwala E.V. 1081 & Composite-15 could be rated as drought tolerant, and cv. Synthetic-551 & cv. Agaithi-72 as drought sensitive. While remaining cultivars were found to be intermediate in response. The sequence of cultivars in term of drought tolerance is not in line with those explained by Achakzai (2006a). Similar trend of results are also received by Achakzai (2006bc). Results further deciphered that by comparing the present study with those of Achakzai

(2006a) there was a sharp increase in fresh weight of seedling of maize cultivars grown in culture media over those grown in non culture media (mannitol only). This might be due to fulfilment of macro and micronutrients by maize seedlings. A maximum increase in root and shoot fresh weight is recorded for cv. Agaithi-72 followed by a minimum in cv. Composite-15 and cv. Synthetic-551 (Table 8).

Table 1. Analysis of variance (ANOVA) for seedling growth of maize cultivars (*Zea mays* L.) in response to imposed water stress level.

Variables	**F-value of variables at an error of 48**			**CV (%)**
	Cultivars (A)	**Stress levels (B)**	**A x B**	
Root length, cm plant^{-1}	2.1987 *	13.3954 *	3.1155 *	14.60
Shoot length, cm plant^{-1}	13.4968 *	959.8399 *	7.3475 *	12.57
Root fresh weight, mg plant^{-1}	250.4100 *	30.2312 *	6.5041 *	5.82
Shoot fresh weight, mg plant^{-1}	56.7698 *	1331.7319 *	20.2251*	6.44
Root oven dry weight, mg plant^{-1}	92.1874 *	0.0982 ns	0.1014 ns	13.13
Shoot oven dry weight, mg plant^{-1}	25.0061 *	17.1634 *	2.8864 *	10.51

* Significant at 5% level of probability and ns = non-significant. CV = coefficient of variation.

Table 2. Effect of four different level of water stress on root length (cm plant^{-1}) of six cultivar of maize (*Zea mays* L.).

Stress Levels (S)	**Maize Cultivars (CV)**						***Mean**
	CV_1	**CV_2**	**CV_3**	**CV_4**	**CV_5**	**CV_6**	
S_1	5.87 bcdef	6.40 abcd	6.52 abc	6.72 abc	6.72 abc	5.49 cdefgh	6.287 a
S_2	6.33 abcd	5.09 defghi	7.09 ab	5.98 bcde	6.41 abcd	7.05 ab	6.324 a
S_3	7.66 a	5.77 bcdef	6.66 abc	5.73 bcdefg	3.94 i	5.63 cdefg	5.898 a
S_4	4.70 efghi	4.17 hi	4.36 ghi	4.72 efghi	4.54 fghi	6.05 bcde	4.757 b
*Mean	6.140 a	5.358 b	6.158 a	5.787 ab	5.402 b	6.054 ab	5.817
CD1(for CV) = 0.6970; CD1 (for S) = 0.5691; CD1 (for S x CV) = 1.394							

Values followed by the same letter within columns (cv) & rows (S), and similarly mean values (*) followed by the same letter within a column and row are not significantly differ with each other at 5% level of probability using LSD test.

Table 3. Effect of four different level of water stress on shoot length (cm plant^{-1}) of six cultivar of maize (*Zea mays* L.).

Stress Levels (S)	**Maize Cultivars (CV)**						***Mean**
	CV_1	**CV_2**	**CV_3**	**CV_4**	**CV_5**	**CV_6**	
S_1	32.10 de	35.33 cd	46.42 a	36.77 c	42.11 b	30.32 e	37.17 a
S_2	10.94 ghi	9.47 hij	15.52 f	14.77 f	12.30 fgh	13.10 fg	12.68 b
S_3	9.13 hijk	8.01 ijklm	10.66 ghi	6.89 jklmn	4.85 mn	8.72 ijkl	8.04 c
S_4	4.78 mn	4.56 n	6.40 jklmn	5.41 mn	5.95 klmn	5.63 lmn	5.46 d
*Mean	14.24 d	14.34 cd	19.75 a	15.96 bc	16.30 b	14.44 cd	15.839
CD1(for CV) = 1.634; CD1 (for S) = 1.334; CD1 (for S x CV) = 3.268							

Values followed by the same letter within columns (cv) & rows (S), and similarly mean values (*) followed by the same letter within a column and row are not significantly differ with each other at 5% level of probability using LSD test.

Results pertaining to root and shoot oven-dry weight (Table 6 & 7) showed that in relation to water tress root dry weight responded non-significantly, while shoot dry weight exhibited significant linear reduction. A maximum reduction in shoot dry weight is obtained in S_4 level of water stress. These findings are in conformity with those described by Ashraf *et al.*, (1996) and Achakzai (2006a). However, by comparing the varietal mean values, both parameters were found to be significant. Maize cv. Agaithi-72 & cv. Yousafwala E.V. 1081 could be rated as drought tolerant and cv. Azam & cv. Synthetic-551 as drought sensitive, while remaining cultivars are rated as drought intermediate. Results further deciphered that by comparing the present study with those of Achakzai (2006a) there is a great increase (75-78%) in dry weight of maize seedling grown in culture media over those grown in non culture media (mannitol only). This might be due to increased metabolic activity and phytoaccumulation of macro and micronutrients by maize seedlings. A maximum increase in both root and shoot dry weight is recorded for cv. Agaithi-72 followed by a minimum in cv. Composite-15 and cv. Synthetic-551 (Table 8).

Table 4. Effect of four different level of water stress on root fresh weight (mg plant^{-1}) of six cultivar of maize (*Zea mays* L.).

Stress Levels (S)	**Maize Cultivars (CV)**						***Mean**
	CV_1	**CV_2**	**CV_3**	**CV_4**	**CV_5**	**CV_6**	
S_1	301 c	246 de	253 d	253 d	223 efg	340 b	269.3 a
S_2	347 ab	184 hij	245 de	217 fg	171 ij	366 a	255.0 b
S_3	347 ab	214 fg	231 def	207 gh	185 hij	339 b	253.8 b
S_4	306 c	163 j	184 hij	188 hi	175 ij	330 b	224.3 c
*Mean	325.3 b	201.8 e	228.3 c	216.3 d	188.5 f	343.8 a	250.625
CD1(for CV) = 11.97; CD1 (for S) = 9.770; CD1 (for S x CV) = 23.93							

Values followed by the same letter within columns (cv) & rows (S), and similarly mean values (*) followed by the same letter within a column and row are not significantly differ with each other at 5% level of probability using LSD test.

Table 5. Effect of four different level of water stress on shoot fresh weight (mg plant^{-1}) of six cultivar of maize (*Zea mays* L.).

Stress Levels (S)	**Maize Cultivars (CV)**						***Mean**
	CV_1	**CV_2**	**CV_3**	**CV_4**	**CV_5**	**CV_6**	
S_1	905 d	1024 c	1243 a	1179 b	1164 b	583 d	1066 a
S_2	453 ijk	448 ijk	712 e	590 f	310 no	537 fg	508.3 b
S_3	431 jk	422 jkl	529 fgh	469 hij	241 p	503 ghi	432.5 c
S_4	361 lmn	339 mn	420 jkl	303 nop	255 op	395 klm	345.5 d
*Mean	537.5 d	558.3 cd	726.0 a	635.3 b	492.5 e	579.5 c	588.167
CD1(for CV) = 31.08; CD1 (for S) = 25.37; CD1 (for S x CV) = 62.15							

Values followed by the same letter within columns (cv) & rows (S), and similarly mean values (*) followed by the same letter within a column and row are not significantly differ with each other at 5% level of probability using LSD test.

Table 6. Effect of four different level of water stress on root oven dry weight (mg plant^{-1}) of six cultivar of maize (*Zea mays* L.).

Stress Levels (S)	**Maize Cultivars (CV)**						**Mean**
	CV_1	**CV_2**	**CV_3**	**CV_4**	**CV_5**	**CV_6**	
S_1	239	126	128	126	127	239	164.2
S_2	242	121	127	125	127	233	162.5
S_3	240	128	128	125	130	244	165.8
S_4	248	123	123	128	123	250	165.8
*Mean	242.3 a	124.5 b	126.5 b	126.0 b	126.8 b	241.5 a	164.583
CD1(for CV) = 17.73; CD1 (for S) = 14.48; CD1 (for S x CV) = 35.46							

*Mean values (*) followed by the same letter within a row are not significantly differ with each other at 5% level of probability using LSD test.

Table 7. Effect of four different level of water stress on shoot oven dry weight (mg plant^{-1}) of six cultivar of maize (*Zea mays* L.).

Stress Levels (S)	**Maize Cultivars (CV)**						***Mean**
	CV_1	**CV_2**	**CV_3**	**CV_4**	**CV_5**	**CV_6**	
S_1	298 ab	300 ab	312 a	300 ab	290 ab	302 ab	300.3 a
S_2	277 ab	280 ab	313 a	280 ab	160 c	293 ab	267.2 b
S_3	279 ab	260 b	287 ab	270 ab	150 c	300 ab	257.7 b
S_4	258 b	260 b	273 ab	190 c	150 c	278 ab	234.8 c
*Mean	278.0 ab	275.0 ab	296.3 a	260.0 b	187.5 c	293.3 a	265.00
CD1(for CV) = 22.85; CD1 (for S) = 18.66; CD1 (for S x CV) = 45.70							

Values followed by the same letter within columns (cv) & rows (S), and similarly mean values (*) followed by the same letter within a column and row are not significantly differ with each other at 5% level of probability using LSD test.

Results based on drought tolerance index (DTI, %) showed that a maximum response (76-100%) is recorded for root as compared with their respective shoot attributes (14-77%). Results also showed that based on cumulative DTI maize cv. Yousafwala E.V. 1081 could be rated as drought tolerant and cv. Synthetic-551 as drought sensitive. While remaining four cultivars viz., Agaithi-72, Composite-15, Azam and Ehsan could be rated as drought intermediate in response, respectively. These findings are not in agreement with those described by Achakzai (2006a) for the same experiment by using no culture solution (Table 9).

Table 8. Increase (%) in seedling growth of maize cultivars grown in mannitol plus culture solution over mannitol solution only (-12.28 bars).

Growth Parameters	**Maize Cultivars**						**Increase (%) in Individual Growth Parameter**
	Agaithi -72	**Azam**	**Composite-15**	**Ehsan**	**Synthetic -551**	**Yousafwala E.V. 1081**	
Root Length	62.77	56.59	46.56	36.23	46.70	55.87	50.79
Shoot Length	71.97	68.64	79.84	71.53	75.29	68.56	72.64
Root Fresh Weight	95.75	77.91	60.33	75.00	75.43	85.15	78.26
Shoot fresh Weight	91.41	75.81	77.14	73.27	59.60	77.47	75.78
Root Dry Wt.	98.79	77.27	53.66	77.34	78.05	85.60	78.45
Shoot Dry Weight	98.06	80.76	77.29	81.05	57.33	87.41	80.32
Cumulative Increase (%)	86.46	72.83	65.80	69.07	65.40	76.68	72.706

Table 9. Drought tolerance index (DTI) of six cultivar of maize (*Zea mays* L.) grown in mannitol plus culture solution.

Growth Parameters	**Maize Cultivars**						**DTI (%) of Individual Growth Parameter**
	Agaithi -72	**Azam**	**Composite-15**	**Ehsan**	**Synthetic -551**	**Yousafwala E.V. 1081**	
Root Length	80.07	65.16	66.87	70.24	67.56	110.20	76.78
Shoot Length	14.89	12.90	13.79	14.71	14.13	18.57	14.83
Root Fresh Weight	101.66	66.26	72.73	74.31	78.48	97.06	81.75
Shoot fresh Weight	39.89	33.10	33.79	25.70	21.90	67.75	37.02
Root Dry Wt.	103.77	97.62	96.09	101.58	96.85	104.60	100.09
Shoot Dry Weight	86.58	86.67	87.50	63.33	51.72	92.05	77.98
Cumulative DTI (%)	71.14	60.29	61.80	58.31	55.11	81.71	64.742

DTI stands for drought tolerance index.

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