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Evaluation of Drought Tolerance in Maize Hybrids

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ABSTRACT

Water deficit is a major problem in semi arid regions of Pakistan. It affects plant growth, yield and eventually leads to a considerable crop failure. Although maize (*Zea mays* L.) is susceptible to water deficit there is a marked genotypic variation in rooting density, morphological and physiological characteristics in maize. A green house experiment was conducted to study the response of spring maize plant growth to soil moisture content under controlled conditions. The seeds of eight maize hybrids (FH 421, FH 810, Pioneer 32-F-10, Pioneer 32-W-86, Monsanto 919, Monsanto 6525, NK 8441 & SS 5050) were sown in pots having the capacity of eight kg soil. A factorial completely randomized design (CRD) with three replications was used. The two field capacities (75% & 100%) were maintained after the reduction of 30% soil moisture. Monsanto 919 performed better in both levels with maximum plant height, leaf area per plant, water potential, osmotic potential, turgor potential and minimum relative saturation deficit, while maize hybrid FH 810 remained sensitive at deficit irrigation (75% field capacity).

Key Words: Maize hybrids; Water deficit; Plant water relations

INTRODUCTION

Maize is an important cereal crop grown all over the world (Farhad *et al*., 2009). In Pakistan diverse maize genotypes i.e., single cross and double cross hybrids, synthetics and composites are being planted. The responses of all these genotypes vary to different agro-management practices, particularly water and nutrient. These variable responses differ mainly due to differences in plant morphology (Benga *et al*., 2001), crowding stress tolerance (Tollenaar & Wu, 1999; Tollenaar & Lee, 2002), intra-specific competition in maize plants for water (Maddonni & Otegui, 2004; Maddonni & Otegui, 2006), plant growth rate (Echarte *et al*., 2000; Aslam *et al*., 2006), crop duration (Ying *et al*., 2000; Echarte *et al*., 2006), relative maturity (Farnham, 2001; Widdicombe *et al*., 2002), sink capacity (Borras & Westgate, 2006; Gambin *et al*., 2006), vertical leaf area profile, nutrient uptake, utilization potential (Valentinuz & Tollenaar, 2006) and yield of different maize hybrids (Golbashy *et al*., 2010).

Water resources have become meager due to climate change, population growth and competition from other water users (Farahani *et al.,* 2007). Water resources for agriculture are decreasing due to increase in demand for irrigation and other non-agricultural water uses (Bacon, 2004). As Maize crop requires about 400 to 600 mm of water during its lifecycle (Singh, 1991) water availability imposes strong and recurring pressure to screen maize hybrids (Bohnert *et al*., 1995; Bray, 1997). Similarly maize inbred lines and hybrids are different in their repose to drought (Saab *et. al.,* 1990). This is evident from the fact that plant distribution and yield in agricultural systems are largely determined by water availability. Plant adaptation to drought involves both morphological and physiological traits (Passioura, 1996; Araus *et al*., 2002). Both long and short-term water deficit budgets lead to many physiological alterations. Long-term drought response includes altered root to shoot ratio (Blum & Arkin, 1984), reduced leaf area (Batanouny *et al*., 1991) and short term include altered osmotic adjustment (Turner *et al*., 1986). Plant reposed to drought by delaying dehydration, where plants maintain relatively high water potential (Kramer & Boyer, 1995). In drought tolerant plants, there are many defense mechanisms such as osmoregulation, antioxidant and hormonal systems, helping plants to stay alive and develop earlier to their reproductive stages (Reddy *et al*., 2004; Sairam & Tyagi, 2004; Ashraf, 2010). Physiological and morphological characteristics such as osmotic adjustment, stomatal behavior, chloroplast activity, leaf water potential, root volume, root weight, leaf area and dry matter production are found different in maize cultivars grown under limited water supply (Weerathaworn *et al.,* 1992; Mian *et al.,* 1993).

The environmental stresses such as drought, high temperature, salinity, air pollution, heavy metals, pesticides and soil pH are major limiting factors in crop production because they affect almost all plant functions (Hernandez *et al*., 2001; Lawlor, 2002). Drought is a major abiotic factor

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that limits agricultural crop production (Nemeth *et al*., 2002; Chaves & Oliveria, 2004; Lea *et al*., 2004; Ramachandra *et al*., 2004; Seghatoleslami *et al.,* 2008; Jaleel *et al*., 2009; Golbashy *et al.,* 2010) it may be due to inhibited cell expansion and reduced biomass production (Ashraf & Mehmood, 1990). Cell membrane stability, osmotic adjustment, reciprocal to cell membrane injury, is a physiological index widely used for the evaluation of drought tolerance (Quan *et al*., 2004).

Understanding physiological behavior of plants under drought conditions may results in predicting drought tolerant varieties of crops (Kerepesi *et al*., 2000). In many plant species under drought condition the alteration in different metabolic activities (Lawlor & Cornic, 2002), the reduction of relative water content in plants and decrease in plant vigor (Halder & Burrage, 2003; Lopez *et al*., 2002) was observed. According to Olaoye (2009) maize seedling response varies with respect to its growth rate at different field capacities of soil and accumulates a variety of compatible solutes such as proline and betaine, an adaptive mechanism of tolerance to salinity and drought (Farooq *et al*., 2009). Keeping in view the above facts, the present study was designed to evaluate the response of maize hybrids under different irrigation regimes.

MATERIALS AND METHODS

Soil properties: The soil used for the experiment was sandy clay loam. Before filling the pots soil samples were collected for various physico-chemical properties as detailed below (Table I).

Field capacity (FC): After seed germination, field capacity of each pot was maintained as per treatments. Soil moisture percentage of each pot was measured on daily basis with the help of soil moisture meter. Each time pots were irrigated to maintain field capacity, when moisture contents were decreased to 30%. This procedure was carried out up to appraisal of seedling.

Crop husbandry: The experiment was started on 7th August 2009 in Agro-climatology Green House, University of Agriculture Faisalabad using completely randomized design (CRD) with factorial arrangement and was replicated thrice. The environment of green house was controlled according to the past five year's weather data of February. Ten seeds were initially planted in a pot but later thinned to keep six vigorous seedlings per pot. In each pot recommended Phosphrous and Potash (each at the rate of 125 kg ha^{-1}) was applied at the time of sowing while Nitrogen (at the rate of 250 kg ha^{-1}) was applied in a two split dose.

Morphological observations: In each pot height of five plants was recorded 24 days after sowing (DAS) with the help of meter rod and then average height was calculated. Leaf area of same plants was measured 24 DAS with the help of portable laser leaf area meter (Laser Area Meter CI-203 & Serial Number 203-2.13-08059).

Table I: Physico-chemical analysis of soil

Characteristics	Values
Sand (%)	65
Silt (%)	17
Clay (%)	18
Texture	Sandy clay loam
Field capacity (%)	22.5
Wilting point (%)	6.95
Soil pH	7.92
E.C. (dS m^{-1})	1.6
Organic mater (%)	0.71

Physiological characteristic: Water potential of 3rd leaf from top at morning time in each pot was measured 24 DAS with the help of Scholander type pressure chamber (Arimad-2 ELE international, Japan). The same leaf was frozen below -20°C for seven days, thawed and the sap extracted by pressing the material with a glass rod. The sap was used directly for the determination of osmotic potential in a vapor pressure osmometer (Wescor, 5500). Turgor pressure was calculated as difference between water potential (ψ_w) and osmotic potential (ψ_s):

$$\psi_p = \psi_w - \psi_s$$

Similarly, 24 DAS relative saturation deficit of 4th leaf from top was collected from each pot at morning time. The upper surface of leaves was cleaned with the help of tissue paper and fresh weight was recorded immediately, then these leaves were placed in the test tube, containing 10 mL distilled water and left over a night at room temperature. These leaves were taken out next day, water was removed with the help of tissue paper from the leaf surface and then weight was recorded again to obtain the saturated weight and relative saturation deficit was calculated as fallows (Ashraf *et al*., 2006).

RSD = (Saturated weight - Fresh weight/Saturated weight) x 100

Statistical analysis: Data was statistically analyzed by using the Fisher's analysis of variance technique and the differences among treatments' means were compared using least significant difference test (Steel *et al.,* 1997). Pearson's correlations were drawn between various attributes using Microsoft Excel Program.

RESULTS AND DISCUSSION

Changes in morphological characters are the ultimate determinants of stress effects on plants (Farooq *et al*., 2009; Jaleel *et al*., 2009). Data showed that plant height was significantly affected by different levels of field capacity (Table II). The comparison of treatments' means revealed that maximum plant height (38.26 cm) was recorded where water was applied according to 100% field capacity (I_2) with Monsanto 919 (H_5) however, it was statistically similar with that where same hybrid was sown with 75% FC. Minimum plant height (21.25 cm) was recorded in FH 810 with 75% FC. Olaoye (2009) observed that plant height of maize

Table II: Effect of water stress on morphological and physiological characteristics of different maize hybrids

Moisture levels	Hybrids	Plant height (cm)	Leaf area per plant (cm^2)	Water potential (-MPa)	Osmotic potential (-MPa)	Turgor potential (MPa)	RSD (%)
75% FC*	FH 421	27.00 h	87.39 j	0.847 d	1.057 e	0.209 e	16.91 c
	FH 810	21.25 m	60.81 k	1.037 a	1.150 a	0.114 f	26.78 a
	Pioneer 32-F-10	29.83 f	108.99 g	0.847 d	1.003 h	0.157 ef	15.38 d
	Pioneer 32-W-86	30.83 e	108.28 g	0.730 e	1.093 c	0.363 d	11.56 f
	Monsanto 919	38.25 a	250.91 c	0.567 h	0.930 l	0.365 d	7.67 i
	Monsanto 6525	25.00 k	61.65 k	0.913 c	1.037 f	0.122 f	12.60 e
	NK 8441	26.00 j	133.52 f	0.677 f	1.060 d	0.380 cd	9.90 g
	SS 5050	26.49 i	92.11 i	0.983 b	1.143 b	0.158 ef	18.62 b
100% FC	FH 421	29.82 f	99.39 h	0.557 i	0.963 k	0.405 cd	5.24 j
	FH 810	34.67 b	286.00 b	0.360 m	0.893 n	0.534 a	4.37 k
	Pioneer 32-F-10	24.32 l	89.64 j	0.533 j	0.923 m	0.391 cd	12.19 e
	Pioneer 32-W-86	32.83 c	152.88 e	0.566 h	0.990 j	0.424 bc	8.68 h
	Monsanto 919	38.26 a	297.0 a	0.357 n	0.890 o	0.533 a	4.22 k
	Monsanto 6525	31.67 d	152.33 e	0.623 g	1.033 g	0.409 bcd	9.26 gh
	NK 8441	28.01 g	149.00 e	0.503 k	0.993 k	0.459 b	4.88 jk
	SS 5050	31.33 d	175.15 d	0.480 l	0.997 i	0.517 a	9.29 gh
LSD (5%)		0.41	4.06	0.001	0.001	0.053	0.83
EMS		0.063	5.72	0.0001	0.0001	0.004	0.25

Figures sharing the same letter in a column do not differ statistically at $P \leq 0.05$
*Field capacity, LSD = Least significant difference, EMS = Error mean square

hybrid increased upto 45.38 cm at 100% field capacity 24 DAS, while it decreased upto 24.69 cm with decreasing field capacity. It has been reported that the plant height of single cross maize hybrid was affected when deficit water was applied at different growth stages (Abo-El-Kheir & Mekki, 2007). Such effect of drought stress might be up to 32.8% (Golbashy *et al.,* 2010). As per correlation analysis, plant height and leaf area, both being growth parameters, showed a significant positive relationship at both field capacities. Relationship of plant height with water relations was non-significant at 100% FC, however drought (75% FC) made it significant; water potential, osmotic potential and RSD decreased with increasing plant height (Table III). The results of Mohammady and Hasannejad (2006) showed that plant height had significant correlation with water relative observations under water stress conditions. Olaoye *et al*. (2009) also showed similar relation of plant height under drought conditions.

The leaf area of different maize hybrids varied significantly and their interaction with irrigation regime was also significant (Table II). Maximum leaf area (297 cm^2) of Monsanto 919 was recorded, which followed by FH 810 (286 cm^2) at 100% FC. Minimum leaf area (60.81 cm^2) was observed in FH 810 at where 75% FC was maintained (I_1) and it was statistically similar with the leaf area of Monsanto 6525 (61.65 cm^2) at I_1. Olaoye (2009) reported that at 100% FC maximum leaf area was recorded, he also concluded that with decrease in field capacity leaf area of different maize hybrids decreased significantly. Granier *et al*. (2006) and Abo-El-Kheir and Mekki (2007) reported that leaf area of maize genotypes was affected by different stress levels. They concluded that intensity of the soil water deficit largely influenced a genotype's leaf area. Leaf area relationship with water related parameters was similar as that of plant height at 75% FC; however water potential and turgor potential showed significant associations with leaf area even with control. Cha-um *et al.* (2010) observed that leaf area correlate significantly under drought and control conditions.

Table III: Correlation coefficients (r) analysis among important morphological and physiological characteristics of maize hybrids at different moisture levels

X-variable	Y-variable	75% FC	100% FC
Plant Height	Leaf Area	0.794*	0.750*
	Water Potential	-0.655*	-0.339
	Osmotic Potential	-0.613*	-0.101
	Turgor Potential	0.389	0.491
	RSD	0.523*	-0.347
Leaf Area	Water Potential	-0.729*	-0.734*
	Osmotic Potential	-0.556*	-0.323
	Turgor Potential	0.500*	0.789*
	RSD	-0.449*	-0.367
Water Potential	Osmotic Potential	0.542	0.658*
	Turgor Potential	-0.826*	-0.785*
	RSD	0.776*	0.350
Osmotic Potential	Turgor Potential	-0.150	-0.216
	RSD	0.534*	0.135
Turgor Potential	RSD	-0.557*	-0.308

* = Significantly different from zero at $p<0.05$
FC = Field Capacity
RSD = Relative Saturation Deficit

Most important and primary effects of water deficit are the hampered leaf water status (Taiz & Zeiger, 2006; Farooq *et al*., 2010). In this study leaf water potential of maize hybrids was significantly affected with field capacity levels (Table II). Lowest leaf water potential (-0.357 MPa) was recorded with Monsanto 919 followed by FH 810 (-0.360 MPa) at 100% FC. While minimum water potential (-1.037 MPa) was recorded in FH 810 at 75% FC and it was followed with SS 5050 at same level of FC. Westgate and Boyer (1985) observed that leaf water potential of well-watered maize seedlings was -0.4 MPa while under water deficit condition water potential decreased up to -1.1 MPa.

Moreover, Medici *et al.* (2003) found that maize hybrid P 6875 showed water potential of -0.78 MPa under control condition and water potential of this hybrid decreased up to -0.96 MPa under water stress condition. Water potential showed significant association with osmotic potential and turgor potential at both FC levels; however this was positive with osmotic potential and negative with turgor potential. There was no relationship of water potential with relative saturation deficit at 100% FC, however this association was strong enough at 75% FC ($r^2 = 0.776$).

Osmotic potential of leaves relatively decreased with the decrease of water content in the plant. The interaction of maize hybrid and field capacity levels was significant (Table II). Maximum osmotic potential of leaves (-0.890 MPa) was observed in Monsanto 919 at I_2 (100% FC), which was followed by FH 810 with I_1 (75% FC). While minimum osmotic potential of leaves (-1.150 MPa) was recorded in FH 810 at I_1. Claudio *et al.* (2006) found that osmotic potential of leaves of well watered plants increased up to -0.90 MPa 40 DAS, while under water stress it decreased up to -1.20 MPa. Osmotic potential showed no association at both FC levels. Cha-um *et al.* (2010) observed that leaf osmotic potential correlate ($r^2 = 0.47$) non-significantly with other water relative observations under drought and control conditions.

Leaf turgor potential increased significantly with the increase of water availability to the plant. Results reveled that interaction of irrigation regime and maize hybrids was significant (Table II). Maximum leaf turgor potential (0.534 MPa) was in FH 810, when grown under 100% FC it was statistically similar with Monsanto 919 and SS 5050 at same level of irrigation. Minimum leaf turgor potential (0.114) was recorded in FH 810 I_1 (75% FC) when grown under 100% FC; it was statistically similar with Monsanto 6525, Pioneer 32-F-10 and SS 5050 at same field capacity. Claudio *et al.* (2006) observed that the leaf turgor potential decreased from 0.54 MPa to 0.180 MPa with the increase of water stress. Significant relation was found between turgor potential and RSD. While Negative sign indicate that turgor potential decreased with increase in RSD. Shirinzadeh *et al.* (2010) reported that under stress condition relation of turgor potential was significant with plant water contents of maize hybrid.

The leaf relative saturation deficit (RSD) increased with the decrease of relative water content of leaf. RSD is one of the most reliable indicators for identifying both the sensitive and drought tolerant types (Ashraf *et al.*, 1994). The data on RSD showed that under water stressed condition the RSD significantly increased (Table II). Minimum relative saturation was recorded in Monsanto 919 (4.22 %) at I_2 (100% FC), which was statistically similar with FH 810 at same field capacity, while it was statistically at par with NK 8441 at same irrigation level. Maximum RSD (26.78%) was observed in FH 810 at I_1. Ashraf *et al.* (2006) found that RSD increased with the increase in salt stress. They observed maximum values for RSD (30.78%) under stress condition in arid region, while lowest value (9.47%) was recorded for RSD. Sanchez-Rodriguez *et al.* (2010) reported that water stress within leaf increased its RSD. The relationships of osmotic potential and turgor potential with RSD were non-significant at 100% FC but significant at 75% FC. Negative sign indicates that turgor potential decreased with increase in RSD and vice versa. Mohammady and Hasannejad (2006) screened out maize hybrids on the basis of leaf water content. The results showed that the relationship of leaf water content was significant with osmotic or turgor potential under drought.

CONCLUSION

Drought affected the morphological and physiological behavior of maize hybrids. Among the spring maize hybrids Monsanto 919 performed best in both fully watered and water stress under conditions of Pakistan, however maize hybrid FH 810 showed best growth under normal condition but it was highly drought sensitive. Correlation analysis indicated that plant height and leaf area might be used as an indicator of water relations in maize plant under drought stress condition.

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