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Morpho-physiological Response of Maize Inbred Lines under Drought Environment

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Abstract: Ten inbred lines of maize viz. MO-17, DK-656, IZI-7103, SYP-31, AYP-17, H-93, B-73, A-660, IZI-4001 and KU-2301 were evaluated under drought stress for different morpho-physiological traits. These traits included yield per plant, seedling survival rate at Treat I, II, III, IV, leaf venation, stomatal frequency, transpiration rate, net photosynthesis, photosynthetically active radiations, hydrophilic colloids, relative water contents, root/shoot ratio and water potential. The experiment was laid out following a randomized complete block design with three replications. The inbred lines were highly significantly different for all the characters studied except net photosynthesis. Maximum variability was observed for net photosynthesis followed by root/shoot ratio. The inbred lines H-93 and IZI-4001 performed best for most of the traits and these could be used in breeding programmes for drought tolerance in maize.

Key words: *Zea mays,* inbred lines, seedling, physiological traits, drought

Introduction

Maize (*Zea mays* L.) is the second leading cereal crop of the world after wheat and is used as food grain. In most of the countries its primary use is for livestock but it is also a source of an increasing number of industrial products. Being a short duration plant, maize has attained a top priority in hilly areas where snow fall and chilling period limit the growing period. In spite of using improved high yielding varieties, production per hectare is not increasing. The average yield of maize in Pakistan was 1511 kg ha^{-1} in 1999 and in 2000 it was again 1511 kg ha^{-1}. (FAO Production Year Book vol.54, 2001). This is due to certain problems and drought is one of them. Drought (a sustainable period without rainfall) is a major factor that limits the area under cultivation and yield. In 1999 the area was 894000 ha and in 2000 it was again 894000 ha. (FAO Production Year Book vol.54, 2001). Water stress is also observed in the irrigated areas due to insufficient supply of water and canal closure. In response to water stress plant faces physiological changes including loss of cell turgor, closing of stomata, reduction in cell enlargement and reduced leaf surface area. All these abnormalities ultimately decrease photosynthesis and respiration (Human *et al.*, 1990, and Hall *et al.*, 1990) and as a result overall production of crop is reduced. Keeping in view the importance of maize in industry and as food grain was a need. The present study was conducted to evaluate stress conditions and to trace a drought resistant gene in different available lines, so that these lines may be used in further breeding programme to evolve drought tolerant varieties to increase per hectare yield.

Materials and Methods

The experimental material comprised of ten elite maize inbred lines viz. MO-17, DK-656, IZI-7103, SYP-31, AYP-17, H-93, B-73, A-660, IZI-4001 and KU-2301. The experiment was conducted in drought chamber (Designed to control different combination of humidity, soil moisture and temperature) and in experimental area of the department of Plant Breeding and Genetics, University of Agriculture Faisalabad. Polythene bags (18 x 9 cm) were filled with fresh river sand washed with distilled water to make it free from nutrients. One seed of each inbred line was sown in each bag at a uniform depth of 3 cms. The experiment was laid out in completely randomized design with three replications. Each replication consisted of 10 seedlings of each inbred line. At three leaf stage, the seedlings were placed in drought chamber. The soil moisture was replenished to a desire level by weighing the individual bags and restoring the deficit if any by adding water. The combinations of drought components (temperature, relative humidity and soil moisture) were used as follows:

Treatment	Temperature (°C)	Moisture (% FC)	Humidity (%)
I	48	25	12
II	48	25	50-70
III	48	50	12
IV	48	50	60-70

FC = Field capacity

When there was 50% mortality, survived seedlings were taken out from drought chamber and Hoagland's solution was applied to the seedlings and their survival rate was recorded after 15 days. The number of survived seedlings was counted in each replication and the survival rate was calculated as:

Table 1: Mean squares of different traits in maize (*Zea mays* L.) under drought conditions

SOV	D.F.	Yield plant^{-1} (g)	Survival Rate (%) Treat I	Treat II	Treat III	Treat IV	Leaf Venation	Stomatal Frequency
Replication	2	2.211	0.033	0.002	0.038	0.024	1.372	1.797
Genotypes	9	419.595**	3477.198**	1600.071**	1455.840**	1589.089**	1.424**	9.641**
Error	18	24.158	0.224	0.012	0.115	0.016	1.452	1.955
CV (%)		6.3591	0.691	0.214	0.709	0.267	3.348	6.636
SOV	D.F.	Transpiration Rate	Net Photosynthesis	PAR	Hydrophilic Colloid.(%)	R.W.C. (%)	Root/Shoot Ratio	Water P. (M Pa)
Replication	2	0	0.01	2640.7	0.00000546	2.466	0.045	0.0005
Genotypes	9	0.005**	0.074	25004.760**	0.000**	99.058**	5.939**	0.00222**
Error	18	0.012	0.036	3667.848	0.000006255	2.633	0.116	0.000389
CV (%)		5.041	16.95	1.91	1.368	1.348	6.92	2.38

** Significant at 0.01 probability level

Table 2: Comparison of means for different traits in maize (*Zea mays* L.) under drought conditions

Genotypes	Yield plant^{-1} (g)	Survival Rate (%) Treat I	Treat II	Treat III	Treat IV	Leaf venation	Stomatal Frequency
MO 17	71.58a	27.53f	32.117e	12.517g	17.913g	11.223bcd	11.780bcd
DK 6546	52.61b	4.55I	6.667h	3.717h	0.00h	11.223bcd	13.223abc
IZI 7103	51.95b	64.70c	53.557b	43.357b	27.507f	10.890cd	13.000abc
SYP 31	48.63bc	31.25e	37.783d	27.500f	33.337e	10.447d	10.000de
AYP 17	40.35cd	60.00d	50.0c	37.900e	42.853c	11.333abcd	9.00e
H 93	39.50d	100.00a	66.667a	41.367c	69.080a	12.333ab	12.00bcd
B 73	37.31d	0.00j	0.00I	0.00I	0.00h	11.667abcd	14.777a
A 660	34.98d	76.43b	20.683g	40.00d	44.440b	12.557a	14.113ab
IZI 4001	34.54d	25.00g	26.350f	66.667a	38.507d	12.337ab	11.000cde
KU 2301	34.32d	5.60h	0.00i	3.450h	0.00h	11.890abc	12.667abcd
Genotypes	Transpiration Rate	Net Photosynthesis	PAR	Hydrophilic Colloid (%)	R.W.C. (%)	Root/Shoot Ratio	Water P. (M Pa).
MO 17	0.200ab	0.600ab	1793.00bc	0.075f	70.333de	2.300efg	0.460de
DK 6546	0.200ab	0.933a	1783.00bc	0.126b	61.717g	3.430bc	0.446e
IZI 7103	0.1000d	0.667ab	1724.333cd	0.126b	78.577a	2.340def	0.4607cde
SYP 31	0.200ab	0.433b	1917.667a	0.003g	64.873fg	6.110a	0.448e
AYP 17	0.200ab	0.633ab	1911.667a	0.103d	74.497bc	2.500de	0.508ab
H 93	0.133cd	0.667ab	1921.333a	0.119c	71.627cd	4.00b	0.498abcd
B 73	0.200ab	0.800ab	1871.00ab	0.105d	69.050e	1.780fgh	0.471bcde
A 660	0.167bc	0.467b	1645.00d	0.093e	62.867g	3.00cd	0.469cde
IZI 4001	0.233a	0.500b	1872.00ab	0.079f	77.047ab	1.333h	0.525a
KU 2301	0.200ab	0.767ab	1830.00abc	0.233a	67.870ef	1.677gh	0.504abc

Means sharing common letters do not differ significantly

$$\text{Survival Rate (\%)} = \frac{\text{Seedlings survived after 15 days}}{\text{Total number of seedlings}} \times 100$$

Five seedlings of each inbred line from each treatment were chosen which survived drought shock. Polythene bags were carefully torn off, seedlings were shaken gently to shed off the sand, washed under tap water taking care that their shoots and roots were not damaged. Fresh roots and shoots were placed in kraft paper bag at 60°C in an electronic oven till they became dry. Thereafter, samples were weighed in milligrams using an electronic balance. Root shoot ratio was determined as:

$$\text{Root shoot ratio} = \frac{\text{Dry root weight}}{\text{Dry shoot weight}}$$

These ten maize inbred lines were also grown in the field following a triplicate Randomized Complete Block Design. The stomatal frequency counts per unit area were made on the upper surface of the leaf under high power (40 X) microscopic field. The leaf samples were examined under low power (10 X) microscope for counting the number of parallel veins. Water potential of the selected plants was measured with the help of gas pressure chamber. The relative water contents were measured as:

$$\text{Relative Water Contents (\%)} = \frac{\text{Fresh weight-Dry weight}}{\text{Turgid weight-Dry weight}} \times 100$$

Hydrophilic colloids were estimated indirectly by the leaf powder method. Transpiration rate, photosynthetically active radiations (PAR) and net photosynthesis were measured using Infra- Red Gas Analyzer (IRGA) Modul LCA-3.

The data recorded were subjected to analysis of variance (Steel and Torrie, 1980). The traits showing significant differences among the genotypes were further subjected to Duncan's New Multiple Range Test to compare the means of the genotypes.

Results and Discussion

The genotypes included in this experiment exhibited highly significant difference for all the traits studied except for net photosynthesis which revealed non-significant differences among genotypes (Table 1). An appreciable variability was recorded for the traits under discussion Maximum variability was observed for net photosynthesis (CV= 16.95%) followed by root shoot ratio (CV= 6.920%), stomatal frequency (CV=6.636%) and yield per plant (CV= 6.359%). The least variability was recorded for survival rate at Treat II i.e. 0.214% and Treat. IV (0.267%). The results are in accordance with the findings of Oregon *et al.* (1993), Nayeem (1989), Metha and Sarkar (1991) and Alam (1965). Dai *et al.* (1990), Wood, (1934) and Ali (1994) also observed significant differences among the genotypes for stomatal frequency, relative water contents, photosynthetically active radiations and root/shoot ratio.

The comparison of means of genotypes for traits showing significant differences were also studied using Duncan's New Multiple Range Test (Table 2). Yield per plant ranged from 71.58 to 34.32 g. The range of survival rate Treat I was recorded from 100.00 to 0.00% while studying survival rate at Treat III the value ranged from 66.667 to 0.00% and in Treat IV the survival rate ranged from 69.080 to 0.00%. The number of parallel veins ranged from 12.557 to 10.447 and the number of stomata per unit area from 14.777 to 9 in case of stomatal frequency. The estimates of transpiration rate were observed to range from 0.233 to 0.1000 m.mole m^{-2} Sec^{-1} and net photosynthesis values ranged from 0.933 to 0.433 M. mole CO_2 m^{-2} Sec^{-1}. Photosynthetically active radiations values ranged from 1921.333 to 16.450 M. mole m^{-2} Sec^{-1}. The percentage values of hydrophilic colloids and relative water contents ranged from 0.233 to 0.003% and 76.557 to 61.717%, respectively. Root shoot ratio ranged from 6.110 to 1.333 and in water potential measurement values ranged from 0.525 to 0.446 M Pa.

H-93 ranked at first position for most of the traits studied and it exhibited maximum value for survival rate at Treat I, II, IV and photosynthetically active radiations but second maximum in leaf venation and root-shoot ratio. The second top position was acquired by IZI-4001 which exhibited the highest value for survival rate treat. III, transpiration rate and water potential. IZI-4001 also retained second position in leaf venation and relative water contents. MO-17 ranked at top in yield per plant, Dk - 656 in net photosynthesis, IZI-7103 in relative water contents. B-73 has highest value in stomatal frequency, A-660 in leaf venation and KU-2301 in hydrophilic colloids.

From all these studies it is concluded that inbred lines H-93 and IZI-4001 performed well and these lines can be used for further breeding programme. Means having the same letters do not differ significantly at 0.05 level of probability by Duncan's New Multiple Range Test.

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