INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2004/06–2–246–251
http://www.ijab.org

Comparative Evaluation and Analysis of Seedling Traits for Drought Tolerance in Maize

IFTIKHAR AHMAD KHAN, SAJIDA HABIB, HAFEEZ AHMAD SADAQAT AND M. HAMMAD NADEEM TAHIR
Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad–38040, Pakistan

ABSTRACT

Twenty four populations were evaluated for seedling traits under normal and water stress conditions. Selection was made on the basis of their mean performance under normal and drought condition. The highest performance was shown by P2-55 and P2-284 for almost all seedling traits and these lines have low to very low susceptibility indices. The results further revealed significant interaction of treatments with populations for emergence percentage, emergence rate index and dry shoot weight whereas, non-significant for others.

Key Words: Maize; S_1 populations; Seedling traits; Drought; Genetic variability

INTRODUCTION

Maize in Pakistan is one of the leading cereal food crops after wheat. It is used extensively for the proportion of starch, corn syrup, dextrose, corn flakes, gluten, grain cake, lactic acid, alcohol, acetone and corn oil. Furthermore, it is also extensively grown as fodder crop for live stock consumption. Very little attention has been paid to the development of maize varieties that are good both for grain and fodder purposes. Drought is an inevitable and recurring feature of agriculture. It has been estimated that about one third of world's potentially arable land suffers from water shortage and most crop yields are often reduced by drought (Kramer, 1980). Maize being sensitive to drought, generally in Pakistan is grown under irrigated conditions. Due to shortage of rains, Pakistan is suffering from acute water shortage. Limitation on water use are being imposed in every crop, rather cropping patterns are being changed and under such circumstances evolution of high yielding maize varieties under drought condition is the dire need to cope with the menace of water-shortage. Research work on seedling traits is an important aspect of any crop breeding Programme. Keeping in view the scarcity of irrigation water in the country, present studies were launched to develop high forage and seed yield under drought conditions based on the performance of seedling characters.

Since the final plant stand of a crop, primarily depends on seedling characteristics. So, assessment of seedlings under drought conditions is necessary for the attainment of good crop stand and hence for better yield because good seedling vigor is related to high grain yield (Mock & McNeill, 1979; Koscielniak & Dubert, 1985).

There are reports in the literature of potential drought resistance traits like extensive viable rooting system that could explore deeper soil layers for water (Mirza, 1956; Bocev, 1963) maize plants with more roots at seedling stage subsequently developed stronger root system, produce more green matter and had higher values for most characters determining seed yield (Bocev, 1963). Significant varietal differences in root growth and development under both normal as well as drought exist among various crop plants including maize (Nour & 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). However, root growth in cultivars intrinsically capable of avoiding drought through enhanced water uptake is increased (Aggarwal & 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 & West, 1984; Thakur & Rai, 1984; Ramadan *et al*., 1985). Therefore, it is necessary to screen breeding lines for rooting traits under drought conditions. Under drought conditions the increase in root weight could be attributed to the fact that roots are increased in search of water, and may also be attributed to increased weight due to accumulation of different solutes. These results are in agreement with the results of Aggarwal and Sinha (1983), Nour and Weibal (1978) and Thakur and Rai (1984).

MATERIALS AND METHODS

Studies on various seedling traits of 24 S_1 maize populations under normal and water stress conditions were conducted in triplicated completely randomized design, in the wire-house of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad during the year 2000–2002. Drought condition was achieved by watering the plants with quantity of water 50% of normal condition. Twelve seeds per S_1 family in a replication were grown in iron trays filled with river sand by keeping row to row and plant to plant distance of 5 and 3 cm, respectively. After two weeks data were recorded for root and shoot length, fresh root and shoot weight, root branching, dry root and shoot weight, fresh seedling weight, and water contents under both conditions.

Data were subjected to analysis of variance (Steel & Torrie, 1980) and mean comparisons were made using Least Significant Difference Test (LSD). Before planting, 100-seeds were counted from each genotype and weighed in grams on electronic balance chyo-MJ-500 for seed index. Emergence index to determine the speed of emergence of seedlings was determined and emergence rate index was calculated from the ratio of emergence index to emergence percentage. The seedlings from each S_1 family were carefully washed free of sand. The plant parts i.e., root and shoot, were separated and fresh shoot and root length was measured using a measuring tape. Fresh shoots and roots obtained by dissecting the seedlings were immediately weighed in grams by using an electronic balance. Fresh shoots and roots from S_1 families were separately put in kraft paper bags and dried for constant dry weight in an electric oven at 70°C and then dry weights were recorded in grams by using electronic balance. Number of branches arising from primary roots of seedlings was regarded as root branching. Tissue water contents of seedlings were estimated by subtracting dry weights from fresh weights, and converting into percentage. Fresh seedling weight was calculated by adding up fresh root weight and fresh shoot weight.

RESULTS

Analysis of variance. Significant (α=0.05-0.01) differences were found among various populations for fresh shoot weight, branches per root, dry shoot weight, dry root weight, water contents and fresh seedling weight,. While non-significant differences were found for emergence percentage, emergence rate index, fresh root weight, shoot length and root length (Table I).

The two treatments showed significant and highly significant differences for all the traits except for branches per root, shoot length and fresh seedling weight. The results further revealed significant interaction of treatments with populations for emergence percentage, emergence rate index and dry shoot weight whereas, non-significant for all other traits studied when the analysis was performed on pooled data from both the treatments i.e., normal and drought.

Analysis of variance was also performed separately under the two treatments to have a deeper look into the nature of variability. Mean squares from analysis of variance for various traits under normal and drought conditions are presented in Table II. Statistical differences among populations were significant for all the traits under normal as well as drought conditions.

Drought drastically affected all seedling traits (Table III) compared with normal conditions except for components of root growth i.e., fresh root weight, dry root weight and root length. Fresh seedling weight also showed an increase under drought conditions due to increase in the fresh root weight. The highest negative impact of drought conditions was observed in emergence rate index (23%) followed by emergence percentage (20.67%), dry shoot weight (16.67%) and fresh shoot weight (12.09%) whereas shoot length was least (0.97%) affected by drought. The highest increase due to drought as evident from Table III

Table I. Estimates of mean squares of various seedling traits in two treatments

Traits	Mean Squares			
	Populations (P) DF = 23	Treatments (T) DF = 1	P X T DF = 23	Error DF= 96
Emergence percentage	191.08^{NS}	2007.79**	208.86*	114.73
Emergence rate index	4.20^{NS}	196.00**	4.52*	2.56
Fresh shoot weight	0.28**	0.46**	0.04^{NS}	0.07
Fresh root weight	0.19^{NS}	0.70**	0.06^{NS}	0.07
Branches per root	3.51*	1.78^{NS}	3.18^{NS}	1.96
Dry shoot weight	0.01*	0.08*	0.01**	0.06
Dry root weight	0.01*	0.05**	0.001^{NS}	0.01
Shoot length	207.26^{NS}	0.44^{NS}	229.06^{NS}	6.73
Root length	4.99^{NS}	151.50**	5.03^{NS}	8.13
Water contents	63.43*	196.00**	34.57^{NS}	25.13
Fresh seedling weight	0.18**	0.13^{NS}	0.15^{NS}	0.19

NS=Non-significant (P>0.05); * =Significant (P<0.05); **=Significant (P<0.01)

Table II. Estimates of mean squares of various seed and seedling traits under normal and drought conditions

Traits	Mean squares			
	NORMAL		DROUGHT	
	Population DF=23	Error DF=46	Population DF=23	Error DF=46
Seed Index	68.19**	1.67	_	_
Emergence percentage	235.15*	127.64	164.78*	87.84
Emergence Rate	2.03*	1.09	6.66*	3.57
Fresh shoot weight	0.11**	0.05	0.21*	0.04
Fresh root weight	0.08*	0.05	o.16*	0.06
Branches per root	3.77*	2.12	2.93*	1.63
Dry shoot weight	0.02*	0.01	0.01*	0.01
Dry root weight	0.01*	0.01	0.02*	0.01
Shoot length	10.38*	5.70	8.59*	4.78
Root length	4.75*	2.66	5.27*	2.99
Water contents	40.66*	19.94	57.33*	28.37
Fresh seedling weight	0.30*	0.11	0.65**	0.15

NS=Non-significant (P>0.05); * =Significant (P<0.05); **=Significant (P<0.01)

Table III. Mean performance of maize populations for various plant traits under normal and drought conditions

Plant Traits	Mean Normal	Mean Drought	Loss %age
Emergence percentage (%)	35.80	28.40	20.67
Emergence Rate	10.00	7.70	23.00
Fresh shoot weight (g)	0.91	0.80	12.09
Fresh root weight (g)	1.11	1.26	-13.51
Branches per root	10.07	9.85	2.18
Dry shoot weight (g)	0.12	0.10	16.67
Dry root weight (g)	0.10	0.14	-40.00
Shoot length (cm)	14.45	14.31	0.97
Root length (cm)	11.31	13.36	-18.13
Water contents (%)	89.14	86.18	3.32
Fresh seedling weight (g)	2.00	2.01	-0.50

was observed in dry root weight (40%) followed by root length (18.13%) and fresh root weight (13.51%).

Comparative Evaluation of Various Populations

Emergence percentage. Under normal conditions the highest emergence percentage was shown by P2-50 followed by P2-302. The two populations were significantly different from each other (Table IV). Under drought conditions (Table V) the highest emergence percentage was observed in different populations i.e., P2-258 and P2-284, than those under normal conditions. Both populations P2-258 and P2-284 improved emergence percentage under drought conditions. Generally the emergence percentage decreases with the deficit of water in the soil as most other lines have shown except P2-258 and P2-284. High emergence percentage is necessary for obtaining optimum plant population stand in the field. The populations/varieties having high germination percentage under normal conditions may have very low germination/emergence under drought conditions as reflected from the present studies, therefore, the varieties need to be evolved under drought conditions.

Emergence rate index (ERI). Maximum performance was shown by P2-282, P2-47, P2-55 and P2-251 under normal conditions and P2-266, P2-257 and P2-254 showed highest performance under drought condition. Under drought conditions no loss in performance was observed in P2-257 and P2-254. Emergence rate is important criteria in breeding for high yield and special is the case under drought conditions because the seedlings with high emergence rate will have edge in competition for space, light and water resources, and eventually will have highest yield compared to others. Drought reduced emergence index in most of the populations, and those showing high emergence rate might be helpful in evolving better performing maize cultivars under drought conditions.

Fresh shoot weight. Under normal and drought conditions maximum mean fresh shoot weight was shown by P2-55 whereas, P2-302 showed minimum performance under drought as well as normal conditions. Maximum loss in performance was shown by P2-306. Drought has drastically affected fresh shoot weight in some lines whereas some populations 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.

Fresh root weight. Table IV showed that P2-55 exhibited maximum performance under normal condition whereas P2-284 showed this behaviour in drought condition (Table V). The inbred which showed minimum loss in performance under drought condition was P2-286 and P2-288. Moreover, root weight increased with water stress.

Under drought conditions the increase in weight could be attributed to the fact that roots became increased in search of water, and may also be attributed to increased weight due to accumulation of different solutes.

Root branching. For the root branching, P2-302 showed maximum performance under normal condition, and inbred P2-284 showed high performance under drought conditions. Inbred P2-251 and P2-286 showed the same behaviour as P2-284.

However, no loss in performance was shown by P2-311. Intercross showed minimum root branching under normal conditions, but its performance was good in drought conditions. Out of all 24 populations it showed maximum

Table IV. Mean performance of maize populations under normal conditions

Populations	E%	FSW	FRW	RB	DSW	FSDW	DRW	SL	RL	WC%
P_2-290	31.52	0.80	1.033	8.33	0.06	1.73	0.14	14.30	14.13	92.67
P_2-306	33.07	1.033	1.133	10.67	0.10	2.03	0.16	17.17	15.47	91.67
P_2-286	36.40	1.10	1.000	9.67	0.07	2.77	0.14	15.27	12.80	88.67
P_2-309	41.00	0.73	1.200	9.33	0.10	1.63	0.15	19.23	14.63	89.33
P_2-311	34.00	0.70	0.93	9.33	0.09	1.63	0.12	12.30	13.60	89.33
P_2-312	25.90	1.07	1.27	11.00	0.09	1.93	0.17	15.47	13.27	93.33
P_2-288	37.57	0.83	1.00	9.67	0.40	1.77	0.15	15.97	13.50	82.67
P_2-47	41.93	0.63	1.03	10.00	0.10	1.67	0.14	15.20	12.80	87.67
P_2-48	37.40	0.83	0.97	9.67	0.21	1.33	0.15	14.47	13.30	81.67
P_2-264	31.30	0.73	0.93	8.67	0.08	1.60	0.11	13.53	12.40	88.33
P_2-51	31.07	0.83	1.20	11.30	0.07	2.00	0.16	15.87	13.47	92.67
P_2-55	44.43	1.27	1.533	11.00	0.09	3.00	0.11	14.97	12.77	92.67
P_2-302	48.04	0.56	0.60	12.33	0.08	1.37	0.14	13.83	12.93	85.00
P_2-284	28.73	1.27	1.13	11.00	0.08	2.84	0.12	13.97	14.10	91.67
P_2-282	26.27	0.90	1.13	10.00	0.07	2.10	0.11	14.50	17.53	80.33
P_2-274	35.60	0.97	1.16	9.33	0.09	2.23	0.15	13.33	12.73	93.00
P_2-50	67.67	1.07	1.53	9.67	0.16	2.50	0.13	12.87	14.30	91.00
P_2-258	38.87	1.00	1.23	10.33	0.10	2.50	0.18	15.07	13.57	91.00
P_2-266	33.33	0.87	1.10	10.33	0.09	2.23	0.08	14.17	12.27	91.00
P_2-257	26.50	0.77	1.07	9.67	0.11	2.23	0.17	13.80	10.80	88.33
P_2-254	37.87	1.23	1.20	10.30	0.08	2.40	0.14	12.50	12.97	91.67
Intercross	31.30	0.83	1.07	7.00	0.11	1.77	0.16	13.13	12.53	88.00
Tall	34.60	0.87	1.23	10.67	0.26	1.93	0.15	9.30	11.43	86.00
P_2-251	31.3	1.10	1.10	10.67	0.09	2.80	0.16	13.90	13.27	91.33
Cd_1	18.57	0.35	0.37	2.39	0.15	0.35	0.06	3.93	2.68	7.34
Cd_2	24.79	0.47	0.49	3.19	0.19	0.47	0.08	5.24	3.58	9.79

E %, Emergence percentage; FSW, Fresh seedling weight (g); FRW, Fresh root weight (g); RB, Root branching; DSW, Dry shoot weight (g); FSDW, Fresh seedling weight (g); DRW, Dry root weight (g); SL, Shoot length (cm); RL, Root length (cm); WC%, Water contents (percentage) gain in performance. Mixed behaviour was observed for branching in roots, some populations showed increase and others decrease under drought conditions. Nevertheless, higher number of branches should contribute towards higher water uptake under drought conditions.

Dry shoot weight. Dry shoot weight ranged from 0.06 (P2-290) to 0.4 (P2-288) under normal conditions and under drought conditions P2-284 showed maximum dry shoot weight. P2-290 showed better performance under drought conditions.

Dry root weight. For dry root weight tall population showed maximum mean performance and P2-286 was second in performance under normal condition, and under drought conditions P2-258 performed the best. Overall mean dry weight reduced in drought conditions. However, no loss in performance was observed under drought condition by inbreds P2-264 and P2-51 and p2 55 and percent gain in efficiency was shown maximum by population P2 284.

Shoot length. Results in Table IV showed that genotype P2-309 exhibited the highest shoot length under normal conditions and P2-251 under drought conditions and inbred P2-302 showed minimum performance under drought conditions while in normal condition its performance was satisfactory. Maximum and minimum loss in performance was shown by P2-309 and Tall population, respectively. Overall shoot length was reduced during water stress.

Root length Root length is positively associated with drought tolerance phenomenon and P2-48 showed the highest root length under normal conditions and P2-282 under drought conditions and maximum gain in performance was observed by genotype P2-282. The plants showing long roots under ample water supply conditions may use up the nutrients necessary for shoot growth and

Table V. Mean performance of maize populations under drought conditions

Populations	E%	FSW	FRW	RB	DSW	FSDW	DRW	SL	RL	WC%
P_2-290	32.83	0.50	1.23	19.33	0.10	1.80	0.06	11.76	11.40	86.33
P_2-306	28.30	0.07	1.33	10.33	0.10	2.10	0.08	14.20	11.20	87.33
P_2-286	22.33	1.13	1.60	11.3	0.06	2.10	0.16	14.43	11.27	92.00
P_2-309	31.80	0.60	1.00	10.67	0.13	2.00	0.11	13.30	12.40	83.00
P_2-311	24.76	0.57	1.07	9.33	0.10	1.63	0.07	12.53	9.13	85.00
P_2-312	23.73	9.73	1.20	9.67	0.12	2.33	0.07	13.47	10.70	84.67
P_2-288	28.8	0.63	1.60	9.00	0.06	1.93	0.09	14.30	11.27	85.67
P_2-47	23.73	0.57	1.13	8.00	0.12	1.63	0.09	13.83	10.20	83.67
P_2-48	29.30	0.67	0.70	9.33	0.08	1.83	0.10	15.40	14.50	74.67
P_2-264	30.57	0.60	0.97	10.00	0.11	1.57	0.11	13.07	10.50	86.33
P_2-51	21.23	0.70	1.27	9.67	0.07	2.03	0.07	15.00	13.13	88.33
P_2-55	26.03	1.50	1.50	8.67	0.09	2.57	0.09	13.67	11.33	92.00
P_2-302	19.70	0.47	0.90	10.33	0.07	1.13	0.06	11.50	9.43	84.00
P_2-284	38.40	1.10	1.73	11.33	0.22	2.37	0.11	17.40	11.63	89.67
P_2-282	32.38	0.93	1.16	10.67	0.06	2.07	0.11	15.60	9.80	91.67
P_2-274	25.23	0.90	1.37	10.33	0.08	2.14	0.12	16.73	11.97	89.67
P_2-50	27.73	0.77	1.27	9.33	0.07	2.33	0.12	15.33	11.20	90.00
P_2-258	55.93	1.00	1.53	11.00	0.09	2.23	0.11	16.90	11.80	91.00
P_2-266	28.77	0.90	1.30	9.67	0.18	1.93	0.07	13.40	10.67	76.67
P_2-257	28.80	1.00	1.23	11.00	0.11	1.83	0.10	16.17	11.23	87.33
P_2-254	32.33	1.00	1.40	9.67	0.10	2.43	0.10	15.50	11.63	90.33
Intercross	22.73	0.53	1.27	9.00	0.11	1.87	0.12	13.13	11.06	87.33
Tall	23.20	0.60	1.30	8.33	0.11	2.03	0.18	13.60	9.97	86.67
P_2-251	21.97	1.23	1.53	11.33	0.10	2.16	0.10	17.47	13.70	90.00
Cd_1	15.40	0.34	0.40	2.09	0.07	0.64	0.05	3.59	2.84	8.75
Cd_2	20.56	0.45	0.54	2.79	0.09	0.85	0.07	4.79	3.79	11.69

E %, Emergence percentage; FSW, Fresh seedling weight (g); FRW, Fresh root weight (g); RB, Root branching; DSW, Dry shoot weight (g); FSDW, Fresh seedling weight (g); DRW, Dry root weight (g); SL, Shoot length (cm); RL, Root length (cm); WC%, Water contents (percentage)

Table VI. Genetic parameters for various seeds and seedling traits under normal and drought conditions

Traits	Normal				Drought			
	GCV	PCV	h^2	G.A.	GCV	PCV	h^2	G.A.
Emergence %	16.60	35.72	0.22	3.92	17.86	37.57	0.23	3.37
Emergence rate	5.35	32.30	0.22	0.37	12.80	27.08	0.22	0.69
Fresh shoot weight	16.17	28.29	0.33	0.12	8.20	37.37	0.05	2.07
Fresh root weight	9.18	22.65	0.16	0.23	14.65	24.06	0.37	0.16
Root branching	7.36	16.22	0.20	0.47	6.69	14.57	0.21	0.43
Dry shoot weight	29.92	10.16	0.08	0.02	22.21	44.63	0.25	0.16
Dry root weight	18.80	40.09	0.22	0.01	11.18	23.85	0.22	0.01
Shoot length	8.71	8.79	0.22	0.81	6.94	6.97	0.17	0.58
Root length	7.39	16.20	0.21	0.53	6.43	15.62	1.10	0.50
Water contents	2.95	5.81	0.26	1.9	3.55	7.11	0.25	2.15
Fresh seedling weight	12.57	20.96	0.34	0.21	17.78	25.66	0.48	0.36

GCV = Genotypic coefficient of variation; PCV = Phenotypic coefficient of variation h^2 = Heritability; GA = Genetic advance seed development. However, the viability of the roots is also important.

Water contents. The results reflected that P2-286 and P2-55 had high performance compared with others under drought condition whereas, under normal conditions population P2-290, P2-51, P2-55 and P2-274 showed the highest performance.

Fresh seedling weight. In fresh seedling weight the highest performance was observed for P2-55 under drought and normal conditions, and minimum was shown by P2-302 under normal condition and by population P2-48 under drought conditions. Maximum loss in performance was shown by population P2-48 under drought conditions and minimum P2-286 which sounds to have the potential to show good performance under drought conditions. Most of the populations showed increase in fresh seedling weight under drought conditions than under normal, which might be attributed to the increase in root weight and length that turned up powerful sink compared to shoot. Roots increase their size in search of water under drought conditions. The results reflected that P2-286 and P2-55 had high performance as compared to others under drought condition whereas, under normal conditions population P2-290, P2-51, P2-55 and P2-274 showed maximum performance and, no decrease in performance was shown by population P2-258 and maximum loss in performance under drought condition was shown by population P2-266. Most of the populations showed increase in fresh seedling weight under drought conditions than under normal, which might be attributed to the increase in root weight and length that turned up powerful sink compared to shoot. Roots increase their size in search of water under drought conditions.

Genetic parameters. Under normal conditions relatively high estimates of genotypic coefficient of variability were observed for dry shoot weight, dry root weight, emergence percentage, fresh shoot weight and fresh seedling weight. Heritability estimates coupled with low to medium for all the traits were observed (Table VI). Under drought condition high genetic variation was observed for dry shoot weight, emergence percentage, fresh seedling weight, fresh root weight, emergence rate and dry root weight. Heritability estimates under drought conditions were more or less similar to those under normal conditions. However, relatively high genetic advance was expected in emergence percentage, fresh shoot weight and water contents.

Enough genetic variability is present for all the seedling traits studied under normal as well as drought conditions. Best performance was shown for almost all characters by P2-55, P2-284, P2-286, P2-290 and P2-309 under drought as well as normal conditions. Two population viz., Tall and intercross used as standard, their performance was lower than most of populations for almost all the characters.

DISCUSSION

Mehdi *et al.* (2001) reported non-significant to significant differences among S_1 families, treatments and interaction between families and treatments in a similar study in maize. Wahab (1961) also reported that depression in germination/emergence is associated with drought conditions. The populations showing improved emergence percentage might need less water for emergence compared to others. High emergence percentage is necessary for obtaining optimum plant population stand in the field. The populations/varieties having high germination percentage under normal conditions may have very low germination/emergence under drought conditions as reflected from the present studies, therefore, the varieties need to be evolved under drought conditions. The populations P2-258 and P2-284 showed the lower most susceptibility and loss in emergence percentage.

Drought has drastically affected fresh shoot weight in some lines whereas some populations 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.

Emergence rate is important criteria in breeding for high yield and special is the case under drought conditions because the seedlings with high emergence rate will have edge in competition for space, light and water resources, and eventually will have highest yield compared to others. Drought reduced emergence index in most of the populations, and those showing high emergence rate with low susceptibility might be helpful in evolving better performing maize cultivars under drought conditions. Moreover, root weight increased with water stress. These results are in agreement with the results of Aggarwal and Sinha (1983), Nour and Weibal (1978), and Thakur and Rai (1984). Under drought conditions the increase in weight could be attributed to the fact that roots became increased in search of water, and may also be attributed to increased weight due to accumulation of different solutes. For the root branching P2-302 showed maximum performance under normal condition, and inbred P2-284 showed high performance under drought conditions. Inbred P2-251 and P2-286 showed the same behaviour as P2-284. Nevertheless, higher number of branches should contribute higher water uptake under drought conditions.

These results tally with the results of Ashraf (1989) who pointed out that plant dry weight is reduced during water stress. Stocker (1962) also showed that plants under drought had smaller epidermal cells.

Ashraf (1989) reported that drought reduced the water content this may be due to high rate of transpiration and low absorption of water in susceptible plants. Mirza (1956) reported similar results. Root growth is beneficial if is increased in response to drought. The plants showing long roots under ample water supply conditions may use up the nutrients necessary for shoot growth and seed development. However, the viability of the roots is also imported.

Similar results were reported by Alam (1985), Ehlig and Lemert (1976), Thaukar and Rai (1984), and Ramadan *et al*. (1985) who reported that water stress decreased length of maize cultivars. Gu *et al*. (1989) also reported that drought stress reduced the plant height.

Overall mean dry weight reduced in drought conditions. Similar results were reported by Shiralipour and West (1984). Dry and fresh weight of the plant reduced during drought period as their leaf size remained small to minimize transpiration ultimately plant dry weight also reduced.

CONCLUSIONS

Under normal conditions relatively high estimates of genotypic coefficient of variability were observed for dry shoot weight, dry root weight, emergence percentage, fresh shoot weight and fresh seedling weight. Heritability estimates coupled with low to medium for all the traits were observed (Table VI). Under drought condition high genetic variation was observed for dry shoot weight, emergence percentage, fresh seedling weight, fresh root weight, emergence rate and dry weight. Heritability estimates under drought conditions were more or less similar to those under normal conditions. However, relatively high genetic advance was expected in emergence percentage, fresh shoot weight and water contents.

Enough genetic variability is present for all the seedling traits studied under normal as well as drought conditions. Best performance was shown for all most all characters by P2-55, P2-284, P2-286, P2-290 and P2-309 under drought as well as normal conditions. Two population viz., Tall and intercross used as standard, their performance was lower than most of populations for almost all the characters.

REFERENCES

Aggarwal, P.K. and S.K. Sinha, 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

Alam, A.N., 1985. Evapotranspiration and yield of corn as related to irrigation timing during silking. *Dissrt. Abst. Int*., 46: 174–5

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.*, 1: 54

Clarke, J.M., 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 Sons, New York

Dai, J.Y., W.L. Gu, X.Y. Shen, B. Zheng, H. Qi and S.F. Cai, 1990. Effect of drought on the development and yield of maize at different growth stages. *J. Shery Agric. Univ*., 21: 181–5

Ehlig, C.F. and R.D. Lemert, 1976. Water use and productivity of wheat under five irrigation treatments. *Soil Sci. Soc. Am. J*., 40: 750–5

Fisher, R.A., and A. Maurer, 1978. Drought resistance in spring wheat cultivars. I. Grain yield responses. *Australian J. Agri. Res*., 29: 897–912

Gregory, P.J., 1989. The role of root characteristics moderating the effects of drought. *Irrigation and Drainage Abst.,* 17: 1439; 1991

Gu, W.L., X.Y. Shen, J.Y. Dai, A.C. Hu, Z.S. Su and J. Chen, 1989. The physiological response of maize to drought at different growth stages. *J. Shen Yang Agri. Univ*., 21: 191–5

Kondo, M., M.V.R. Murty and D.V. Araqones, 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., and F. Dubert, 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

Kramer. P.J., 1980. Drought stress and the origin of adaptation. In: Turner, N.C. and P.J. Kramer (eds.), *Adaptation of Plants to Water and High Temperature Stress*. John Wiley and Sons, New York

Maiti, R.K., L.E.D. Amaya, S.I. Cardana, A.M.O. Oimas, M.De La Rosa–Ibarra, and H. De Leoncastillo, 1996. Genotypic variability in maize cultivars for resistance to drought and salinity at seedling stage. *J. Pl. Physiol*., 148: 741–4

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

Mirza, O.K., 1956. Relationship of root development to drought resistance of plants. *Indian J. Agron*., 1: 41–6

Mock, J.J. and M.J. McNeill, 1979. Cold tolerance of maize inbred lines adapted to various latitude in North America. *Crop Sci*., 19: 239–41

Nour, M.A. and D.E. Weibal, 1978. Evaluation of root characteristics in grain sorghum. *Agron. J*., 70: 217–8

Ramadan. H.A., S.N. Al–Niemi, and T.T. Hamdan, 1985. Water stress, soil type and phosphorus effects on corn and soybean, I. Effect on growth. *Iraqi J. Agric. Sci.*, 3: 137–44

Shiralipour, A. and S.H. West, 1984. Inhibition of specific protein synthesis in maize seedlings during water stress. *Proc. Soil and Crop Sci. Soc. Florida*., 43: 102–6

Steel, R.G.D. and J.H. Torrie, 1980. *Principles and Procedures of Statistics: A Biometrical Approach.* McGraw Hill Book Co., New York, USA

Stocker, O., 1962. Physiological and morphological changes in plants due to water deficiency, plant water relationships in arid and semi–arid conditions. *Rev. Res. Proc. Medrid Syrop., UNESCO, Paris*

Thakur, P.S. and V.K. Rai, 1984. Water stress effect on maize cultivars during early stage of growth. *Indian J. Ecol*., 11: 92–8

Wahab, A., 1961. Salt tolerance of various varieties of agricultural crops at germination stage. In: Salinity Problem in Arid Zones. *Proc. Tebran Symp. UNESCO, Paris*., 185–92

(Received 08 October 2003; Accepted 19 February 2004)