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EFFECTS OF WATER STRESS ON MAIZE CULTIVARS DURING THE VEGETATIVE STAGE

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ABSTRACT

The effects of water stress on the vegetative growth of nine cultivars of maize, Agaiti 72, Akbar, Comp 15, EV 1081, EV 5081, EV 6081, Sadaf, Sultan and Sunehri, grown for 7 weeks, were assessed. There were close relationships between biomass production and water content, and water relations of all cultivars in response to repeated droughting except in cv Agaiti 72. The cv Akbar and EV 6081, having lower fresh and dry biomass of shoot and water content, had both low leaf water potential (ψw) and turgor potential (ψp). By contrast, the high biomass producing cv Comp 15, EV 108, Sadaf, Sultan, and Sunehri had higher ψw and ψp. Selection criteria based on high leaf water potential and turgor potential during early vegetative growth are, therefore, suggested as means for screening maize cultivars/lines. Sufficient intercultivar variation in response to water stress was observed suggesting that selection of individuals with increased drought resistance seems possible within maize.

INTRODUCTION

Shortage of water is one of the most prevalent causes of moisture stress to crops in arid and semi-arid regions. During periods of drought irrigation water is insufficient to meet the demands of the crops. However exploration of appropriate genetic variability for drought resistance in important crop species has been emphasized by many workers (Atsmon 1973; Hurd 1 76; Parsons 1982; Quisenberry 1982).

As a cross-pollinated crop, maize (*Zea mays* L.) may have considerable intra-or inter-varietal variability for drought resistance which can be further exploited by appropriate breeding programmes to develop drought resistant cultivars/lines or hybrids of the crop. This paper examines the pattern of inter-varietal variation in response to moisture stress in nine cultivars of maize and also draws parallels with drought resistance and different physiological parameters.

MATERIAL AND METHODS

Seeds of five commercial cultivars, Agaiti 72, Akbar, Sadaf, Sultan, and Sunehri, and four breeding lines of *Zea mays*, Comp 15, EV 1081, EV 5081, and EV 6081 were obtained from the Ayub Agricultural Research Institute, Faisalabad, Pakistan.

About 300 seeds of each cultivar were sown in petri-dishes. After five days, five seedlings of comparable size of each cultivar were transplanted, equidistant from each other, into 24-cm plastic pots; each pot contained 4.71 kg oven dried sandy loam soil, and fine gravel placed on the soil surface to minimize evaporation. The experiment had three blocks in a randomized complete block design. Each block had nine cultivars and three drought treatments. The experiment was placed in a well-lit glasshouse at $24+3^0$C day temperature and $12+2^0$C night temperature.

The experiment had two sets, each with three blocks i.e. one set for physiogical analysis and the other for obtaining fresh and dry weight data. A total of 81 pots were used in each set.

The watering treatments were begun when the seedlings were 28 days old, and the drying treatment continued for 22 days. Prior to drought treatment, the plants were weekly provided with full strength nutrient solution. The watering treatments were as follows :

T_0 — Watering each day to field capacity throughout the experiment (soil moisture content 20.6%).

T_1 — The plants droughted twice, until wilting occurred, and rewatered to field capacity (one cycle of drought is one time wilting and rewatering). Soil moisture content at wilting $= 9.8\% \pm 0.6\%$.

T_2 — The plants droughted 4 times as in T_1.

The treatment T_1 was begun when the two cycles of T_2 had been completed. The plants were considered wilted when 2-3 leaves of a plant were wilted. After the droughted plants had begun wilting, these plants and the control plants were rehydrated by watering the soil to field capacity. At the end of the drought treatments all measurements for different parameters were made between 9 and 10 a.m.

After completion of the drought treatments, data were obtained for the fresh and dry weights of shoots and their ratio, per cent plant water content, and osmotic potential of expressed leaf sap (ψs).

The one youngest, fully expanded leaf from each plant was excised for the measurement of osmotic potential of the leaves (ψs). The leaf material was frozen in 2.0 cm^3 polypropylene tubes for two weeks, thawed, and the sap extracted by crushing the material with a metal rod. After centrifugation at 8000 X g for 4 minutes, the sap was used directly for osmotic potential determination in an osmometer TP 10B (Camlab Limited).

Leaf water potential (ψw) measurements were made for the excised lamina of the youngest, fully expanded leaf from each plant using the water potential apparatus (Chas. W. Cook & Sons, Birmingham, U.K.) Turgor potential (ψp) was calculated as the difference between leaf water potential and osmotic potential.

RESULTS AND DISCUSSION

Shoot fresh weight

The effect of increasing water stress on shoot fresh weight of the nine cultivars is presented in Fig. 1. The responses of the cultivars to increasing drought cycles are also given in Fig. 1, presented as per cent of controls to allow comparison of the

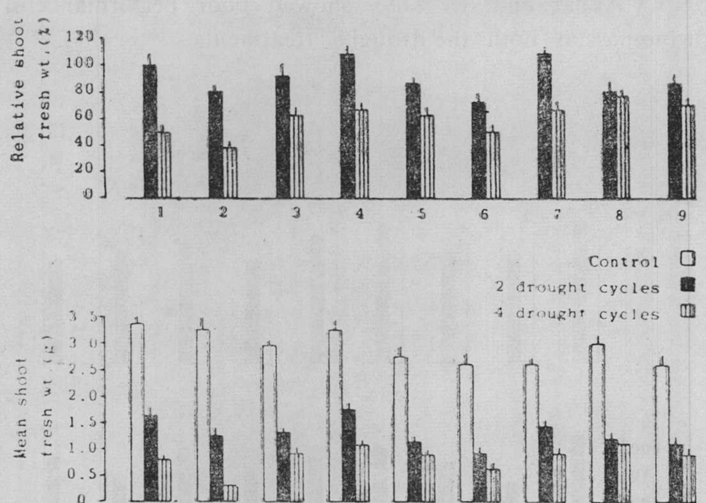

Fig. 1. Mean fresh weight of shoot (g/plant) of nine cultivars of maize at different drought treatments. Key to cultivars: 1, Agaiti 72; 2, Akbar; 3, Comp 15; 4, EV 1081; 5, EV 5081; 6, EV 6081; 7, Sadaf; 8, Sultan; 9, Sunehri

relative performance of the cultivars. Analysis of variance of the data showed that water stress caused overall significant reductions in shoot fresh weight ($p \leq 0.001$) Cultivars also differed significantly ($p \leq 0.01$) but, the cultivars X treatment interaction was non-significant.

Shoot fresh weight data, expressed as percentage of controls. clearly showed that increasing drought cycles markedly reduced shoot fresh weight in cv Agaiti 72, Akbar and EV 6081. However, the responses of the rest of the six cultivars were similar (more than 30% of fresh weight).

Shoot dry weight

Data for mean shoot dry weight and relative dry weight of the nine maize cultivars (Fig. 2) indicated that increasing water stress significantly reduced shoot dry weight ($p \leq 0.001$). Cultivars differed significantly ($p \leq 0.001$) but the cultivars X treatment interaction was again statistically non-significant. Shoot dry weight data expressed as percentage of controls (Fig. 2) showed that dry weights of the cultivars were not decreased by the droughting treatments as markedly as the fresh weight. Cultivars had differing response to increasing water stress cycles. Cv Agaiti 72), Akbar and EV 6081 had relative dry weights less than 8(% at the highest water deficit treatment. Cv Agaiti 72 had the highest relative shoot dry weight (112.8%) at the first drought treatment, but its weight was markedly reduced at a highest drought treatment (78.8). Cv Akbar and Ev 6081 showed poor performance in terms of relative in shoot biomass at both the drought treatments.

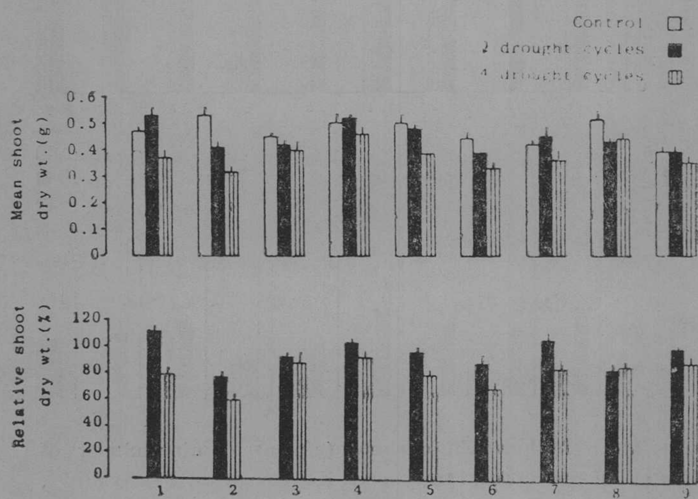

Fig. 2. Mean dry weight of shoot (g/plant) of nine cultivars of maize at different drought treatments. Key to cultivars: as in Fig. 1.

Shoot fresh weight : dry weight ratio

Data for shoot fresh weight : dry weight ratio (Fig. 3) showed that repeated water stress treatment caused significant reductions ($P \leq 0.001$) of shoot fresh weight : dry weight ratio. There were significant overall cultivar differences ($p \leq 0.001$) Cultivars X treatment interaction was also significant ($p \leq 0.05$), this being particularly due to the difference in fresh weight : dry weight ratios in the control treatment. Cultivars did not differ significantly in the two drought treatments.

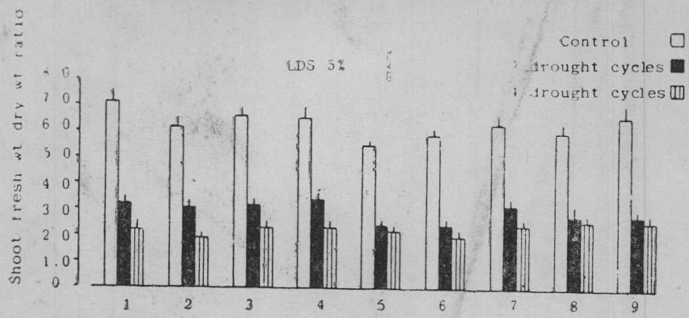

Fig. 3. Mean shoot fresh weight : dry weight ratio of nine cultivars of maize at different drought treatments. Key to cultivars : as in Fig. 1.

Water content

Data for per cent water content determined on a fresh weight basis of the nine cultivars are presented in Fig. 4. Water stress markedly affected the per cent water content of all the cultivars ($p \leq 0,001$). The overall difference between the cultivars was significant ($p \leq 0.01$), and the responses of the different cultivars to increasing water stress cycles was also significant ($p \leq 0.05$). Cv EV 5081 and EV 6081 had significantly lower water content than the other cultivars ($p \leq 0.05$) at the first drought treatment. Although Cv Akbar was as good as the other relatively drought resistant cultivar at the first drought treatment, it had the lowest per cent water content as compared to other cultivars at the highest drought treatment.

Leaf osmotic potential, water potential, and turgor potential

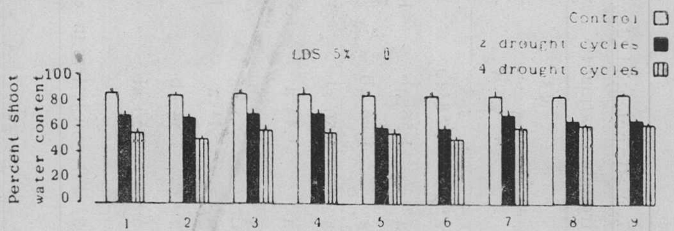

Fig. 4. Mean per cent shoot water content (fresh weight basis) of nine cultivars of maize at different crought treatments. Key to cuiti-vars : as Fig. 1.

Increasing water deficit cycles had significantly marked effect ($p \leq 0.01$) on the leaf osmotic potential (ψs) of the all nine cultivars (Table 1). However cultivars showed significantly different responses to increasing water stress ($p \leq 0.05$). At the two

Table 1. Mean leaf osmotic potential (ψs = -MPa), water potential (ψs = -MPa), and turgor potential (ψs = MPa) of nine8ultivars at different irought treatments.

Cultivars	ψs			ψw			ψp		
	Cont	4 cycle	2 cycel	Cont	2 cycle	4 cycle	Cont	2 cycle	4 cycle
Agaiti 72	1.27 a*	1.58 ab	1.47 b	0 74 a	1.11 a	1.23 b	0.53 ab	0 46 ac	0.24 a
Akbar	1.19 a	1.56 ab	1.76 a	0.68 a	1.32 b	1.51 a	0.51 a	0.35 bd	0.25 a
Comp 15	1.35 a	1.46 ab	1.59 ab	0.81 a	1.22 a	1.22 b	0.54 ab	0.44 a	0.37 b
EV 1081	1.25 a	1.50 ab	1.55 b	0.66 a	0.96 a	1.16 b	0.59 ab	0.54 c	0.39 b
EV 5081	1.24 a	1.44 a	1.56 b	0.68 a	1.05 a	1.23 b	0.56 ab	0.39 b	0.33 ab
EV 6081	1.28 a	1.69 b	1.80 a	0.70 a	1.42 b	1.48 a	0.58 ab	0.27 b	0.32 ab
Sadaf	1.24 a	1.41 a	1.59 ab	0.64 a	0.87 a	1.18 b	0.60 ab	0.54 c	0.41 b
Sultan	1.31 a	1.54 ab	1.66 ab	0.70 a	1.11 a	1.21 b	0.61 b	0.43 a	0.45 b
Sunehri	1.20 a	1.50 ab	1.58 ab	0.62 a	1.03 a	1.16 b	0 58 ab	0 47 ac	0.42 b

* Means foilowad by different letters in each column are statistically different at α = 0.05 by the Duncan's multiple range test

drought cycles treatment, cv Akbar and EV 6081 had significantly lower ($p \leq 0.05$) ψs than the other cultivars.

Data for leaf water potential showed that cultivars had varying responses to increasing water stress intensity ($p \leq 0.05$). Cv Akbar and EV 6081 had lower ψw at the first drought treatment than the other cultivars.

The data for leaf turgor potential (ψp) showed that the responses of cultivars to increasing drought cycles were significantly different ($p \leq 0.05$). Cv Comp 15, EV 1081, Sadaf, Sultan, and Sunehri had significantly greater turgor potential than the other cultivars after two drought cycles. Cv Akbar and EV 6081 had the lowest values of ψp at the same treatment. After four repeated drought cycles, cv Comp 15, EV 1081, Sadaf, Sultan and Sunehri had significantly greater ψp ($p \leq 0.05$ than the other cultivars.

All the cultivars examined in this study showed varying responses to increasing water deficit. The production of lower fresh and dry biomass by cv Akbar and EV 6081 as a result of repeated drought cycles clearly reflects their sensitivity to drought. In addition, their lower fresh weight : dry weight ratios may be due to low water content in their shoots. By contrast cv Comp 15, EV 1081, Sadaf, Sultan and Sunehri showed comparatively better performance in all growth parameters i.e., shoot fresh weight, shoot dry weight, shoot fresh weight : dry wight ratio, and per cent water content. The observed increase in dry biomass of these 5 cultivars suggests an active accumulation of solutes as a result of repeated droughting, which may be a possible mechanism for osmotic adjustment (Hsiao, 1973).

If the parallels are drawn with the data of growth parameters (Fig. 1-4) and water relations of nine cultivars (Table 1), it is quite clear that high biomass producing cultivars such as Comp 15, EV 1081, Sadaf, Sultan, and Sunehri had greater ψw and ψp in order to resist water stress condition. In fact maintenance of higher leaf water potential and higher turgor potential have often been considered as indicatore of drough resistance mechanisms in plants (O' Toole and Moya 1978; Kramer 1983; Lorenz et al 1987).

Cv Akbar and EV 6081 maintained a significantly lower ψs than the other cultivars at all drought treatments. The reduction in osmotic petential is often considered as an important adaptive strategy for drougdt resistance, particularly when active accumulation of organic solutes takes place as a result of water stress and leads to maintenance of turgor at lower water potential (Jones and Turner 1987; Lorenz et al. 1987). The lower osmotic potential in Cv Akbar and EV 6081 may be due to reduction in water content (Fig. 4) as a result of its loss from cells during dehydration. The relatively drought resistant cv Comp 15, EV 1081, Sadaf, Sultan, and

Sunehri maintained their leaf osmotic potential higher since they also maintained high leaf water content and leaf water potential.

The data for leaf turgor potential and water potential of all cultivars were highly correlated (Table 1). Higher turgor potential values were observed in cv comp 15, EV 1081, Sadaf, Sultan, and Sunehri which had ψw during water stress conditions than significantly higher the other cultivars.

From the results presented here it may be concluded that both leaf water potential and leaf turgor potential may be appropriate indicators of drought resistance and, therefore, could be used as selection criteria for isolating drought resistant maize genotypes, lines, hybrids or varieties, particularly at the vegetative stage. However, the validity of these selection criteria at other growth stages of maize has been argued by Ackerson (1983) because the relationship between ψp and ψw changes at and during different stages of growth and may also vary from variety to variety. A contrasting relationship can be seen in cv Agaiti 72 which had ψw colse to those of drought resistant cultivars but its ψp was significantly lower (O.24 MPa).

The work presented here deals only with the drought resistance in the vegetative stage. The resistance observed in cv Comp 15, EV 1081, Sadaf, Sultan, and Sunehri may or may not be conferred at later stages. Nevertheless resistance at every growth stage and particularly at the young stage is of considerable value.

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