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Response of Maize Single Cross -10 to Water Deficits During Silking and Grain Filling Stages

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Abstract: Two field experiments were carried out at the Agricultural Experimental Station of National Research Centre at Shalakan (Kalubia Governorate) during 2004 and 2005 seasons to study the effect of water deficits at different reproductive stages on growth, some physiological aspects and yield of maize plants. Water stress at either silking or grain filling stages caused significant reduction in the different growth parameters studied at 90 days after planting as compared with the continuous 15-days irrigation regime. The same effect was also observed for yield characters. The grain yield was reduced by 27.9 and 35.5 % when plants subjected to water deficits at silking and grain filling stages in comparison to the plants received normal irrigation, respectively. The water content in maize leaves was significantly decreased by decreasing soil moisture content (missing one irrigation during different growth stages). On the other hand, water deficits significantly increased cell sap concentration and consequently its osmotic pressure as well as proline content in maize leaves when comparing with the control plants.

Key words: Water deficits · maize single cross · yield · growth

INTRODUCTION

Drought stress in plants occurs when evaporative demand exceeds water uptake. Deficit water budgets lead to numerous physiological alterations, both in the long term and the short term. Long-term drought responses include altered root to shoot ratio [1] and/or reduced leaf area [2]. Short-term responses include altered stomatal function [3] and/or osmotic adjustment [4]. According to Kramer and Boyer [5] plants respond to drought either by delaying dehydration where the plant maintains a relatively high plant water potential or by tolerating dehydration where the plant continues to function but at lower plant water potentials. Plants that delay dehydration often exhibit reduced transpiration by reducing stomatal conductivity thereby maintaining a higher plant water potential. Plants that rely on tolerating dehydration experience lower plant water potentials but exhibit active osmotic adjustment that maintains turgidity and supports transpiration.

Drought has different effects on maize plants depending on the development stage at which it occurs. Previous reports showed that stress during tasseling and silking was most harmful and stress during grain filling was more drastic than that during the vegetative stage [6]. Further studies demonstrated that stress during early vegetative growth was more drastic than that during the grain filling stage [7]. Additional data indicated that drought during pre or post silking reduced the grain yield by 9 and 10 % compared to the conventional irrigation, respectively [8].

The objective of this study was to investigate the response of maize plants to water deficits imposed at silking and grain filling stages.

MATERIALS AND METHODS

Two field experiments were carried out during 2004 and 2005 seasons at the Agricultural Experimental Station of National Research Centre at Shalakan (Kalubia Governorate) to study the effect of water deficits at different reproductive stages on growth, some physiological aspects and yield of maize plants. The adopted irrigation treatments were as follows: 1) Control where maize plants received 5 irrigations at 15 days intervals after the first irrigation, 2) Missing one irrigation at silking stage (66 days from sowing) and 3) Missing one irrigation at grain filling stage (81 days from sowing). For each irrigation treatment four plots were used, each plot was 3×3.5 m. The design for this experiment was randomize complete block design with four replications.

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Table 1: Soil characteristics of the experimental sites

Sand (%)	16
Silt (%)	30
Clay (%)	54
Texture	Clay
Field capacity (%)	34.5
Wilting point (%)	13.7
Soil reaction pH	8.2
E.C. (dS m^{-1})	0.8
Organic matter (%)	2.1
Calcium carbonate (%)	4.0

The growing season extends over a period of about four months from June to October. The air temperature during this period has mean monthly values ranging from 23.2 to 27.4°C. The mean minimum monthly values never come below 16.1°C and the mean maximum monthly values rise to 35.6°C in July. The humidity of the air is generally high. The mean minimum relative humidity fluctuated between 20 and 37% and the mean maximum ranged between 70 and 84 %. The wind velocity did not exceed 2 km h^{-1} during the experimental period. Soil characteristics of the experimental locations are shown in Table 1.

Grains of maize (*Zea mays* L.) cv. Single cross -10 (SC-10), which were obtained from Agricultural Research Centre, Giza, Egypt, were sown on 14 and 21 June in 2004 and 2005 seasons, respectively. The regular tillage and agricultural operations of growing maize of the location were followed. Representative plant samples were collected after 90 days from sowing and their growth criteria were recorded i.e. plant height (cm), number of green leaves, total leaf area per plant (cm^2) and dry weight of shoot and root per plant (g). The concentration of total soluble solids (T.S.S.) in the cell sap was recorded using refractometer and the corresponding values of osmotic pressure (atm) were then obtained from tables given by Gusev [9]. The proline (μmole/fresh weight) was determined according to Bates *et al.* [10]. After harvest the following data were recorded: grain yield per fed (ardab/fed.), stover yield per fed (ton/fed.), shelling percentage (%) and 100-grain weight (g). The obtained data were subjected to statistical analysis of variance according to Snedecor and Cochran [11] and the combined analysis was done according to Steel and Torrie [12]. When significant differences ($p< 0.05$) were detected, the Least Significant Difference (LSD) test was used to comparing the mean values

RESULTS AND DISCUSSION

Vegetative growth: Data presented in Table 2 show that subjecting maize plants to water deficits i.e. missing one

Table 2: Effect of drought stress at different reproductive stages on vegetative growth of maize plants after 90 days from sowing (combined analysis of 2004 and 2005 seasons)

Irrigation treatments	Plant height (cm)	No. of green leaves per plant	Total leaf area per plant (cm^2)	Dry wt. of shoot per plant (g)	Dry wt. of root per plant (g)
Irrigation every 15 days	288.33	16.33	3427.28	295.41	69.54
Missing one irrigation at silking stage	248.67	13.33	2935.69	278.47	68.12
Missing one irrigation at grain filling stage	265.33	13.67	2994.13	287.52	68.73
LSD at 5 % level	6.04	0.75	322.00	15.47	2.80

Table 3: Effect of drought stress at different reproductive stages on water status measured in maize plants after 90 days from sowing (combined analysis of 2004 and 2005 seasons)

Irrigation treatments	Water content (%)	Cell sap concentration (%)	Osmotic pressure (Atm)	Proline (μmole/g fresh wt.)
Irrigation every 15 days	70.63	8.33	6.71	12.70
Missing one irrigation at silking stage	66.48	10.17	8.40	20.10
Missing one irrigation at grain filling stage	66.37	10.67	8.87	16.73
LSD at 5% level	0.83	1.10	0.99	0.60

irrigation at different reproductive stages significantly reduced plant height, number and area of leaves per plant as well as dry weight of shoot and root per plant after 90 days from sowing as compared with the control. The depression in these growth parameters as a results of water deficits may be attributed to the loss of turgor which affects the rate of cell division and enlargement. In this concern, Kramer and Boyer [5] reported that the growth of plants is controlled by rates of cell division and enlargement and by the supply of organic and inorganic compounds required for the synthesis of new protoplasm and cell walls. Cell enlargement is particularly dependent on at least a minimum degree of cell turgor and stem and leaf elongations are quickly checked or stopped by water deficits. Many investigators Batanouny *et al.* [2], Ahmed and Mekki [7], El-Sheikh [8], El-Noemani *et al.* [13] and Mahrous [14] reported that growth criteria of maize plants were reduced when plants were subjected to drought stress through decreasing number of irrigations or prolonging the irrigation intervals.

Water status: The collected data (Table 3) show that the water content in maize leaves was significantly

Table 4: Effect of drought stress at different reproductive stages on yield and its component (combined analysis of 2004 and 2005 seasons)

Irrigation treatments	Grain yield (ardab*/fed)	Stover yield (ton/fed)	Shelling (%)	100-grain weight (g)
Irrigation every 15 days	26.10	5.71	83.38	35.30
Missing one irrigation at silking stage	18.81	4.51	77.64	31.99
Missing one irrigation at grain filling stage	16.81	3.91	72.30	31.51
LSD at 5 % level	0.66	0.35	5.22	2.49

*One ardab = 140 kg grains

decrease by missing one irrigation during different growth stages. A reverse trend could be detected concerning the cell sap concentration and proline content values. The total soluble solids concentration in the cell sap and consequently its osmotic pressure in maize leaves were significantly increased by increasing soil moisture stress. Also, decreasing soil moisture content by missing one irrigation at any of the studied reproductive stages significantly increased the proline content in maize leaves in comparison with the control. The observed increase in cell sap concentration might be attributed to the osmotic adjustment (osmoregulation) of maize plants in order to maintain its turgidity and to overcome the increased resistance of water uptake in the root. According to Bohnert and Jensen [15] osmotic adjustment under water stress was achieved mainly be active accumulation of solutes either by uptake of inorganic ions from the external medium or by synthesis of organic somotic such as simple carbohydrates, organic acids and amino acids. These results are in agreement with those obtained by Batanouny *et al.* [2].

Yield and its components: Data presented in Table 4 show that missing one irrigation at any of the studied reproductive stages significantly decreased grain and stover yield per feddan. The result added also that shelling percentage and 100-grain weight followed the same trend. Simpson [16] reported that the variations in yield and its components due to drought stress at different growth stages could be ascribed to the impairment of many metabolic and physiological processes in plants. In this regard, Song *et al.* [17] showed that water stress led to slower pollen and filament development decreased filament fertility and resulted in a reduction in grain number and weight per ear. Similar results were recorded by Batanouny *et al.* [2], Grant *et al.* [6], Ahmed and Mekki [7] and El-Sheikh [8].

The present data reveal further that the extent of yield reduction was greatly governed by the time of water stress. The grain yield was reduced by 27.9 and 35.5 % when the plants were exposed to missing irrigation at silking and grain filling stages in comparison to the plants received normal irrigation, respectively. The lowest seed yield was obtained from missing one irrigation at grain filling stage. The finding is in agreement with those obtained by Kostandi and Soliman [18] who stated that the depressing effects of water stress were comparatively, high at grain filling, intermediate at tasselling and silking and low at vegetative growth stages. In this respect, Westgate [19] suggested that grain water status is affected directly by drought and may be an important determinant of grain development and that a water deficit after anthesis shortens the duration of grain filling by causing premature desiccation of the endosperm and by limiting embryo volume. Similar results were recorded by Grant *et al.* [6] and Ahmed and Mekki [7].

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