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Effects of Water Stress on Growth and Photosynthetic Pigments of Corn (*Zea mays* L.) Cultivars

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ABSTRACT

Studies on the response of two cultivars, Baimisal-4 and Sunahry of corn (*Zea mays* L.) were carried out. Experiments were carried out in earthen pots filled with washed and sterilized sand. Half strength Hoagland's solution was applied for irrigation. D-Mannit was used as osmoticum. The water stress retarded the growth by inhibiting root/shoot length and dry mass production. The concavity (rolling) and reduction leaf area was observed. Water stress reduced the leaf potential up to –10 bars in –14.038 bars osmotic potential medium. Although the chlorophyll and carotene contents of leaves were increased but due to the shift of chlorophyll 'a' absorbance to shorter wavelength, the growth remained slow.

Key Words: Water stress; *Zea mays*; Chlorophyll;

INTRODUCTION

Agriculture in Pakistan dates back to Neolithic times. Pakistan is a land of subsistence agriculture. The main emphasis is on the production of food crops that account for about 70% of the cropped area. About 23% of the total land area is cultivated. Although the cropped area has increased from 14.6 to 22.15 million hectares from 1947-48 to 1993-94: a hefty increase of about 52% but still about 61 million hectare of land is lying as a wasteland due to aridity and salinity (GOP, 1993-94). Aridity is a dominant factor for limiting the economical crop production in this country.

Drought is one of the most important a-biotic stress factor (Dash & Mohanty, 2001), which affects almost every aspect of plant growth. The drought tolerance of plants can be characterized by growth response, changes in water relations of tissues exposed to low water potential, accumulation of ions in tissues and stomatal conductance of leaves, etc. (Blum, 1988).

Water is a major constituent of living organisms. It comprises about 80-90% of fresh weight of herbaceous plants and over 50% of woody plants (Arnon, 1972; Fitter, 1981). Water furnishes a suitable medium for many biochemical reactions. The crop plants are usually under stress at one growth stage or another. The plant species able to with stand such stresses have great economic importance.

Maize (*Zea mays* L.) is one of the important cereal crop of Pakistan and it ranks third in cultivated area and production after wheat and rice. The average production of maize during the last five years was 1565 thousand tones whereas it remained at 1652 tonnes during the year 1999-2000 (GOP, 1999-00). The existing varieties have high potential for commercial exploitation. The soil and climatic conditions of Pakistan are also ideal for maize production but the yield is very low as compared to the maize growing countries (Chaudhry & Malik, 2000). Thus it is a pre-requisite to select the promising cultivars for different regions in order to speed up economical crop production.

The work presented here deals with the effects of water stress on growth, morphology and chlorophyll contents of two corn (*Zea mays* L.) cultivars.

MATERIALS AND METHODS

The certified seeds of two cultivars of Corn (*Zea mays* L.) namely, Baimisal-4 and Sunahry were obtained from Agricultural Research Institute, Quetta, Balochistan, Pakistan. Four different treatment i.e., 0.00, -4.679, -9.358 and –14.038 bar osmotic potential were prepared by adding an osmoticum D-Mannit in Half strength Hoagland's nutrient solution (Hoagland & Arnon, 1938) calculated as by Ting (1981). All the solutions were prepared in de-ionized water.

Seedlings were grown in 20 inches diameter perforated earthen pots containing 2 kg washed and sterilized sand. 30 seeds were sown in each pot. Each pot was irrigated by 100 mL solution of the respective treatment on alternate day. Each treatment was replicated thrice. All the studies were carried out at $25^oC \pm 5$. After seven days of germination, thinning was carried out and only 10 seedlings per pot were left. The seedlings were harvested after a period of eight weeks and following parameters were recorded i.e., Root, shoot length were measured by ruler scale, root, shoot material was dried at 80^oC in hot air oven, leaf area was measured and calculated as by Ting (1981)

Chlorophyll Contents

Chlorophyll extraction. The chlorophyll was extracted by the method of Tran *et al.* (1995).

Estimation of chlorophyll and carotene contents. The optical density (O.D.) of the extracted chlorophyll was measured at 625, 645 and 663 nm by using Spectrophotometer Hitachi U-2000.

Total chlorophyll, chlorophyll a, b and carotene contents were calculated by the following formulae of Sharf (1981).

$$\text{Total Chlorophyll (mg/g)} = \text{O.D. (625 nm)} \times \frac{1000}{34.5} \times \frac{V}{1000} \times W$$

$$\text{Chlorophyll 'a' (mg/g)} = 12.7(\text{O.D.663 nm}) - 2.69(\text{O.D.645 nm}) \times \frac{V}{1000} \times W$$

$$\text{Chlorophyll'a' (mg/g)} = 0.0229(\text{O.D.645 nm}) + 0.00488(\text{O.D.663 nm})$$

$$\text{Carotene (mg/g)} = (\text{O.D.480 nm}) - 0.144(\text{O.D.663 nm}) - 0.6308(\text{O.D.645 nm})$$

Wavelength Scanning of chlorophyll. Wave length scanning of chlorophyll (400–700 nm) was carried out by scanning program WL SCAN of Spectrophotometer Hitachi U-2000 and the scans were drawn accordingly.

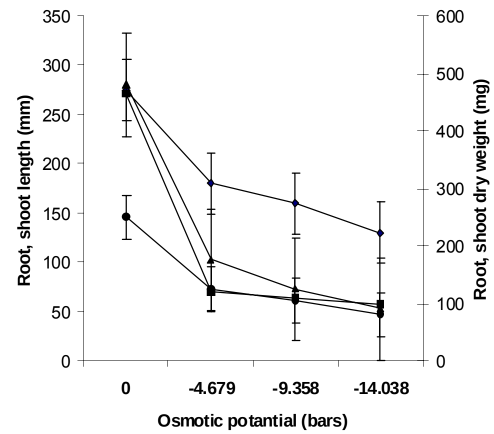
Statistical analyses. All the data analysis was carried out by using SAS statistical software package (SAS, 1989, 1990).

RESULTS AND DISCUSSION

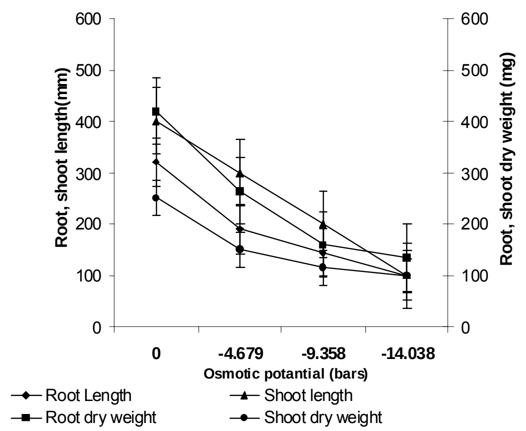
Growth results from the interaction of all the processes within the plant and is expressed as increment in dry mass, volume, length or area of cells (Lambers *et al.*, 1998). In present studies, water stress retarded the seedling growth of corn cultivars by inhibiting root/shoot length and dry mass production, etc. The growth pattern of both the corn cultivars in response to water stress was similar i.e., the growth was inversely proportional to the osmotic stress, however, the variation in intensity of drought was observed. As compared with control, the root/shoot length was reduced to 47.27/21.50 and 31.25/25.00% of Corn cultivar Baimisal-4 and Sunahry where as the %age for their dry weight was 21.50/32.00 and 32.14/40.00%, respectively at -4.308 bars osmotic potential. The shoot was affected more than root (Fig. 1). Cellular growth is one of the most sensitive plant processes to water stress and is reduced long before photosynthesis or stomatal conductance (Hsiao, 1973). Water stress results in decrease in osmotic potential of the medium, which in turn reduce the turgor pressure and water potential of the cell sap. This reduction may be smaller, similar or larger than the osmotic potential of the medium (Bernstein & Hayward, 1958; Gale *et al*., 1976). Growth and turgor pressure of the cells are directly related to each other (Kramer, 1969). Drought conditions also influence the root/shoot elongation process by affecting turgidity of the cells (Allen *et al*., 1976). Water stress not only restricted the elongation of root/shoot cells but also the production of dry mass (Fig. 1). Our results are in line with Akbar and Yabuno (1974) that the dry weight was decreased with the elevation in water stress. The rolling of leaves along with the reduction in average leaf area was observed in both the cultivars. The maximum reduction in leaf area was recorded at osmotic potential –14.038 bars

Fig. 1. Effect of water stress on root/shoot length and dry weight of corn (*Zea mays* L.) cultivars

Baimisal-4



Sunahry



which was 69.09 % for Baimisal-4 and 80.00 % for Sunahry as compared with control (Fig. 2). The smaller size of the leave resulted due to the smaller size of cells due to drought conditions (Nilsen & Orcut, 1996). Meiri and Poljakoff-Mayber (1970) have also reported the reduction in leaf area in response to drought. Concavity (rolling of leaves) of leaves at higher osmotic potentials was also observed as by O' Toole and Cruz (1980). Fig. 3 shows that the leaf water potential was decreased with increase in the osmotic potential (water stress) of the medium. The plants of cultivar Baimisal-4 and Sunahry, adjusted their leaf water potential to –10 and –9 bars, respectively against the external osmotic potential of –14.038 bars. Galle *et al.* (2002) have also reported a decrease in leaf osmotic potential of wheat.

Fig. 2. Effects of water stress on leaf area of corn (*Zea mays* L.) cultivars

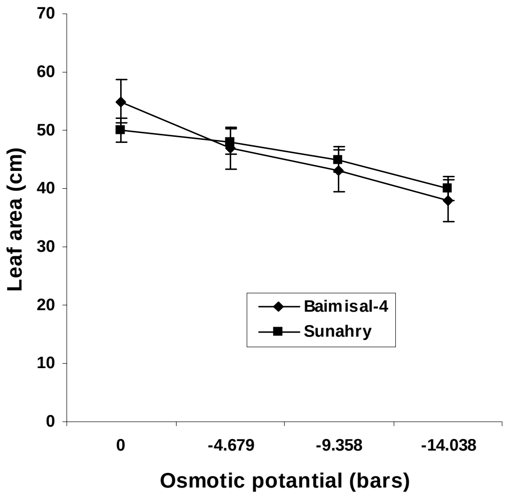
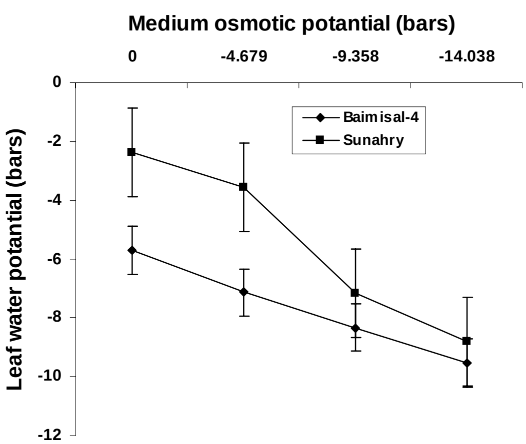


Fig. 3. Effects of water stress on leaf water potential of corn (*Zea mays* L.) cultivars



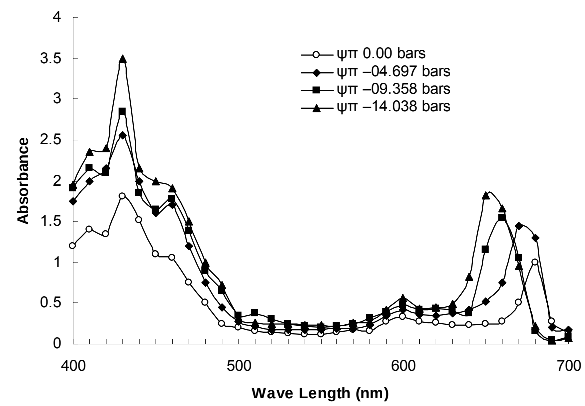
Under drought conditions with lower cell water potential, the expansion of developing cells is limited and the growth is reduced. In present studies that turgor pressure is fairly maintained under moderate stress, but the reduction in cell wall expansibility (plasticity) was still observed. The trigger for the stiffening of cell walls seems to be a combination of hydraulic and chemical (ABA) signals (Zhang & Davies, 1990). The smaller cell size of leaves in response to drought reduces the potential for carbon gain (Nilsen & Orcut, 1996), thus the growth is retarded. The increase in plasticity may also influence the stomatal conductance. Jones (1992) has reported that largest reduction in photosynthesis may actually be due to the reduction in leaf area, leaf growth and development.

The total chlorophyll and carotene contents of corn cultivars increased with an increase in water stress. Maximum increase in total chlorophyll contents was recorded in case of cultivar Baimisal-4, which was 308.43 % of control at –14.038 bars osmotic potential. In both the cultivars the increase in chlorophyll ‘a’ was recorded whereas reverse was true for chlorophyll ‘b’. Although an increase in carotenes was observed in both the cultivars but was not significant in case of cultivar Sunahry (Table I). Zimmerman (1985) has also reported an increase in chlorophyll contents at –5.00 bars osmotic potential in case of *Azolla*.

The rate of photosynthesis determine the rate of growth of plants which is supported by the interaction of two separate photosystems I (wavelength longer than 680) and II (Wavelength Shorter than 680) of light driven reactions. The sum of the rates of photosynthesis at these

Fig. 4. Effects of water stress on Absorption spectra of photosynthetic pigments of corn (*Zea mays* L.) cultivars

Baimisal-4



Sunahry

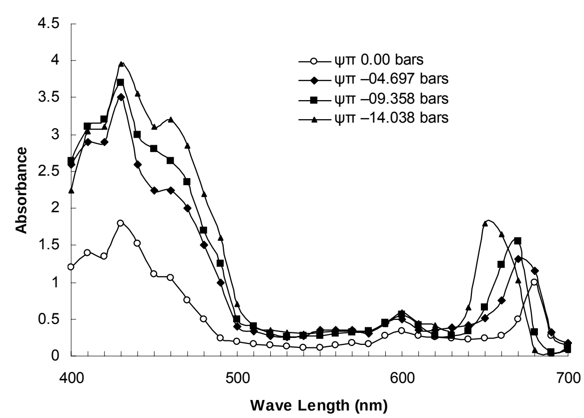


Table I. Effects of water stress on chlorophyll and carotene contents of leaves of Corn (*Zea mays* L.) cultivars (Average of 5 extracts)

Osmotic Potential	Total Chlorophyll mg g^{-1}	Chlorophyll 'a' mg g^{-1}	Chlorophyll 'b' mg g^{-1}	Carotene mg g^{-1}
		Cultivar Baimisal-4		
00.000	14.220	12.200	02.020	307.360
-04.697	34.320	27.320	07.000	423.690
-09.358	36.390	28.870	07.520	570.720
-14.038	43.860	33.180	10.680	698.580
L.Sd. p=0.05	05.390	02.720	02.670	NS
		Cultivar Sunahry		
00.000	17.900	10.000	07.900	245.000
-04.697	23.600	14.300	09.300	259.000
-09.358	26.800	16.600	10.200	567.000
-14.038	29.900	19.000	10.900	601.000
L.Sd. p=0.05	04.562	03.20	02.50	070.000

two weave lengths is greater than the sum of rates at each wave length (Darnell *et al*., 1986). The absorption spectrum of photosynthetic pigments in response to water stress (Fig. 4) reveal that maximum light was absorbed in two distinct regions i.e., from wave length 400-500 nm, the blue to violet region and 600 to 700 nm, the orange to red region. The absorption of light in both the regions increased with the increase in water stress. However, the peaks of maximum absorption of chlorophyll 'a' were shifted to shorter wavelengths. This may be due to the alteration in composition of chlrophyll 'a'. The shifting of maximum peak of chlorophyll 'a' dropped the efficiency of photosystem II (decrease in electron transport). This proves that although the chlorophyll contents (Chlorophyll 'a') increased in water stress but the overall growth remained depressed (Fig. 1,2,3). It has also been reported that under stress conditions the internal concentration of CO_2 become high which decrease the carboxylation efficiency which in turn decrease the photsystem II activity (decrease in electron transport) (Ramanjulu *et al.*, 1998). Yordanov *et al.* (2000) has observed the decrease in photoposphorylation in response to water stress, too.

CONCLUSIONS

It can be safely concluded from the results of the present studies that the retardation in growth by water stress was mainly due to the decrease in the efficiency of photsystem II of corn (*Zea mays* L.) cultivars,

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