J. Agric. Sci. Mansoura Univ., 27 (4): 2041 - 2052, 2002

# MAIZE HYBRIDS AS INFLUENCED BY DROUGHT STRESS UNDER DRIP IRRIGATION AT NUBARIA REGION

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## ABSTRACT

A field experiment was conducted in sandy soil under drip irrigation at Aly Mubarak Res. Farm, Nubaria during 2000 and 2001 growing seasons to study the effect of two water irrigation treatments, i.e. 100 and 50% of the evaporated water column from the evaporation pan on yield and yield components, growth characters, relative water content (RWC), and leaf proline content (LPC) of four maize hybrids, i.e. SC.122 (W), SC.129 (W), SC.155 (Y), and SC.161 (Y). The two water treatments represent well watered (non-stressed) and water stressed environments. Results cleared significant differences between the two stress levels for all studied traits except for ear diameter, No. of rows/ear, and RWC in 2000 growing season, and for No. of days to mid silking and LPC in 2001 season. Also, significant differences were found among the four hybrids for all studied traits except for grain yield (both years), no. of ears/100 plants and RWC in 2001 season. Water stress resulted in 30.3-43.2% reduction in grain yield in 2000 season, and 11.6-20.0% in 2001 growing season. Reductions due to water stress in No. of ears/100 plants, ear length and diameter, No. of rows/ear, No. of kernels/row, 100-kernel weight, and plant height were 8.1-20.8%, 9.1-14.3%, 0.7-4.5%, 1.4-3.7%, 13.1-23.6%, 6.4-12.8%, and 0.2-10.1%, respectively. RWC of plant leaves was lower under water stress than under normal irrigation by 5.5, 6.8, and 2.2% at 52, 62, and 90 days growth stage, as an average of the two years. Considerable changes in LPC occurred in plants under stress at the three plant growth stages especially at 62 days (flowering stage). LPC increased by 10.7, 41.1, and 19.9% at 52, 62, and 90 days as compared to values under normal irrigation. RWC and LPC at critical period of plant growth (flowering) may be used as indicators of drought stress of maize plants, but more investigations are recommended.

## INTRODUCTION

Drought has different effects on grain yield depending on the stage of development at which it occurs (Jensen, 1968; Fisher and Maurer, 1978; Salwau, 1985; and Osman and Khalifa, 2001). Also, yield losses due to drought stress could vary from one area or one season to another and could reach 50% or more (Denmead and Shaw, 1960; Mc Pherson and Boyer, 1977; Salwau, 1985; and Mahgoub *et al.*, 2001). Drought during the vegetative growth stage affects yield potential by determining the leaf area and photosynthetic capacity that is available during grain set and filling, whereas drought during flowering reduces yield potential directly by decreasing the total number of grains. Drought at postanthesis results in incomplete grain filling. The productivity of cereals is substantially reduced by drought during flowering stages (Hale and Orcutt, 1987). Maize (*Zea maya* L.) is particularly sensitive to drought during flowering (Sinclair *et al.*, 1990), the major mechanism being a delayed silking, such that pollen is shed asynchronously from tassels before the silks are receptive (Westgate, 1994 and Mahgoub *et al.*, 2001). Drought during booting and flowering in sorghum greatly reduced grain yield (Crauford and Peacock, 1993). Also, ear length and diameter, number of kernels/row, and ear weight were significantly affected by water stress especially at critical periods of plant growth (El-Marsafawy, 1991; El-Sabbagh, 1993; Attia *et al.*, 1994; and Osman and Khalifa, 2001). Using 28 days irrigation interval (stress irrigation), Attia *et al.*(1994) obtained 28.4-33.3 grain yield reduction compared with 14 days irrigation interval (normal irrigation). Also, Osman and Khalifa (2001) reported 18.6-21.3% yield reduction using the same stress level at Nubaria region.

Various physiological plant traits may ascribe a degree of plant adaptation to suffering from drought stress environments. The morphological and physiological responses of plants to water deficits, generally, vary with the severity as well as the duration of the stress. Only the most sensitive processes are altered by a mild stress. As the stress increases, these changes intensify, and additional processes become affected. In addition to the degree and duration of water stress, the stage of plant growth at which stress occurs is also important in determining the effects of water stress on plant growth and yield (Fageria, 1992).

Leaf relative water content (RWC) was proposed as a good indicator of plant water status (Sinclair and Ludlow, 1985) because RWC, through its relation to cell volume, may be more closely reflects the balance between water supply to the leaf and transpiration rate. The free amino acid proline, which increases proportionately faster than other amino acids in plant leaves under water stress, has been suggested as an evaluating parameter for irrigation scheduling and for selecting drought resistant cultivars (Bates *et al.*, 1973). In areas apt to moisture stress during growing season, improved tolerance of maize hybrids to drought stress has contributed significantly to yield improvement of maize (Tollenaar *et al.*, 1994a).

This investigation aimed to study the effect of water stress started after 30-40 days from planting on (1) yield, yield components, and growth parameters, and (2) leaf free proline and relative water content as physiological parameters at different stages of growth, under drip irrigation system at Nubaria Region.

## MATERIALS AND METHODS

A field experiment was conducted in sandy soils at Aly Mubarak Farm in Nubaria Region under drip irrigation system during 2000 and 2001 growing seasons. Four maize single crosses (S.C.) were chosen for the study, i.e. SC.122 (W), SC.129 (W), SC.155 (Y) and SC.161 (Y). Two water irrigation treatments were used, i.e. 100% and 50% of the evaporated water column from the evaporation pan as a non-stressed and water stressed treatments, respectively. A split plot design with four replications was used. The main plots were assigned to water treatments, while subplots were allocated for maize hybrids. Plot size consisted of 3 rows of 6 m long and 80 cm apart. Seeds were planted along the drip line with 25 cm hill spacing giving a plant population density of about 21,000 plants/fad. Until 30 days from planting in 2000 season and 40 days in 2001 season, the whole experiment received the same quantity of water (100% of the evaporation pan), thereafter, the water stress treatment (50% of the evaporation pan) was initiated and continued until maturity. Irrigation was implemented on daily basis.

Maize plants received 150 kg N, 24 kg $K_2O$, and 30 kg $P_2O_5$/fad. N and K fertilizers were applied at 10 and 6 equal weekly doses, where P was applied at planting. All other recommended agronomic practices for cultivation such as weed and pest control were followed.

Three fresh-leaf samples were taken for physiological determination of percentage relative water content (RWC) and leaf proline content (LPC, μg/g FW) as physiological indicators of the plant status under the implemented water stress treatments. Sampling time was at 52, 62, and 90 days after planting (DAP) representing pre-flowering, flowering, and completion of grain filling stages. Samples were collected between 11:00 am and 2:00 pm. Leaf disks were taken from two plants in each plot. The leaf disks were divided into 2 groups; one group for RWC determination and the other one was immersed immediately in the cooled proline extraction solution (3% aqueous sulfosalicylic acid solution). Samples were taken to the lab under cooled conditions and were kept refrigerated until extraction and determination of leaf proline content (Bates *et al.*, 1973). Samples were measured by spectrophotometer and repeated twice. The relative water content was calculated according to the equation given by Schonfeld *et al.*(1988):

$$RWC (\%) = 100 * (FW - DW) / (TW - DW)$$

where;

FW: is the leaf fresh weight,

TW: is the turgid weight, and

DW: is the dry weight (oven drying)

Data for number of days from planting to 50% tasselling and silking, plant height (based on 5 plants/plot), and number of ears/plant were collected during the season. Harvested ears were weighed and 5 kg/plot were taken for recording seed moisture percentage, ear length and diameter, number of rows/ear, number of kernels/row, and 100-kernel weight.

Analysis of variance and least significant difference test (L.S.D) for split-plot design were used to assess variation among the four maize hybrids and the irrigation treatments for all measured variables according to Snedecor and Cochran (1980).

## RESULTS AND DISCUSSION

Mean squares for grain yield, number of ears/100 plants, ear length and diameter, number of rows/ear, number of kernels/row, number of days to 50% tasselling and silking, plant height, relative water content (RWC), and leaf proline content (LPC) are presented in Table 1. Results indicated either

**Table (1): Mean squares for the ten measured characters under normal and stress water treatments in 2000 and 2001 seasons.**

| S.O.V. | d.f. | Grain yield | | No. of ears /100 plants | | Ear length | Ear diameter | No. of rows / ear | No. of kernels / row | 100-kernel weight | 50% tasselling | 50% silking | Plant height | Relative water content | | Leaf proline content |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2000 | 2001 | 2000 | 2001 | 2000 | 2000 | 2000 | 2000 | 2000 | 2001 | 2001 | 2001 | 2000 | 2001 | 2001 |
| Replications | 3 | 0.77 | 5.79 | 20.67 | 39.58* | 0.96 | 0.004 | 0.018 | 1.63 | 1.19 | 0.42 | 1.21 | 462.8* | 26.35* | 1.24 | 1.16 |
| Stress | 1 | 291.21** | 135.96* | 1666.67** | 780.12* | 24.81** | 0.070 | 0.634 | 228.17* | 54.00** | 10.13* | 3.13 | 1326.1* | 98.58 | 620.40* | 66.89* |
| Stress/reps | 3 | 2.70 | 12.37 | 10.17 | 68.37 | 0.16 | 0.011 | 0.146 | 5.54 | 3.68 | 0.88 | 0.71 | 151.2 | 24.68 | 13.58 | 2.21 |
| Hybrid | 3 | 113.27 | 9.84 | 104.94** | 9.08 | 15.69** | 0.152* | 1.056* | 217.17** | 40.69** | 31.58** | 31.71** | 774.8** | 68.50** | 1.44 | 78.34** |
| Stress x hybrid | 3 | 2.06 | 2.59 | 36.33 | 13.54 | 0.19 | 0.009 | 0.034 | 0.94 | 1.27 | 6.38 | 6.88 | 242.9 | 42.22 | 15.64 | 5.96 |
| Error | 18 | 2.05 | 4.57 | 14.47 | 12.67 | 1.02 | 0.042 | 0.320 | 7.97 | 2.67 | 0.65 | 0.51 | 126.5 | 8.66 | 2.48 | 2.22 |

*, ** indicate significant and highly significant at 0.05 and 0.01 probability levels, respectively.

significant or highly significant differences between the two stress levels for all studied traits except for ear diameter, no. of rows/ear, and RWC in 2000 season, and for no. of days to 50% silking and LPC in 2001 season. Differences among hybrids were significant for all studied traits except for grain yield (both seasons), no. of ears/100 plants and RWC in 2001 season.

### A. Effect of water stress on yield and yield components

Means for grain yield and yield components are presented in Table 2.

#### 1. Grain yield

Results indicated that supplying 50% of plant water requirements (50% of the evaporated water column from the evaporation pan) caused significant yield reduction in both years ranged from 30.3-43.2% in 2000 season and 11.6-20.0% in 2001. Yield reduction in 2001 was much less than that of 2000 because water stress in 2001 was imposed at 40 days after planting rather than 30 days in 2000. Moreover, temperature recorded at the experimental site in 2000 season (data not shown) was higher than that of 2001 which enhanced the stress effect on growing plants. SC.161 exhibited the lowest reduction (30.3%) in grain yield, while SC.155 showed the highest reduction (43.2%) in grain yield due to water stress. Imposing water stress at early vegetative growth (30 days after planting, DAP) showed that non of the tested hybrids had high tolerance level to drought stress, however, some differences among hybrids existed. These results are similar to those obtained by Mc Pherson and Boyer (1977), Porró and Cassel (1986), Eck (1986), Nour Eldein *et al.*(1986), Abd El-Mawgood *et al.*(1999), Abo-Grab and Osman (1999), El-Ganayni *et al.*(2000), and Mahgoub *et al.*(2001). Mc Pherson and Boyer (1977) obtained 47-69% reduction in grain yield when maize plants were subjected to water deficiency during most of the grain filling period. Abo Grab and Osman (1999) found that drought induced at flowering reduced grain yield by 34.4%, while El-Ganayni *et al.*(2000) indicated that soil moisture stress at pre-flowering, flowering, and post-flowering stages reduced grain yield by 42, 23, and 54%, respectively.

#### 2. Number of ears/100 plants

Results presented in Table 2 also indicated that reduction in number of ears/100 plants in 2000 ranged from 9.5-20.8% and from 8.1-13.2% in 2001. No strong relation was found between yield reductions and decrease in number of ears/100 plants except for SC.161 in 2000 where it had the lowest reduction in yield and number of ears/100 plants. These results are in harmony with those obtained by Nour Eldein *et al.*(1986), Abd El-Mawgood *et al.*(1999), El-Ganayni *et al.*(2000), and Mahgoub *et al.*(2001). Abd El-Mawgood *et al.*(1999) obtained 11% reduction in no. of ears/plant when maize plants were irrigated at 20 days interval (stressed) instead of normal irrigation at 12-days interval. Mahgoub *et al.*(2001) found that water stress imposed for about 35 days from pre-flowering to grain-filling growth stages reduced no. of ears/plant by an average of 30%.

Table (2): Grain yield, number of ears/100 plants, ear length, ear diameter, number of rows/ear, number of kernels/row, 100-kernel weight, number of days to 50% tasselling and silking, and plant height for the 4 tested hybrids under normal and stress water treatment in 2000 and 2001 seasons.

| S.O.V. | Grain yield (ard./fad.) | | Ears /100 plants (no.) | | Ear length (cm) | Ear diameter (cm) | Rows / ear (no.) | Kernels / raw (no.) | 100-kernel weight (g) | 50% tasselling (day) | 50% silking (day) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2001 | 2000 | 2001 | 2000 | 2000 | 2000 | 2000 | 2000 | 2001 | 2001 | 2001 |
| **SC.122** | | | | | | | | | | | | |
| 100% | 22.07 a* | 25.39 a | 101.0 a | 104.8 a | 18.67 a | 4.20 a | 14 33 a | 43.33 a | 32.60 a | 60.8 a | 63.5 a | 277.8 a |
| 50% | 13.73 b | 20.32 b | 81.7 b | 95.1 b | 16.87 b | 4.17 a | 14.10 a | 37.67 b | 29.20 b | 60.8 a | 63.8 a | 277.3 a |
| Reduction % | 37.8 | 20.0 | 19.1 | 9.3 | 9.6 | 0.7 | 1.6 | 13.1 | 10.4 | 0.0 | +0.3** | 0.2 |
| **SC.129** | | | | | | | | | | | | |
| 100% | 17.07 a | 25.17 a | 94.3 a | 103.0 a | 18.27 a | 4.13 a | 14.60 a | 41.67 a | 29.80 a | 59.8 a | 62.3 a | 273.3 a |
| 50% | 10.47 b | 20.35 b | 74.7 b | 94.5 a | 16.60 b | 4.07 a | 14.40 a | 36.00 b | 27.90 a | 59.8 a | 63.2 b | 262.5 a |
| Reduction % | 38.7 | 19.1 | 20.8 | 8.3 | 9.1 | 1.4 | 1.4 | 13.6 | 6.4 | 0.0 | +0.9 | 4.0 |
| **SC.155** | | | | | | | | | | | | |
| 100% | 12.90 a | 21.96 a | 94.3 a | 104.8 a | 15.87 a | 4.40 a | 13.73 a | 31.00 a | 34.43 a | 59.5 a | 62.2 a | 270.5 a |
| 50% | 7.33 b | 19.42 a | 76.0 b | 91.0 b | 13.60 | 4.20 b | 13.40 a | 23.67 b | 30.04 b | 55.8 b | 59.0 b | 243.3 b |
| Reduction % | 43.2 | 11.6 | 19.4 | 13.2 | 14.3 | 4.5 | 2.4 | 23.6 | 12.8 | -3.7 | -3.2 | 10.1 |
| **SC.161** | | | | | | | | | | | | |
| 100% | 23.53 a | 25.11 a | 97.3 a | 102.3 a | 19.60 a | 4.53 a | 14.67 a | 41.33 a | 36.37 a | 56.8 a | 59.5 a | 263.9 a |
| 50% | 16.17 b | 21.03 b | 88.1 b | 94.0 a | 17.20 b | 4.40 a | 14.13 a | 35.33 b | 33.70 a | 56.0 a | 59.0 a | 250.0 b |
| Reduction % | 30.3 | 16.2 | 9.5 | 8.1 | 12.2 | 2.9 | 3.7 | 14.5 | 7.3 | -0.8 | -0.5 | 5.3 |
| L.S.D$_{0.05}$ | 2.88 | 3.96 | 5.6 | 9.3 | 0.71 | 0.18 | 0.67 | 4.13 | 3.37 | 1.05 | 0.95 | 13.8 |
| C.V. | 9.3 | 9.6 | 4.3 | 3.6 | 5.9 | 4.8 | 4.0 | 7.8 | 5.1 | 1.4 | 1.2 | 4.2 |

* For each hybrid, stress level means in 2000 and 2001 with the same letter are not significantly different.

** For no. of days to 50% tasselling and silking, the difference between the two stress levels is expressed in days.

**3. Ear length and diameter**

Results indicated that the reduction in ear length under water deficit conditions ranged from 9.1-14.3%, while for ear diameter it was from 0.7-4.5% (Table 2), which indicated that ear length was more affected by water stress than ear diameter. The two white single crosses, i.e. SC.122 and SC.129 were less affected by water stress, for these two traits, than the other two yellow single crosses. Abd El-Mawgood *et al.*(1999) and Mahgoub *et al.*(2001) reported similar results. Abd El-Mawgood *et al.*(1999) obtained 13 and 11% reduction in ear length and diameter, respectively.

**4. Number of rows/ear**

Water stress had little effect on number of rows/ear, since the reduction in this trait for the 4 tested hybrids ranged from 1.4-3.7%. This trait is highly heritable and normally less affected by biotic or abiotic stresses. El-Ganayni *et al.*(2000) obtained 4% reduction in number of rows/ear when water stress was imposed at either pre-flowering or flowering stages.

**5. Number of kernels/row**

As a result of reduction in ear length due to water stress, number of kernels/row was proportionally reduced. Results showed that reduction in no. of kernels/row ranged from 13.1-23.6%. SC.155 had the highest reduction in no. of kernels/row (23.6%). El-Ganayni *et al.*(2000) indicated that pre-flowering stress caused 22% reduction in number of kernels/row.

**6. Kernel weight**

Results indicated that reduction in 100-kernel weight ranged from 6.4-12.8% as a result of water deficit which was imposed on the 4 tested hybrids. This trait is normally positively correlated with grain yield and more affected by water stress at grain filling period. Similar results were obtained by Nour Eldein *et al.*(1986), Abd El-Mawgood *et al.*(1999), and Mahgoub *et al.*(2001). Abd El-Mawgood *et al.*(1999) reported 19% reduction in 100-kernel weight as they used prolonged irrigation intervals (every 20 days) as compared to regular irrigation intervals (12 days).

**7. Number of days to 50% tasselling and silking**

The 4 tested hybrids varied considerably in their reaction to the imposed water stress. For SC.122 and SC.129, water stress caused no change in tasselling dates, while it caused slight delay in silking. Both yellow single crosses behaved differently, since water stress resulted in 3.7 and 0.8 days early tasselling and, unexpectedly, 3.2 and 0.5 days early silking for SC.155 and SC.161, respectively. Abd El-Mawgood *et al.*(1999) reported 2.3 days silking delay under moderate water stress (irrigation every 20 days) along the season. El-Ganayni *et al.*(2000) indicated that drought stress at pre-flowering stage delayed silking by 7.4 days.

Table (3): Relative water content (RWC), and leaf proline content (LPC) for the 4 tested hybrids under stressed and normal (control) irrigation at different growth stages in 2000 and 2001 seasons.

| Character and sampling stage (day) | SC.122 (W) | | | | SC.129 (W) | | | | SC.155 (Y) | | | | SC.161 (Y) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | | 2001 | | 2000 | | 2001 | | 2000 | | 2001 | | 2000 | | 2001 | |
| | Stress | Control | Stress | Control | Stress | Control | Stress | Control | Stress | Control | Stress | Control | Stress | Control | Stress | Control |
| A) Relative water content (%) | | | | | | | | | | | | | | | | |
| 52 D | 75.4 a* | 85.4 b | 89.4 a | 94.9 b | 83.7 a | 85.9 a | 86.1 a | 94.9 b | 84.5 a | 88.2 a | 89.1 a | 95.2 b | 80.1 a | 82.9 a | 90.8 a | 95.2 b |
| 62 D | 70.2 a | 78.9 b | 91.4 a | 96.2 b | 79.8 a | 83.3 b | 84.3 a | 95.6 b | 68.1 a | 76.2 b | 85.8 a | 94.9 b | 78.1 a | 82.7 a | 89.6 a | 93.6 b |
| 90 D | 88.9 a | 90.9 a | 87.2 a | 92.9 b | 90.4 a | 90.1 a | 91.8 a | 94.5 a | 91.9 a | 91.9 a | 89.1 a | 95.5 b | 91.9 a | 90.7 a | 89.0 a | 91.3 a |
| B) Leaf proline content (µg/g FW) | | | | | | | | | | | | | | | | |
| 52 D | - | - | 7.31 a | 6.22 a | - | - | 8.45 a | 5.87 b | - | - | 8.51 a | 9.18 a | - | - | 6.44 a | 6.48 a |
| 62 D | - | - | 13.51 a | 7.90 b | - | - | 11.04 a | 10.23 a | - | - | 21.24 a | 13.44 b | - | - | 8.07 a | 6.60 b |
| 90 D | - | - | 6.51 a | 5.17 a | - | - | 6.82 a | 5.81 a | - | - | 8.65 a | 6.51 b | - | - | 5.34 a | 4.98 a |

* For each hybrid, stress level means with the same letter are not significantly different.

Table (4): Means for relative water content (RWC), in 2000 and 2001, and leaf proline content (LPC), in 2001, under stress and normal irrigation conditions.

| Growth stage (day) | Relative water content (%) | | | | | | Leaf proline content (µg/g FW) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2000 season | | | 2001 season | | | 2001 season | | |
| | Stress | Normal | RWC decrease (%) | Stress | Normal | RWC decrease (%) | Stress | Normal | Proline increase (%) |
| 52 | 80.9 | 85.6 | 4.7 | 88.8 | 95.0 | 6.2 | 7.68 | 6.94 | 10.7 |
| 62 | 74.0 | 80.3 | 6.3 | 87.8 | 95.1 | 7.3 | 13.46 | 9.54 | 41.1 |
| 90 | 90.0 | 90.9 | 0.0 | 89.3 | 93.6 | 4.3 | 6.74 | 5.62 | 19.9 |

### 8. Plant height

Moderate reduction in plant height was obtained only for SC.155 (10.3%) and SC.161 (5.3%). It was expected to have more plant height reduction than obtained, but it seemed that the reduction obtained in grain yield was much clear with yield-forming traits than growth characters (plant height and flowering). These results are similar, especially for tasselling, to those obtained by Porro and Cassel (1986), Nour Eldein *et al.*(1986), Abd El-Mawgood *et al.*(2000), El-Ganayni *et al.*(2000), Osman and Khalifa (2001), and Khalifa *et al.*(2001). Porro and Cassel (1986) indicated that plant height was reduced when irrigation was frequently delayed by 4 days than normal irrigation time. Osman and Khalifa (2001) reported 9.2% reduction in plant height when using 28 days water interval rather than 14 days, while in a similar study, Khalifa *et al.*(2001) obtained 7.0-9.2% plant height reduction.

### 9. Relative water content (RWC)

Leaf relative water content for each hybrid was measured at 52 days (pre-flowering), 62 days (flowering), and 90 days (end of grain filling period) in 2000 and 2001 growing seasons (Table 3). Means of RWC for each growth stage, across hybrids, and percentage of RWC decrease due to imposed water stress are presented in Table 4. Results indicated that differences in leaf RWC under stress and normal irrigation, for each hybrid, was significant only at 52 and 62 days. RWC for stressed plants was higher at 52 days (pre-flowering) compared with 62 days (flowering) since metabolic activities at flowering stage are at the highest rates and require higher irrigation water supply. At 90 days growth stage, plants had almost completed the grain filling period and, therefore, water requirements at this stage, are relatively low. This could be the reason for insignificant differences for RWC between stressed and non-stressed plants at this stage. Decrease in RWC in stressed plants, across hybrids, at 52, 62, and 90 days was 4.7, 6.3, and 0.0%, respectively in 2000 season, while it was 6.2, 7.3, and 4.3%, respectively in 2001 season.

### 10. Leaf proline content (μg/g FW, LPC)

Results of LPC for each hybrid at 52, 62, and 90 days after planting (DAP) for 2001 season are presented in Table 3. Means of LPC for each growth stage, across hybrids, and percentage of LPC increase due to imposed water stress are presented in Table 4. Results indicated that LPC was significantly higher in stressed plants than non-stressed only at 62 DAP (flowering stage) except for S.C.129. Differences between stressed and well watered plants at 52 DAP (pre-flowering) and 90 DAP (end of grain filling) were insignificant except for SC.129 at 52 DAP and SC.155 at 90 DAP. Increase in LPC in stressed plants, across hybrids, at 52, 62, and 90 DAP was 10.7, 41.1, and 19.9%, respectively. Results of LPC are encouraging but need to be confirmed over more growing seasons and over a wide range of genotypes before deciding if LPC at critical period of plant growth (flowering stage) can be used as an indicator for plant water status under drought stress. Also, correlation between yield and LPC at different stages of plant growth need more investigations.

The most sensitive physiological process to drought is photosynthesis. This process could be reduced markedly due to less water availability especially in $C_4$ plants such as maize plants. So, water shortage lead to inhibited photosynthetic activities of maize plants and as a result, less assimilates. Therefore, the whole plant growth and yield are affected.

Results of this study revealed that the late vegetative and flowering stages were the most sensitive to drought in maize plants. It is strongly recommended to control irrigation during these periods to obtain higher biomass production, and consequently good yield. On the other hand, both tested physiological characters, i.e. RWC and LPC need more investigations and special care at time of estimation if to be considered as a selection criteria in drought breeding programs.

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# دراسة تأثير الجفاف على هجن الذرة الشامية تحت نظام الرى بالتنقيط فى منطقة النوبارية

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أقيمت تجربة حقلية بالأراضى الرملية تحت نظام الرى بالتنقيط بمزرعة على مبارك البحثية بالنوبارية خلال عامى ٢٠٠٠، ٢٠٠١ لدراسة تأثير معاملتين من مياه الرى وهما الرى عند ١٠٠%، ٥٠% فى عمود الماء المتبخر من حلة البخر على محصول الحبوب ومكوناته، بعض صفات النمو، المحتوى النسبى للمياه بأوراق النبات (RWC) ، بالإضافة لمحتوى الأوراق من الحمض الأمينى برولين (LPC) وذلك لأربعة هجن فردية من الذرة الشامية هى هـ.ف.١٢٢، هـ.ف.١٢٩، هـ.ف.١٥٥، هـ.ف.١٦١. وتمثل معاملتى مياه الرى: الرى العادى (١٠٠% من حلة البخر) والإجهاد المائى (٥٠% من حلة البخر).

أوضحت النتائج وجود فروق معنوية بين معاملتى الرى لكل الصفات تحت الدراسة ماعدا صفة قطر الكوز وعدد الصفوف بالكوز والمحتوى المائى النسبى للأوراق فى موسم ٢٠٠٠، وكذلك عدد الأيام حتى منتصف فترة خروج الحرائر ومحتوى الأوراق من البرولين فى موسم ٢٠٠١. وجدت كذلك فروق معنوية بين الهجن الأربعة لكل الصفات تحت الدراسة ماعدا صفة محصول الحبوب (كلا موسمى النمو)، عدد الكيزان/١٠٠ نبات والمحتوى النسبى للمياه بالأوراق فى موسم ٢٠٠١.

نتج عن معاملة الإجهاد المائى إنخفاض فى محصول الحبوب تراوح مابين ٣٠,٣–٤٣,٢% عام ٢٠٠٠، وكذلك مابين ١١,٦–٢٠,٠% عام ٢٠٠١. حدث كذلك إنخفاض فى عدد الكيزان/١٠٠ نبات، طول وقطر الكوز، عدد الصفوف بالكوز، عدد الحبوب بالصف، وزن الـ ١٠٠ بذرة، وإرتفاع النبات كنتيجة للإجهاد المائى كالتالى: ٨,١–٢٠.٨%، ٩,١–١٤,٣%، ٠,٧–٤,٥%، ١,٤–٣,٧%، ١٣,١–٢٣,٦%، ٦,٤–١٢,٨%، ٠,٢–١٠,١% على التوالى.

كانت قيم المحتوى المائى النسبى بالأوراق تحت ظروف الإجهاد المائى أقل من مثيلتها تحت ظروف الرى العادى بقيم قدرها ٥,٥%، ٦,٨%، ٢,٢% عند ٥٢، ٦٢، ٩٠ يوم من عمر النبات على التوالى وذلك كمتوسط لسنتى الدراسة. كذلك حدثت تغيرات جوهرية فى محتوى الأوراق من الحمض الأمينى برولين تحت ظروف الإجهاد المائى عند مراحل النمو الثلاث السابقة خاصة عند مرحلة ٦٢ يوم من الزراعة (مرحلة التزهير). لقد زاد الحمض الأمينى برولين بالأوراق بنسبة ١٠,٧%، ٤١,١%، ١٩.٩% عند عمر ٥٢، ٦٢، ٩٠ يوم على التوالى مقارنة بمثيلاتها تحت معاملة الرى العادى. إن محتوى الأوراق من الحمض الأمينى برولين تحت ظروف الإجهاد المائى عند المراحل الحرجة من نمو النبات خاصة مرحلة التزهير يمكن أن تستخدم كمقياس أو مدلول لتقييم مدى مقاومة الأصناف للإجهاد المائى. ولكن يوصى بعمل المزيد من البحوث فى هذا المجال قبل الوصول إلى إستنتاج نهائى.