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# EFFECT OF PLANTING DENSITY AND SKIPPING IRRIGATION AT CERTAIN GROWTH STAGES ON YIELD POTENTIALITY OF SOME MAIZE HYBRIDS

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## ABSTRACT

Two field experiments were conducted in the Experimental Farm of Gemmeiza Agriculture Research Station, Agricultural Research Center (ARC), Egypt during two growing seasons (2011 and 2012) to study the effect of three planting densities (20, 24 , and 28 thousand plants/fad.) and two missing irrigations (the 3rd and 5th irrigations or missing the 4th and 6th irrigations) out of six irrigations normally scheduled at 15 days intervals on yield potentiality of four maize hybrids (S.C. 10, S.C. 173, T.W.C. 324 and T.W.C. 352). Concerning the obtained results, the combined analysis revealed that applied 6 irrigations gave the highest means of the different studied characters, skipping the 3rd and 5th irrigations gave lower growth and grain yield attributes followed in descending order by missing the 4th and 6th irrigations. Then, both irrigation treatments caused significant reduction in grain and biological yields/fad., which reached 17.54 and 9.75% in grain yield as well as 10.36 and 11.19% in biological yield compared with normal irrigation, respectively. Maize hybrid S.C. 10 was superior in most growth and yield attributes as it recorded the highest grain and biological yields/fad., followed by S.C. 173 and T.W.C. 324 as well as T.W.C. 352 in descending order. Meantime, S.C. 173 produced the highest ear length and chlorophyll content. While T.W.C. 352 gave the highest mean for each of cob diameter, number of rows/ear and grain protein content. Data of the combined analysis revealed also, that increasing planting density from 20 to 24 and 28 thousand plants/fad., significantly increased leaf area index and grain and biological yields/fad., but, significantly decreased ear length. Planting density had significant effect on each of days to 50% tasseling and silking, LAI, stem diameter, plant height, ear height and diameter, cob diameter, number of rows/ear, number of kernels/row, thousand grain weight and protein content. Where their averages were decreased with the increase of density. The most interacting effect was observed between maize hybrids on one hand and each of water stress and planting density on the other hand. S.C. 10 and S.C. 173 as well as T.W.C. 324 had the highest grain yield averages under both normal and skipping the 4th and the 6th irrigations. However, under skipping the 3rd and the 5th irrigations, S.C. 173 and both S.C. 10 and T.W.C. 324 had higher grain yields than T.W.C. 352. Under both low and medium densities, each of S.C. 10, S.C. 173 and T.W.C. 324 recorded almost equal grain yield (ard./fad.) averages being heavier than T.W.C. 324 and T.W.C. 352. For both S.C. 10 and S.C. 173 any increase in planting density caused a significant increase in grain yield. For T.W.C. 324 both medium and high densities gave equal grain yield being heavier than low density whereas T.W.C. 352 recorded the highest grain yield from high density.

**Key words:** Irrigation treatments, maize hybrids, planting densities.

## INTRODUCTION

Maize is one of the most important cereal crops under global cultivation, which used mainly in animal and poultry feeding and, to less extent, in human consumption.

Furthermore, it is used in several important industries such as corn oil, starch and fructose sugar. Recently, maize is widely miss used in extracting ethanol and biobutanol that is used as fuel besides oil.

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In Egypt, maize is considered as one of the main cereal crops, comes the third after wheat and rice. Maize is very essential either for the human food or animal feeding in addition to a common ingredient for industrial products. It plays a vital source of daily human food because maize flour is mixed with wheat flour by 20 % for bread making. Also, maize is used as a feed for livestock whether fresh, silage or grains. Since, the total cultivated area of maize crop in Egypt reached about 2.204 million faddans* in 2012 season, producing 7.200 million tons, thus the average production of maize is 23.02 ardabs/fad. The recent high productivity has been realized as a result of releasing high yielding hybrids resistant to major pests, in addition to a good package of recommendations. But, this amount covered about sixty percent of maize consumption in Egypt.

There are many biotic and abiotic stresses responsible for losses in crop yield worldwide. Abiotic stresses like drought, heat, excessive rain, water logged soil, wind and extensive cold *etc.* (Löffler *et al.,* 2005 and Setimela *et al.,* 2005) and most likely within individual fields (Bruce *et al.,* 2002). Drought is one of the most important abiotic stress factor (Bruce *et al.,* 2002), which affects almost every aspect of plant growth (Sadras and Milroy, 1996; Aslam *et al.,* 2006). Drought, or more generally, limited water availability is the main factor limiting crop production (Seghatoleslami *et al.,* 2008 and Golbashy *et al.,* 2010 A). Therefore, drought is a permanent constraint to agricultural production in many developing countries, and an occasional cause losses of agricultural production in developed ones (Ceccarelli and Grando, 1996).

Planting density is one of the major factors determining the ability of the crop plant to capture resources, modifying crop density and plant arrangement may be seen as a way of changing crop spatial and temporal structure and, by this means, the use of crop resources.

With increasing plant density to a definite point, yield is increased and then, even though water and nutrients are not limiting factors, yield is decreased. Main factor of grain yield loss in maize under high densities has been attributed to several factors which result in a noticeable, decrease in grain number and weight and hence grain yield per cob. Such effect were indicated by several investigators included Afsharmanesh (2007), khalil (2007) Sikandar *et al.* (2007); Ahmad *et al.* (2008); Raouf *et al.* (2009) and Sharifi *et al.* (2009). Therefore the present study aimed to find out the possibility of saving irrigation water through skipping two irrigation out of six ones normally given under Gemmeiza locality using four promising hybrids planted at three planting densities and their effect on growth and grain yield potentiality.

# MATERIALS AND METHODS

The current investigation was carried out in the Experimental Farm of Gemmeiza Agriculture Research Station, Agricultural Research Center (ARC), Egypt. Three field trials were conducted during 2011 and 2012 summer growing seasons. One trail for each water treatment, as follows:

## Irrigation Treatments (S)

1-Normal irrigations (S-1), wherein 6 irrigations were applied at 22, 34, 45, 60, 75 and 90 days from planting.

2- Missing the 3rd and 5th irrigations (45 and 75 days from plating). (S-2)

3- Missing the 4th and 6th irrigations (60 and 90 days from plating). (S-3)

The experimental design used in each experiment was a split–plot design in four replications. The main plots were assigned for maize hybrids and plant population densities (distance between plants) were randomly distributed in the sub– plots. Combined analysis was done over the irrigation treatments, where, replications were nested within irrigation treatments. Each field trail consisted of twelve treatments which were the combination of four hybrids and three plant population densities, as follows:

## Maize Hybrids (H)

1. Single Cross (S.C.) 10 (Sd. 7 x Sd. 63): A white single cross released by Maize Res. Dept.
2. Single Cross (S.C.) 173 (Gz. 647 x Gz. 666): A yellow single cross released by Maize Res. Dept.

3. Three way cross (T.W.C.) 324 (S.C. 24 x Sd.7) A white Three way cross released by Maize Res. Dept.
4. Three way cross (T.W.C.) 352 (S.C. 52 x Gm. 1021) A yellow Three way cross released by Maize Res. Dept.

## Planting Densities (D)

1. 20 000 plants/fad., (26 cm between hills, 24 hills/row). (D-1)
2. 24 000 plants/fad., (22 cm between hills, 28 hills/row). (D-2)
3. 28 000 plants/fad., (19 cm between hills, 32 hills/row). (D-3)

Each plot consisted of four ridges, each ridge was 6 m long and 80 cm in width. The outer two ridges ($1^{st}$ and $4^{th}$) were considered as borders.

### Soil mechanical and chemical analyses of

1. Soil samples at (0 – 15) and (15- 50 cm depth) were taken from the experimental site before planting for physical and chemical analyses.
2. Soil samples at (0 – 15) and (15- 50 cm depth) were taken from irrigated and un-irrigated furrows two days after each irrigation and weighed for estimating moisture content. Results of mechanical and chemical analyses are presented in Table 1.

## Meteorological Data

Meteorological data (monthly temperature $C^o$ and relative humidity) of El-Gemmeiza district during the two growing seasons 2011 and 2012 are shown in Table 2.

The previous crop was wheat in both years. Planting was done on June $9^{th}$ in 2011 season, and June $12^{th}$ in 2012 season. Ordinary super phosphate (15.5% $P_2O_5$) at the rate of 200 kg $fad.^{-1}$, was applied before planting. Three grains were hand planted in each hill. Thinning to one plant per hill was done before the first irrigation. Hoeing twice was done for controlling weeds before the first and second irrigations. Nitrogen fertilizer in the form of urea (46.6% N) at the rate of 120 kg N $fad^{-1}$, was applied in two equal doses before the first and the second irrigations, respectively. Recommended pest control was applied when necessary.

## The Amount of Irrigation Water Used

$Q = CA\sqrt{2gh}$ where

Q is the discharge rate ($cm^3$/sec), C is the discharge coefficient of the spile (which was estimated empirically to be 0.61), g is the acceleration of gravity (980 $cm/sec^2$), A is the spile cross sectional area and h is the effective water head above the spile. The effective water head was measured several times during irrigation and the average value of 8.3 cm was used in this study. In all treatments the water was applied to the plot until the propagating wave of in-flowing water reaches the end of the furrows. The time required to irrigate the plot was recorded to calculate the amount of water applied (Table 3 and 4).

### Studied characters

1. Days to 50 % tasseling.
2. Days to 50 % silking.
3. Leaf area index (LAI).
4. Stem diameter (cm).
5. Chlorophyll content (mg $m^{-2}$).
6. Plant height (cm).
7. Ear height (cm).
8. Ear length (cm).
9. Ear diameter (cm).
10. Cob diameter (cm).
11. Number of rows $ear^{-1}$
12. Number of kernels $row^{-1}$.
13. 1000 – kernel weight (g).
14. Grain yield in ardab per faddan (ard. $fad.^{-1}$). It was recorded at harvest from the second and third ridges of each plot. Grain yield was adjusted to moisture content of 15.5 % and transformed to ardab per faddan (one ardab = 140 kg and one faddan = 4200 $m^2$).
15. Biological yield in ton per faddan (ton $fad^{-1}$).
16. Grain protein content.

### Statistical analysis

The obtained data for each spacing trail were statistically analyzed as split–plot design according to Snedecor and Cochran (1967). Treatment means were compared according to the LSD test. In the tables of the analysis of variance *,** indicate significant at 0.05 and 0.01 levels of probability, respectively as described by Waller and Duncan's (1969).

**Table 1. Soil mechanical and chemical analyses of the experimental sites during 2011 and 2012 seasons**

| Soil properties | 2011 | | 2012 | |
|---|---|---|---|---|
| | Depth (cm) | | | |
| | 0 –15 | 15 –50 | 0 –15 | 15 –50 |
| | Mechanical analysis | | | |
| Clay (%) | 43.49 | 43.13 | 42.34 | 34.42 |
| Silt (%) | 41.88 | 37.92 | 40.23 | 33.19 |
| Fine sand (%) | 14.02 | 18.52 | 16.68 | 31.87 |
| Coarse sand (%) | 0.61 | 0.43 | 0.75 | 0.52 |
| Texture class | Clay | | | |
| | Chemical analysis | | | |
| Organic matter (%) | 1.04 | 0.83 | 1.01 | 0.81 |
| Available N (ppm) | 42.00 | 40.00 | 60.00 | 51.00 |
| Available P (ppm) | 4.50 | 3.40 | 5.40 | 4.70 |
| Exchangeable K (ppm) | 2.35 | 2.03 | 3.25 | 3.05 |
| pH (1 : 2.5) | 8.10 | 8.00 | 8.25 | 7.10 |
| E.C. (m.mhos/cm at 25 C°) | 3.55 | 3.60 | 3.03 | 2.51 |
| $Ca^{++}$ (mgm/100 g) | 2.80 | 1.98 | 3.28 | 3.10 |
| $Mg^{++}$ | 1.05 | 1.03 | 1.90 | 1.73 |
| $Na^{+}$ | 2.57 | 2.88 | 3.55 | 3.24 |
| $HCO_3^{-}$ | 2.10 | 2.05 | 2.57 | 2.60 |
| $SO_4^{--}$ | 7.30 | 6.75 | 8.25 | 8.65 |

**Table 2. Monthly maximum and minimum temperature ($C^0$) and relative humidity (%) at the experimental site during the two growing seasons**

| Month | Temperature ($C^o$) | | | | Relative humidity (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2011 | | 2012 | | 2011 | | 2012 | |
| | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. |
| June | 33.4 | 28.0 | 36.2 | 30.6 | 84.5 | 42.4 | 86.7 | 42.7 |
| July | 36.0 | 26.2 | 37.3 | 31.5 | 84.0 | 42.0 | 85.2 | 43.08 |
| August | 35.3 | 24.5 | 36.7 | 25.9 | 84.4 | 41.5 | 84.9 | 42.3 |
| September | 34.0 | 24.8 | 35.02 | 26.0 | 83.7 | 41.9 | 85.6 | 42.5 |
| October | 33.8 | 22.4 | 34.10 | 25.3 | 83.6 | 40.6 | 83.8 | 41.2 |

* The source of this data is Ministry of Agriculture and Reclamation of Soils, Agriculture Research Center (ARC), Central Management of Agriculture Guideline, Bulletin of Agricultural Meteorological Data.

**Table 3. Averages of applied water ($m^3$/faddan) under the different irrigation treatments, 2011 season.**

| Irrigation Event | Date | Irrigation treatments | | |
|---|---|---|---|---|
| | | Traditional (Six irrigations were applied) | Deficit I (Omitting watering at the 3rd and 5th irrigations) | Deficit II (Omitting watering at the 4th and 6th irrigations) |
| Planting | 09/06/2011 | 610.00 | 610.00 | 610.00 |
| First | 01/07/2011 | 350.63 | 350.63 | 350.63 |
| 2nd | 14/07/2011 | 231.00 | 231.00 | 231.00 |
| 3rd | 27/07/2011 | 434.76 | | 455.75 |
| 4th | 13/08/2011 | 548.40 | 613.59 | |
| 5th | 29/08/2011 | 477.83 | | 599.90 |
| 6th | 12/09/2011 | 424.10 | 833.80 | |
| Total | | 3076.72 | 2639.02 | 2247.28 |

**Table 4. Averages of applied water ($m^3$/faddan) under the different irrigation treatments, 2012 season**

| Irrigation Event | Date | Irrigation treatments | | |
|---|---|---|---|---|
| | | Traditional (Six irrigations were applied) | Deficit I (Omitting watering at the 3rd and 5th irrigations) | Deficit II (Omitting watering at the 4th and 6th irrigations) |
| **Planting** | 12/06/2012 | 643.51 | 643.51 | 643.51 |
| **First** | 05/07/2012 | 399.25 | 399.25 | 399.25 |
| **2nd** | 17/07/2012 | 240.62 | 240.62 | 240.62 |
| **3rd** | 30/07/2012 | 370.26 | | 395.02 |
| **4th** | 15/08/2012 | 599.40 | 676.12 | |
| **5th** | 30/08/2012 | 440.32 | | 610.80 |
| **6th** | 17/09/2012 | 410.60 | 790.30 | |
| **Total** | | 3103.96 | 2749.8 | 2289.2 |

# RESULTS AND DISCUSSION

## Days to 50% Tasseling, Days to 50% Silking and Leaf Area Index (LAI).

### Effect of irrigation treatments

The results confirm highly significant differences among the three irrigation treatments, concerning days to 50% tasseling, days to 50% silking and leaf area index of maize in both seasons and their consolidated data (Table 5). The plants irrigated normally produced the greatest trail averages followed by those received irrigation with skipping the 4th and 6th irrigations, whereas the lowest values were obtained from plants irrigated with skipping the 3rd and 5th irrigations. This was true in the two seasons and their combined with the exception of the second season for days to 50% tasseling and days to 50% silking. Irrigation skipping the 3rd and 5th irrigations and missing the 4th and 6th irrigations caused a significant reduce in leaf area index reached to 36.5% and 20.6% compared with normal irrigation, respectively (Combined data). The reduction in LAI values of maize as response to water stress, may be attribulted to its harmful effect on the inhibition of cell division and enlargement and, in turn producing lower leaf area/plant and consequently LAI. These results are in line with those reported by Khan *et al.* (2001), Monneveux *et al.* (2006), Abdelmula and Salih (2007), Ghooshchi *et al.* (2008), Farré and Faci (2009) and Rong Yang (2012).

### Maize hybrids differences

It is obvious from Table 5 that, the four cultivars differed significantly in both seasons in each the aforementioned characters , where S.C. 10 and T.W.C. 324 had the highest values followed by T.W.C. 352. Also, S.C. 173 was inferior to both S.C. 10 and T.W.C. 324. The differences in these characters among the evaluated maize hybrids might be attributed to the genetically variation. These results agreed with there reported by Hassan (2000), Mahfouz (2004), Nofal *et al.* (2005), Mahgoub and El-Shenawy (2006) and Mukhtar *et al.* (2012).

### Planting density effect

In both seasons, varying planting density from 20 to 24 and then 28 thousand Plants/fad., were without significant effect on days to 50% tasseling and days to 50% silking of maize. This was ascertained also by the combined analysis of their pooled data. However significant differences were detected in leaf area index in the two seasons and their combined, where 28 thousand Plants/fad., had higher (Table 5) LAI than 20 or 24 thousand plants/fad. These results are in well agreement with those obtained by Abdelmula and Salih (2007), Leilah *et al.* (2009) and Rong Yang (2012).

### Interaction effects

In general, under all maize hybrids any missing in the irrigation, either 3rd and 5th irrigations, or 4th and 6th irrigation decreased significantly leaf area index. Under normal irrigation the superior hybrid was S.C.10 followed by T.W.C. 324 and both T.W.C. 352 and S.C. 173 while under both skipping irrigation treatments, S.C. 10 was superior hybrid in leaf area index followed by both S.C. 173 and T.W.C. 324 and meantime, T.W.C. 352 showed the lowest leaf area index (Table 5 a).

**Table 5. Number of days to 50% tasseling , number of days to 50% silking and leaf area index (LAI) as affect by irrigation treatments, maize hybrids, planting densities and their interactions in 2011, 2012 seasons and their combined data**

| Main effects and interactions | Days to 50 % tasseling | | | Days to 50 % silking | | | Leaf area index (LAI) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | Combined | 2011 | 2012 | Combined | 2011 | 2012 | Combined |
| **Irrigation treatments ( S):** | | | | | | | | | |
| **Normal irrigations (S-1)** | 61.17 a | 58.73 a | 59.95 a | 61.60 a | 59.98 a | 60.79 a | 3.49 a | 3.76 a | 3.63 a |
| **Missing the 3rd and 5th irrigations (S-2)** | 59.17 c | 57.63 b | 58.40 c | 59.90 c | 58.71 b | 59.30 c | 2.82 c | 2.49 c | 2.66 c |
| **Missing the 4th and 6th irrigations (S-3)** | 60.25 b | 58.48 a | 59.37 b | 60.10 b | 59.63 a | 59.87 b | 3.06 b | 2.97 b | 3.01 b |
| **F. test** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| **Maize hybrids (H) :** | | | | | | | | | |
| **S.C. 10** | 63.17 a | 61.72 a | 62.44 a | 63.72 a | 63.00 a | 63.36 a | 3.59 a | 3.38 a | 3.48 a |
| **S.C. 173** | 55.53 c | 54.39 c | 54.96 c | 55.75 c | 55.47 c | 55.61 c | 2.86 c | 3.11 c | 2.98 c |
| **T.W.C. 324** | 63.36 a | 61.36 a | 62.36 a | 64.00 a | 62.61 a | 63.31 a | 3.24 b | 3.19 b | 3.22 b |
| **T.W.C. 352** | 58.72 b | 55.64 b | 57.18 b | 58.67 b | 56.67 b | 57.67 b | 2.81 c | 2.61 d | 2.71 d |
| **F. test** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| **planting densities (1000 plants $fad^{-1}$), (D):** | | | | | | | | | |
| **20 (D-1)** | 60.29 | 58.27 | 59.28 | 60.63 | 59.46 | 60.04 | 2.64 b | 2.97 c | 2.81 c |
| **24 (D-2)** | 60.10 | 58.27 | 59.19 | 60.48 | 59.42 | 59.95 | 3.02 b | 3.06 b | 3.04 b |
| **28 (D-3)** | 60.19 | 58.29 | 59.24 | 60.50 | 59.44 | 59.97 | 3.71 a | 3.19 a | 3.45 a |
| **F. test** | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | ** | ** | ** |
| **Interactions:** | | | | | | | | | |
| **S x H** | ** | * | N.S. | ** | N.S. | N.S. | ** | ** | ** |
| **S x D** | N.S. | N.S. | N.S. | N.S. | * | N.S. | N.S. | ** | ** |
| **H x D** | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | ** | ** | ** |

*,** indicate significant at 0.05 and 0.01 levels of probability, respectively. N.S. = Not significant.

For all irrigation treatments it was always true that, increasing density from 20 to 24 and 28 thousand plants/fad., gradually increased leaf area index (Table 5b). Also, under the three densities, leaf area index was significantly the lowest by skipping 3rd and 5th irrigation.

For S.C. 10 and T.W.C. 324 as well as T.W.C. 352 it was always true that, increasing planting density from 20 to 24 and 28 thousand plants/fad., gradually increased leaf area index, while for S.C. 173 hybrid the high density of 28 thousand plants/fad., on one hand had gave higher leaf area index compared to both the medium (24 thousand plants/fad.) and the low (20 thousand plants/fad.) densities on the other hand. Under both the low as well as the high densities S.C. 10 gave the highest leaf area index followed by T.W.C. 324 and S.C. 173 whereas the lowest leaf area index was recorded by T.W.C. 352. However under the medium density, both S.C. 10 and T.W.C. 324 had the highest leaf area index whereas the lowest leaf area index recorded by both T.W.C. 352 and S.C. 173 (Table 5 c).

## Stem Diameter, Chlorophyll Content and Plant Height

### Effect of irrigation treatments

Data in Table 6 shows that normal irrigation produced the largest stem diameter followed by those received irrigation with skipping the 3rd and 5th irrigations or missing the 4th and 6th irrigations, however, in the second season the differences were not significant. Regarding chlorophyll content and plant height, plants irrigated normally produced the highest averages followed by those received irrigation with skipping the 4th and 6th irrigations whereas the lowest values were obtained from plants irrigated with skipping the 3rd and the 5th irrigations with the exception of first season in plant height. Skipping the 3rd and the 5th irrigations or skipping the 4th and the 6th irrigations caused a significant reduction in plant height which reached 4.30% and 2.94% compared with normal irrigation, respectively (combined data). These results clearly indicated that the two skipping irrigation treatments were equally effective in decreasing stem diameter, however, missing the 3rd irrigation and the 5th one was more drastic regarding decreasing plant height than starting missing irrigation by the 4th and the 6th irrigations. These results refer to the sensitivity of younger than the older plants to withholding irrigation. This probably could be attributed to the active growth of younger maize plants which were adversely affected by the early withholding of the 3rd irrigation where plants were about 45 days in age. These results are in line with those reported by Dong-Yin and Taixin (2001); Dass *et al.* (2001), Neill *et al.* (2006) and Abdelmula and Salih (2007).

### Maize hybrids differences

Maize hybrids varied significantly in stem diameter, chlorophyll content and plant height in both seasons and their combined Table (6), where S.C. 10 had the largest stem diameter and tallest plants followed by T.W.C. 324 compared with the other maize hybrids. Mean through, T.W.C. 352 and S.C. 173 hybrids appeared to produce higher stem diameter and lower plant height in two seasons and their combined, since S.C.10 hybrid surpassed T.W.C. 324 by about 7.54 % (the combined analysis). But S.C. 173 and T.W.C. 352 hybrids appeared to produce higher chlorophyll content fallowed by T.W.C. 324 and S.C.10 in the two seasons and the combined data. These results are in accordance with those of Eisa (1998), Amer *et al.* (2004), Mahgoub and El-Shenawy (2006), Khalil (2007) and Sharifi *et al.* (2009).

### Planting density effect

Planting density had no significant effect on stem diameter and plant height in both seasons and the combined analysis as well as leaf chlorophyll content in the first season. However, significant differences were detected in chlorophyll content of maize in the second season and their combined, where 28 and 24 thousand plants/fad., had higher chlorophyll content than 20 thousand plants/fad. (Table 6). These results are in agreement with those of Soliman *et al.* (1995), Dong-Yin and Taixin (2001) and Abd El-All (2002).

### Interaction effects

In general, under both normal irrigation and skipping the 4th and the 6th irrigations the superiority in stem diameter was for hybrids S.C. 10 and T.W.C. 324 followed by S.C. 173 with no differences between them and meantime, T.W.C. 352 showed the lowest stem diameter. While under skipping the 3rd and the 5th irrigations, S.C. 10 was the superior hybrid followed by T.W.C. 324 and both T.W.C.352

**Table 5 a. Effect of interaction between maize hybrids and irrigation treatments on leaf area index (LAI) (combined)**

| Maize hybrids ( H.) / Irrigation treatments (S) | S.C. 10 | S.C. 173 | T.W.C. 324 | T.W.C. 352 |
|---|---|---|---|---|
| S -1 | A<br>4.188 a | C<br>3.209 a | B<br>3.883 a | C<br>3.221 a |
| S -2 | A<br>2.949 c | B<br>2.723 c | B<br>2.723 c | C<br>2.226 c |
| S -3 | A<br>3.314 b | B<br>3.039 b | B<br>3.039 b | C<br>2.682 b |

**Table 5 b. Effect of interaction between planting densities and irrigation treatments on leaf area index (LAI) (combined)**

| Planting densities (D) / Irrigation treatments (S) | D -1 | D -2 | D -3 |
|---|---|---|---|
| S -1 | C<br>3.353 a | B<br>3.479 a | A<br>4.043 a |
| S -2 | C<br>2.347 c | B<br>2.589 c | A<br>3.030 c |
| S -3 | C<br>2.717 b | B<br>3.042 b | A<br>3.275 b |

**Table 5 c. Effect of interaction between planting densities and maize hybrids on leaf area index (LAI) (combined)**

| Planting densities (D) / Maize hybrids (H) | D -1 | D -2 | D -3 |
|---|---|---|---|
| S.C. 10 | C<br>3.187 a | B<br>3.336 a | A<br>3.928 a |
| S.C. 173 | B<br>2.799 b | B<br>2.795 b | A<br>3.384 b |
| T.W.C. 324 | C<br>2.920 b | B<br>3.339 a | A<br>3.386 b |
| T.W.C. 352 | C<br>2.316 c | B<br>2.678 b | A<br>3.135 c |

Table 6. Stem diameter, chlorophyll content and plant height as affected by irrigation treatments, maize hybrids, planting densities and their interactions in 2011, 2012 seasons and their combined data

| Main effects and interactions | Stem diameter (cm) | | | Chlorophyll content (mg m$^{-2}$) | | | Plant height (cm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | Combined | 2011 | 2012 | Combined | 2011 | 2012 | Combined |
| **Irrigation treatments ( S.):** | | | | | | | | | |
| **Normal irrigations (S-1)** | 2.33 a | 2.33 | 2.33 a | 676.84 a | 640.18 a | 658.51 a | 265.04 a | 251.92 a | 258.48 a |
| **Missing the 3$^{rd}$ and 5$^{th}$ irrigations (S-2)** | 2.26 b | 2.28 | 2.27 b | 644.16 c | 586.68 c | 615.42 c | 253.48 b | 242.17 c | 247.80 c |
| **Missing the 4$^{th}$ and 6$^{th}$ irrigations (S-3)** | 2.28 b | 2.30 | 2.29 b | 653.70 b | 611.08 b | 632.39 b | 256.54 b | 245.65 b | 251.09 b |
| **F. test** | ** | N.S. | ** | ** | ** | ** | ** | ** | ** |
| **Maize hybrids (H.):** | | | | | | | | | |
| **S.C. 10** | 2.44 a | 2.38 a | 2.41 a | 630.53 c | 566.74 d | 598.63 d | 287.08 a | 275.47 a | 281.27 a |
| **S.C. 173** | 2.17 c | 2.33 b | 2.25 c | 674.27 a | 652.92 a | 663.59 a | 246.81 c | 240.69 c | 243.74 c |
| **T.W.C. 324** | 2.37 b | 2.29 b | 2.33 b | 656.61 b | 604.79 c | 630.70 c | 266.56 b | 253.58 b | 260.06 b |
| **T.W.C. 352** | 2.19 c | 2.20 c | 2.20 d | 671.52 a | 626.14 b | 648.83 b | 232.97 d | 216.56 d | 224.76 d |
| **F. test** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| **Planting densities (1000 plants fad$^{-1}$), (D):** | | | | | | | | | |
| **20 (D-1)** | 2.31 | 2.32 | 2.31 | 657.58 | 606.36 b | 631.97 b | 259.98 | 246.65 | 253.31 |
| **24 (D-2)** | 2.28 | 2.31 | 2.29 | 657.88 | 614.46 a | 636.17 a | 257.42 | 245.94 | 251.67 |
| **28 (D-3)** | 2.29 | 2.28 | 2.28 | 656.24 | 617.12 a | 638.18 a | 257.67 | 247.15 | 252.40 |
| **F. test** | N.S. | N.S. | N.S. | N.S. | * | * | N.S. | N.S. | N.S. |
| **Interactions:** | | | | | | | | | |
| **S x H** | N.S. | ** | * | * | ** | ** | ** | N.S. | * |
| **S x D** | N.S. | * | ** | N.S. | ** | * | * | ** | N.S. |
| **H x D** | N.S. | ** | N.S. | * | ** | ** | * | * | N.S. |

*,** indicate significant at 0.05 and 0.01 levels of probability, respectively. N.S. = Not significant.

and S.C. 173. Under S.C. 173 and T.W.C. 352 plants received normal irrigation on hand, had higher stem diameter compared to the two skipping irrigation treatments on the other hand, while S.C. 10 recorded higher stem diameter when received both normal and skipping the 3rd and the 5th irrigations, but stem diameter of T.W.C. 324 did not affected by irrigation treatments (Table 6a).

Under the low density (20 thousand plants/ fad.), skipping irrigation at 4th and 6th irrigations on one hand, gave larger stem diameter than both normal irrigation and skipping the 4th and the 6th irrigations on the other hand. But, under both the medium and high densities, normal irrigation gave higher stem diameter than both other irrigation treatments. Under normal irrigation, the medium and high densities had higher stem diameter compared to low density, while under skipping the 3rd and the 5th irrigations varying plant density did not affect stem diameter. Whereas, under skipping the 4th and the 6th irrigations the highest value of stem diameter recorded by low density (20 thousand plants/fad.) (Table 6 b).

In general, in all maize hybrids, missing the 3rd and the 5th irrigation or the 4th and the 6th irrigation decreased significantly leaf chlorophyll content. Under normal irrigations the superior hybrid was S.C. 173 followed by both T.W.C. 324 and T.W.C. 352. Meantime S.C. 10 showed the lowest chlorophyll content, while under skipping the 3rd and the 5th irrigations, S.C. 173 was the superior hybrid in chlorophyll content followed by T.W.C. 352 , T.W.C. 324 and S.C. 10. Whereas under skipping the 4th and the 6th irrigations higher values of chlorophyll content were recorded by both S.C. 173 and T.W.C. 352, meantime both T.W.C. 324 and S.C. 10 showed lower chlorophyll content (Table 6 c).

Generally, under all maize planting densities, any missing irrigation treatments decreased significantly chlorophyll content. Under normal irrigation, both the medium density (24 thousand plants/fad.) and high density (28 thousand plants/fad.) on one hand had higher chlorophyll contents compared to low density on the other hand, while under skipping the 3rd and the 5th irrigations higher chlorophyll content recorded by the higher density. But, under skipping the 4th and the 6th irrigations it was true that, varying planting density did not affect chlorophyll content (Table 6d).

For S.C. 10 and T.W.C. 352 hybrids both the medium and high densities on one hand had higher chlorophyll contents compared to the low density (20 thousand plants/fad.) on one hand, while for S.C. 173, the higher chlorophyll content recorded by both low and high densities, whereas higher chlorophyll content for T.W.C. 324 recorded under both low and medium densities and meantime high density showed the lowest chlorophyll content. Under both medium and high densities both S.C. 173 and T.W.C. 352 had higher chlorophyll contents however the lowest chlorophyll content was recorded by S.C. 10. Under the low density (20 thousand plants/fad.) S.C. 173 gave the highest chlorophyll content followed by both T.W.C. 352 and T.W.C. 324 and meantime S.C. 10 showed the lowest chlorophyll content (Table 6 e).

Under all irrigation treatments the superior hybrid was S.C. 10 , followed by T.W.C. 324 and S.C. 173. Meantime T.W.C. 352 showed the lowest plant height. Under S.C. 10 and T.W.C. 324 both plants received normal irrigation and skipping irrigation at 4th and 6th irrigations on one hand, had taller plants compared with the skipping 3rd and 5th irrigations on the other hand, while S.C. 173 recorded taller plants when received normal irrigation, whereas T.W.C. 352 showed longer plants under both normal irrigations and skipping 3rd and 5th irrigations (Table 6 f).

## Ear Height, Ear Length and Ear Diameter as well as Cob Diameter

### Effect of irrigation treatments

The water regime treatments affected significantly the ear characters (height, length and diameter) and cob diameter, where the water stressed gave significant reduction in these traits when compared with the normal irrigation (Table 7). This was the case in the two seasons and also in the combined data. But, in the first season and the combined, no clear trend could be detected for cob diameter. Irrigation skipping at 3rd and 5th irrigations and skipping 4th and 6th irrigation caused a significant reduction in ear length and ear diameter reached to 10.92 and 5.89 % as well

**Table 6 a. Effect of interaction between maize hybrids and irrigation treatments on stem diameter (combined)**

| Maize hybrids ( H.) / Irrigation treatments (S) | S.C. 10 | S.C. 173 | T.W.C. 324 | T.W.C. 352 |
|---|---|---|---|---|
| S -1 | A<br>2.435 a | B<br>2.329 a | AB<br>2.347 a | C<br>2.209 a |
| S -2 | A<br>2.405 a | C<br>2.153 c | B<br>2.312 a | C<br>2.200 b |
| S -3 | A<br>2.391 b | B<br>2.260 b | AB<br>2.327 a | C<br>2.170 b |

**Table 6 b. Effect of interaction between planting densities and irrigation treatments on stem diameter (combined)**

| Planting densities (D) / Irrigation treatments (S) | D -1 | D -2 | D -3 |
|---|---|---|---|
| S -1 | B<br>2.276 b | AB<br>2.330 a | A<br>2.382 a |
| S -2 | A<br>2.288 b | A<br>2.269 b | A<br>2.252 b |
| S -3 | A<br>2.374 a | B<br>2.279 ab | B<br>2.216 b |

**Table 6 c. Effect of interaction between maize hybrids and irrigation treatments on chlorophyll content ($mgm^{-2}$) (combined)**

| Maize hybrids ( H.) / Irrigation treatments (S) | S.C. 10 | S.C. 173 | T.W.C. 324 | T.W.C. 352 |
|---|---|---|---|---|
| S -1 | C<br>615.563 a | A<br>689.923 a | B<br>664.140 a | B<br>664.400 a |
| S -2 | D<br>568.633 b | A<br>646.330 b | C<br>614.870 b | B<br>631.857 c |
| S -3 | B<br>611.707 a | A<br>654.520 b | B<br>613.093 b | A<br>650.230 b |

**Table 6 d. Effect of interaction between planting densities and irrigation treatments on chlorophyll content (mgm$^{-2}$) (combined)**

| Planting densities (D) / Irrigation treatments (S) | D -1 | D -2 | D -3 |
|---|---|---|---|
| S -1 | B<br>654.077 a | A<br>665.017 a | AB<br>655.625 a |
| S -2 | B<br>611.100 c | B<br>609.085 c | A<br>626.082 b |
| S -3 | A<br>629.917 b | A<br>634.402 b | A<br>632.842 b |

**Table 6 e. Effect of interaction between planting densities and maize hybrids on chlorophyll content (mgm$^{-2}$) (combined)**

| Planting densities (D) / Maize hybrids ( H) | D -1 | D -2 | D -3 |
|---|---|---|---|
| S.C. 10 | B<br>585.923 c | A<br>600.353 c | A<br>609.627 c |
| S.C 173 | A<br>673.890 a | B<br>651.833 a | A<br>665.050 a |
| T.W.C. 324 | A<br>632.333 b | A<br>635.323 b | B<br>624.447 b |
| T.W.C. 352 | B<br>635.713 b | A<br>657.163 a | A<br>653.610 a |

**Table 6 f. Effect of interaction between maize hybrids and irrigation treatments on plant height (cm) (combined)**

| Maize hybrids (H) / Irrigation treatments (S) | S.C. 10 | S.C. 173 | T.W.C. 324 | T.W.C. 352 |
|---|---|---|---|---|
| S -1 | A<br>287.531 a | C<br>252.156 a | B<br>264.823 a | D<br>229.407 a |
| S -2 | A<br>275.408 b | C<br>237.908 b | B<br>253.825 b | D<br>224.075 ab |
| S -3 | A<br>280.875 ab | C<br>241.167 b | B<br>261.542 a | D<br>220.792 b |

**Table 7. Ear height, ear length, ear diameter and cob diameter as affected by irrigation treatments, maize hybrids, planting densities and their interaction in 2011, 2012 seasons and the combined data**

| Main effects and interactions | Ear height (cm) | | | Ear length (cm) | | | Ear diameter (cm) | | | Cob diameter (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | Combined | 2011 | 2012 | Combined | 2011 | 2012 | Combined | 2011 | 2012 | Combined |
| **Irrigation treatments (S) :** | | | | | | | | | | | | |
| **Normal irrigations (S-1)** | 149.92 a | 148.44 a | 149.18 a | 21.70 a | 20.33 a | 21.02 a | 4.90 a | 4.74 a | 4.82 a | 2.87 a | 2.87 a | 2.87 a |
| **Missing the 3rd and 5th irrigations (S-2)** | 143.23 b | 141.90 b | 142.54 b | 19.68 c | 18.22 c | 18.95 c | 4.00 c | 4.14 c | 4.07 c | 2.14 b | 2.73 c | 2.43 b |
| **Missing the 4th and 6th irrigations (S-3)** | 146.29 b | 142.33 b | 144.33 b | 20.87 b | 18.83 b | 19.85 b | 4.75 b | 4.31 b | 4.53 b | 2.89 a | 2.82 b | 2.85 a |
| **F. test** | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| **Maize hybrids (H.):** | | | | | | | | | | | | |
| **S.C. 10** | 169.17 a | 164.86 a | 167.01 a | 20.97 b | 19.88 a | 20.42 a | 4.61 | 4.44 | 4.53 | 2.58 b | 2.76 c | 2.67 b |
| **S.C. 173** | 131.11 c | 130.92 c | 131.01 c | 22.35 a | 19.98 a | 21.17 a | 4.56 | 4.41 | 4.48 | 2.58 b | 2.79 b | 2.69 b |
| **T.W.C. 324** | 152.06 b | 148.81 b | 150.43 b | 21.09 b | 19.09 b | 20.09 b | 4.49 | 4.39 | 4.44 | 2.59 b | 2.76 c | 2.68 b |
| **T.W.C. 352** | 133.58 c | 132.31 c | 132.94 c | 18.59 c | 17.54 c | 18.07 c | 4.56 | 4.34 | 4.45 | 2.77 a | 2.91 a | 2.84 a |
| **F. test** | ** | ** | ** | ** | ** | ** | N.S. | N.S. | N.S. | ** | ** | ** |
| **Planting densities (1000 plants fad$^{-1}$), (D):** | | | | | | | | | | | | |
| **20 (D-1)** | 147.35 | 143.17 | 145.26 | 20.93 a | 19.33 | 20.13 a | 4.55 | 4.42 a | 4.49 | 2.64 | 2.80 b | 2.72 |
| **24 (D-2)** | 146.83 | 144.33 | 145.58 | 20.64 b | 18.99 | 19.82 b | 4.57 | 4.34 b | 4.45 | 2.65 | 2.76 c | 2.70 |
| **28 (D-3)** | 145.25 | 145.17 | 145.21 | 20.68 b | 19.05 | 19.87 b | 4.55 | 4.43 a | 4.49 | 2.60 | 2.85 a | 2.73 |
| **F. test** | N.S. | N.S. | N.S. | * | N.S. | * | N.S. | * | N.S. | N.S. | ** | N.S. |
| **Interactions:** | | | | | | | | | | | | |
| **S x H** | * | * | N.S. | N.S. | ** | ** | N.S. | ** | * | N.S. | ** | * |
| **S x D** | N.S. | * | N.S. | N.S. | N.S. | N.S. | N.S. | ** | * | N.S. | ** | ** |
| **H x D** | ** | ** | ** | N.S. | N.S. | N.S. | N.S. | * | N.S. | N.S. | * | * |

*,** indicate significant at 0.05 and 0.01 levels of probability, respectively. N.S. = Not significant.

as 18.42 and 6.40% compared with normal irrigation, respectively (combined data). These results are in accordance with those stated by Betran *et al.* (2003), Monneveux *et al.* (2006) and Golbashy *et al.* (2010 A).

**Maize hybrids differences**

As shown in Table 7, maize hybrids showed significant differences in ear characters and cob diameter except ear diameter reflecting their different genetic background. S.C. 10, followed by T.W.C. 324 had higher ear height and both T.W.C. 352 and S.C. 173 gave lower values for this character in the two seasons and their combined. S.C. 10 hybrids surpassed T.W.C. 324 by about 9.92% in the combined analysis for ear height, Concerning the ear length, S.C.10 and S.C. 173 receded higher length followed by T.W.C. 324, whereas T.W.C. 352 gave the lowest ear length. In regard to cob diameter, T.W.C. 352 gave the highest values for cob diameter, whereas the other three hybrids were equal in cob diameter (combined data). But, all maize hybrids among the studied factors did not significantly differed in ear diameter in the two growing seasons and combined data (Table 7). While, T.W.C. 352 surpassed T.W.C. 324 by about 5.63 % in the combined analysis for cob diameter. These results are in line with those reported by Younis *et al*. (1994); El-Habbak and Shams El-Din (1996); Hassan (2000), Khalil (2001), Nofal *et al.* (2005) and Mahgoub and El-Shenawy (2006).

**Planting density effect**

Planting density had no significant effect on ear height in the two seasons and their combined, ear diameter in the first season as well as ear and cob diameter in the first season and the combined however, significant differences were detected in ear length in the first season and combined data, where 20 thousand plants/fad., had higher ear length than 24 or 28 thousand plants/fad., whereas 20 and 28 thousand plants/fad., had higher ear diameter than 24 thousand plants/fad., in the second season only with no significant differences between 20 and 28 thousand plants/fad. In the second season cob diameter of 28 thousand plants/fad., had higher cob diameter than 20 and 24 thousand plants/fad., (Table 7). These results are in agreement with those obtained by Younis *et al*. (1994); Mohamed (1999); Said and Gabr (1999); Abd El-All (2002); Katta and Abd El-Aty (2002); Marchao *et al.* (2005) and Sorin *et al*. (2009).

**Interaction effects**

S.C. 10 hybrid appeared to produce higher ear height under different planting densities followed by T.W.C. 324 and meantime S.C. 173 as well as T.W.C. 352 showed lower ear height. Under the density of 20 thousand plants/fad., on one hand, was higher than that under 24 and 28 thousand plants/fad., on the other hand. But, with S.C. 173, higher ear height recorded by 24 thousand plants/fad., followed by both 20 and 28 thousand plants/fad., while T.W.C. 324 recorded higher ear height under both 20 and 28 thousand plants/fad., However with T.W.C. 352 it was true that, varying planting densities did not affect ear height (Table 7 a).

In general, under all maize hybrids, any irrigation skipping decreased significantly ear length. Under normal irrigation the superior hybrid was S.C.173 followed by both S.C.10 and T.W.C. 324 and meantime, T.W.C. 352 showed the lowest ear length, while, under skipping 3$^{rd}$ and 5$^{th}$ irrigations, S.C. 173 was the superior hybrid in ear length followed by S.C. 10 and T.W.C. 324 as well as T.W.C. 352. Whereas under skipping 4$^{th}$ and 6$^{th}$ irrigations, the higher value of ear length recorded by both T.W.C. 324 and S.C. 10 followed by S.C. 173 and meantime T.W.C. 352 showed the lowest ear length (Table 7b).

Generally, under all maize hybrids any missing irrigation treatments decreased significantly ear diameter. Under normal irrigation the superior hybrids were S.C.10 and S.C. 173 followed by both T.W.C. 324 and T.W.C. 352, while under skipping 3$^{rd}$ and 5$^{th}$ irrigations both T.W.C. 352 and S.C. 173 as well as S.C.10 gave larger ear diameter and meantime T.W.C. 324 showed the lowest ear diameter. But, under any maize hybrids, irrigation treatment (S-3) did not affect ear diameter (Table 7 c).

In general, it could be concluded that, under the medium and high densities any missing irrigation (3$^{rd}$ and 5$^{th}$ irrigations and skipping 4$^{th}$ and 6$^{th}$ irrigations) decreased significantly ear diameter, but under density of 20.000 plants/fad., both normal irrigation and skipping 4$^{th}$ and 6$^{th}$ irrigations gave higher stem diameter compared

Table 7 a. Effect of interaction between Planting densities and maize hybrids on ear height (cm) (combined)

| Maize Hybrids ( H) \ Planting densities (D) | D -1 | D -2 | D -3 |
|---|---|---|---|
| S.C. 10 | A<br>170.415 a | B<br>165.498 a | B<br>165.123 a |
| S.C 173 | B<br>128.998 c | A<br>135.623 c | B<br>128.415 d |
| T.W.C. 324 | AB<br>150.248 b | B<br>148.540 b | A<br>152.498 b |
| T.W.C. 352 | A<br>131.373 c | A<br>132.665 c | A<br>134.790 c |

Table 7 b. Effect of interaction between maize hybrids and irrigation treatments on ear length (cm) (combined)

| Irrigation treatments (S) \ Maize hybrids ( H) | S.C. 10 | S.C. 173 | T.W.C. 324 | T.W.C. 352 |
|---|---|---|---|---|
| S -1 | B<br>21.742 a | A<br>22.383 a | B<br>21.308 a | C<br>18.625 a |
| S -2 | B<br>19.583 b | A<br>20.683 b | C<br>18.058 c | D<br>17.483 b |
| S -3 | B<br>19.938 b | AB<br>20.433 b | A<br>20.917 b | C<br>18.100 a |

Table 7 c. Effect of interaction between maize hybrids and irrigation treatments on ear diameter (cm) (combined)

| Irrigation treatments (S) \ Maize hybrids ( H) | S.C. 10 | S.C. 173 | T.W.C. 324 | T.W.C. 352 |
|---|---|---|---|---|
| S -1 | A<br>4.950 a | AB<br>4.850 a | B<br>4.750 a | B<br>4.742 a |
| S -2 | AB<br>4.082 c | A<br>4.095 c | B<br>3.995 c | A<br>4.112 c |
| S -3 | A<br>4.542 b | A<br>4.508 b | A<br>4.583 b | A<br>4.500 b |

**Table 7 d. Effect of interaction between Planting densities and irrigation treatments on ear diameter (cm) (combined)**

| Planting densities (D) / Irrigation treatments (S) | D -1 | D -2 | D -3 |
|---|---|---|---|
| S -1 | A<br>4.813 a | A<br>4.813 a | A<br>4.844 a |
| S -2 | AB<br>4.098 b | B<br>3.970 c | A<br>4.145 c |
| S -3 | A<br>4.544 a | A<br>4.575 b | A<br>4.481 b |

**Table 7 e. Effect of interaction between maize hybrids and irrigation treatments on cob diameter (cm) (combined).**

| Maize hybrids (H) / Irrigation treatments (S) | S.C. 10 | S.C. 173 | T.W.C. 324 | T.W.C. 352 |
|---|---|---|---|---|
| S -1 | A<br>2.846 a | A<br>2.908 a | A<br>2.754 b | A<br>2.967 a |
| S -2 | A<br>2..342 b | A<br>2.404 c | A<br>2.429 c | A<br>2.546 b |
| S -3 | B<br>2.821 a | B<br>2.742 b | B<br>2.846 a | A<br>3.004 a |

**Table 7 f. Effect of interaction between Planting densities and irrigation treatments on cob diameter (cm) (combined)**

| Planting densities (D) / Irrigation treatments ( S) | D -1 | D -2 | D -3 |
|---|---|---|---|
| S -1 | A<br>2.878 a | A<br>2.872 a | A<br>2.856 a |
| S -2 | A<br>2.441 c | A<br>2.362 b | A<br>2.487 b |
| S -3 | A<br>2.841 b | A<br>2.878 a | A<br>2.851 a |

**Table 7 g. Effect of interaction between Planting densities and maize hybrids on cob diameter (cm) (combined)**

| Maize hybrids ( H) \ Planting densities (D) | D -1 | D -2 | D -3 |
|---|---|---|---|
| **S.C. 10** | A<br>2.679 a | A<br>2.633 b | A<br>2.696 b |
| **S.C 173** | A<br>2.737 a | A<br>2.633 b | A<br>2.683 b |
| **T.W.C. 324** | A<br>2.671 a | A<br>2.687 b | A<br>2.670 b |
| **T.W.C. 352** | B<br>2.772 a | A<br>2.862 a | A<br>2.860 a |

with skipping 3rd and 5th irrigations. Under normal irrigation and skipping 4th and 6th irrigations it was true that, varying planting densities did not affect ear diameter while under skipping 3rd and 5th irrigations, the both high and low densities recorded higher stem diameter compared with the medium density (Table 7 d).

It could be concluded that, under S.C. 10 and T.W.C. 352, normal irrigation and skipping 4th and 6th irrigations gave higher cob diameter, but under S.C. 173, plants received normal irrigation had higher cob diameter followed by plants skipped 4th and 6th irrigations and meantime plants under skipping 3rd and 5th irrigations showed lowest cob diameter. However, the opposite was true under the hybrid T.W.C. 324 since, cob diameter was higher with skipping 4th and 6th irrigations than with the other irrigation treatments. When maize plants were irrigated normally or skipped the 3rd and 5th irrigations, the four maize hybrids had equal cob diameter, but under skipping 4th and 6th irrigations cob diameter of T.W.C. 352 was superior compared with other maize hybrids (Table 7 e).

Under all irrigation treatments it was true that, varying planting densities did not affect cob diameter of maize hybrid. Whereas, under the medium and high densities, both normal irrigation and skipping 4th and 6th irrigations gave higher cob diameter compared with skipping 3rd and 5th irrigations, but under low density of 20.000 plants/fad., any missing irrigation decreased significantly cob diameter compared with normal irrigation which recorded higher cob diameter (Table 7 f).

It was clear that, under the three planting densities, cob diameter of four maize hybrids did not affect with the exception T.W.C. 352 which recorded the highest value under both medium and high density. Under each of S.C. 10 and S.C. 173 as well as T.W.C. 324 it was true that, varying planting density did not affect cob diameter recorded by both medium and high densities and meantime the low density showed the lowest cob diameter (Table 7 g).

## Number of rows/ear, Number of kernels/ row and Thousand Kernel Weight

### Effect of irrigation treatments

Data in Table 8 confirm high significant differences among the three irrigation treatments in each of the aforementioned characters. Plants irrigated normally produced the highest averages followed by those received irrigation with skipping the 4th and the 6th irrigations, whereas the lowest averages were recorded by plants irrigated with missing the 3rd and the 5th irrigations. This was true in the two seasons and their combined with the exception of the second season of thousand kernel weight. In pooled data, skipping irrigation at 3rd and 5th irrigations and missing 4th and 6th irrigations caused a significant reduction in number of kernels/row and thousand kernel weight reached to 10.74 and 4.00 % as well as 5.41 and 2.23% compared with normal irrigation, respectively. It is clear that water stress which was imposed during the early and late growth stages may tended to be decreased considerably the capacity of the source to assimilate enough photosynthates translocated to the sink *i.e.* developing grains

**Table 8. Number of rows/ ear, number of kernels /row and 1000 – kernel weight as affected by irrigation treatments, maize hybrids, planting densities and their interactions in 2011, 2012 seasons and their combined data.**

| Main effects and interactions | Number of rows/ ear | | | Number of kernels /row | | | 1000 – kernel weight (g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | Combined | 2011 | 2012 | Combined | 2011 | 2012 | Combined |
| **Irrigation treatments ( S):** | | | | | | | | | |
| **Normal irrigations (S-1)** | 15.29 a | 14.97 a | 15.13 a | 45.88 a | 45.07 a | 45.47 a | 462.63 a | 421.60 a | 442.12 a |
| **Missing the 3rd and 5th irrigations (S-2)** | 12.96 c | 11.99 c | 12.48 c | 42.65 c | 39.42 c | 41.04 c | 432.58 c | 406.25 b | 419.42 c |
| **Missing the 4th and 6th irrigations (S-3)** | 14.46 b | 13.19 b | 13.83 b | 44.94 b | 42.49 b | 43.72 b | 447.46 b | 417.45 a | 432.45 b |
| **F. test** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| **Maize hybrids (H):** | | | | | | | | | |
| **S.C. 10** | 13.82 b | 12.72 b | 13.27 c | 44.88 b | 40.23 b | 42.56 b | 485.69 a | 448.51 a | 467.10 a |
| **S.C. 173** | 14.42 a | 13.77 a | 14.10 b | 46.13 a | 45.59 a | 45.86 a | 437.94 c | 401.93 c | 419.94 c |
| **T.W.C. 324** | 13.89 b | 12.98 b | 13.44 c | 45.33 a | 44.81 a | 45.07 a | 448.28 b | 434.90 b | 441.59 b |
| **T.W.C. 352** | 14.82 a | 14.06 a | 14.44 a | 41.62 c | 38.67 b | 40.15 c | 418.31 d | 375.07 c | 396.69 d |
| **F. test** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| **planting densities (1000 plants $fad^{-1}$), (D):** | | | | | | | | | |
| **20 (D-1)** | 14.31 | 13.36 | 13.83 | 44.28 | 41.76 b | 43.02 | 451.19 | 415.00 | 433.10 |
| **24 (D-2)** | 14.22 | 13.39 | 13.81 | 44.80 | 42.14 b | 43.47 | 446.46 | 412.78 | 429.62 |
| **28 (D-3)** | 14.18 | 13.40 | 13.79 | 44.39 | 43.07 a | 43.73 | 445.02 | 417.53 | 431.27 |
| **F. test** | N.S. | N.S. | N.S. | N.S. | * | N.S. | N.S. | N.S. | N.S. |
| **Interactions:** | | | | | | | | | |
| **S x H** | ** | ** | ** | ** | N.S. | N.S. | ** | ** | ** |
| **S x D** | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | ** | N.S. | * |
| **H x D** | ** | N.S. | * | * | N.S. | N.S. | ** | N.S. | ** |

*,** indicate significant at 0.05 and 0.01 levels of probability, respectively. N.S. = Not significant.

through filling period and in the end, lighter thousand grain weight was observed. These results are in consistent with those reported on growth and yield attributes namely stem diameter, leaf chlorophyll content and plant height (Table 6). Here, it could be said that increasing soil moisture tension by skipping the 3rd and the 5th irrigations led to a disturbance in the most physiological processes in maize plants and consequently was reflected in a decrease of kernel number/row and thousand kernel weight. These results are in harmony with those of Khan *et al.* (2001), Khan *et al.* (2003), Ti-da *et al.* (2006) and Golbashy *et al.* (2010 A).

### Maize hybrids differences

Results in Table 8 exhibit significant differences among the four maize hybrids. The combined analysis data indicated that T.W.C. 352 and S.C. 173 plants produced higher number of rows/ear, while T.W.C. 324 or S.C. 10 hybrids produced lower number of rows/ear. S.C. 173 followed by T.W.C. 324 had the highest number of kernels/row and both S.C. 10 and T.W.C. 352 produced lower averages for this character in the two seasons and their combined. Concerning thousand kernel weight, S.C. 10 produced the heaviest thousand kernel weight followed by T.W.C. 324 and then S.C. 173 whereas T.W.C. 352 gave the lighter thousand kernel weight. This picture is clearly true in both seasons beside their combined. The results show that S.C. 173 hybrid surpassed T.W.C. 352 hybrid by about 10.84, 17.60 and 14.22% in both seasons and in their pooled data for number of kernels/row. Whereas S.C. 10 hybrid increased by about 16.11, 19.58 and 17.75% over T.W.C. 352 hybrid in both seasons and their pooled data for thousand kernel weight. These results are in harmony with those of Eisa (1998), El-Sheikh (2000), Hassan (2000), Khalil (2001), El-Bana (2001), Mahfouz (2004), Nofal *et al.* (2005) and Khalil (2007).

### Planting density effect

Changing the plant population density of maize from 20.000 to 24.000 and 28.000 plants/fad., did not reflect any significant effect on the number of rows/ear, number of kernels/row and thousand kernel weight with the exception of the number of kernels/row in the second season. This was true in both seasons and the combined analysis, but the highest number of kernels/row was recorded by dense planting of 28.000 plants/fad., (Table 8). These results are in accordance with those stated by Shams El-Din and El-Habbak (1996); Eisa (1998); Abo-Shetaia *et al.* (2002); Franc and Bavec (2002); Marchao *et al.* (2005); Raouf *et al.* (2009) and Sharifi *et al.* (2009).

### Interaction effects

Under all maize hybrids with the exception of S.C. 10, skipping the irrigation decreased significantly number of rows/ear, but under S.C. 10, number of rows/ear was higher with both normal irrigation and skipping at 4th and 6th irrigations than the skipping at 3rd and 5th irrigations. In general, when maize hybrids were grown under normal irrigation, the number of rows/ear of T.W.C. 352 was higher than that under both T.W.C. 324 and S.C. 173, and meantime S.C. 10 showed the lowest value. However, under skipping the 3rd and the 5th irrigations, the four maize hybrids had equal number of rows/ear, but under skipping the 4th and 6th irrigations, T.W.C. 352 and S.C. 173 gave higher number of rows than S.C. 10 and T.W.C.324 hybrids (Table 8 a).

It was clear that, under all maize hybrids, the number of rows/ear was not affected by varying planting densities. Under low density, number of rows/ear of both T.W.C. 352 and S.C. 173 on one hand was higher than that under both T.W.C. 324 and S.C. 10, while under medium density, number of rows/ear of all maize hybrids did not affect by planting density. However, under high density (28000 plants/fad.), number of rows/ear of T.W.C. 352 was higher than that under the other three maize hybrids (Table 8 b).

Under normal irrigation the superior hybrid was S.C. 10, while under both skipping irrigation treatments, the superior hybrids were S.C. 10 and T.W.C. 324, and meantime both T.W.C. 352 and S.C. 173 showed lower thousand kernel weight. Under S.C. 10 and T.W.C. 352 plants received normal irrigation on one hand had higher thousand kernel weight compared to the two skipping irrigation treatments on the other hand, while S.C. 173 recorded higher thousand kernel weight when

**Table 8 a. Effect of interaction between maize hybrids and irrigation treatments on number of rows/ear (combined)**

| Irrigation treatments ( S) / Maize hybrids (H) | S.C. 10 | S.C. 173 | T.W.C. 324 | T.W.C. 352 |
|---|---|---|---|---|
| S -1 | C<br>13.825 a | B<br>15.117 a | B<br>14.967 a | A<br>16.608 a |
| S -2 | A<br>12.429 b | A<br>12.871 c | A<br>12.187 c | A<br>12.412 c |
| S -3 | B<br>13.558 a | A<br>14.300 b | B<br>13.150 b | A<br>14.300 b |

**Table 8 b. Effect of interaction between planting densities and maize hybrids on number of rows/ear (combined)**

| Maize hybrids (H) / Planting densities (D) | D -1 | D -2 | D -3 |
|---|---|---|---|
| S.C. 10 | A<br>13.296 b | A<br>13.075 a | A<br>13.442 b |
| S.C 173 | A<br>14.058 a | A<br>14.329 a | A<br>13.900 b |
| T.W.C. 324 | A<br>13.604 b | A<br>13.283 a | A<br>13.417 b |
| T.W.C. 352 | A<br>14.379 a | A<br>14.533 a | A<br>14.408 a |

**Table 8 c. Effect of interaction between maize hybrids and irrigation treatments on thousand kernel weight (g) (combined)**

| Irrigation treatments ( S) / Maize hybrids (H) | S.C. 10 | S.C. 173 | T.W.C. 324 | T.W.C. 352 |
|---|---|---|---|---|
| S -1 | A<br>487.375 a | B<br>429.375 a | B<br>429.083 b | B<br>422.625 a |
| S -2 | A<br>454.417 b | B<br>396.458 b | A<br>444.958 a | B<br>381.833 b |
| S -3 | A<br>459.527 b | B<br>433.975 a | A<br>450.725 a | C<br>385.600 b |

**Table 8 d. Effect of interaction between planting densities and irrigation treatments on thousand kernel weight (g) (combined)**

| Irrigation treatments ( S) / Planting densities (D) | D -1 | D -2 | D -3 |
|---|---|---|---|
| S -1 | A<br>448.813 a | A<br>441.125 a | A<br>436.406 a |
| S -2 | A<br>421.563 b | A<br>419.156 b | A<br>417.531 b |
| S -3 | B<br>428.913 b | B<br>428.5769 b | A<br>439.881 a |

**Table 8 e. Effect of interaction between planting densities and maize hybrids on thousand kernel weight (g) (combined)**

| Maize hybrids ( H.) \ Planting densities (D) | D -1 | D -2 | D -3 |
|---|---|---|---|
| **S.C. 10** | A<br>471.283 a | A<br>467.700 a | A<br>462.325 a |
| **S.C. 173** | A<br>417.700 c | A<br>418.242 c | A<br>423.867 b |
| **T.W.C. 324** | B<br>442.950 b | B<br>430.533 b | A<br>451.283 a |
| **T.W.C. 352** | A<br>400.450 d | A<br>401.992 d | B<br>387.617 c |

received both normal or skipping 4th and 6th irrigations whereas T.W.C. 324 recorded higher thousand kernel weight when both skipped irrigation treatments were applied and meantime normal irrigation showed the lowest weight (Table 8 c).

Both the low and medium densities (20.000 and 24.000 plants/fad.) under normal irrigation on one hand, gave higher thousand kernel weight than both skipping irrigation treatments on the other hand. But, under high density, both normal and skipping 4th and 6th irrigations gave higher thousand kernel weight than that under skipping 3rd and 5th irrigations. Under both normal irrigations and skipping 3rd and 5th irrigation, thousand kernel weight did not affected by varying planting density, whereas under skipping 4th and 6th irrigations, the high density had higher thousand kernel weight compared to both low and medium densities. (Table 8 d).

For T.W.C. 352, both low and medium densities gave higher thousand kernel weight compared to high density (28.000 plants/fad.), while for T.W.C. 324 the higher thousand kernel weight was achieved when dense planting was applied. Both S.C. 10 and S.C. 173 did not affected by varying planting densities. Under both the low and medium densities S.C.10 gave the highest thousand kernel weight followed by T.W.C. 324 and S.C. 173 whereas the lowest value was recorded by T.W.C. 352. However, under high density 28.000 plants/fad., both S.C. 10 and T.W.C. 324 hybrids gave heavier thousand kernel weight followed by S.C. 173 and meantime T.W.C. 352 showed the lowest thousand kernel weight (Table 8 e).

## Grain and Biological Yields and Grain Protein Content

### Effect of irrigation treatments

Irrigating the plants normally, produced the highest averages of grain and biological yields/fad., followed by those received irrigation with skipping the 4th and 6th irrigations, whereas the lowest yields were obtained from plants irrigated with missing the 3rd and the 5th irrigations. This was true in the two seasons and their combined with the exception of the second season of biological yield/fad., but the reverse was true for protein content, where plants irrigated with missing the 4th and the 6th irrigations had higher protein content followed by those received irrigation with missing the 3rd and the 5th irrigations, whereas the lowest values were obtained from plants irrigated normally. The results of both seasons and the combined analysis were the same for protein content. In pooled data, both skipping irrigation treatments ($S_2$ and $S_3$) caused significant reductions in grain yield/fad., and biological yield/fad., which reached 17.54 and 9.75% as well as 10.63 and 11.19% compared with normal irrigation, respectively. Data in (Table 9), indicated clearly that skipping the 4th and the 6th irrigations gave a pronounced increase in protein content when compared with the second treatment (moderately stress) or third one (normal irrigation). High soil moisture deficits reduces the capacity of maize plants for building up metabolites and this might account much to depress the photosynthetic efficiency of leaves with consequent reduction in most growth and yield parameters (Table 9)

**Table 9. Grain yield (ard. fad.$^{-1}$), biological yield tons fad.$^{-1}$ and grain protein content as affected by irrigation treatments, maize hybrids, planting densities and their interactions in 2011, 2012 seasons and their combined data**

| Main effects and interactions | Grain yield (ard fad.$^{-1}$) | | | Biological yield (tons fad.$^{-1}$) | | | Grain protein content (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | Combined | 2011 | 2012 | Combined | 2011 | 2012 | Combined |
| **Irrigation treatments ( S):** | | | | | | | | | |
| **Normal irrigations (S-1)** | 33.72 a | 30.89 a | 32.30 a | 13.18 a | 12.05 a | 12.62 a | 9.52 c | 10.75 c | 10.14 c |
| **Missing the 3rd and 5th irrigations (S-2)** | 30.24 c | 24.72 c | 27.48 c | 11.59 c | 10.28 b | 10.94 c | 10.26 b | 11.37 b | 10.82 b |
| **Missing the 4th and 6th irrigations (S-3)** | 32.46 b | 26.39 b | 29.43 b | 12.45 b | 10.25 b | 11.35 b | 10.80 a | 11.95 a | 11.38 a |
| **F. test** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| **Maize hybrids (H):** | | | | | | | | | |
| **S.C. 10** | 35.55 a | 29.04 a | 32.30 a | 15.03 a | 13.04 a | 14.03 a | 9.62 c | 10.14 d | 9.88 d |
| **S.C. 173** | 36.15 a | 26.52 c | 31.34 b | 11.06 c | 9.17 d | 10.11 c | 10.41 b | 11.84 b | 11.13 b |
| **T.W.C. 324** | 33.72 b | 27.21 b | 30.46 b | 13.41 b | 11.35 b | 12.38 b | 9.68 c | 10.98 c | 10.33 c |
| **T.W.C. 352** | 23.14 c | 26.56 c | 24.85 c | 10.15 d | 9.87 c | 10.00 c | 11.07 a | 12.47 a | 11.77 a |
| **F. test** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| **planting densities (1000 plants fad$^{-1}$), (D):** | | | | | | | | | |
| **20 (D-1)** | 27.55 c | 24.55 c | 26.05 c | 11.45 c | 10.32 c | 10.89 c | 10.30 | 11.41 | 10.86 |
| **24 (D-2)** | 32.99 b | 26.76 b | 29.88 b | 12.54 b | 10.69 b | 11.62 b | 10.26 | 11.39 | 10.83 |
| **28 (D-3)** | 35.88 a | 30.69 a | 33.28 a | 13.24 a | 11.55 a | 12.40 a | 10.06 | 11.27 | 10.65 |
| **F. test** | ** | ** | ** | ** | ** | ** | N.S. | N.S. | N.S. |
| **Interactions:** | | | | | | | | | |
| **S x H** | * | ** | ** | ** | ** | ** | ** | * | ** |
| **S x D** | ** | * | ** | ** | ** | ** | ** | ** | ** |
| **H x D** | ** | * | ** | ** | ** | ** | * | N.S. | * |

*,** indicate significant at 0.05 and 0.01 levels of probability, respectively. N.S. = Not significant.

Ardab = 140 kg (grain moisture content 15.5 %).

and yield parameters (Table 9) and, in turn the final grain and biological yields/fad. These results are in agreement with Those reported by Boonparadub *et al.* (2001), Betran *et al* (2003), Ti-da *et al*. (2006), Golbashy *et al.* (2010 B) and Khodarahmpour and Hamidi (2012).

### Maize hybrids differences

Data in Table 9 indicate significant differences among the four maize hybrids in grain and biological yields/fad. and grain protein content. The combined analysis data show that S.C. 10 plants produced the highest grain yield/fad., followed by S.C. 173 or T.W.C. 324, otherwise T.W.C. 352 hybrid produced the lowest value for this character. These results followed the same pattern of most yield attributes formerly discussed which all indicated the superiority of S.C. 10 on other maize hybrids. The averages of grain yield/fad., amounted to 32.30 , 31.34, 30.46 and 24.85 ard./fad., for S.C. 10, S.C. 173 , T.W.C. 324 and T.W.C. 352 in the same followed order. Concerning biological yield/fad. S.C. 10 produced the highest biological yield followed by T.W.C. 324 whereas T.W.C. 352 and S.C. 173 gave the lowest yield. This picture is clearly true in both seasons and their combined. But, in grain protein content the reverse was true where the combined analysis and the two seasons revealed that T.W.C. 352 followed by S.C. 173 had higher averages than S.C. 10 and T.W.C. 324 which gave the lowest protein content. The result show that S.C. 10 hybrid recorded increases of about 48.07, 32.12 and 40.3% over T.W.C. 352 hybrid in both seasons and in their pooled data for biological yield ton/fad. The obtained results are in agreement with those reported by Said and Gabr (1999), El-Sheikh (2000); Abo-Shetaia *et al.* (2002); Amer *et al.* (2004) and Khalil (2007).

### Planting density effect

Grain and biological yields of maize hybrids were significantly and consistently increased with raising density from 20.000 to 24.000 and 28.000 plants/fad., in both seasons and their combined. However, planting density had no significant effect on grain protein content of maize in both seasons and the combined analysis. The superiority in grain yield/fad., amounted to 12.82 and 21.72% for increasing planting density from 20 to 24 and 28 thousand plants/fad., respectively. Such results could be attributed to the superiorly of yield attributes. Any increase in maize density caused a significant increase in biological yield/fad., as 10.89, 10.62 and 12.40 ton/fad, whereas, the increase reached about 7.00 and 14.00% due to increasing planting density of maize from 20.000 to 24.000 and 28.000 plants/fad., (Table 9). Similar results were obtained by Said and Gabr (1999); El-Sheikh (2000); Abo-Shetaia *et al*. (2002), Amer *et al.* (2004); Marchao *et al*. (2005), Afsharmanesh (2007), Khalil (2007); Sikandar *et al*. (2007); Ahmad *et al*. (2008) and Sharifi *et al*. (2009).

### Interaction effects

Under all maize hybrids with the exception of S.C. 173, both skipping irrigation treatments decreased significantly grain yield ard./fad., but grain yield ard./fad., under S.C. 173 was higher with both normal irrigation and skipping the 3$^{rd}$ and the 5$^{th}$ irrigations than under the skipping the 4$^{th}$ and the 6$^{th}$ irrigations. Generally, S.C. 10 and S.C. 173 as well as T.W.C. 324 had higher grain yield in both normal and skipping the 4$^{th}$ and the 6$^{th}$ irrigations, but T.W.C. 352 had the lowest grain yields, however, under skipping the 3$^{rd}$ and the 5$^{th}$ irrigations, S.C. 173 and both S.C. 10 and T.W.C. 324 had higher grain yield than T.W.C. 352 (Table 9 a).

For all irrigation treatments it was always true that, increasing planting density from 20 to 24 and 28 thousand plants/fad., gradually increased grain yield/fad. (Table 9b). Also, under the low and high densities, grain yield/fad., was significantly the lowest by skipping the 3$^{rd}$ and the 5$^{th}$ irrigations, while the highest grain yield/fad., was due to normal irrigation followed by irrigation with skipping 4$^{th}$ and 6$^{th}$ irrigations. Maize plants of medium density had higher grain yield/fad., in normal irrigation, but had equal grain yield under skipping the 3$^{rd}$ and the 5$^{th}$ irrigations and the 4$^{th}$ and the 6$^{th}$ irrigations. The response of grain yield/fad., to the increase of planting density was much higher for the normally irrigated plants (12.07 ard./fad.) than for the stressed ones (6.59 and 7.37 ard./fad), for skipping 3$^{rd}$ and 5$^{th}$ irrigations and 4$^{th}$ and 6$^{th}$ irrigations respectively). These results clearly indicated that dense planting imposed more adverse effect on water stressed plants. This also indicates that withholding irrigation at 45 days (3rd irrigation) and 75 days (5th irrigation) subjected maize plants to more inter plant competition than delaying withholding irrigation to 60 days (4th irrigation) and 90 days (6th irrigation) This adverse effect was absented in all growth and yield attributes and could account for the much more decrease in the response of grain yield/fad., to the increase of planting density presented in (Table 9b).

Under both low and medium densities each of S.C. 10 , S.C. 173 and T.W.C. 324 had equal grain yield ard./fad., being higher than that of T.W.C. 352. But, under the heavy density, both S.C. 10 and S.C. 173 had equal grain yield ard./fad., being heavier than T.W.C. 324 and T.W.C. 352. For both S.C. 10 and S.C. 173 any increase in planting density caused a significant increase in grain yield ard/fad. For T.W.C. 324 both medium and high densities gave equal grain yield ard./fad., being higher than low density. For T.W.C. 352 the heaviest grain yield ard./fad., was obtained from high density and meantime both low and medium densities showed the lowest grain yield ard./fad., (Table 9c).

Generally T.W.C. 324 and T.W.C. 352 gave the same biological yield ton/fad. when both skipping irrigation treatments were applied being lower than in normal irrigation. However, S.C. 173 had the same biological yield ton/fad., when irrigated normally or skipping 3rd and 5th irrigations being higher than skipping the 4th and the 6th irrigations. For S.C. 10 heaviest biological yield ton/fad., was obtained from normal irrigation followed by skipping the 4th and the 6th irrigations and the 3rd and the 5th irrigations. When skipping 3rd and 5th irrigations treatment was applied, S.C. 10 gave the heaviest biological yield ton/fad., followed by T.W.C. 324 and S.C. 173 while T.W.C. 352 gave the lowest (Table 9 d).

Under normal and skipping the 4th and the 6th irrigations, it was true that, increasing planting density from 20 to 24 and 28 thousand plants/fad., gradually increased biological yield ton/fad., but had equal biological yield ton/fad., under skipping the 3rd and the 5th irrigations with three planting densities. Under both the low and medium densities, normal irrigation on the one hand gave higher biological yield ton/fad., than both skipping the 3rd and the 5th irrigations or the 4th and the 6th irrigations on the other hand. Also, under high density biological yield ton/fad., was significantly the lowest by skipping 3rd and 5th irrigations while the highest grain yield was due to normal irrigation followed by irrigation with skipping the 4th and the 6th irrigations (Table 9 e).

Under low density, S.C. 173 and T.W.C. 352 had equal biological yields ton/fad., being lower than of S.C. 10 and T.W.C. 324 which gave higher biological yields ton/fad. For S.C.10 and S.C. 173 as well as T.W.C. 324 any increase in planting density caused a significant increase in biological yield ton/fad. For T.W.C. 352, both low and medium densities had equal biological yields ton/fad., being lighter than high density (Table 9 f).

Generally, S.C. 173 and T.W.C. 324 as well as T.W.C. 352 gave the same protein percentage when irrigation skipping treatments were applied being higher than in normal irrigation. However, S.C. 10 gave the same protein percentage when was irrigated with normal or skipping 3rd and 5th irrigations being lower than in skipping the 4th and the 6th irrigations. When maize hybrids were the same under the three irrigation treatments, both S.C. 173 and T.W.C. 324 did not differ from the other two hybrids but T.W.C. 352 gave the highest protein percentage while S.C. 10 gave the lowest (Table 9 g).

For normal irrigation both medium and high densities gave the same protein percentage being lower than in low density, but had equal protein percentage under skipping the 3rd and the 5th irrigations or the 4th and the 6th irrigations with the three planting densities. Under low and high densities, skipping 4th and the 6th irrigation treatments had high protein percentage, but under medium density both skipping irrigation treatments had the same protein percentage being higher than in normal irrigation (Table 9 h).

Maize hybrids varied in their interaction with plant density, *i.e.*, S.C. 10 and T.W.C. 324 did not interact significantly, meanwhile S.C. 173 and T.W.C. 352 interacted and recorded the highest values under D-1 and the lowest under D-3. T.W.C 352 had the highest protein percentage compared to the other hybrids over the three densities. Under both low and high densities T.W.C. 352 gave highest protein

**Table 9 a. Effect of interaction between maize hybrids and irrigation treatments on grain yield (ard. fad.$^{-1}$). (combined)**

| Irrigation treatments ( S) \ Maize hybrids (H.) | S.C. 10 | S.C. 173 | T.W.C. 324 | T.W.C. 352 |
|---|---|---|---|---|
| S -1 | A<br>35.381 a | A<br>32.488 a | A<br>32.869 a | B<br>28.480 a |
| S -2 | B<br>29.345 c | A<br>31.720 a | B<br>27.739 c | C<br>21.106 c |
| S -3 | A<br>32.160 b | A<br>29.808 b | A<br>30.777 b | B<br>24.962 b |

**Table 9 b. Effect of interaction between planting densities and irrigation treatments on grain yield (ard. fad.$^{-1}$). (combined)**

| Irrigation treatments ( S) \ Planting densities (D) | D -1 | D -2 | D -3 |
|---|---|---|---|
| S -1 | C<br>28.255 a | B<br>32.632 a | A<br>36.027 a |
| S -2 | C<br>23.604 c | B<br>28.636 b | A<br>30.192 c |
| S -3 | C<br>26.294 b | B<br>28.357 b | A<br>33.629 b |

**Table 9 c. Effect of interaction between planting densities and maize hybrids on grain yield (ard. fad.$^{-1}$). (combined)**

| Maize hybrids (H) \ Planting densities (D) | D -1 | D -2 | D -3 |
|---|---|---|---|
| S.C. 10 | C<br>27.622 a | B<br>32.572 a | A<br>36.691 a |
| S.C. 173 | C<br>26.344 a | B<br>31.724 a | A<br>35.947 a |
| T.W.C. 324 | B<br>27.685 a | A<br>31.406 a | A<br>32.295 b |
| T.W.C. 352 | B<br>22.553 b | B<br>23.797 b | A<br>28.197 c |

**Table 9 d. Effect of interaction between maize hybrids and irrigation treatments on biological yield ton/fad. (combined)**

| Irrigation treatments ( S) \ Maize hybrids (H) | S.C. 10 | S.C. 173 | T.W.C. 324 | T.W.C. 352 |
|---|---|---|---|---|
| S -1 | A<br>16.033 a | C<br>10.394 a | B<br>13.525 a | C<br>10.507 a |
| S -2 | A<br>12.140 c | C<br>10.239 a | B<br>11.834 b | D<br>9.524 b |
| S -3 | A<br>13.918 b | C<br>9.701 b | B<br>11.781 b | C<br>9.994 b |

**Table 9 e. Effect of interaction between planting densities and irrigation treatments on biological yield ton/fad. (combined)**

| Irrigation treatments (S) \ Planting densities (D) | D -1 | D -2 | D -3 |
|---|---|---|---|
| S -1 | C<br>11.551 a | B<br>12.667 a | A<br>13.626 a |
| S -2 | A<br>10.258 b | A<br>11.028 b | A<br>11.517 c |
| S -3 | C<br>10.848 b | B<br>11.153 b | A<br>12.044 b |

**Table 9 f. Effect of interaction between planting densities and maize hybrids on biological yield ton/fad. (combined)**

| Maize hybrids (H) \ Planting densities (D) | D -1 | D -2 | D -3 |
|---|---|---|---|
| S.C. 10 | C<br>13.200 a | B<br>13.965 a | A<br>14.927 a |
| S.C. 173 | C<br>9.058 c | B<br>10.262 c | A<br>11.012 c |
| T.W.C. 324 | C<br>11.500 b | B<br>12.449 b | A<br>13.191 b |
| T.W.C. 352 | B<br>9.784 c | B<br>9.789 d | A<br>10.452 d |

**Table 9 g. Effect of interaction between maize hybrids and irrigation treatments on grain protein content (%) (combined)**

| Irrigation treatments (S) \ Maize hybrids (H) | S.C. 10 | S.C. 173 | T.W.C. 324 | T.W.C. 352 |
|---|---|---|---|---|
| S -1 | B<br>9.392 b | A<br>10.929 b | B<br>9.524 b | A<br>10.704 b |
| S -2 | C<br>9.721 b | A<br>11.418 a | B<br>10.038 a | A<br>12.089 a |
| S -3 | B<br>10.532 a | AB<br>11.027 a | B<br>11.430 a | A<br>12.522 a |

**Table 9 h. Effect of interaction between planting densities and irrigation treatments on grain protein content (%) (combined)**

| Irrigation treatments ( S) \ Planting densities (D) | D -1 | D -2 | D -3 |
|---|---|---|---|
| S -1 | A<br>10.624 b | B<br>10.023 b | B<br>9.764 c |
| S -2 | A<br>10.720 b | A<br>11.026 a | A<br>10.704 b |
| S -3 | A<br>11.221 a | A<br>11.428 a | A<br>11.484 a |

**Table 9 i. Effect of interaction between planting densities and maize hybrids on grain protein content (%) (combined)**

| Maize Hybrids ( H.) \ Planting densities (D) | D -1 | D -2 | D -3 |
|---|---|---|---|
| **S.C. 10** | A<br>9.708 c | A<br>10.084 b | A<br>9.852 c |
| **S.C. 173** | A<br>11.451 b | AB<br>11.153 a | B<br>10.771 b |
| **T.W.C. 324** | A<br>10.250 c | A<br>10.392 b | A<br>10.350 b |
| **T.W.C. 352** | A<br>12.021 a | A<br>11.674 a | B<br>11.631 a |

percentage followed by T.W.C. 324 and S.C. 173 whereas the lowest value recorded by S.C. 10. However, under medium density both T.W.C. 352 and S.C. 173 gave the same protein percentage being higher than both T.W.C. 324 and S.C. 10. with skipping 3rd and 5th irrigations or 4th and 6th irrigations being higher than in normal irrigation. However, S.C. 10 gave the same protein percentage when was irrigated with normal or skipping 3rd and 5th irrigations being lower than in skipping or 4th and 6th irrigations. When maize was same under the three irrigation treatments, both S.C.173 and T.W.C. 324 did not differ from the other two hybrids but T.W.C. 352 gave the highest protein percentage while S.C. 10 gave the lowest (Table 9 i).

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## تأثير كثافة الزراعة وإسقاط الري عند مراحل نمو معينة على القدرة الإنتاجيـة لبعض هجن الذرة الشامية

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أقيمت تجربتان حقليتان بالمزرعة التجريبية بالجميزة التابعة لمركز البحوث الزراعية خلال الموسمين ٢٠١١ ، ٢٠١٢ وذلك لدراسة تأثير ثلاث كثافات زراعيــة (٢٠ ، ٢٤ ، ٢٨ ألف نبات/فدان) وثلاث معاملات للإجهاد المائي (الري العادي بمعدل ست ريات، إسقاط كل من الرية الثالثة عند ٤٥ يوم والرية الخامسة عند ٧٥ يوم من الزراعــة ، إسقاط الرية الرابعة عند ٦٠ يوم والرية السادسة عند ٩٠ يوم من الزراعـة) على القدرة الإنتاجيـة لأربعــة من هجن الذرة الشامية (اثنان من الهجن الفردية ، الهجين الفردي ١٠ ، الهجيـن الفردي ١٧٣ واثنان من الهجن الثلاثيـة ، الهجين ثلاثي ٣٢٤ ، الهجين الثلاثي ٣٥٢) ويمكن تلخيص النتائج كما يلي: أوضحت نتائج التحليل التجميعي للموسمين أن الري بمعدل ست ريات (الري العادي) أعطى أعلى المتوسطات للصفات تحت الدراسة، وفي نفس الوقت أدى أسقاط الرية الثالثة عند ٤٥يوم والراية الخامسة عند ٧٥ يوم من الزراعة إلى الحصول على أقل المتوسطات، لكن كان العكس بالنسبة لنسبة البروتين بالحبوب حيث أدى إسقاط الري عند ٦٠ ، ٩٠ يوم من الزراعـة (الرية الرابعة والسادسة) إلى زيادة نسبة البروتين بينما سجلت أقل نسبة للبروتين في المعاملـة (الري العادي ست ريات)، طبقا لبيانات التحليل التجميعي فأن إسقاط كل من الريتين الثالثة والخامسة أو عند إسقاط الريتين الرابعة والسادسة أدى إلى نقص معنوي في محصول الحبوب والمحصول البيولوجي وصل إلى ١٧,٥٤ ، ٩,٧٥% وكذلك ١٠,٣٦، ١١,١٩% وذلك بالمقارنة بالري التقليدي على الترتيب. كان تأثير الهجن معنويا على معظم الصفات المدروسة حيث تفوق الهجين الفردي ١٠ في معظم صفات النمو ومساهمات المحصول ومحصول الحبوب والمحصول البيولوجي/فدان ثم تلاه الهجين الفردي ١٧٣ والهجين الثلاثي ٣٢٤ وكذلك الهجين الثلاثي ٣٥٢ على الترتيب. وكان تفوق الهجين الفردي ١٠ بسبب تفوقه في كل من عدد الأيام حتى ظهور ٥٠% من النورة المذكرة والمؤنثة ، قطر الساق ، دليل مساحة الأوراق ، ارتفاع النبات ، وارتفاع الكوز ، وزن الـ ١٠٠٠ حبة. في حين تفوق الهجين الفردي ١٧٣ في محتوى الأوراق من الكلوروفيل، طول الكوز. بينما تفوق الهجين الثلاثي ٣٥٢ في قطر القولحة ، عدد السطور/الكوز ، محتوى الحبوب بالبروتين. بينما تساوت الهجن الأربعة في قطر الكوز خلال موسمي الزراعة والتحليل المشترك للبيانات. وأوضح التحليل المشترك للبيانات أن زيادة الكثافة النباتية من ٢٠ إلى ٢٤ إلى ٢٨ ألف نبات/فدان أدت إلى زيادة معنوية في كل من دليل مساحة الأوراق، ومحصولي الحبوب والبيولوجي للفدان ولكن انخفض معنوياً طول الكوز في حين لم يؤثر تغير الكثافة النباتية على كل من عدد الأيام حتى ظهور ٥٠% من النورة المذكرة والمؤنثة، دليل مساحة الأوراق ، قطر الساق، ارتفاع النبات ، وارتفاع الكوز وقطره ، قطر القولحة ، وعدد السطور/الكوز ، عدد الحبوب بالسطر ، وزن الـ ١٠٠٠ حبة ، نسبة البروتين. بينما أدت زيادة الكثافة النباتية من ٢٠ إلى ٢٤ إلى ٢٨ ألف نبات/فدان لزيادة معنوية في كل من محتوى الأوراق من الكلوروفيل وطول الكوز. وأوضحت نتائج التحليل التجميعي للموسمين وجود تداخل فعل بين هجن الذرة الشامية من ناحية وبين كل من معاملات الإجهاد المائي والكثافة النباتية حيث لوحظ أن الهجينان الفرديان ١٠ ، ١٧٣ وكذلك الهجين الثلاثي ٣٢٤ أعطوا أعلى محصول حبوب باستخدام معاملة الري العادي (الست ريات) وكذلك عند إسقاط الريتين الرابعة والسادسة بينما أعطى الهجين الثلاثي ٣٥٢ أقل محصول حبوب/الفدان. بينما كان ترتيب الهجن عند إسقاط الريتين الثالثة والخامسة تفوق الهجين الفردي ١٧٣ ثم كل من الهجين الفردي ١٠ والهجين الثلاثي ٣٢٤ عن الهجين الثلاثي ٣٥٢. تساوى محصول الهجينان الفرديان ١٠ ، ١٧٣ والهجين الثلاثي ٣٢٤ عند استخدام الكثافة النباتية المنخفضة والمتوسطة (٢٠ ، ٢٤ ألف نبات/فدان) وكانا أعلى من محصول الهجين الثلاثي ٣٥٢ بينما عند استخدام الكثافة العليا ٢٨ ألف نبات/فدان، تساوى محصول كل من الهجينان الفرديان ١٠ ، ١٧٣ وكانا أعلى محصولا من الهجينان الثلاثيان ٣٢٤ ، ٣٥٢ ، بالنسبة للهجين الفردي ١٠ والهجين الفردي ١٧٣ فأن أي زيادة في الكثافة النباتية أدى إلى زيادة معنوية في محصول الحبوب/فدان بينما بالنسبة للهجين الثلاثي ٣٢٤ فأن استخدام الكثافة المتوسطة والعليا (٢٤ ، ٢٨ ألف نبات/فدان) أعطى أعلى محصول حبوب /فدان عن الكثافة المنخفضة (٢٠ ألف نبات/فدان) بينما سجل الهجين الثلاثي ٣٥٢ أعلى محصول حبوب/فدان باستخدام الكثافة العليا (٢٨ ألف نبات/فدان) بينما سجل أقل محصول حبوب/فدان عند استخدام الكثافة المنخفضة والمتوسطة (٢٠، ٢٤ ألف نبات/فدان).

**المحكمـون:**

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