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# Evaluation of some maize hybrids under water stress conditions

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## ABSTRACT

Two field experiments were conducted at Gemmeiza Agriculture Research Station; the first was under normal irrigation and the second was under water stress by skipping the third and fourth irrigations during the two seasons 2018 and 2019, to study the response of 16 maize hybrids to water stress. A strip plot design with four replications was used in each year. Combined analysis across two years revealed that, significant or highly significant differences were detected between two years for the most of traits. Highly significant differences were found between normal irrigation and water stress treatment for all studied traits. Hybrids showed highly significant differences for all studied traits. The highest single crosses for grain yield plant$^{-1}$ were SC 128 followed by SC 132 under normal irrigation and water stress conditions, meanwhile the highest three-way cross was TWC 321 under normal irrigation and TWC 368 under water stress. Single crosses SC 178 and SC 176 also three-way crosses TWC 352 and TWC 368 were able to tolerate drought. Correlation coefficient was significant and positive between each of ear length and number of kernels row$^{-1}$ with grain yield plant$^{-1}$ under normal irrigation and between 100 kernel weight and grain yield plant$^{-1}$ under normal and stress irrigation.

***Keywords***: Zea mays, Maize, Hybrid, Drought, Water stress.

## INTRODUCTION

Maize (*Zea mays* L.) is one of the most important food and feed crops in Egypt and the world. It is a multipurpose crop with a wide adaptability to different agro-climatic conditions. Water shortage has been a challenge to sustainable maize production in irrigated agriculture regions. Adaptation of drought tolerant hybrids could be a management strategy for maize production under water limited conditions. Water deficit (drought) can be defined as the absence of adequate moisture necessary for normal plant growth and to complete its life (Zhu, 2002). Evaluation and breeding for drought tolerance is so important nowadays to forecast the decrease in water resources and climate changes. Climate change with its harmful changes will deeply reduce soil water available for plant uptake (Rurinda *et al*. 2015), and maize production is menaced by this phenomenon (Žalud *et al*. 2017). Therefore, much breeding and agronomic researches have been designed to improve maize production under drought conditions (Campos *et al*. 2004). Drought tolerant maize hybrids could help to maintain high yield under water limited conditions (Cooper *et al*. 2014, Sammons *et al*. 2014 and Mounce *et al*. 2016). When the available soil moisture was decreased, ear length, 1000 grain weight and grain yield were decreased (Ainer *et al*. 1986). Also plant height and ear height were significantly decreased by water stress (El-Nomany *et al*. 1990). Meanwhile, number of days to 50% silking was increased by water deficit (Moursi 1997 and El-Ganayni *et al*. 2000). Skipping the third, fourth or fifth irrigation reduced grain yield by 21, 19.9, and 17%, respectively (AbdEl-Gawad *et al*. 1980). Grain yield was significantly decreased by progressive drought during either vegetative or reproductive stage. The decrease in grain yield was largely caused by the decrease in number of kernels per ear (Mi *et al*. 2018).

The objectives of this study were to investigate the effect of water stress on growth, yield and yield components of some maize hybrids and identify high yielding hybrids under water limited conditions.

## MATERIALS AND METHODS

Four white maize single crosses (SC 10, SC 128, SC 130, SC 132), five yellow maize single crosses (SC 162, SC 166, SC 168, SC 176, SC 178), three white maize three-way crosses (TWC 321, TWC 324, TWC 329) and four yellow maize three-way crosses (TWC 352, TWC 353, TWC 360 and TWC 368) were evaluated at Gemmeiza Agricultural Research Station in the two seasons 2018 and 2019. A strip plot design with four replications was used in each year. The vertical factor was two irrigation treatments; the first was under normal irrigation and the second was under water stress by skipping the third and fourth irrigations and the horizontal factor was 16 hybrids. Plot size was four ridges, 6.00 m long, 0.80 m apart and 0.25 m between hills. Two seeds were planted per hill and later thinned out to one plant per hill before the first irrigation. The recommended packages of agronomic practices were followed to achieve a good growth, except skipping the third and fourth irrigations in the second irrigation treatment. The data were collected on number of days to 50% silking which was recorded as the number of days from planting date to the time when 50% of plants in the plot produced visible silks. Plant height was measured after flowering on 10 guarded plants plot$^{-1}$ in cm from ground to the point of flag leaf insertion. Ear height was recorded after flowering on 10 guarded plants plot$^{-1}$ as

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distance in cm from the ground to the ear leaf. Ear length (cm), number of rows ear$^{-1}$, number of kernels row$^{-1}$ were measured as an average of five ears from five guarded plants. Grain yield plant$^{-1}$ was recorded from 10 guarded plants and grain yield (g) was adjusted at 15.5% grain moisture. 100-kerenel weight (g) was weighed from grains adjusted at 15.5% moisture. Homogeneity of error variance among years was determined by Bartlett (1936) test. Combined analysis of variance across two years was done according to Snedecor and Cochran (1967).

The drought susceptibility index was calculated only for grain yield per plant using a generalized formula according to Fischer and Maurer, (1978) as follows:

$$\mathbf{DSI = (1 - Yd / Yp) / D}$$

**where**

**DSI = An index of drought susceptibility.**

**Yd = Performance of a genotype under drought stress.**

**Yp = Performance of the same genotype under normal irrigation.**

**D = Drought intensity = 1-[(mean Yd of all genotypes) / (mean Yp of all genotypes)].**

Low drought susceptibility index (DSI < 1) is synonymous with high drought stress tolerance.

Simple correlation coefficients were calculated among all the traits and adjusted grain yield plant$^{-1}$ in normal irrigation and water stress conditions by substituting corresponding variance and covariance in the formulae given by (Gomez and Gomez, 1984).

## RESULTS AND DISCUSSION

**Effect of years:**

Significant or highly significant differences were detected between two years for all studied traits, except for grain yield plant$^{-1}$ and number of kernels row$^{-1}$ (Table-1). The highest mean values were observed for all traits in 2019 season, except for days to 50% silking and grain yield plant$^{-1}$ which were the highest in 2018 season.

**Table 1. Effect of years on eight studied traits.**

| Year | Days to 50% silking | Plant height (cm) | Ear height (cm) | Grain yield plant$^{-1}$ (g) | Ear length (cm) | Number of rows ear$^{-1}$ | Number of kernels row$^{-1}$ | 100 kernel weight (g) |
|---|---|---|---|---|---|---|---|---|
| 2018 | 64.05 | 240.39 | 133.67 | 124.62 | 23.10 | 14.46 | 43.35 | 40.10 |
| 2019 | 63.62 | 246.44 | 138.05 | 123.03 | 23.87 | 14.99 | 44.04 | 41.05 |
| F test | * | ** | ** | n.s | * | * | n.s | ** |

***, ** and n.s refer to significant at 0.05 and 0.01 probability levels and not significant, respectively.**

**Effect of irrigation treatments:**

Effects of irrigation treatments on eight traits (Table 2), showed that highly significant differences were observed between normal irrigation and water stress treatment for all studied traits. The water stress by preventing third and fourth irrigations affects on silk emergence to be appeared later than normal irrigation. Also, water stress treatment made plants shorter and the position of ears lower than normal irrigation. For grain yield plant$^{-1}$ and its components, i.e. ear length, number of rows ear$^{-1}$, number of kernels row$^{-1}$ and 100 kernel weight, the water stress decreased them significantly as compared with normal irrigation. Grain yield plant$^{-1}$ under water stress was decreased by 21.5% compared to normal irrigation. These results may be due to effects of water stress on morphology, photosynthesis, and dry matter accumulation in plants. Payero *et al.* (2008) reported that water stress can affect on growth, development and physiological processes of maize plants, which reduce biomass yield. Various researchers reported that maize grain yield and its components were significantly influenced by irrigation regime treatments (Abd El-Mottaleb, 1987; Khan *et al.*, 2001; Moser *et al.*, 2006; Golbashy *et al.,* 2010; Vazirimehr *et al.,* 2014; Abd El-wahed *et al.*, 2015; Hao *et al.*, 2016 and Gheysari *et al.*, 2017).

**Table 2. Effects of irrigation treatments on eight studied traits.**

| Irrigation | Days to 50% silking | Plant height (cm) | Ear height (cm) | Grain yield plant$^{-1}$ (g) | Ear length (cm) | Number of rows ear$^{-1}$ | Number of kernels row$^{-1}$ | 100 kernel weight (g) |
|---|---|---|---|---|---|---|---|---|
| Normal irrigation | 62.70 | 251.21 | 141.56 | 138.79 | 24.51 | 15.27 | 44.95 | 41.71 |
| Water stress | 64.98 | 235.62 | 130.16 | 108.86 | 22.45 | 14.17 | 42.44 | 39.44 |
| F test | ** | ** | ** | ** | ** | ** | ** | ** |

**** refer to significant at 0.01 probability level.**

**Effect of hybrids:**

Data in Table 3, showed highly significant differences among hybrids for all studied traits. The single cross 166 was the earliest single cross (62.75 days) while TWC 353 was the earliest three way cross (62.62 days). Single crosses for plant height ranged from 236.56 cm (SC 130) to 252.50 cm (SC 162), meanwhile three-way crosses ranged from 237.81 cm (TWC 352) to 250.62 cm (TWC 329). For ear height, SC 10 was the highest ear placement and SC 176 has the lowest ear placement also, TWC324 was the highest ear placement and TWC 360 has the lowest ear placement. Grain yield plant$^{-1}$ ranged from 113.39 g for SC 176 to 139.50 g for SC 128 and from 114.52 g for TWC 353 to 126.72 g for TWC 321 for single crosses and three-way crosses, respectively. The best single crosses for grain yield were SC 128, SC 132 and SC 10 meanwhile the best three-way crosses were TWC 321, TWC 368 and TWC 324. For ear length single crosses ranged from 23.06 cm (SC 178) to 24.67 cm (SC 168) while, three-way crosses ranged from 20.54 cm to 24.87 cm for TWC 353 and TWC 368, respectively. For number of rows ear$^{-1}$, it ranged from 13.92 (SC10) to 15.07 (SC 132) and from 14.12 (TWC 324) to 15.54 (TWC 352). For number of kernels row$^{-1}$ single crosses ranged from 42.85 (SC 176) to 45.09 (SC 128) and three-way crosses ranged from 40.30 (TWC 353) to 45.38 (TWC 329). For 100 kernel weight, the lowest single cross value was SC162 (38.49 g) and the highest value was SC 132 (43.12 g) also

TWC 352 was the lowest value (37.82 g) and TWC 360 was the highest value (42.50 g). Differences between these hybrids may be attributed to the genetic background of hybrids, which plays on important role for the uptake of available nutrients and water as well as light interception. The varietal differences were found by other researchers which indicated high differences among hybrids studied for drought tolerance (Golbashy *et al.*, 2010 and Mi *et al.*, 2018).

**Table 3. Effect of hybrids on eight studied traits.**

| Hybrid | Days to 50% silking | Plant height (cm) | Ear height (cm) | Grain yield plant$^{-1}$(g) | Ear length (cm) | Number of rows ear$^{-1}$ | Number of kernels row$^{-1}$ | 100 kernel weight (g) |
|---|---|---|---|---|---|---|---|---|
| SC 10 | 64.25 | 248.75 | 141.56 | 132.83 | 23.41 | 13.92 | 44.81 | 42.42 |
| SC 128 | 63.87 | 239.06 | 134.06 | 139.50 | 23.98 | 14.50 | 45.09 | 42.71 |
| SC 130 | 63.87 | 236.56 | 131.25 | 121.76 | 23.61 | 14.81 | 43.89 | 39.51 |
| SC 132 | 64.37 | 245.31 | 136.87 | 136.99 | 24.25 | 15.07 | 45.04 | 43.12 |
| SC 162 | 64.37 | 252.50 | 134.69 | 115.72 | 23.86 | 14.34 | 44.88 | 38.49 |
| SC 166 | 62.75 | 237.19 | 136.56 | 122.77 | 23.76 | 15.00 | 43.65 | 40.68 |
| SC 168 | 63.19 | 240.31 | 139.06 | 129.95 | 24.67 | 14.71 | 44.62 | 40.68 |
| SC 176 | 63.31 | 239.69 | 130.94 | 113.39 | 23.16 | 14.50 | 42.85 | 39.60 |
| SC 178 | 64.62 | 245.31 | 137.81 | 125.44 | 23.06 | 14.53 | 43.65 | 41.09 |
| TWC 321 | 63.62 | 247.50 | 135.94 | 126.72 | 22.86 | 14.43 | 42.88 | 40.18 |
| TWC 324 | 64.31 | 243.44 | 141.25 | 122.59 | 23.93 | 14.12 | 43.68 | 40.27 |
| TWC 329 | 64.56 | 250.62 | 137.50 | 116.37 | 24.54 | 14.78 | 45.38 | 40.34 |
| TWC 352 | 63.37 | 237.81 | 137.50 | 119.88 | 21.40 | 15.54 | 40.58 | 37.82 |
| TWC 353 | 62.62 | 245.62 | 132.81 | 114.52 | 20.54 | 14.64 | 40.30 | 39.46 |
| TWC 360 | 64.37 | 240.94 | 130.31 | 116.46 | 23.82 | 15.29 | 43.68 | 42.50 |
| TWC 368 | 63.94 | 244.06 | 135.62 | 126.26 | 24.87 | 15.40 | 44.19 | 40.26 |
| F test | ** | ** | ** | ** | ** | ** | ** | ** |

**** refer to significant at 0.01 probability level.**

**Effect of the interaction between years and irrigation treatments:**

The results in Table 4, showed that the interaction between years and water treatments (normal and stress irrigation) was significant in days to 50% silking and number of rows ear$^{-1}$ and highly significant in ear length, indicating that mean of water treatments were affected by years in these traits. The lowest value for days to 50% silking was observed in normal irrigation in 2018 season and the highest value was obtained under water stress in 2018 season. The highest values were obtained under normal irrigation in 2019 season, meanwhile the lowest values were obtained under water stress in 2018 for most studied traits.

**Table 4. Effect of the interaction between years and irrigation treatments on eight studied traits.**

| Irrigation | Year | Days to 50% silking | Plant height (cm) | Ear height (cm) | Grain yield plant$^{-1}$ (g) | Ear length (cm) | Number of rows ear$^{-1}$ | Number of kernels row$^{-1}$ | 100 kernel weight (g) |
|---|---|---|---|---|---|---|---|---|---|
| Normal irrigation | 2018 | 62.27 | 250.00 | 140.55 | 137.35 | 24.64 | 15.25 | 44.97 | 41.34 |
| | 2019 | 63.14 | 252.42 | 142.58 | 140.22 | 24.39 | 15.30 | 44.93 | 42.07 |
| Water stress | 2018 | 64.98 | 230.78 | 126.80 | 111.88 | 21.55 | 13.67 | 41.74 | 38.85 |
| | 2019 | 64.97 | 240.47 | 133.52 | 105.84 | 23.35 | 14.68 | 43.15 | 40.03 |
| F test | | * | n.s | n.s | n.s | ** | * | n.s | n.s |

***, ** and n.s refer to significant 0.05 and 0.01 probability levels and non significant, respectively.**

**Effects of the interaction between hybrids and years:**

The performances of hybrids in the two seasons are presented in Table.5. Hybrids didn't differ significantly in all traits, except days to 50% silking, plant height and ear height. For days to 50% silking, the lowest value were found for TWC 353 (62.50 days) in 2018 season and for TWC 324 (62.38 days) in 2019 season while the highest value were found for SC 178 (65.13 days) in 2018 season and for SC 166 (64.38 days) in 2019 season. Tallest plants were observed in TWC 329 (251.88 cm) in 2018 season and SC 162 (255.00 cm) in 2019 season while the shortest plants were observed for TWC 352 (228.75 cm) in 2018 season and for SC 176 (237.50 cm) in 2019 season. The lowest ear height was found for TWC 360 (126.87 cm) in 2018 season and for SC 176 (128.75 cm) in 2019 season, while the highest ear height was found for SC 10 (141.25 cm) in 2018 season and for SC 178 (144.37 cm) in 2019 season.

**Effect of the interaction between hybrids and water treatments:**

The interaction between hybrids and water treatments was significant or highly significant for all traits (Tables 6 and 7), suggesting that rank of hybrids differed from water treatment to another. For days to 50% silking, all hybrids earlier under normal irrigation (N) than water stress (WS), meaning that the water deficit delayed silk emergence. The earliest hybrids under normal irrigation (N) were TWC 353 followed by SC 128 and SC 168, while the earliest hybrids under water stress (WS) were SC 166 followed TWC 353. For plant and ear height all hybrids under N were taller than WS. The tallest hybrids for plant height under N were TWC 329 followed by SC 162, while under WS were SC 162 followed by TWC 368. The highest hybrids for ear height were SC 10 and TWC 324 under N and SC 166 under WS. The longest hybrids for ear length were TWC 368 followed by SC 168 under N and TWC 329 followed by TWC 368 under WS. For number of rows ear$^{-1}$, the highest hybrids were TWC 352 followed by TWC 360 under N and TWC 368 followed by SC 166 under WS. For number of kernels row$^{-1}$, the highest hybrids were SC 128 followed by SC 10 under N and TWC 329 followed by SC 132 under WS. For 100-kernels weight the highest hybrids were SC 132 followed by SC 128 under N and WS. Abd El-Latif *et al.* (2011) found that the interaction between crosses and irrigation treatments was significant for days to 50% silking, 100 kernel weight, number of kernels row$^{-1}$, number of rows ear-1 and plant and ear height.

**Table 5. Effect of interaction between hybrids and years on eight studied traits.**

| Hybrid | Year | Days to 50% silking | Plant height (cm) | Ear height (cm) | Grain yield plant$^{-1}$ (g) | Ear length (cm) | Number of rows ear$^{-1}$ | Number of kernels row$^{-1}$ | 100 kernel weight (g) |
|---|---|---|---|---|---|---|---|---|---|
| SC 10 | 2018 | 64.50 | 251.25 | 141.25 | 130.88 | 23.02 | 13.74 | 44.49 | 41.67 |
| | 2019 | 64.00 | 246.25 | 141.87 | 135.00 | 23.79 | 14.11 | 45.12 | 43.17 |
| SC 128 | 2018 | 63.88 | 232.50 | 129.37 | 137.12 | 23.56 | 14.17 | 44.47 | 41.59 |
| | 2019 | 63.88 | 245.62 | 138.75 | 141.88 | 24.39 | 14.82 | 45.71 | 43.84 |
| SC 130 | 2018 | 64.00 | 229.38 | 128.12 | 122.66 | 23.22 | 14.47 | 43.72 | 39.49 |
| | 2019 | 63.75 | 243.75 | 134.37 | 120.86 | 23.99 | 15.15 | 44.06 | 39.54 |
| SC 132 | 2018 | 64.50 | 236.88 | 133.75 | 139.56 | 23.86 | 14.85 | 44.92 | 43.27 |
| | 2019 | 64.25 | 253.75 | 140.00 | 134.41 | 24.64 | 15.29 | 45.15 | 42.97 |
| SC 162 | 2018 | 63.63 | 250.00 | 129.37 | 115.27 | 23.45 | 14.11 | 44. 67 | 38.84 |
| | 2019 | 63.00 | 255.00 | 140.00 | 116.17 | 24.26 | 14.56 | 45.09 | 38.15 |
| SC 166 | 2018 | 64.88 | 234.38 | 134.37 | 126.24 | 22.89 | 14.60 | 42.80 | 40.04 |
| | 2019 | 64.38 | 240.00 | 138.75 | 119.31 | 24.62 | 15.40 | 44.50 | 41.32 |
| SC 168 | 2018 | 63.13 | 231.25 | 134.37 | 130.39 | 24.31 | 14.27 | 44.09 | 40.37 |
| | 2019 | 64.13 | 249.37 | 143.75 | 129.51 | 25.02 | 15.14 | 45.15 | 40.99 |
| SC 176 | 2018 | 64.63 | 241.88 | 133.12 | 112.59 | 22.24 | 14.37 | 42.29 | 39.49 |
| | 2019 | 64.00 | 237.50 | 128.75 | 114.20 | 24.09 | 14.62 | 43.41 | 39.72 |
| SC 178 | 2018 | 65.13 | 241.88 | 131.25 | 125.82 | 22.96 | 14.45 | 43.05 | 40.26 |
| | 2019 | 64.00 | 248.75 | 144.37 | 125.06 | 23.16 | 14.61 | 44.25 | 41.92 |
| TWC 321 | 2018 | 64.50 | 247.50 | 136.25 | 129.24 | 22.21 | 13.99 | 42.01 | 39.36 |
| | 2019 | 64.25 | 247.50 | 135.62 | 124.20 | 23.51 | 14.87 | 43.75 | 41.00 |
| TWC 324 | 2018 | 63.13 | 243.75 | 140.00 | 123.05 | 23.61 | 13.81 | 42.67 | 40.12 |
| | 2019 | 62.38 | 243.12 | 142.50 | 122.14 | 24.25 | 14.42 | 44.69 | 40.42 |
| TWC 329 | 2018 | 63.00 | 251.88 | 133.12 | 118.35 | 24.47 | 14.60 | 45.49 | 40.14 |
| | 2019 | 63.38 | 249.37 | 141.87 | 114.40 | 24.60 | 14.95 | 45.27 | 40.54 |
| TWC 352 | 2018 | 63.50 | 228.75 | 140.62 | 120.67 | 21.36 | 15.54 | 40.32 | 37.72 |
| | 2019 | 63.25 | 246.88 | 134.37 | 119.09 | 21.44 | 15.54 | 40.84 | 37.91 |
| TWC 353 | 2018 | 62.50 | 245.00 | 130.00 | 121.37 | 20.22 | 14.36 | 40.51 | 39.19 |
| | 2019 | 62.75 | 246.25 | 135.62 | 107.66 | 20.86 | 14.92 | 40.09 | 39.74 |
| TWC 360 | 2018 | 64.63 | 235.63 | 126.87 | 117.91 | 23.80 | 14.85 | 43.47 | 40.70 |
| | 2019 | 64.13 | 246.25 | 133.75 | 115.01 | 23.84 | 15.74 | 43.89 | 44.30 |
| TWC 368 | 2018 | 64.38 | 244.38 | 136.87 | 122.95 | 24.35 | 15.16 | 44.66 | 39.30 |
| | 2019 | 63.50 | 243.75 | 134.37 | 129.56 | 25.40 | 15.64 | 43.71 | 41.21 |
| F test | | ** | * | ** | n.s | n.s | n.s | n.s | n.s |

***, ** and n.s refer to significant 0.05 and 0.01 probability levels and non significant, respectively.**

**Table 6. Effect of the interaction between hybrids and water irrigations on seven studied traits.**

| Hybrid | Water irrigation | Days to 50% silking | Plant height (cm) | Ear height (cm) | Ear length (cm) | Number of rows ear$^{-1}$ | Number of kernels row$^{-1}$ | 100 kernel weight (g) |
|---|---|---|---|---|---|---|---|---|
| SC 10 | N | 63.00 | 257.50 | 148.12 | 24.62 | 14.04 | 47.12 | 44.71 |
| | WS | 65.50 | 240.00 | 135.00 | 22.19 | 13.81 | 42.49 | 40.14 |
| SC 128 | N | 61.87 | 240.62 | 138.12 | 25.04 | 15.19 | 47.49 | 44.80 |
| | WS | 65.87 | 237.50 | 130.00 | 22.91 | 13.81 | 42.70 | 40.62 |
| SC 130 | N | 62.87 | 243.12 | 138.75 | 25.17 | 15.27 | 45.84 | 40.70 |
| | WS | 64.87 | 230.00 | 123.75 | 22.04 | 14.35 | 41.95 | 38.32 |
| SC 132 | N | 63.37 | 255.00 | 145.00 | 25.22 | 15.86 | 46.39 | 45.40 |
| | WS | 65.37 | 235.62 | 128.75 | 23.27 | 14.27 | 43.69 | 40.85 |
| SC 162 | N | 63.37 | 260.00 | 139.37 | 25.06 | 14.96 | 46.36 | 39.37 |
| | WS | 65.37 | 245.00 | 130.00 | 22.65 | 13.71 | 43.40 | 37.61 |
| SC 166 | N | 62.00 | 241.87 | 136.87 | 24.90 | 15.40 | 44.35 | 41.02 |
| | WS | 63.50 | 232.50 | 136.25 | 22.61 | 14.60 | 42.95 | 40.33 |
| SC 168 | N | 61.87 | 249.37 | 145.62 | 26.25 | 15.27 | 46. 71 | 41.41 |
| | WS | 64.50 | 231.25 | 132.50 | 23.09 | 14.14 | 42.52 | 39.95 |
| SC 176 | N | 62.00 | 241.87 | 133.12 | 24.64 | 14.97 | 44.81 | 40.19 |
| | WS | 64.62 | 237.50 | 128.75 | 21.69 | 14.02 | 40.89 | 39.02 |
| SC 178 | N | 63.00 | 256.87 | 142.50 | 23.74 | 14.97 | 44.99 | 41.90 |
| | WS | 66.25 | 233.75 | 133.12 | 22.39 | 14.09 | 42.31 | 40.29 |
| TWC 321 | N | 62.75 | 255.00 | 146.87 | 24.24 | 14.84 | 44.40 | 40.96 |
| | WS | 64.50 | 240.00 | 125.00 | 21.49 | 14.02 | 41.36 | 39.40 |
| TWC 324 | N | 63.62 | 253.12 | 148.12 | 25.19 | 14.46 | 44.42 | 41.36 |
| | WS | 65.00 | 233.75 | 134.37 | 22.67 | 13.77 | 42.94 | 39.19 |
| TWC 329 | N | 63.12 | 267.50 | 141.87 | 25.26 | 15.70 | 46.84 | 42.00 |
| | WS | 66.00 | 233.75 | 133.12 | 23.81 | 13.85 | 43.92 | 38.67 |
| TWC 352 | N | 62.25 | 241.87 | 147.50 | 21.46 | 16.54 | 41.29 | 38.81 |
| | WS | 64.50 | 233.75 | 127.50 | 21.34 | 14.54 | 39.87 | 36.82 |
| TWC 353 | N | 60.87 | 256.25 | 138.12 | 20.92 | 15.27 | 40.35 | 40.39 |
| | WS | 64.37 | 235.00 | 127.50 | 20.16 | 14.01 | 40.25 | 38.54 |
| TWC 360 | N | 64.00 | 251.25 | 136.25 | 24.29 | 16.11 | 44.26 | 44.27 |
| | WS | 64.75 | 230.62 | 124.37 | 23.35 | 14.47 | 43.10 | 39.72 |
| TWC 368 | N | 63.25 | 248.12 | 138.75 | 26.32 | 15.72 | 45.02 | 41.84 |
| | WS | 64.62 | 240.00 | 132.50 | 23.42 | 15.07 | 43.35 | 38.67 |
| F test | | ** | ** | * | ** | * | ** | ** |

*** and ** refer to significant 0.05 and 0.01 probability levels, respectively.  N: normal irrigation  WS: water stress**

**Table 7. Estimates of grain yield plant$^{-1}$ for 16 hybrids under normal irrigation and water stress and drought sensitivity index (DSI) across two years.**

| Hybrid | Grain yield plant$^{-1}$ (g) | | DSI |
|---|---|---|---|
| | N | WS | |
| SC10 | 152.15 | 113.51 | 1.18 |
| SC128 | 159.84 | 119.16 | 1.18 |
| SC130 | 139.79 | 103.74 | 1.20 |
| SC132 | 154.89 | 119.09 | 1.07 |
| SC162 | 127.87 | 103.57 | 0.89 |
| SC166 | 137.64 | 107.91 | 1.00 |
| SC168 | 143.67 | 116.22 | 0.88 |
| SC176 | 125.22 | 101.76 | 0.87 |
| SC178 | 137.15 | 113.74 | 0.79 |
| TWC321 | 149.45 | 103.99 | 1.41 |
| TWC324 | 138.49 | 106.70 | 1.07 |
| TWC329 | 134.21 | 98.54 | 1.23 |
| TWC352 | 128.11 | 111.65 | 0.60 |
| TWC353 | 124.64 | 104.40 | 0.75 |
| TWC360 | 130.30 | 102.63 | 0.99 |
| TWC368 | 137.15 | 115.36 | 0.74 |
| Mean | 138.79 | 108.87 | |

**N: normal irrigation WS: water stress**

For grain yield plant$^{-1}$ (table 7), all hybrids increased under N than under WS. The highest hybrid for grain yield plant$^{-1}$ were SC 128 followed by SC 132, SC 10 and TWC 321 under N and SC 128 followed by SC 132, SC 168 and TWC 368 under WS, meaning that SC 128 and SC 132 were the highest for grain yield plant$^{-1}$ under both N and WS. Abou-Ellil (1992) and Abd El-Latif *et al.* (2011) found that the interaction between maize genotypes and irrigation regimes was significant for grain yield.

Drought sensitivity index (DSI) is used as parameter to provide estimate for stress tolerance, where low value<1 indicates to high drought stress tolerance. The drought sensitivity index values for single crosses ranged from 0.79 for SC 178 to 1.2 for SC 130. The best drought tolerant single crosses were SC 178 followed by SC 176, SC 168 and SC 162. Meanwhile for three-way crosses, DSI ranged from 0.6 for TWC 352 to 1.41 for TWC 321. The best drought tolerant three-way crosses were TWC 352, TWC 368, TWC 353 and TWC 360. From above results the single crosses SC 178 and SC 176, also the three-way crosses TWC 352 and TWC 368 have the ability to tolerate drought.

**Effect of the interaction between hybrids x years x water irrigations:**

The performance of hybrids under normal and water stress conditions in the two seasons 2018 and 2019 are presented in Table 8.

**Table 8. Effect of the interaction between hybrid x year x water treatments on eight studied traits.**

| Hybrid | Year | Days to 50% silking | | Ear height (cm) | | Ear length (cm) | | 100 kernel weight (g) | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | WS | N | WS | N | WS | N | WS |
| SC 10 | 2018 | 63.75 | 65.25 | 150.00 | 132.50 | 24.70 | 21.35 | 44.50 | 38.85 |
| | 2019 | 62.25 | 65.75 | 146.25 | 137.50 | 24.55 | 23.02 | 44.92 | 41.42 |
| SC 128 | 2018 | 61.50 | 66.25 | 135.00 | 123.75 | 25.27 | 21.85 | 44.70 | 38.47 |
| | 2019 | 62.25 | 65.50 | 141.25 | 136.25 | 24.80 | 23.97 | 44.90 | 42.77 |
| SC 130 | 2018 | 63.50 | 64.25 | 137.50 | 118.75 | 25.25 | 21.20 | 40.80 | 38.17 |
| | 2019 | 62.25 | 65.25 | 140.00 | 128.75 | 25.10 | 22.87 | 40.60 | 38.47 |
| SC 132 | 2018 | 63.50 | 65.50 | 140.00 | 127.50 | 25.27 | 22.45 | 45.50 | 41.05 |
| | 2019 | 63.25 | 65.25 | 150.00 | 130.00 | 25.17 | 24.10 | 45.30 | 40.65 |
| SC 162 | 2018 | 63.50 | 65.50 | 136.25 | 122.50 | 24.40 | 20.02 | 39.42 | 38.25 |
| | 2019 | 63.25 | 65.25 | 142.50 | 137.50 | 24.07 | 22.95 | 39.32 | 36.97 |
| SC 166 | 2018 | 62.50 | 63.75 | 136.25 | 132.50 | 25.25 | 21.97 | 40.35 | 39.72 |
| | 2019 | 61.50 | 63.25 | 141.25 | 136.25 | 25.12 | 23.37 | 41.70 | 40.95 |
| SC 168 | 2018 | 61.50 | 64.50 | 145.00 | 123.75 | 25.40 | 23.55 | 40.75 | 40.00 |
| | 2019 | 62.25 | 64.50 | 146.25 | 141.25 | 25.12 | 24.07 | 42.07 | 39.90 |
| SC 176 | 2018 | 62.50 | 64.75 | 135.00 | 131.25 | 25.20 | 21.70 | 39.55 | 39.42 |
| | 2019 | 61.50 | 64.50 | 131.25 | 126.25 | 24.92 | 23.60 | 40.82 | 38.62 |
| SC 178 | 2018 | 63.75 | 66.00 | 141.25 | 121.25 | 25.05 | 20.72 | 41.47 | 39.05 |
| | 2019 | 62.25 | 66.50 | 145.00 | 143.75 | 24.75 | 24.50 | 42.32 | 41.52 |
| TWC 321 | 2018 | 63.75 | 64.50 | 146.25 | 126.25 | 26.70 | 21.92 | 40.25 | 38.47 |
| | 2019 | 61.75 | 64.25 | 147.50 | 123.75 | 25.80 | 24.25 | 41.67 | 40.32 |
| TWC 324 | 2018 | 64.75 | 64.50 | 151.25 | 128.75 | 24.62 | 19.85 | 41.90 | 38.35 |
| | 2019 | 62.50 | 65.50 | 145.00 | 140.00 | 24.65 | 23.52 | 40.82 | 40.02 |
| TWC 329 | 2018 | 64.00 | 66.25 | 137.50 | 128.75 | 24.20 | 21.72 | 41.37 | 38.90 |
| | 2019 | 62.25 | 65.75 | 146.25 | 137.50 | 23.27 | 23.05 | 42.62 | 38.45 |
| TWC 352 | 2018 | 62.25 | 64.75 | 157.50 | 123.75 | 21.60 | 21.12 | 39.25 | 36.20 |
| | 2019 | 62.25 | 64.25 | 137.50 | 131.25 | 21.55 | 21.32 | 38.37 | 37.45 |
| TWC 353 | 2018 | 60.75 | 64.25 | 133.75 | 126.25 | 20.70 | 19.75 | 40.05 | 38.32 |
| | 2019 | 61.00 | 64.50 | 142.50 | 128.75 | 21.15 | 20.57 | 40.72 | 38.75 |
| TWC 360 | 2018 | 64.50 | 64.75 | 133.75 | 120.00 | 24.62 | 22.97 | 44.50 | 36.90 |
| | 2019 | 63.50 | 64.75 | 138.75 | 128.75 | 23.95 | 23.72 | 46.05 | 42.55 |
| TWC 368 | 2018 | 64.25 | 64.50 | 137.50 | 136.25 | 26.47 | 22.22 | 42.07 | 36.52 |
| | 2019 | 62.25 | 64.75 | 141.25 | 127.50 | 26.17 | 24.62 | 41.60 | 40.82 |
| F test | | ** | | * | | * | | * | |

*** and ** refer to significant 0.05 and 0.01 probability levels, respectively. N: normal irrigation WS: water stress**

The interaction between the three factors was significant for days to 50% silking, ear height, ear length and 100 kernel weight, while for other traits was not significant, meaning that the interaction between hybrids and years was affected by water treatment. The earliest hybrids in 2018 season were TWC 353 followed by SC 128 and SC168 under N and SC 166 followed by SC 130 and TWC 353 under WS while the earliest hybrids in 2019 were TWC 353 followed by SC 166 and SC 176 under N and SC 166 followed by TWC 321 and TWC 352 under WS. For ear height, the highest hybrids in 2018 were TWC 352 and TWC 324 under N and TWC 368 followed by SC 10 and SC 166 under WS while in 2019 were SC 132 followed by TWC 321 under N and SC 178 followed by SC 168 under WS. For ear length the longest ears in 2018 were hybrids TWC 321 followed by TWC 368 under N and SC 168 followed by TWC 360 under WS, while the longest ears in 2019 were hybrids TWC 368 followed by TWC 321 under N and TWC 368 followed by SC 178 under WS. For 100 kernel weight the highest hybrids in 2018 were SC 132 followed by SC 128 under N and SC 132 followed by SC 168 under WS while in 2019 were TWC 360 followed by SC 132 under N and SC 128 followed by TWC 360 under WS.

Estimates of simple correlation coefficient between grain yield plant$^{-1}$ and other traits are presented in Table 9. Simple correlation coefficient between grain yield plant$^{-1}$ and each of ear length and number of kernels row$^{-1}$ under normal irrigation were positive and significant, while the correlation between grain yield plant$^{-1}$ and 100 kernel weight under normal irrigation and water stress were significant, meaning that increased ear length and number of kernels row$^{-1}$ under N and 100 kernel weight under N and WS are the cause of increased grain yield and *vice versa*.

**Table 9. Estimates of correlation coefficients between grain yield plant$^{-1}$ and other studied traits under normal and stress irrigation(WS).**

| Trait | Grain yield plant$^{-1}$ | |
|---|---|---|
| | N | WS |
| Days to 50% silking | 0.104 | 0.182 |
| Plant height | -0.038 | 0.065 |
| Ear height | 0.411 | 0.303 |
| Ear length | 0.424* | 0.215 |
| Number of roWS ear$^{-1}$ | -0.296 | 0.190 |
| Number of kernels row$^{-1}$ | 0.620** | 0.142 |
| 100 kernels weight | 0.652** | 0.489** |

***, ** refer to significant at 0.05 and 0.01 probability levels, respectively.**
**N: normal irrigation WS: water stress**

Also grain yield plant$^{-1}$ under N and WS might be improved through selection for high 100 kernel weight. Khatun *et al.* (1999) mentioned that grain yield plant$^{-1}$ was positively and significantly correlated with 1000 grain weight, number of kernels ear$^{-1}$ and ear height. Aminu and Izge (2012) found that 100-seed weight exhibited positive and significant correlation with grain yield under water stress conditions.

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# تقييم بعض هجن الذرة الشامية تحت ظروف الإجهاد المائي

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**قسم بحوث الذرة الشامية – معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية – جيزة – مصر**

تم إجراء تجربتين بمحطة البحوث الزراعية بالجميزة الاولى تحت ظروف الري الطبيعي والثانية تحت ظروف الاجهاد المائي عن طريق إسقاط الرية الثالثة والرابعة خلال موسمي 2018 ، 2019 , لدراسة تحمل 16 هجين للإجهاد المائي. استخدم تصميم الشرائح المنشقة بأربعة مكررات في جميع التجارب. تم عمل التحليل التجميعي وأظهرت النتائج ان الاختلافات بين السنتين معنوي او عالية المعنوية لغالبية الصفات. كما اظهرت وجود معنوية عالية بين ظروف الري العادية وظروف الاجهاد المائي في كل الصفات. أظهرت الهجن اختلافات عالية المعنوية لكل الصفات. تأثرت متوسطات الهجن بمعاملات الري المختلفة حيث كان أعلى الهجن الفردية للمحصول هـ ف 128و هـ ف 132 تحت ظروف الري العادي وظروف الاجهاد المائي بينما اعلى الهجن الثلاثية هي هـ ث 321 تحت ظروف الري العادي و هـ ث 368 تحت ظروف الاجهاد المائي. أفضل الهجن في تحمل الجفاف هي الهجن الفردية هـ ف178 و هـ ف 168 كذلك الهجن الثلاثية هـ ث 352 و هـ ث 368 طبقا لدليل حساسية الجفاف. تبين معنوية الارتباط بين طول الكوز وعدد الحبوب بالصف مع محصول النبات تحت ظروف الري العادي كذلك معنوية الارتباط بين وزن 100 حبة ومحصول النبات تحت كل من ظروف الري العادي وظروف الاجهاد المائي.