# Performance of Some New White Maize Crosses under Water Stress Condition

A.S.M. AL-Deeb[1],Noura A. Hassan[1], M.S. Abd El-Latif[1], H.A.A. Mohamed[1]and A.K. Abdelhalim[2]

1. Maize Res. Dept., Field Crops Res. Inst., ARC, Egypt.
2. Water Req. and Field Irri. Res. Dept., Soil, Water and Env. Res. Inst., ARC, Egypt.

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**ABSTRACT:**The field experiment was conducted at Sids Agriculture Research Station in two planting dates (mid-May and mid-June) during 2021season to investigate the response of 23 new maize hybrids and four check hybrids under two irrigation treatments; every12 days (normal irrigation) and every 24 days (water stress). A split split plot design with three replications was used, where the main plots occupied by two planting dates and the irrigation treatments were in sub-plot while 27 hybrids distributed randomly in the sub-sub-plots during seasons. Combined analysis revealed that mean grain yield of planting date at mid-June was significantly increased than at mid-May dates (22.4*vs.*16.6 ard/fed). Also, mean grain yield under normal irrigation 26.8 ard/fed was significant higher than under water stress 12.1 ard/fed (A grain yield reduction 55%). Total water amount used at first planting date (mid-May) was 2913 $m^3$/fed under normal irrigation and 1622 $m^3$/fed under water stress (water saving 44%). Mean while, total water amount at second planting date (mid-June) was 2647$m^3$/fed under normal irrigation and 1453 $m^3$/fed under water stress (water saving of 45%). Means of all crosses under normal irrigation were higher than under water stress for plant height (cm), ear height (cm) and grain yield (ard/fed), whereas the opposite obtained for days to 50% silking. Three single crosses, Nub72×Nub89 followed by Nub79×Nub89 and Nub79×Nub86 and one three-way cross SC24×Nub86 recorded the highest grain yield under normal irrigation and water stress and had the best values for water productivity (WP), yield response factor (Ky) and drought susceptibility index (DSI), indicated that hybrids had higher tolerance under water deficit.

***Keywords****: Zea mays, water stress, drought, tolerance, DSI and Ky.*

## INTRODUCTION

Maize (*Zea mays* L.) is one of the most important food and fodder crops in Egypt and the world. In Egypt, the area of the maize in 2023 season was 3.2 million Fadden with total production 7.6 million ton (Egypt State Information Service). Change of climate and water deficit were the tow problems for maize production. So, developing many crosses between new genotypes during 2020 season and investigated 2021 season to found maize hybrids tolerance for water stress.

According **Ainer *et al* (1986)** found that under water stress grain yield/feddan was decreased. Also, **Ibrahim *et al* (1992)** found that grain yield/feddan were significantly decreased with the increase of irrigation intervals (10, 14 and 18 days).However, **Atta-Allah (1996)** studied the effect of irrigation intervals (10, 15 and 20 days) on plant height, ear height and grain yield traits. He found that these traits were significantly increased with shorting irrigation interval. On the other hand, **Abdel-Mawgood *et al* (1999)** studied the effect of three water regimes varying irrigation intervals (12, 16 and 20 days) on different traits. They found that the differences among the three water regimes were highly significant for days to 50% silking, plant height, ear height and grain yield per plant. Also, **Oyekale *et al* (2008)** stated that the usefulness of drought susceptibility index (DSI) for determining drought stress and suggest that maize hybrids with DSI values around 0.6 from field trials have potentials for satisfactory productivity under drought stress. Over and above, **Karasu *et al* (2015)** reported that, irrigation levels significantly affected the maize grain yield. However, **Shankar *et al* (2022)** stated that, drought tolerant of hybrids can help maintain high maize productivity under limited water conditions. while, **Shojaei *et al* (2022)** state that, it can be possible through traditional breeding programs to achieve remarkable genetic progress in improving maize yield under conditions of water stress associated with high temperatures**.** as soon as, **Khatibi *et al* (2022)** reported that, the productivity of the maize crop depends largely on the amount of water available through the interval between the emergence of male and female inflorescences and up to a period of two weeks after the appearance of silks during this stage, the total number of grains in the plant is determined, water stress during that stage negatively effects the seed nodes, also the exposure of plants during the different stages of growth to severe water stress negatively effects plant height and ear height, and at the same time the increase in the number of days in which the formation of silk reaches 50% due to the lack of water. Planting dates are one of the important factors in maize cultivation. In Egypt maize is planted successfully from mid-April to mid-August, although most of the area is planted between May to mid-June as optimum period for production. All of, **El-Hosary (1988), Al-Ahmed *et al* (2004), Khallil *et al* (2013) and Abd El-Aty*et al* (2014)** found significant differences between planting date and their interaction with genotypes for grain yield days to 50% silking, plant height and ear height.

The objective of this investigation is: to study the effects of planting date and water stress treatment on days to 50% silking, plant height, ear height and grain yield to identify the best genotypes under different planting date and irrigation treatments.

## MATERIALS AND METHODS

Fifteen white inbred lines developed at Nubaria maize breading program, one white inbred line developed at Sids maize breeding program and two promising single crosses (SC 21 and SC 24) were randomly crossed to produce 21 white single crosses and two three-way crosses at Nubaria Agriculture Research Station to investigate tolerance for water stress at sids region in 2021 season. These 23 new hybrids in addition to four commercial hybrids (SC10, SC128, TWC321 and TWC324) were evaluated under two planting dates (15 May and 15 June) at Sids Agriculture Research Station in 2021 season. Split Split plot design with three replicates was used at each planting date. Two planting dates as main plot, two irrigation treatments as sub-plots; irrigation each 12 days (normal irrigation) and irrigation each 24 days (water stress),while the 27 hybrids were randomly allocated to the sub-sub-plots.

Plot size was one ridge 0.80 m apart, 0.25 m between hills with long 4 m. Two grains were planted per hill and later thinned to one plant. The recommended agronomic practices were done except irrigation treatments. The data were recorded for number of days from planting to mid-silking for each plot. Plant height was measured in (cm) from ground surface to flag leaf. Ear height was measured in (cm) from ground surface to ear leaf. Grain yield ardab/feddan(ard/fed) adjusted to 15.5% grain moisture.

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

$$\mathbf{DSI = (1 - Y_d/Y_p)/D}$$

where:

| | | |
|---|---|---|
| **DSI** | = | An index of drought susceptibility. |
| **$Y_d$** | = | Performance if a genotype under drought stress. |
| **$Y_p$** | = | 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.

### <u>Calculation of water requirements</u>:

**1. Reference Evapotranspiration ($ET_o$):**

The reference evapotranspiration ($ET_o$) value using data from the agricultural weather station were available and the Penman-Monteith method was used in **CROPWAT** model **(Smith, 1992)**, described by **Allen *et al*. (1998)** was used to calculate $ET_o$ as follows:

**Penman-Monteith Method:** Penman-Monteith equation is given as:

$$ETo = \frac{0.408\,\Delta\,(Rn - G) + \gamma\,[900/(T + 273)]\,U_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34\,U_2)}$$

where:

| | | |
|---|---|---|
| **Rn** | = | net radiation (MJ $m^{-2}d^{-1}$) |
| **G** | = | soil heat flux (MJ $m^{-2}d^{-1}$) |
| **Δ** | = | slope of vapor pressure and temperature curve ($kPaC^{o-1}$) |
| **$\gamma$** | = | psychrometric constant (kPa $C^{o-1}$) |
| **$U_2$** | = | wind speed at 2 m height ($ms^{-1}$) |
| **$e_s$-$e_a$** | = | vapor pressuredeficit (kPa) |
| **T** | = | mean daily air temperature at 2 m height (C°) |

The input parameters needed to calculate $ET_o$ using the CROPWAT model **(Smith, 1992)** are air temperature, relative humidity, sunshine hours, and wind speed. The data from Sids Station was used in this study. The average monthly meteorological data used in calculating $ET_o$ values for the 2021 growing season are listed in **Table (1).**

**Table 1.Agro-meteorological data and reference evapotranspiration values.**

| Month | T. min. ($^0$C) | T. max.($^0$C) | RH. (%) | WS. (m/sec) | $ET_o$.(mm) |
|---|---|---|---|---|---|
| **May** | 19.60 | 37.90 | 27.10 | 4.13 | 8.94 |
| **June** | 21.10 | 37.20 | 32.90 | 3.46 | 8.99 |
| **July** | 23.80 | 39.30 | 32.80 | 3.70 | 9.55 |
| **August** | 23.60 | 39.60 | 34.50 | 3.64 | 9.22 |
| **September** | 21.10 | 36.10 | 43.40 | 3.82 | 7.95 |
| **October** | 18.00 | 31.70 | 47.60 | 3.17 | 5.75 |

**T (air Temperature) - RH (Relative Humidity) - WS (Wind Speed)**

## 2. Crop Evapotranspiration (ETc):

The crop evapotranspiration (ETc) values were calculated according to equation of **Doorenbos and Pruitt (1977):**

$$ETc = EToXKc$$

$ET_c$ = Crop evapotranspiration (mm/day).
$ET_o$ = Evapotranspiration (mm/day).
$K_c$ = Crop coefficient of maize (0.87, 1.0, 1.85 and 0.81) for maize growth stages.

## 3. Amount of applied irrigation water (AIW):

The amounts ofwater applied was calculatedaccording to **Vermeiren and Jopling (1984)** as follows:

$$AIW = \frac{ETc}{Ea}$$

AIW = Applied Irrigation Water depth (mm/day).
$E_a$ = Irrigation application efficiency (60 % for surface irrigation system used under experimental conditions).

## 4. Water productivity (WP):

Water productivity is generally defined as economical crop yield per cubic meter of applied water consumption. It was calculated according to **Ali *et al* (2007)**.

$$WP = \frac{GY}{AIW}$$

WP = Water Productivity (kg /m$^3$).
GY = Grain Yield (kg /fed).
AIW = Applied Irrigation Water of the growing season (m$^3$/fed).

## 5. Yield response factor (Ky):

The Ky represents the relationship between relative evapotranspiration reduction (1-$\frac{ETa}{ETm}$) and relative yield reduction (1-$\frac{Ya}{Ym}$) it was determined using the method given by **Doorenbos and Kassam (1979).** as follows:

$$(1 - \frac{Ya}{Ym}) = Ky\ (1 - \frac{ETa}{ETm})$$

$Ya$ = Actual harvested yield.
$Ym$ = Maximum harvested yield.
$Ky$ = Yield response factor.
$ETa$ = Actual evapotranspiration.
$ETm$ = Maximum evapotranspiration.

Total water amount at normal irrigation treatment was about (2913 m$^3$/fed) at first planting date, while it was about (1622 m$^3$/fed) for the water stress treatment at the same planting date. The amount of irrigation water for normal treatment at second planting date was about (2647 m$^3$/fed), while it was about (1454 m$^3$/fed) for water stress treatment. The percentage of irrigation water saving was about 44% for first date and 45% for the second date **(Table 2)**.

**Table 2. Amount of used irrigation water at Sids Agriculture Research Station in 2021season for two planting dates.**

| Irrigation Number | Planting date | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 15-May | | | | 15-June | | | |
| | Normal | | Stress | | Normal | | Stress | |
| | Mm | m$^3$/fed | Mm | m$^3$/fed | mm | m$^3$/fed | mm | m$^3$/fed |
| **Irri. 1** | 79.75 | 335 | 79.75 | 335 | 76.12 | 320 | 76.12 | 320 |
| **Irri. 2** | 77.77 | 327 | 0.00 | 0 | 77.73 | 326 | 0.00 | 0 |
| **Irri. 3** | 76.12 | 320 | 76.12 | 320 | 78.65 | 330 | 78.65 | 330 |
| **Irri. 4** | 76.12 | 320 | 0.00 | 0 | 78.65 | 330 | 0.00 | 0 |
| **Irri. 5** | 78.65 | 330 | 78.65 | 330 | 63.80 | 268 | 63.80 | 268 |
| **Irri. 6** | 78.65 | 330 | 0.00 | 0 | 63.80 | 268 | 0.00 | 0 |
| **Irri. 7** | 76.90 | 323 | 76.90 | 323 | 63.80 | 268 | 63.80 | 268 |
| **Irri. 8** | 74.80 | 314 | 0.00 | 0 | 63.80 | 268 | 0.00 | 0 |
| **Irri. 9** | 74.80 | 314 | 74.80 | 314 | 63.80 | 268 | 63.80 | 268 |
| **Irri. 10** | 12.60 | 53 | 0.00 | 0 | 4.16 | 17 | 0.00 | 0 |
| **Total** | **693.56** | **2913** | **386.22** | **1622** | **630.15** | **2647** | **346.17** | **1453.91** |

**Irri= Irrigation, mm = Millimeter, fed =feddan**

**Statistical Analysis:**

Split Split plot design with three replications was used at each planting date. Two planting dates was main plot, two irrigation treatments as sub-plots; irrigation each 12 days (normal irrigation) and irrigation each 24 days (water stress), while the 27 hybrids were randomly allocated to the sub-sub-plots. Homogeneity of error variance was found, therefore, the combined analysis over two planting date for the studied traits was done. The studied traits were analyzed using proc. Anova by **SAS software version 9.1 (2008)**.

**RESULTS AND DISCUSSION**

The results on **(Table 3),** showed that significant or highly significant differences between two planting dates (D) were detected for days to 50% silking, plant height, ear height and grain yield. Also, highly significant differences values were observed of irrigation treatments (I) for grain yield, while the interaction between (D×I) was not significant for all studied traits. These results agreed with those of **Gheysari *et al* (2017) and El-Sabagh *et al* (2018).** Significant or highly significant differences were observed for the tested hybrids (H) and their interactions (H×D),(H×I) and (H×D×I) for all studied traits except (H×D×I) for plant and ear heights. These results are in agreement with those of **El-Hosary (1988) and Abd El-Latif*et al* (2011)**.

**Table3. Analysis of variance for days to 50% silking, plant height, ear height and grain yield across two planting date.**

| SOV | Df | Days to 50% Silking | Plant height | Ear height | Grain yield |
|---|---|---|---|---|---|
| **Planting date (D)** | 1 | 1503.72** | 54444.44* | 30917.36* | 1265.23** |
| **Error a** | 4 | 7.90 | 3009.88 | 2057.56 | 28.06 |
| **Irrigation (I)** | 1 | 38.72$^{ns}$ | 24544.44$^{ns}$ | 11200.69$^{ns}$ | 10383.84** |
| **D× I** | 1 | 18.78$^{ns}$ | 259.57$^{ns}$ | 434.03$^{ns}$ | 130.06$^{ns}$ |
| **Error b** | 4 | 12.19 | 7232.09 | 2636.57 | 24.59 |
| **Hybrids (H)** | 26 | 88.23** | 513.001** | 290.04** | 91.94** |
| **H× D** | 26 | 13.63** | 297.17** | 174.42** | 18.34** |
| **H× I** | 26 | 17.37** | 194.93* | 117.68* | 17.33** |
| **H× D × I** | 26 | 19.34** | 131.21 $^{ns}$ | 112.56 $^{ns}$ | 19.65** |
| **Error c** | 208 | 3.49 | 110.65 | 72.15 | 6.31 |
| **CV%** | - | 2.91 | 4.97 | 7.57 | 11.87 |

***, ** Indicate significant at 0.05 and 0.01 levels of probability, respectively.**

Effects of planting dates on four studied traits are shown in **(Table4)**, the means for plant height, ear height and grain yield were higher at mid-June than mid-May. While the reverse was obtained for days to 50% silking, meaning that the planting date at mid-June increased grain yield, plant height, ear height and earliness. **El-Hosary (1988), Sedhom (1994) and Amer *et al* (2001)** found that, planting dates differed for grain yield. **Awad *et al* (1993) and Salem (1993)** reported that planting in June gave the highest grain yield.

**Table4. Effect of planting date on four studied traits.**

| Planting date | Days to 50% Silking | Plant height (cm) | Ear height (cm) | Grain yield(ard/fed) |
|---|---|---|---|---|
| **Mid-May** | **66.6** | **198.9** | **102.5** | **16.6** |
| **Mid-June** | **62.3** | **224.8** | **121.9** | **22.4** |
| **$LSD_{0.05}$** | **0.87** | **16.93** | **13.99** | **1.64** |

Effect of irrigation treatments on four studied traits are presented in **(Table 5)**, the results showed that mean of grain yield under normal irrigation (26.8 ard/fed) was higher than under water stress (12.1 ard/fed), meaning that water stress decreased grain yield. This result agreed with this of **Abd El-Latif *et al* (2011)**.

**Table5. Effect of irrigation treatments on four studied traits.**

| Irrigation | Days to 50% Silking | Plant height (cm) | Ear height (cm) | Grain yield (ard/fed) |
|---|---|---|---|---|
| **Normal Irrigation** | **64.1** | **220.5** | **118.1** | **26.8** |
| **Water Stress** | **64.7** | **203.1** | **106.4** | **12.1** |
| **$LSD_{0.05}$** | **1.1** | **26.3** | **15.9** | **3.1** |

Mean performance of 27 hybrids under two planting dates for all studied traits are shown in **(Table 6)**.For days to 50% silking all hybrids were earlier under mid-June (D-2) than mid-May (D-1). The hybrids ranged from 57.7 days for (Nub80×Nub 65) to 71.5 days for (Nub86×Nub 89) under D-1 and from 56.8 days for (Nub80×Nub 65) to 64.8 for (Nub73×Nub86) under D-2. The best hybrids for earliness compared with the check SC128 were (Nub55 ×Nub68), (Nub77×Nub56), and (Nub80×Nub65) under both D-1 and D-2. As for plant height, all hybrids under (D-1) were shorter than (D-2), the hybrids ranged from 186.7 cm for (Nub69 × Nub76) to 214.2 cm for (Nub76×Nub86) under D-1 and from 196.7 cm for (Sd10×Nub 86) to 239.2 cm for TWC324 under D-2. For ear height, all hybrids except (Sd10×Nub86) were higher under D-2 than D-1 and ranged from 95.0 cm for (Nub77×Nub86) to 109.2 cm for (SC24×Nub86) under D-1 and from 102.0 cm for (Sd10×Nub86) to 134.2 cm for (SC10 and TWC 324) under D-2. For grain yield, all hybrids were higher under D-2 than D-1.The hybrids under D1 ranged from 12.8 ard/fed for (Nub71×Nub86) to 27.6 ard/fed for (Nub72×Nub89), while under D2 ranged from 18.5 ard/fed for (SC21×Nub86) to 28.1 ard/fed for (Nub79×Nub86). The three single crosses (Nub72 ×Nub89), (Nub79×Nub86) and (Nub79× Nub89) had significantly higher grain yield than the best check SC 128 under D-1, while only hybrid (Nub79×Nub86) did not differ significantly from SC 128 under D-2. Three-way cross (SC24× Nub86) was significantly higher than the best check TWC 321 for grain yield under D-1 and D-2. The above superior hybrids will be evaluated in advanced evaluation stages.

**Table 6.Mean performance of 27 hybrids under two planting dates for four studied traits.**

| Hybrid | Days to 50% Silking | | Plant height (cm) | | Ear height (cm) | | Grain yield (ard/fed) | |
|---|---|---|---|---|---|---|---|---|
| | **D-1** | **D-2** | **D-1** | **D-2** | **D-1** | **D-2** | **D-1** | **D-2** |
| **Nub55×Nub68** | **60.7** | **59.5** | **203.4** | **223.4** | **104.2** | **117.5** | **18.0** | **22.7** |
| **Nub55×Nub86** | **66.4** | **60.7** | **197.5** | **226.7** | **103.4** | **115.0** | **18.7** | **21.5** |
| **Nub55×Nub89** | **65.7** | **60.2** | **202.5** | **232.5** | **102.5** | **129.2** | **18.1** | **24.1** |
| **Nub68×Nub89** | **67.2** | **61.7** | **196.7** | **211.7** | **96.7** | **113.4** | **18.4** | **24.5** |
| **Nub69×Nub76** | **65.0** | **59.7** | **186.7** | **215.8** | **100.8** | **115.8** | **17.6** | **23.2** |
| **Nub69×Nub86** | **64.4** | **63.7** | **198.4** | **225.8** | **102.5** | **121.7** | **14.6** | **21.1** |
| **Nub71×Nub86** | **71.2** | **64.5** | **197.5** | **222.5** | **104.2** | **120.0** | **12.8** | **21.3** |
| **Nub71×Nub89** | **70.8** | **63.8** | **188.4** | **230.8** | **100.0** | **127.5** | **20.8** | **26.6** |
| **Nub72×Nub86** | **66.5** | **63.2** | **210.0** | **233.4** | **108.4** | **130.8** | **19.9** | **22.6** |
| **Nub72×Nub89** | **68.2** | **62.2** | **200.0** | **224.2** | **104.2** | **122.5** | **27.6** | **27.8** |
| **Nub73×Nub86** | **68.7** | **64.8** | **200.0** | **210.8** | **100.0** | **110.0** | **19.8** | **21.9** |
| **Nub73×Nub89** | **69.2** | **64.0** | **200.8** | **233.4** | **104.2** | **133.4** | **22.8** | **22.2** |
| **Nub76×Nub86** | **67.4** | **64.0** | **214.2** | **231.7** | **111.7** | **125.0** | **17.8** | **21.4** |
| **Nub77×Nub56** | **60.5** | **57.0** | **195.0** | **231.7** | **100.8** | **128.4** | **21.6** | **21.9** |
| **Nub77×Nub86** | **63.0** | **58.0** | **187.5** | **227.5** | **95.0** | **122.5** | **14.2** | **20.2** |
| **Nub78×Nub55** | **66.2** | **61.5** | **196.7** | **227.5** | **101.7** | **124.2** | **18.5** | **24.7** |
| **Nub79×Nub86** | **67.8** | **63.4** | **201.7** | **225.0** | **103.4** | **122.5** | **23.6** | **28.1** |
| **Nub79×Nub89** | **67.7** | **62.4** | **195.8** | **226.7** | **105.8** | **126.7** | **23.4** | **27.3** |
| **Nub80×Nub65** | **57.7** | **56.8** | **192.5** | **227.5** | **100.0** | **123.4** | **19.2** | **23.1** |
| **Nub86×Nub89** | **71.5** | **64.0** | **195.8** | **210.0** | **97.0** | **115.8** | **17.5** | **20.1** |
| **Sd10×Nub86** | **71.0** | **63.0** | **195.0** | **196.7** | **103.4** | **102.5** | **18.7** | **18.9** |
| **SC21×Nub86** | **70.8** | **64.5** | **199.2** | **210.8** | **98.4** | **107.5** | **18.0** | **18.5** |
| **SC24×Nub86** | **66.0** | **61.5** | **206.7** | **223.4** | **109.2** | **120.8** | **23.5** | **27.2** |
| **SC10** | **65.7** | **65.4** | **201.7** | **239.2** | **102.5** | **134.2** | **18.7** | **22.2** |
| **SC128** | **65.0** | **63.0** | **202.5** | **230.0** | **100.0** | **122.5** | **20.9** | **28.0** |
| **TWC321** | **66.4** | **63.5** | **201.7** | **231.7** | **100.0** | **126.7** | **17.8** | **24.2** |
| **TWC324** | **66.4** | **64.4** | **201.7** | **239.2** | **105.8** | **134.2** | **17.8** | **19.0** |
| **$LSD_{0.05}$** | **2.11** | | **11.90** | | **9.61** | | **2.84** | |

**D (planting date), Nub (Nubaria), SC (Single Crosses), TWC (Three-Way Crosses).**

The results in **Table (7)**, showed that all hybrids were higher for grain yield under normal irrigation (N) than water stress (S), the hybrids under (N) ranged from 22.6 ard/fed for

(Nub69×Nub86) to 32.9 ard/fed for (Nub72× Nub89). Mean while the hybrids under (S) ranged from 11.2 ard/fed for (Nub71×Nub86) to 22.5 ard/fed for (Nub72×Nub89). The Three new white single crosses (Nub72×Nub89), (Nub79×Nub86) and (Nub79×Nub89) had higher for grain yield under normal irrigation and water stress than the best check SC 128. While the three-way cross (SC24×Nub86) significantly out-yielded under normal irrigation and water stress the best check TWC 324, meaning the grain yield for hybrids were decreased under water stress. The same results were obtained by **Song *et al* (2019), Abd-Elaziz *et al* (2020), Asrat (2021), Su *et al* (2022), Schwartz *et al* (2022), Shojaei *et al* (2022) and Khatibi *et al* (2022).** The hybrids (Nub72× Nub89), (Nub79×Nub86), (Nub79×Nub8) and (SC24×Nub86) had the highest water productivity (WP) values (1.66, 1.60, 1.60 and 1.57 kg/m$^3$) under normal irrigation and (2.05, 1.82,1.72 and 1.79 kg/m$^3$)under water stress. **Habliza and Abdel halim (2017)** found that average crop water productivity values increased with decreasing applied water. The hybrids (Nub55 ×Nub89),(Nub71×Nub86),(Nub77×Nub8) and (Nub80×Nub65) had the highest yield response factor (Ky) values, (1.28, 1.14, 1.11 and 1.09) respectively, this is an indicator of these hybrids low tolerance under deficit water, on the other hand,hybrids(Nub72×Nub86),(Nub72×Nub89),(Nub73×Nub8)(Nub79×Nub86),(Nub79×Nub89),(Sd10×Nub86), and (SC24×Nub86) give Lowe values (0.62, 0.70, 0.82, 0.82, 0.90, 0.75 and 0.81 respectively), which means that these hybrids had higher tolerance under water deficit. Drought sensitivity index (DSI) is used to provide estimate for stress tolerance, where low value < 1 indicates a high drought stress tolerance. For this parameter, the new crosses (Nub72×Nub86), (Nub72×Nub89),(Sd10×Nub86), (Nub79×Nub86) and (SC24×Nub86) had an index about 0.67, 0.76, 0.81, 0.88 and 0.88, respectively. On the other hand, the crosses (Nub55×Nub89)and (Nub71× Nub86) had the highest index for grain yield (1.37 and 1.23,respectively). From above results the three single crosses (Nub72×Nub89), (Nub79× Nub89) and (Nub79×Nub86) and one three-way cross (SC24×Nub86) recorded the highest grain yield under normal irrigation and water stress and had the best values for water productivity (WP), yield response factor (Ky) and drought sensitivity index (DSI).The superior crosses under water stress condition may be used in new lands where the water irrigation is considered the main unavailable factor. The varietal differences were found by some researchers which indicated high differences among hybrids studied for drought tolerance **Golbashy *et al* (2010), Khayatnezhad *et al* (2010), Moradi *et al* (2012) and Abd-Elaziz *et al* (2020).**

**Table (7). Effect of the interaction between hybrids and water treatment on grain yield (ardb/fed), Water productivity (WP), Yield response factor (KY) and drought susceptibility index (DSI).**

| Hybrid | Grain yield (ard/fed) | | AIW (m$^3$/fed) | | WP (Kg/m$^3$ water) | | KY | DSI |
|---|---|---|---|---|---|---|---|---|
| | N | S | N | S | N | S | | |
| Nub55×Nub68 | 25.9 | 14.8 | 2780 | 1538 | 1.30 | 1.35 | 0.95 | 1.02 |
| Nub55×Nub86 | 26.5 | 13.7 | 2780 | 1538 | 1.33 | 1.25 | 1.07 | 1.15 |
| Nub55×Nub89 | 29.6 | 12.6 | 2780 | 1538 | 1.49 | 1.15 | 1.28 | 1.37 |
| Nub68×Nub89 | 27.8 | 15.1 | 2780 | 1538 | 1.40 | 1.37 | 1.02 | 1.09 |
| Nub69×Nub76 | 25.5 | 15.2 | 2780 | 1538 | 1.28 | 1.38 | 0.90 | 0.96 |
| Nub69×Nub86 | 22.6 | 13.2 | 2780 | 1538 | 1.14 | 1.20 | 0.92 | 0.99 |
| Nub71×Nub86 | 23.0 | 11.2 | 2780 | 1538 | 1.16 | 1.02 | 1.14 | 1.23 |
| Nub71×Nub89 | 30.1 | 17.3 | 2780 | 1538 | 1.52 | 1.57 | 0.94 | 1.02 |
| Nub72×Nub86 | 24.7 | 17.8 | 2780 | 1538 | 1.24 | 1.62 | 0.62 | 0.67 |
| Nub72×Nub89 | 32.9 | 22.5 | 2780 | 1538 | 1.66 | 2.05 | 0.70 | 0.76 |
| Nub73×Nub86 | 25.6 | 16.1 | 2780 | 1538 | 1.29 | 1.47 | 0.82 | 0.89 |
| Nub73×Nub89 | 28.3 | 16.6 | 2780 | 1538 | 1.43 | 1.51 | 0.92 | 0.99 |
| Nub76×Nub86 | 25.1 | 14.1 | 2780 | 1538 | 1.26 | 1.28 | 0.97 | 1.05 |
| Nub77×Nub56 | 27.0 | 16.5 | 2780 | 1538 | 1.36 | 1.50 | 0.86 | 0.93 |
| Nub77×Nub86 | 22.9 | 11.5 | 2780 | 1538 | 1.15 | 1.05 | 1.11 | 1.19 |
| Nub78×Nub55 | 26.7 | 16.5 | 2780 | 1538 | 1.34 | 1.50 | 0.85 | 0.91 |
| Nub79×Nub86 | 31.7 | 20.0 | 2780 | 1538 | 1.60 | 1.82 | 0.82 | 0.88 |
| Nub79×Nub89 | 31.8 | 18.9 | 2780 | 1538 | 1.60 | 1.72 | 0.90 | 0.97 |
| Nub80×Nub65 | 28.0 | 14.3 | 2780 | 1538 | 1.41 | 1.30 | 1.09 | 1.17 |
| Nub86×Nub89 | 24.4 | 13.3 | 2780 | 1538 | 1.23 | 1.21 | 1.01 | 1.09 |
| Sd10×Nub86 | 22.7 | 15.0 | 2780 | 1538 | 1.14 | 1.37 | 0.75 | 0.81 |
| SC21×Nub86 | 23.4 | 13.2 | 2780 | 1538 | 1.18 | 1.20 | 0.97 | 1.04 |
| SC24×Nub86 | 31.1 | 19.7 | 2780 | 1538 | 1.57 | 1.79 | 0.81 | 0.88 |
| SC10 | 25.4 | 15.5 | 2780 | 1538 | 1.28 | 1.41 | 0.87 | 0.93 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **SC128** | **31.1** | **17.8** | **2780** | **1538** | **1.57** | **1.62** | **0.95** | **1.02** |
| **TWC321** | **26.0** | **16.0** | **2780** | **1538** | **1.31** | **1.46** | **0.85** | **0.92** |
| **TWC324** | **24.2** | **12.5** | **2780** | **1538** | **1.22** | **1.14** | **1.07** | **1.15** |
| **LSD $_{0.05}$** | **2.84** | | **-** | | **-** | | **-** | **-** |

**N=(Normal irrigation), S=(Water stress), Nub=(Nubaria), SC=(Single Crosses), TWC=(Three Way Crosses).**

**In Table 8,** the results showed that, the number of days to 50% silking, for all hybrids were earlier under normal irrigation compared with water stress condition, indicating that the water deficit delayed silk emergence. The hybrids ranged from 56.7 days for (Nub80×Nub65) to 67.5 days for (Nub71×Nub86)under (N) while ranged from 57.8 days for (Nub80×Nub65) to 68.5 days for (SC21×Nub86) under (S). The hybrids (Nub55×Nub68), (Nub77×Nub56), (Nub77×Nub86) and (Nub80×Nub65) were earlier than the best check SC128 under normal irrigation and water stress. The influence of hybrids by different irrigation treatments for days to 50% silking has been investigated by Meany researchers **Song *et al* (2019), Abd-Elaziz *et al* (2020), Asrat (2021), Chukwudi *et al* (2022) and Saad-Allah *et al* (2022).** For plant height, means of all hybrids under normal irrigation were higher than water stress condition. The shortest hybrid was (Sd10×Nub86) under (N) and (Nub76×Nub86) under (S).The selected single crosses (Nub68×Nub89), (Nub69×Nub76), (Nub86×Nub89) and (Sd10×Nub86) and the three-way cross (SC21×Nub86) had low means under (N) and (S). Influence on plant height of hybrids by irrigation treatments was obtained by many researchers **Abd El-latif *et al* (2011), Aslam *et al* (2013), Rekaby *et al* (2017), Song *et al* (2019), Abd-Elaziz *et al* (2020), Chukwudi *et al* (2022) and Saad-Allah *et al* (2022)**. For ear height, the lower mean value was 105.8 cm for (Sd10×Nub86) under (N) and 95.9 cm for (SC21×Nub86) under (S), while the highest value was 131.7 cm for TWC 324 under (N) and 116.7 cm for (Nub72×Nub86) under (S). The selected new single crosses (Nub68×Nub89), (Nub73× Nub86) and (Sd10×Nub86) and new three-way cross (SC21×Nub86) had low values for ear height under (N) and(S). These results are in agreement with **Abd El-latiff *et al* (2011), Aslam *et al* (2013), Rekaby *et al* (2017), Song *et al* (2019), Abd-Elaziz *et al* (2020) and Saad-Allah *et al* (2022).**From above results the selected hybrids can be used in breeding programs for earliness and plant density tolerant.

**Table 8.Effect of the interaction between hybrids and irrigation treatments on days to 50% silking, plant height and ear height**.

| **Hybrid** | **Days to 50% silking** | | **Plant height(cm)** | | **Ear height(cm)** | |
|---|---|---|---|---|---|---|
| | N | S | N | S | N | S |
| **Nub55×Nub68** | **58.7** | **61.5** | **220.05** | **206.7** | **114.2** | **107.6** |
| **Nub55×Nub86** | **63.2** | **63.9** | **215.85** | **208.4** | **113.4** | **105.0** |
| **Nub55×Nub89** | **61.0** | **64.9** | **232.55** | **202.6** | **125.1** | **106.7** |
| **Nub68×Nub89** | **62.9** | **66.0** | **215.05** | **193.4** | **112.5** | **97.6** |
| **Nub69×Nub76** | **60.1** | **64.6** | **214.20** | **188.4** | **115.1** | **101.7** |
| **Nub69×Nub86** | **61.3** | **66.7** | **222.55** | **201.7** | **120.1** | **104.2** |
| **Nub71×Nub86** | **67.5** | **68.2** | **215.05** | **205.1** | **117.6** | **106.7** |
| **Nub71×Nub89** | **67.0** | **67.6** | **222.55** | **196.7** | **124.2** | **103.4** |
| **Nub72×Nub86** | **64.7** | **65.0** | **227.55** | **215.9** | **125.0** | **114.2** |
| **Nub72×Nub89** | **64.9** | **65.5** | **220.05** | **204.2** | **115.9** | **110.9** |
| **Nub73×Nub86** | **66.0** | **67.5** | **217.50** | **193.4** | **112.5** | **97.5** |
| **Nub73×Nub89** | **65.5** | **67.7** | **229.20** | **204.9** | **128.4** | **109.2** |
| **Nub76×Nub86** | **64.9** | **66.5** | **228.35** | **217.6** | **120.1** | **116.7** |
| **Nub77×Nub56** | **58.5** | **59.0** | **224.20** | **202.5** | **120.9** | **108.4** |
| **Nub77×Nub86** | **60.2** | **60.8** | **210.00** | **205.0** | **110.1** | **107.6** |
| **Nub78×Nub55** | **62.4** | **65.3** | **215.90** | **208.4** | **115.9** | **110.1** |
| **Nub79×Nub86** | **65.1** | **66.2** | **217.55** | **209.2** | **116.7** | **110.1** |
| **Nub79×Nub89** | **64.9** | **65.4** | **222.55** | **200.0** | **121.7** | **109.2** |
| **Nub80×Nub65** | **56.7** | **57.8** | **217.55** | **202.6** | **114.2** | **110.9** |
| **Nub86×Nub89** | **67.4** | **68.2** | **213.40** | **192.6** | **115.9** | **97.5** |
| **Sd10×Nub86** | **66.9** | **67.2** | **204.20** | **187.6** | **105.8** | **100.1** |
| **SC21×Nub86** | **66.9** | **68.5** | **215.85** | **194.2** | **109.9** | **95.9** |
| **SC24×Nub86** | **62.9** | **64.7** | **218.40** | **211.7** | **117.4** | **112.6** |
| **SC10** | **63.4** | **67.7** | **233.40** | **207.5** | **128.4** | **108.4** |
| **SC128** | **63.1** | **64.9** | **217.55** | **215.1** | **113.4** | **109.2** |
| **TWC321** | **63.9** | **66.1** | **229.20** | **204.2** | **123.4** | **103.4** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **TWC324** | **63.1** | **67.7** | **235.00** | **205.9** | **131.7** | **108.4** |
| **LSD $_{0.05}$** | **2.11** | | **11.90** | | **9.61** | |

**N(Normal), S(Stress), Nub(Nubaria), SC (Single Crosses), TWC(Three Way Crosses).**

## CONCLUSION

The mean grain yield at mid-June planting date was significantly more than at mid-May planting date. Also, mean grain yield under normal irrigation was significantly higher than under water stress. Grain yield reduction was 55% and save about 45% under water stress treatment. Three single crosses (Nub72×Nub89), (Nub79× Nub89) and (Nub79×Nub86) and new three-way cross (SC24×Nub86) gave the best values for grain yield under both normal irrigation and water stress and had desirable values for WP, KY and DSI, indicating that these hybrids were tolerant under water deficit.

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## الملخص العربي

# أداء بعض هجن الذرة الشامية الجديدة تحت ظروف الإجهاد المائى.

أيمن سالم محمد الديب[1]،نورة على حسن[1]، محمود شوقى عبداللطيف[1]، هانى عبدالله عبدالمجيد محمد[1]،
عبدالهادى خميس عبد الحليم[2]

1-قسم بحوث الذرة الشامية – معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية.

2-قسم بحوث المقننات المائية والرى الحقلى – معهد بحوث الأراضى والمياه والبيئة – مركز البحوث الزراعية.

أجريت تجربة حقلية بمحطة البحوث الزراعية بسدس في موعدين للزراعة (منتصف مايو ومنتصف يونيو) خلال الموسم 2021 تحت معاملتين للرى:الأولى الرى كل 12 يوم (الرى العادى) والثانية الرى كل 24 يوم (إجهاد مائى) لدراسة استجابة 23 هجيناً جديداً من الذرة الشامية البيضاء وأربعة هجن مقارنة. تم إستخدام تصميم القطع المنشقة مرتين فى ثلاثة مكررات لكل ميعاد زراعة بحيث اشتملت القطع الرئيسية على مواعيد الزراعة والقطع المنشقة الاولي اشتملت علي معاملات الرى واشتملت القطع المنشقة الثانية على الهجن موزعة عشوائيا. أظهر تحليل التباين المشترك أن ميعاد الزراعة فى منتصف يونيو كان أعلى إنتاجية فى محصول الحبوب عن ميعاد الزراعة فى منتصف مايو (22.4 أردب/فدان مقابل 16.6 أردب/فدان). كذلك كان متوسط إنتاجية محصول الحبوب تحت الرى العادى 26.8 أردب/فدان أعلى مقارنة تحت ظروف الإجهاد المائى 12.1 أردب/فدان (نسبة إنخفاض محصول الحبوب 55%). كان إجمالى كمية المياه المستخدمة فى الرى لميعاد الزراعة الأول 2913 م$^3$/فدان تحت ظروف الرى العادى، 1622 م$^3$/فدان تحت ظروف الإجهاد المائى (44% توفير لمياه الرى). بينما كانت كمية المياه المستخدمة فى الرى لميعاد الزراعة الثانى 2647 م$^3$/فدان تحت ظروف الرى العادى و1453 م$^3$/فدان تحت ظروف الإجهاد المائي (45% توفير لمياه الرى). كانت متوسطات جميع الهجن تحت الرى العادى أعلى منها تحت ظروف الإجهاد المائي لصفات إرتفاع النبات وإرتفاع الكوز ومحصول الحبوب، والعكس لصفة عدد الأيام حتى ظهور 50% من حرائر النورات المؤنثة. أعطت ثلاثة هجن فردية وهى (Nub72 × Nub89) و (Nub79 × Nub89) و (Nub79×Nub86) والهجين الثلاثى (SC24×Nub86) أعلى إنتاجية لمحصول الحبوب تحت ظروف الرى العادى وتحت ظروف الإجهاد المائى ، كما أنها أعطت أفضل قيم مرغوبة فى إنتاجية المحصول لكل م$^3$ من المياه (WP)، وعامل استجابة المحصول (Ky) ودليل الحساسية للجفاف (DSI) والتى تشير إلى تحمل هذه الهجن لظروف الإجهاد المائى.