# Productivity Response of Some Maize (*Zea mays* L.) Hybrids To Stress and Nonstress Irrigation Water

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## ABSTRACT

Water deficit reduces grain yield of maize and other grain crops. The objectives of this study were to assess the productivity of ten maize hybrids (SC.10, SC.125, SC.129, SC155, SC162, TWC311, TWC321, TWC324, TWC327 and TWC352) under two varying water supplies (100 and 75% from adequate amount), to assess the level of tolerance of these hybrids under water deficit and to determine the associations among hybrids performance under adequate and deficit water conditions. The results showed that water deficit caused significant decreases in grain yield and other agronomic traits. The losses of grain yield, as affected by water deficit, across single-cross hybrids, were significantly higher than three-way hybrids. Under adequate water, SC10 and TWC324 gave the highest grain yield across years (10.52 and 9.71 Mg $ha^{-1}$), while, under deficit water, TWC321, TWC327 and SC162 had the highest grain yields (8.26, 7.19, and 7.62 Mg $ha^{-1}$, respectively). Grain yield reduction, due to water deficit, ranged from 6.0 to 30.5% for the tested hybrids. According to susceptible index (SI), TWC321 and TWC327 were the most tolerant hybrids to water deficit (0.27 and 0.33), followed by TWC311 (0.64), SC129 (0.72) and TWC352 (0.78). According to drought tolerance efficiency (DTE), TWC321 and TWC327 hybrids had the highest mean (94 and 92%). According to drought depression percentage (DD%), TWC321 and TWC327 had the lowest values (6.0 and 8.0%). Therefore, these hybrids might be more tolerant to water deficit. The results showed that water deficit was increased in the anthesis-silking interval (ASI) and silk emergence was delayed. SC129 was the least delayed hybrid under water deficit. For ASI, the lowest affected hybrids were SC162 and SC129. Significant positive correlation was observed between grain yield depression and SI ($r$ = 0.99, $p \leq 0.01$). Also, significant negative correlation was observed for DTE with both grain yield depression and SI ($r$ = -0.99, $p \leq 0.01$). Significant positive correlation was observed between $GY_{adq}$ and $GY_{def}$ ($r$ = 0.66, $p \leq 0.05$). It might be concluded that SC10 and TWC324 were the best hybrids under optimum conditions, while, TWC321 and TWC327 were more suitable hybrids under deficit water conditions.

***Key words: maize, water deficit, drought, dte, si, asi.***
***Abbreviations: $GY_{adq}$, grain yield under adequate water; $GY_{def}$, grain yield under deficit water; DD, drought depression; ASI, anthesis-silking interval; DTE, drought tolerance efficiency; SI, susceptibility index; SC, single-cross; TWC, three-way cross; Mg $ha^{-1}$, ton per hectare.***

## INTRODUCTION

Available water is one of the most limiting factors in maize production. Drought is estimated to cause average annual yield losses in maize of about 17% in the tropics (Edmeades *et al* 1989). Water deficit reduces grain yield of maize and other grain crops. Denmead and Shaw (1960) found that water stress reduced maize grain yield by 25, 50 and 21% prior to, during and after silking, respectively, compared with the nonstressed plots. Claasen and Shaw (1970) concluded that water stress, at 75% silking, resulted in greater reduction in maize grain yield (53% of the nonstressed), compared with stress during vegetative periods or three weeks after silking(15 and 30% of the nonstressed, respectively).

Drought stress may limit grain yield of maize by reducing the harvest index (HI, the fraction of crop dry matter allocated to the grain). This can occur even in the absence of a strong reduction in total crop dry matter accumulation, if a short period of stress coincides with the critical developmental stage around silking. Alternatively, water stress may prevent ovary fertilization by reducing silk receptivity (Bassetti and Westgate, 1993), or low kernel water potential may cause kernel growth to cease prematurely (Grant *et al.,* 1989; Schussler and Westgate, 1991). This later effect may lead to a reduced HI, even if water stress occurs late in the grain filling stage (Westgate, 1994).

Maize is particularly sensitive to water stress in the period from one week before to two weeks after flowering (Grant *et al.,* 1989). Drought during this period results in an easily measured increase in the anthesis-silking interval (ASI), as silk emergence is delayed (Edmeades *et al.,* 2000) and in grain abortion (Boyle *et al.,* 1991). Grain abortion commonly occurs during the first two to three weeks after silking (Westgate and Boyer, 1986; Schussler and Westgate, 1991). The most drought tolerant cultivar had the least delay in silking under water stress conditions. El-Sayed (1998) reported that water stress caused a significant delay in silking date when water stress was imposed at pre-flowering stage.

Maize is relatively insensitive to water stress imposed during early vegetative growth stages because water demand is relatively low and plants can be adapted to water stress to reduce the impact of subsequent periods of water stress (Shaw, 1977). However, maize grain yield is sensitive to water stress from just before silking through grain fill stage (Shaw, 1977; Hall *et al.*, 1981; Westgate and Boyer, 1986), with the greatest degree of sensitivity occurring during the period of kernel number determination (Andrade *et al.*, 2002). Hall *et al.* (1981) indicated that kernel number was most sensitive to stress between tasseling and just after silking.

Maize breeders succeeded in increasing average grain yield in the past 70 years, with 60% of the historic increase attributed to genetic improvement (Duvick, 1992). The genetic improvement has been more specifically ascribed to increase stress tolerance (Duvick, 1992; Tollenaar *et al.*, 1994).

The study of Tollenaar (1989) showed that a newer hybrid was more tolerant of water and nitrogen stress than the older hybrid. Thus, it was hypothesized that more recently developed hybrids should be more tolerant to these stresses than older hybrids.

The objectives of this study were: (*i*) to assess the responses of some maize hybrids under adequate and deficit water supply, (*ii*) to assess the level of tolerance of these hybrids under 75% of water requirement and (*iii*) to determine the associations between hybrids performance under adequate and deficit water conditions.

## MATERIALS AND METHODS

The present experiment was conducted at Nubaria Agriculture Research Station (latitude ≈ 29° 5; longitude ≈ 31° 9; altitude ≈ 0), during the growing summer seasons of 2007 and 2008. The soil at the site is a sandy clay loam (sand ≈ 64.6; silt ≈ 12.5; clay ≈ 22.9%) with pH ≈ 8.2. The crop was grown under drip irrigation system. Treatments consisted of two water levels (deficit and adequate irrigation) and ten maize hybrids (three white single-cross hybrids; i.e., SC.10, SC.125, SC.129; two yellow single-cross hybrids; i.e., SC155, SC162; four white three-way hybrids; i.e., TWC311, TWC321, TWC324, TWC327 and one yellow three-way hybrid, TWC352). These hybrids were selected because of their differences in genetic background. The hybrid, SC10, was included because it was the most popular and widely grown hybrid in Egypt. The experimental design was a split-plot design, with three replications, with the water levels as whole plots (24 rows, 70 cm wide and 6 m long) and the maize hybrids as sub-plots (two rows with 30 cm for hills). Each replication was divided into two main plots that differed in water supply (deficit and adequate water).

Water treatments (deficit and adequate irrigation) were initiated after 25 days from planting. Beginning on these dates, water was applied at a day interval. The adequate irrigation treatment received the amount of required water (about 6192 $m^3$ $ha^{-1}$), while, the deficit treatment received, approximately, 75% of this amount (about 4644 $m^3$ $ha^{-1}$),. This was continued through the remainder of the growing season. Each hybrid was seeded at a density of about 47620 plants $ha^{-1}$. A starter fertilizer was applied at the rate of 36 kg N, 50 kg $P_2O_5$ and 60 kg $K_2O$ $ha^{-1}$ at planting. The other recommended N fertilizer (about 300 kg N $ha^{-1}$) was completed at the proper time. Weed control was accomplished through herbicide application and cultivation. Pests were controlled with pesticide applications as needed.

As the error variance for the two years was homogeneous, as indicated by Barttlet test of significance, therefore, the combined analysis of variance was run, according to Steel and Torrie (1980). Analysis of variance for the studied characters was performed, using PROC ANOVA (Mixed model) of SAS software (version 9.1, 2003). Water treatment and hybrids were treated as fixed effects, while, years and replications were random effects. Mixed model FLSD was used the dominator of F as an error, where, test of significance for W was Y x W, and for H was Y x H. Treatment means were compared by FLSD and calculated, using SAS software.

Susceptibility index (SI) was estimated by using the formula, suggested by Fisher and Maurer (1978):

SI = [(Yi-adq – Yi-def)/Yi-adq] / [(adq - def) / adq]

where, Yi-adq was the yield of hybrid under adequate water; Yi-def was the yield of hybrid under deficit water; □adq was the overall yield of hybrids under adequate water and □def was the overall yield of hybrids under deficit water.

Drought tolerance efficiency (DTE) was estimated by using formula given by Fisher and Wood (1981), as follows:

DTE % = (Yield under stress / Yield under non-stress) x 100

Data were recorded for ears weight per plot (kg $plot^{-1}$), shelled, grain moisture was adjusted to 15.5 g $kg^{-1}$ and grain yield was converted to ton per hectare (Mg $ha^{-1}$). Number of days to mid-silking (d), anthesis-silking interval (d) and plant and ear heights (cm), also, were recorded.

Associations between grain yield and the other agronomic variables were determined with phenotypic correlations, using hybrid means across years by PROC CORR of SAS software (version 9.1, 2003).

## RESULTS AND DISCUSSION

Significant differences were detected between years for all the studied traits (Table 1). Water adequate vs. deficit was significantly affected for all the studied traits at the combined ANOVA model. Test for the effect of water regime was not sensitive as the dominator had a single degree of freedom, showing significance of plant height. Significant differences were observed among the evaluated hybrids for grain yield and number of days to mid-silking and anthesis-silking interval. Year x hybrid interaction, only, was significant for ear height. Water x hybrid interaction was significant for all the studied traits, except for ASI interval and plant height. Year x water x hybrid interaction was only significant for plant height (Table 1).

**Grain ield:**

Under deficit water, grain yield averaged, across hybrids, was 7.11 Mg ha$^{-1}$, while, grain yield was 8.70 Mg ha$^{-1}$ under adequate water (Table 2). No significant decrease, in grain yield, was observed across years, although the percentage of grain yield decrease, due to water deficient, was 22.5%. Insignificance of the effect of water might be due to the insensitivity of the F-test.

Regarding hybrids, the overall-mean of the evaluated single crosses was insignificantly higher than the three-way crosses under adequate water (8.89 vs. 8.46 Mg ha$^{-1}$), while, the opposite results were observed under deficit water (6.87 vs. 7.35 Mg ha$^{-1}$, Table 3). The depression of grain yield, as affected by water regime, across single-crosses, were significantly higher than three-way hybrids (2.02 and 1.11 Mg ha$^{-1}$), with depression percentage of 22.8 and 13%, respectively.

Under adequate water, SC.10 gave the highest grain yield across years (10.52 Mg ha$^{-1}$), followed by TWC324 (9.71 Mg ha$^{-1}$), then, SC162 (9.28 Mg ha$^{-1}$), while, SC155 had the lowest grain yield (7.12 Mg ha$^{-1}$, Table 3). Under deficit water, TWC321, TWC324 and SC162 had the highest grain yields across years (8.26, 7.77 and 7.62 Mg ha$^{-1}$, respectively, Table 3). Average grain yield of single crosses, at adequate irrigation, was significantly higher than that under deficit irrigation. For three-way crosses, the different was not significant.

Drought depression percentage of grain yield, due to water deficit, ranged from 6.0 to 31% for the tested hybrids (Table 3). Among the single-cross hybrids, SC129 had the lowest depression to water deficit (1.36 Mg ha$^{-1}$, with depression of 16%), followed by SC162, which had 1.66 Mg ha$^{-1}$ with 18% decrease. The three-way hybrids were less affected by water regime than single-cross hybrids across years (Table 3). Among these hybrids, TWC321 and TWC327 had the lowest grain yield depression (0.53 and 0.58 Mg ha$^{-1}$, respectively), with drought depression percentage of 6.0 and 8%. On the other hand, TWC324 had the highest grain yield reduction (1.94 Mg ha$^{-1}$), with depression percentage of 20%. It was noticed that SC10 had the highest grain yield depression percentage among the single-cross hybrids (31%), while, TWC324, which was genetically related with SC10, had the highest depression percentage among the three-way hybrids (20%).

**Table 1: Mean squares of grain yield and other traits for ten hybrids evaluated under adequate and deficit water in 2007 and 2008 seasons.**

| Source of variation | DF | Grain Yield | Number of days to mid-silking | Anthesis-silking interval | Plant height | Ear height |
|---|---|---|---|---|---|---|
| Years (Y) | 1 | 94.74** | 27.07** | 3.00* | 11485.6** | 36331.2** |
| Reps / Y | 4 | 1.25 | 0.49 | 0.28 | 51.5 | 90.5 |
| Water treatments (W) | 1 | 83.21 | 44.41 | 29.01 | 7022.7** | 5306.7 |
| Y x W | 1 | 8.96* | 1.01 | 1.01 | 3.3 | 149.6 |
| Error (a) | 4 | 0.99 | 0.51 | 0.28 | 325.8 | 379.9 |
| Hybrids (H) | 9 | 7.34* | 35.47** | 3.41* | 135.7 | 127.8 |
| Y x H | 9 | 1.64 | 1.17 | 0.62 | 172.0 | 112.9* |
| W x H | 9 | 2.22* | 11.24** | 1.95 | 177.1 | 92.2* |
| Y x W x H | 9 | 0.59 | 0.39 | 0.69 | 97.7** | 24.1 |
| Error (b) | 76 | 0.54 | 0.42 | 0.37 | 29.0 | 40.1 |
| CV | | 9.3 | 1.0 | 21.6 | 2.4 | 5.5 |

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

According to susceptible index (SI), a hybrid is more susceptible to water deficit if SI ≥ 1, while, it is more tolerant if SI ≥ 1. Therefore, TWC321 and TWC327 were the most tolerant hybrids to water deficit (0.27 and 0.33), followed by TWC311 (0.64), SC129 (0.72) and TWC352 (0.78). On the other hand, among single-cross hybrids, SC10 and SC155 hybrids were more susceptible to water deficit (1.38 and 1.30, respectively, Table 3), while, SC129 and SC162 were tolerant to water deficit (0.72 and 0.81%).

According to drought tolerance efficiency (DTE), TWC321 and TWC327 hybrids had the highest means (94 and 92%), therefore, these hybrids might be more tolerant to water deficit (Table 3). Also, TWC311, SC129, TWC352 and SC162 hybrids were tolerant to water deficit (86, 84, 83 and 82%, respectively). On the other hand, SC10 and SC155 hybrids were more susceptible to water deficit and had 69 and 71% of DTE, respectively. Deshmukh *et al.*, (2004) reported that the drought tolerant genotype had the highest drought tolerance efficiency, the minimum susceptible index and the minimum reduction in grain yield due to moisture stress.

The present results showed that water stress caused a differential decrease in grain yield, which varied from hybrid to another. These results were in accordance with those obtained by Essam (1992), Vicente *et al.*, (1999), Azeez *et al.*, (2005) and Balbaa (2007). They reported significant differences among maize genotypes under differed drought treatments for grain yield. The present results showed that grain yield tolerance to drought depended on the genotype under evaluation rather than the type of hybrid, however, the average depression of the single-crosses was higher than three-way crosses.

**Table 2: Means of grain yield and other traits for adequate and deficit water as an average of ten hybrids evaluated in 2007 and 2008.**

| Water treatment | Grain yield | Number of days to mid-silking | Anthesis-silking interval | Plant height | Ear Height |
|---|---|---|---|---|---|
| | (Mg ha$^{-1}$) | days | | cm | |
| Adequate water | 8.70 | 62.2 | 2.3 | 235.1 | 121.4 |
| Deficit water | 7.11 | 64.2 | 3.5 | 219.7 | 108.2 |
| Drought depression | 1.59 | -2.2 | -1.2 | 15.4* | 13.2 |
| Drought depression % | 22.5 | -3.5 | -52.1 | 6.6 | 10.9 |
| FLSD $_{(0.05)}$ | ---- | ---- | ---- | 2.3 | ---- |

* Indicates significant at 0.05 level of probability.

**Table 3: Means of grain yield under adequate and deficit water, drought depression (DD), drought depression percentage (DD%), susceptible index (SI) and drought tolerance efficiency (DTE) for ten hybrids evaluated across 2007 and 2008.**

| Hybrid | Grain yield | | | | | |
|---|---|---|---|---|---|---|
| | Adequate | Deficit | DD | DD | SI | DTE |
| | Mg ha$^{-1}$ | | | % | | % |
| SC10 | 10.52 | 7.31 | 3.21 | 31.0 | 1.38 | 69 |
| SC125 | 8.99 | 7.18 | 1.81 | 20.1 | 0.91 | 80 |
| SC129 | 8.55 | 7.19 | 1.36 | 16.0 | 0.72 | 84 |
| SC155 | 7.12 | 5.08 | 2.04 | 29.6 | 1.30 | 71 |
| SC162 | 9.28 | 7.62 | 1.66 | 18.0 | 0.81 | 82 |
| Average | 8.89 $^{a}$ | 6.87 $^{b}$ | 2.02* | 22.8 | ----- | --- |
| TWC311 | 8.14 | 6.98 | 1.16 | 14.0 | 0.64 | 86 |
| TWC321 | 8.79 | 8.26 | 0.53 | 6.0 | 0.27 | 94 |
| TWC324 | 9.71 | 7.77 | 1.94 | 20.0 | 0.90 | 80 |
| TWC327 | 7.77 | 7.19 | 0.58 | 8.0 | 0.33 | 92 |
| TWC352 | 7.90 | 6.54 | 1.36 | 17.0 | 0.78 | 83 |
| Average | 8.46 $^{a}$ | 7.35 $^{a}$ | 1.11 | 13.0 | ---- | ---- |
| LSD0.05 | | 1.0 | | | | |

* Significant at 0.05 probability level.
Means of the two groups of hybrids having the same letter are not significance, according to $FLSD_{0.05}$.

Data in Fig.1 showed that SC10 had the highest grain yield under adequate water, followed by TWC324 and SC162, while, TWC321, TWC324 and SC162 gave the highest grain yield under deficit water conditions. The lowest grain yield was observed for SC155 under both adequate and deficit water conditions. Furthermore, the least depression, in grain yield, was observed for TWC321 and TWC327.

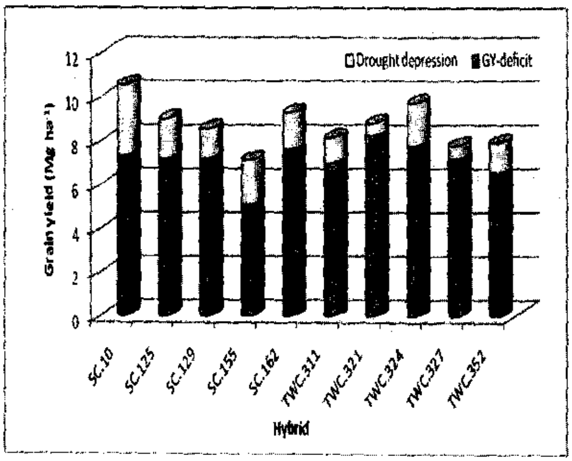


**Fig.1: Grain yield under adequate and deficit water and drought depression for ten hybrids evaluated under adequate and deficit water as an average of 2007 and 2008.**

**Number of days to mid-silking:**

Significant differences were detected, among hybrids, for number of days to mid-silking across years (Table 1). Also, water x hybrid interaction was highly significantly different ($p \leq 0.01$). Results showed that water deficit treatment caused a delay in silk emergence by 2.2 days for combined data (Table 2). Mean number of days to mid-silking, under both water treatments, was more for single-cross hybrids than for three-way hybrids (62.6 and 64.9 vs. 61.4 and 63.5, respectively, Table 4). Among single-cross hybrids, SC125 and SC155 had the highest significant delay in silk-emergence than the other hybrids under water treatment across years (-4.7* and -4.1* d, respectively), while, SC129 had the least delay under the same conditions (-0.6 d). Among three-way hybrids; TWC311, TWC324 and TWC352 were significantly affected by water deficit, where, they were delayed by -3.0, -2.5 and -3.5 d, respectively. On the other hand, TWC321 and TWC327 were not significantly affected by water deficit treatment (-0.5 and -0.6 d, respectively).

Delay in silk-emergence, due to water stress treatment, which was obtained in this study, was in accordance with results stated by Frederick *et al.*, (1989) and El-Sayed (1998). They reported that water stress caused a significant delay in silking date, when water stress was imposed at pre-flowering.

**Table 4: Number of days to mid-silking and anthesis-silking interval for ten maize hybrids evaluated under adequate and deficit water across two years.**

| Hybrid | Number of days to mid-silking | | | Anthesis-silking interval (ASI) | | |
|---|---|---|---|---|---|---|
| | Adequate | Deficit | Depression | Adequate | Deficit | Depression |
| | | day | | | day | |
| SC 10 | 63.1 | 64.1 | -1.0* | 3.0 | 4.5 | -1.5* |
| SC 125 | 62.3 | 67.0 | - 4.7* | 2.0 | 4.0 | -2.0* |
| SC 129 | 62.8 | 63.4 | - 0.6 | 2.7 | 3.4 | -0.7 |
| SC 155 | 59.5 | 63.6 | - 4.1* | 2.7 | 4.6 | -1.9* |
| SC 162 | 65.3 | 66.5 | -1.2* | 2.0 | 2.6 | -0.6 |
| **Average** | 62.6 a | 64.9 a | - 2.3 a | 2.5 | 3.8 | -1.3 a |
| TWC 311 | 60.3 | 63.3 | - 3.0* | 3.0 | 4.0 | -1.0* |
| TWC 321 | 62.3 | 62.8 | - 0.5 | 2.0 | 2.5 | -0.5 |
| TWC 324 | 62.1 | 64.6 | - 2.5* | 2.3 | 3.7 | -1.4* |
| TWC 327 | 63.1 | 63.7 | - 0.6 | 2.0 | 2.5 | -0.5 |
| TWC 352 | 59.5 | 63.0 | - 3.5* | 1.8 | 3.3 | -1.5* |
| **Average** | 61.4 b | 63.5 b | - 2.0 a | 2.2 a | 3.2 b | -1.0 a |
| $FLSD_{0.05}$ | | 0.8 | | | 1.1 | |

* Significant at 0.05 probability level.
Means of the two groups of hybrids having the same letter are not significant, according to $FLSD_{0.05}$.

**Anthesis-silking interval:**

Significant differences were observed among hybrids, at combined data, for anthesis-silking interval (ASI) (Table 1). Water stress increased the ASI by 1.2 day (Table 2). Under adequate water treatment, the difference between mean of single-crosses and three-way hybrids was not significant (2.5 vs. 2.2 days). Also, under deficit water treatment, no difference was observed between them (3.8 vs. 3.2 days, Table 4). In addition, mean of depression was not different for single-cross than three-way hybrids (-1.3 vs. 1.0). Among single-cross hybrids; SC125, SC155 and SC10 were significantly affected by water deficit (-2.0, -1.9 and -1.5 d, respectively), while, the lowest affected hybrids were SC162 and SC129 (-0.6, and -0.7 d, respectively. Among three-way hybrids; TWC352, TWC324 and TWC311 were significantly affected by water deficit treatment (-1.5, -1.4 and -1.0 d, respectively), while, TWC321 and TWC327 hybrids were more tolerant to deficit water, therefore, these hybrids might be more suitable under deficit water conditions than the other hybrids.

These results are in agreement with those of Grant *et al.*, (1989) and Edmeades *et al.*, (2000), where, they reported that water stress, during flowering period, resulted in an easily measured increase in the anthesis-silking interval (ASI), as silk emergence was delayed. Also, El-Sayed (1998) found that water stress caused a significant increase (delay) in silking date by 7.4, 6.1 and 6.7 days in three genotypes.

Maize is thought to be more susceptible to stresses at flowering than many crops, because of the large distance between male and female organs, exposing pollen and fragile stigmatic tissues to desiccating conditions during pollination (Banziger *et al.*, 2000).

**Plant and ear heights:**

Significant differences were detected between years, water treatments and year x water x hybrid interaction for plant height at combined analysis (Table 1). Plants were significantly shorter under water deficit (219.7 vs. 235.1 cm), with significant drought depression of 15.4 cm and DD% by 6.6% (Table 2). Also, mean ear height was lower for water deficit (108.2 vs. 121.4 cm). No significant differences were observed for drought depression between means of single-cross and three-way hybrids for plant and ear heights (Table 5). Depression of plant height, due to water deficit, was insignificant for SC155 and SC129 (5.2 and 7.5cm). Also, depression in mean ear height, due to water deficit treatment, was low for TWC311, SC155 and TWC321 (6.8, 7.8 and 8.8 cm, respectively).

**Association between grain yield and other variables:**

To determine the associations between hybrid performance under deficit and adequate levels of water, simple correlation analysis was conducted, using mean yields of the hybrids grown under both levels of water. This analysis revealed that hybrid grain yield, under the two water regimes, was significantly associated ($r$ = 0.66, $p \leq 0.05$). Thus, on the average, a high yielding hybrid would be high under both conditions.

**Table 5: Mean plant and ear heights for ten maize hybrids evaluated under adequate and deficit water across two years.**

| Hybrid | Plant height | | | Ear height | | |
|---|---|---|---|---|---|---|
| | Adequate | Deficit | Depression | Adequate | Deficit | Depression |
| | | cm | | | cm | |
| SC 10 | 237.2 | 220.8 | 16.4* | 124.3 | 111.3 | 13.0* |
| SC 125 | 233.3 | 216.7 | 16.6* | 121.3 | 110.7 | 10.6* |
| SC 129 | 229.3 | 221.8 | 7.5 | 121.5 | 109.3 | 12.2* |
| SC 155 | 227.7 | 222.5 | 5.2 | 117.0 | 109.2 | 7.8* |
| SC 162 | 252.7 | 218.5 | 34.2* | 132.3 | 107.8 | 24.5* |
| **Average** | 236.0 a | 220.1 a | 15.9 a | 123.3 a | 109.6 a | 13.6 a |
| TWC 311 | 233.3 | 218.0 | 15.3* | 118.3 | 111.5 | 6.8* |
| TWC 321 | 232.2 | 216.0 | 16.2* | 116.3 | 107.5 | 8.8* |
| TWC 324 | 235.2 | 220.2 | 15.0* | 125.5 | 107.0 | 18.5* |
| TWC 327 | 235.7 | 221.8 | 13.9* | 122.2 | 104.0 | 18.2* |
| TWC 352 | 232.3 | 219.5 | 12.8* | 114.7 | 102.2 | 12.5* |
| **Average** | 233.7 a | 219.1 a | 14.6 a | 119.4 b | 106.4 b | 12.9 a |
| $FLSD_{(0.05)}$ | | 12.8 | | | 6.4 | |

* Significant at 0.05 probability level.
Means of the two groups of hybrids having the same letter are not significant, according to $FLSD_{0.05}$.

**Table 6: Phenotypic correlation among grain yield under adequate water ($GY_{adq}$), grain yield under deficit water ($GY_{def}$), drought depression (DD), susceptibility index (SI), drought tolerant efficiency (DTE), number of days to mid-silking (SLK), anthesis-silking interval (ASI), plant height (PLHT) and ear height (ERHT) for ten maize hybrids across 2007 and 2008.**

| | $GY_{adq}$ | $GY_{def}$ | DD | SI | DTE | SLK | ASI | PLHT |
|---|---|---|---|---|---|---|---|---|
| $GY_{adq}$ | 1.00 | | | | | | | |
| $GY_{def}$ | 0.66* | 1.00 | | | | | | |
| DD | 0.28 | -0.52 | 1.00 | | | | | |
| SI | 0.28 | -0.53 | 0.99** | 1.00 | | | | |
| DTE | -0.28 | 0.53 | -0.99** | -0.99** | 1.00 | | | |
| SLK | 0.52 | 0.51 | 0.04 | -0.04 | 0.03 | 1.00 | | |
| ASI | -0.25 | -0.61 | 0.49 | 0.49 | -0.49 | -0.22 | 1.00 | |
| PLHT | 0.39 | 0.25 | 0.11 | 0.11 | -0.12 | 0.59 | -0.43 | 1.00 |
| ERHT | 0.65* | 0.32 | 0.35 | 0.34 | -0.35 | 0.83* | 0.04 | 0.66* |

*, ** indicate significance at the 0.05 and 0.01 levels of probability, respectively.

Significant positive correlation was observed between grain yield depression and susceptible index (SI) ($r$ = 0.99**), While, it was negatively correlated with drought tolerant efficiency (DTE). These results would indicate that the three coefficients, for measuring crop tolerance to water stress, were similar and the best among them was drought depressed, as it was possible to test its significance. Significant positive correlation was observed between plant height and ear height ($r$ = 0.66, $p \le 0.05$). The three measurements of tolerance were independent from silking date and ASI.

Finally, it might be concluded that SC10 and TWC324 were suitable hybrids under adequate water, while, TWC321 and TWC327 were more suitable hybrids under deficit water conditions.

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## الملخص العربى

# الإستجابة الإنتاجية لبعض هجن الذرة الشامية للإجهاد وعدم الإجهاد المائى للرى

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- تهدف هذه الدراسة الى تقدير انتاجية عشرة هجن من الذرة الشامية (SC.10, SC.125, SC.129, SC155, SC162, TWC311, TWC321, TWC324, TWC327 and TWC352)، تحت مستويين مختلفين من الماء (١٠٠% و٧٥% من الإحتياجات) وتقدير مستوى تحمل هذه الهجن لنقص المياه بالإضافة إلى تحديد العلاقة بين كفاءة الهجن تحت ظروف الإجهاد وعدم الإجهاد المائى.
- أوضحت النتائج أن نقص مياه الرى أدت إلى نقص فى كمية محصول الحبوب وأيضا للصفات الآخرى تحت الدراسة ، وأن النقص فى محصول الحبوب فى الهجن الفردية كان أكثر منه فى الهجن الثلاثية.
- أعطى الهجين الفردى "١٠" والهجين الثلاثى "٣٢٤" – تحت ظروف الرى المثلى – أعلى محصول للحبوب كمتوسط للموسمين ، حيث كان ١٠,٥٢ و٩,٧١ طن للهكتار ، بينما أعطت الهجن الثلاثية " ٣٢١ و٣٢٤ و٣٢٧" وكذلك الهجين الفردى "١٦٢" أعلى محصول للحبوب (٨,٢٦ و ٧,٧٧ و ٧,١٩ و٧,٦٢ طن للهكتار على التوالى) تحت ظروف نقص المياه. وترواحت نسبة الإنخفاض فى محصول حبوب الهجن للإجهاد المائى من ٦ إلى ٣٠,٥%.
- بناء على معامل الحساسية لنقص المياه (SI) ، كانت الهجن الثلاثية "٣٢١ و ٣٢٧" هى أكثر الهجن تحملا لنقص المياه ، يليها الهجين الثلاثى "٣١١" والهجين الفردى "١٢٩" وكذلك الهجين الثلاثى "٣٥٢".
- على ضوء معامل تحمل الجفاف (DTE) ، أعطى الهجينان الثلاثيان "٣٢١ و ٣٢٧" أعلى القيم لهذا المعامل، وبالتالى فانهما يعتبران أفضل الهجن تحملا للجفاف ، يليهما الهجين الثلاثى "٣١١" والهجين الفردى "١٢٩" وكذلك الهجين الثلاثى "٣٥٢" والهجين الفردى "١٦٢".
- كان الهجين الفردى "١٢٩" أقل الهجن تأثرا بنقص المياه من حيث عدد الأيام حتى متوسط ظهور الحريرة ، كما أن الهجينين الثلاثيين "٣٢١ و ٣٢٧" لم يظهرا تأثيرًا معنويًا فى عدد الأيام بنقص المياه.
- بالنسبة للفترة بين انتثار حبوب اللقاح وظهور الحرائر (ASI) ، كان الهجينان الفرديان "١٢٩ و ١٦٢" هما أقل الهجن تأثرا بنقص مياه الرى ، وأيضا لم يتأثر الهجينان الثلاثيان "٣٢١ و ٣٢٧" معنويا بنقص مياه الرى.
- أظهرت النتائج وجود علاقة ارتباط موجبة معنوية بين متوسط محصول الحبوب – تحت ظروف الرى المثلى – ومحصول الحبوب تحت ظروف الجفاف. كذلك كانت هناك علاقة إرتباط سالبة معنوية بين معامل تحمل الجفاف (DTE) وكل من الإنخفاض الراجع للجفاف ومعامل الحساسية (SI) ، وكانت معاملات الارتباط قريبة من الواحد الصحيح (٠,٩٩) مما يوصى باستعمال الانخفاض فى المحصول كدليل على تحمل الجفاف. وكان معامل الإرتباط غير معنوى بين ASI وبين المقاييس الثلاثة لتحمل الجفاف.
- أظهرت الدراسة أن الهجين الفردى "١٠" والهجين الثلاثى "٣٢٤" أفضل الهجن تحت ظروف الرى المثلى ، بينما كان الهجينان الثلاثيان "٣٢١ و ٣٢٧" أفضل الهجن تحت ظروف نقص مياه الرى.