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# GENETICS OF SOME GRAIN SORGHUM TRAITS UNDER DIFFERENT WATER-STRESS CONDITIONS

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## ABSTRACT

Five cms lines of grain sorghum and 5 restorers of variable tolerance to drought were crossed in 1999 season to make 25 $F_1$'s. In 2000 season, parents and crosses were evaluated in field experiments at two locations (Assiut and Shandaweel) under full irrigation (control),water stress at preflowering (GS2) and postflowering (GS3) stages. The objectives were to study heterosis , combining ability, type of gene action and heritability for some yield and agronomic attributes under different drought stress conditions. Average heterobeltiosis was at maximum for plant height followed by grain yield /plant under both stress and non-stress conditions. Heterobeltiosis for grain yield in the cross (A-88006 x R-89022) was 47.5 and 92.7 % under stress at GS2 and GS3, respectively. The restorers V-112 and R-90011 and the cms lines B-1 and B-102 were the best general combiners for grain yield under stressed and non-stressed conditions. The crosses A-37 X V-112, A-37 X RTX82BDM499 under all soil moisture regimes, A-88005 x R-90011 under control and stress at GS3 and A-88006 X R-90011 under control and stress at GS2 had the most favourable SCA effects for grain yield. Additive ($\delta^2_A$) variance was appreciably larger than dominance ($\delta^2_D$) variance for all studied traits under all irrigation treatments, except plant height under stress at GS3, where the opposite was true. Overdominance (a >1) was noted for leaf area under all irrigation regimes and plant height under stress at GS3, complete dominance (a=1) for grain yield under stress at GS2 and GS3 and partial dominance for 50% flowering under all soil-moisture regimes, plant height and grains/panicle under control and stress at GS2, 1000-grain weight under control and stress at GS3 and grain yield under control. No dominance was shown by 1000-grain weight under stress at GS2 and grains/panicle under stress at GS3. Heritability in the narrow sense was higher under control than under stress conditions for all studied traits, except 1000 – grain weight . The highest genetic advance from selection could be obtained through selection under optimum irrigation conditions for grain yield /plant (29.8 %) , selection under stress conditions at GS2 stage for plant height (31.2 %) and selection under stress at GS3 for grains/panicle (40.6 %) , 1000-grain weight (22.2 %) and leaf area (14.4 %).

Key words: ***Grain sorghum, Heterosis ,Combining ability ,Heritability ,Selection gain ,Drought stress.***

## INTRODUCTION

Attempts have been made to improve the drought tolerance of grain sorghum cultivars, i.e to develop new cultivars of high and stable yield under low soil-moisture conditions. However the problem has been to conduct an efficient breeding program for such a complicated character. Several investigators studied individual characters of direct relation to drought tolerance in grain sorghum. They recommended growing of hybrids under soil moisture stress, because they exhibit heterosis (Hoffmann *et al*1984, Blum *et al* 1990,1992, Khizzah *et al* 1995 and Oosterom *et al* 1996.) Identifying the genetic behavior of traits that contribute to drought tolerance in grain sorghum is important pre-requisite for a successful breeding programme to improve drought tolerance. Reviewing the literature showed that previous studies on the inheritance of traits related to drought tolerance in grain sorghum were very scarce (Khizzah *et al*1995, Al-Naggar *et al*1999) The delay by plant breeders to incorporate drought stress tolerance into breeding programs is related to the huge task of accurate testing the genetic control of this character. Therefore, this investigation aimed at estimating heterosis, variances and effects due to general (GCA) and specific (SCA) combining ability, type of gene action, heritability and predicted genetic advance from selection for some agronomic and yield attributes under water-stress and non-stress conditions.

## MATERIALS AND METHODS

Twenty-five $F_1$ fertile hybrids were made in 1999 between 5 restorer (R) lines and 5 cytoplasmic male sterile (cms) lines. Parents varied in their drought tolerance (based on previous field experiments). The tolerant parents consisted of 3 restorer lines (R-89016, R-90011 and V-112) and one cms line (B-102). The susceptible lines consisted of 2 restorers (R-89022 and RTX82BDM499) and 4 cms lines (B-1, B-37, B-88005 and B-88006). In the 2000 season, two field experiments were conducted on the 1 st of July at the Agric. Res. Station of Assiut University (Assiut Governorate) and on the 3 rd of July at Shandaweel Agric. Res. Station, FCRI, ARC (Sohag Governorate) to evaluate the 35 genotypes (10 parental lines and their 25 $F_1$ fertile hybrids) under three watering regimes, i.e. pre- flowering drought stress (GS2) (by withholding irrigation for 30 days from panicle initiation to anthesis), post- flowering drought stress (GS3) (by withholding irrigation for 40 days from anthesis to maturity) and normal irrigation schedule (control).

A split- plot design with three replications was used where the three irrigation treatments were allotted to the main plots and the 35 genotypes to sub plots. Each sub- plot consisted of one row of 5 m long and 70 cm wide with a total area of 3.5 square meters. Sowing was done in hills 20 cm apart along the ridges. Hills were thinned to two plants per hill after 20 days from sowing and before the first irrigation. Pest control and other agricultural practices were done as recommended.

All measurements were the average of 5 guarded plants taken randomly from each plot after heading (at the end of stress period) or at harvest time, except for days to mid– bloom (50% flowering), which was measured on a plot basis. Data were collected for days to mid-bloom, plant height from soil surface to the top of the panicle, leaf area (LA) (LA = leaf length x leaf width x 0.75) using the 6 *th* leaf from the top, 1000- grain weight, number of grains / panicle and grain yield / plant.

Data of each location and data combined over locations in absolute and relative values were subjected to a regular analysis of variance of a split plot design according to Steel and Torrie (1980). The sum of squares for genotypes was partitioned into components due to parents, $F_1$ hybrids and parents vs. $F_1$ hybrids. Mean squares of the genotypes X environment interaction from the combined analysis (environment was considered either locations, water stress treatments, or their interactions) were also partitioned into components involving parents, $F_1$'s and parents vs. $F_1$'s with environment. Line X tester analysis (Kempthorne 1957) was done for each irrigation regime to estimate general and specific combining ability of the tested females and males and various types of gene effects and their interactions with locations. The expected mean squares are based on the assumption that both parents and environments effects are random, so estimates of the components of genetic variances are interpreted relative to a base reference population and how they interact with environments (Hallauer and Miranda 1981).

Average degree of dominance a was calculated from the following equation $a = (2\delta^2_D / \delta^2_A)^{1/2}$ ,where $\delta^2_D$ and $\delta^2_A$ are dominance and additive variances, respectively. The estimates of average degree of dominance a were used to determine the type of dominance, as follows:a = 0 indicates no dominance ,a < ± 1 indicates positive or negative partial dominance,a = ± 1 indicates positive or negative complete dominance anda > ± 1 indicates positive or negative overdominance. Narrow-sense heritability ($h^2_n$) was calculated according to Hallauer and Miranda (1981) .Genetic advance (GA) from direct selection was calculated according to Becker (1984 ) using a 10 % selection intensity.

## RESULTS AND DISCUSSION

### Heterosis

The contrast between parents and crosses (ANOVA data not presented) was significant for most traits suggesting significant non-additive gene effect (heterosis). The heterosis x location interaction was significant for most traits, suggesting that the expression of heterosis was not stable across the two locations. The exceptions were days to 50 % flowering and 1000-grain weight where heterosis was stable across locations. The heterosis x irrigation treatment interaction was significant for most traits, suggesting that the expression of heterosis was not stable among irrigation treatments.

The expression of useful heterosis (heterobeltiosis) i.e the degree of superiority of the $F_1$ over the better parents, averaged over locations differed for the different studied traits (Table 1). Average heterobeltiosis across all crosses ranged from –0.36 % for days to 50% flowering to 56.1 % for plant height under control, from –1.9 % for leaf area to 61.7 % for plant height under stress at GS2 and from –3.69 % for leaf area to 61.7 % for plant height under stress at GS3 stage. Plant height showed maximum heterobeltiosis under all soil moisture regimes, followed by grain yield (20.4, 20.0 and 24.6 %) under control, stress at GS2 and stress at GS3, respectively.

Significant negative heterosis for days to 50 % flowering (earliness) is observed for 13, 9 and 11 hybrids tested under normal irrigation, water stress at GS2 and stress at GS3, respectively, indicating that these hybrids were earlier than the earliest parent. The crosses tested under full irrigation exhibited heterobeltiosis values for 50 % flowering ranging from –4.3 % (A-102 X R-89016) to 5.6 % (A-37 X R-89016). When the crosses were tested under water stress at GS2 they exhibited heterosis values ranging from –5.4 % (A-1 X R-90011) to 7.5 % (A-37 X RTX82BDM499), while under stress at GS3 they showed heterosis estimates ranging from –1.6 % for (A-102 X RTX82BDM499) to 5.4 % (A-102 X R-89022).

For plant height, all hybrids showed positive heterobeltiosis indicating that these hybrids are taller than the tallest parent. Significant and positive heterosis is manifested in 25, 24 and 25 crosses tested under control, stress at GS2 and stress at GS3, respectively. Range of heterobeltiosis for plant height was from 13.4 % (A-102 X R-89022) to 100 % (A-37 X V-112) in the control treatment, from 0.79 % (A-102 X R-90011) to 115.8 % (A-102 X V-112 ) under water stress at GS2 and from 22.9 % (A-1 X RTX82BDM499) to 161.5 % (A-102 X R-89022) under water stress at GS3 stage

## Table 1. Estimates of heterobeltiosis in sorghum $F_1$ crosses tested under three irrigation regimes over two locations in 2000.

| | Crosses | Cont. | GS2 | GS3 | Cont. | GS2 | GS3 | Cont. | GS2 | GS3 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Days to 50% flowering | | | Plant height | | | Leaf area | | |
| 1 | A-1 X R-89016 | 0.0 | -2.6** | 0.0 | 66.0** | 64.9** | 59.8** | -7.4** | -4.6** | -9.0** |
| 2 | A-1 X R-89022 | 1.4* | -4.0** | -1.4* | 33.0** | 28.8** | 24.3** | 0.7 | 2.8 | 0.60 |
| 3 | A-1 X R-90011 | -1.4* | -5.4** | 1.4* | 63.4** | 54.6** | 56.1** | -0.9 | 8.6** | 8.0 |
| 4 | A-1 X V-112 | 1.4* | -2.6** | 0.0 | 68.7** | 56.7** | 58.8** | 11.6** | 0.5 | 3.8** |
| 5 | A-1 X RTX | 0.0 | 4.5** | 0.0 | 41.4** | 9.5** | 22.9** | -12.6** | -22.0** | -18.0** |
| 6 | A-37 X R-89016 | 5.6** | 1.3* | 4.2** | 57.0** | 33.0** | 94.1** | -21.9** | -22.3** | -26.0** |
| 7 | A-37 X R-89022 | 2.8** | 2.6** | 4.2** | 46.3** | 15.6** | 35.9** | 5.3** | -1.8 | -2.7** |
| 8 | A-37 X R-90011 | 2.8** | 4.0** | 4.2** | 66.1** | 39.4** | 58.7** | 4.3** | 5.5** | 10.2** |
| 9 | A 37 X V-112 | 1.4* | 1.3* | 1.4* | 102** | 95.4** | 99.1** | 7.6** | -2.9 | 5.0* |
| 10 | A-37 X RTX | 3.1** | 7.5** | 4.6** | 50.5** | 47.3** | 44.8** | 2.0** | 0.0 | 5.0** |
| 11 | A-102 X R-89016 | -4.3** | 1.3* | -1.4* | 32.2** | 56.4** | 33.1** | -19.8** | -17.2** | -21.0** |
| 12 | A-102 X R-89022 | 0.0 | 5.3** | 5.4** | 13.4** | 47.5** | 161.0** | 1.7** | 3.5* | 0.26 |
| 13 | A-102 X R-90011 | -2.8** | -1.3* | -1.4* | 39.5** | 0.79 | 48.4** | -10..0** | -1.6 | -2.4* |
| 14 | A-102 X V-112 | -1.4* | 0.0 | -1.4* | 63.7** | 115.8** | 78.4** | 2.6** | 3.5* | 4.0** |
| 15 | A-102 X RTX | -3.2** | 1.5* | -1.6* | 50.5** | 36.8** | 32.3** | 7.6** | 3.6* | 3.2** |
| 16 | A-88005 X R-89016 | -2.8** | 0.0 | 0.0 | 55.5** | 48.5** | 48.6** | -12.6** | 11.3** | 17.0** |
| 17 | A-88005 X R-89022 | -1.4* | -2.7** | 1.4* | 55.5** | 58.1** | 58.5** | -4.2** | 6.4** | -9.7** |
| 18 | A-88005 X R-90011 | 1.4* | 1.3* | 0.0 | 65.8** | 60.9** | 67.5** | 10.7** | -0.1 | 2.3* |
| 19 | A-88005 X V-112 | -1.4* | 0.0 | -1.4* | 77.7** | 90.4** | 83.7** | 2.7** | 8.8** | 9.5** |
| 20 | A-88005 X RTX | -1.5* | 1.5* | 1.5* | 61.6** | 26.3** | 52.1** | -0.9 | -8.3** | 7.9** |
| 21 | A-88006 X R-89016 | 0.0 | -2.6** | 1.3* | 33.8** | 55.1** | 36.1** | 4.3** | 6.2** | 4.7** |
| 22 | A-88006 X R-89022 | -2.7** | -3.9** | -1.4* | 69.8** | 110.2** | 82.3** | 3.6* | 2.3 | -2.5** |
| 23 | A-88006 X R-90011 | -1.4* | -1.3* | -1.4* | 50.7** | 74.5** | 54.6** | 6.0** | 0.0 | 0.8 |
| 24 | A-88006 X V-112 | 1.4* | 0.0 | 4.0** | 90.4** | 122.4** | 106** | 10.3** | -3.6* | -0.3 |
| 25 | A-88006 X RTX | -3.2** | 4.5** | 0.0 | 50.5** | 32.6** | 45.8** | 4.0** | -6.1** | -4.8** |
| | Average | -0.36 | 0.4 | 0.66 | 56.1 | 55.2 | 61.7 | -0.21 | -1.99 | -3.69 |

| | Crosses | No. grains/panicle | | | 1000 grain weight | | | Grain yield/plant | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A-1 X R-89016 | 10.2** | 32.2** | 13.2** | 23.3** | 12.0** | 0.0 | 30.1** | 18.7** | 21.8** |
| 2 | A-1 X R-89022 | 45.6** | -7.5 | 30.2** | 12.0** | 14.5** | 21.3** | 64.0** | 23.7** | 86.6** |
| 3 | A-1 X R-90011 | 2.3 | -11.0** | -8.1** | 9.6* | 12.6** | 1.1 | 45.5** | 23.5** | 37.9** |
| 4 | A-1 X V-112 | 39.5** | 58.0** | 46.8** | 2.2 | -7.5* | -7.2* | 46.7** | 44.5** | 34.4** |
| 5 | A-1 X RTX | -9.2 | 7.2 | -4.8 | 18.3** | 16.5** | 18.0** | 7.0 | 37.7** | 15.4** |
| 6 | A-37 X R-89016 | -20** | 17.6** | -15** | 3.6 | -0.8 | 2.3 | 11.4** | 6.8** | -4.3* |
| 7 | A 37 X R-89022 | 9.4 | -0.5 | 5.7 | -5.8 | -11.6** | -11.8** | 14.3** | 15.1** | 7.0** |
| 8 | A-37 X R-90011 | 7.1 | 6.4* | 3.4 | -17.3** | -17.2** | -22.1** | 28.7** | 32.6** | 31.4** |
| 9 | A-37 X V 112 | 0.0 | 2.6 | 0.45 | 14.8* | 9.4** | 11.2** | 12.8** | 12.2** | 23.7** |
| 10 | A-37 X RTX | 18.7** | -8.8 | 16** | 7.0 | -8.2* | -12.7** | 15.5** | 3.7 | -1.8 |
| 11 | A-102 X R-89016 | -6.6 | 30.0** | -1.6 | -5.0 | -0.8 | 7.2* | 1.3 | 21.8** | 15.6** |
| 12 | A-102 X R-89022 | -21** | -25.0** | -17** | -10.1* | -2.9 | -16.6** | 27.7** | 0.40 | 32.0** |
| 13 | A-102 X R-90011 | 15.8** | 0.5 | 11.8** | -9.0* | -13.8** | -8.9** | 44.5** | 32.9** | 46.5** |
| 14 | A-102 X V-112 | 19.5** | 13.8** | 19** | 13.4** | 8.3* | 14.8** | 37.3** | 21.5** | 46.0** |
| 15 | A-102 X RTX | -6.2 | 5.0 | -2.5 | 2.0 | 3.3 | -2.0 | 5.0 | 45.4** | -8.6** |
| 16 | A-88005 X R-89016 | -14** | 19.7** | -11** | 0.0 | -1.6 | 1.7 | 3.3 | 15.8** | 0.3 |
| 17 | A-88005 X R-89022 | 16.5* | 1.3 | 12.3** | 2.3 | -4.8 | 0.8 | 35.6** | 11.7** | 32.5** |
| 18 | A-88005 X R-90011 | -14** | -9.0** | -14** | -14.8** | -17.6** | 14.2** | 11.8** | 20.3** | 21.0** |
| 19 | A-88005 X V-112 | -14* | -2.4 | -13** | 15.2** | -2.6 | 10.8** | 1.0 | 3.8 | -6.6** |
| 20 | A-88005 X RTX | -31.0** | -22.0** | -29.0** | -2.7 | -3.2 | 0.8 | 17.5** | 4.2 | -3.5 |
| 21 | A-88006 X R-89016 | -9.5* | 10.7* | 11.8** | 0.0 | 4.5 | 1.4 | 4.6 | 1.6 | 8.0** |
| 22 | A-88006 X R-89022 | 20.4** | 10.0* | 20.5** | 24.6** | 10.3** | 19.6** | 5.8 | 47.5** | 92.7** |
| 23 | A-88006 X R-90011 | -0.1 | -11.0** | -6.8* | -6.6 | -6.7 | -11.0** | 28.1** | 18** | 26.0** |
| 24 | A-88006 X V-112 | -14* | 3.6 | -6.8* | 14.8** | 5.3 | 15.6** | 10.7** | 6.5** | 12.8** |
| 25 | A-88006 X RTX | -7.6 | 10.6* | -1.5 | -1.6 | -3.6 | -12.8** | 0.70 | 28.9** | 49.2** |
| | Average | 1.5 | 5.3 | 1.1 | 3.61 | -0.25 | 1.4 | 20.4 | 20.0 | 24.6 |

For leaf area, significant positive heterobeltiosis was exhibited in 15, 8 and 8 crosses under control, water stress at GS2 and at GS3, respectively.

The number of hybrids was 7, 7 and 12 under control, water stress at GS2 and at GS3, respectively which showed significant negative heterosis for LA. Range of heterobeltiosis for LA was from –21.9 % (A-37 X R-89016) to 11.6 % (A-1 X V-112) under control, from –22.3 % (A-37 X R-89016) to 11.3 % (A-88005 X R-89016) under stress at GS2 and from–26.0 % (A-37 X R-89016) to 10.2 % (A-37 X R-90011) under stress at GS3.

For 1000-grain weight significant positive heterobeltiosis values were shown by 9, 7 and 9 crosses under control, water stress at GS2 and at GS3, respectively. On the other hand 4, 6 and 8 crosses showed significant negative heterobeltiosis for 1000-grain weight under respective soil moisture regimes. Ranges were from –17.3 % (A-37 X R-90011) to 24.6 % (A-88006 X R-89022) under control, from –17.6 % (A-88005 X R-90011) to 16.5 % (A-1 X RTX -82 BDM-499) under water stress at GS2 and from –22.1 % (A-37 X R-90011) to 21.3 % (A-1 X R-89022) under stress at GS3. The hybrids A-1 X R-89022, A-1 X RTX82BDM499 and A-88006 X R-89022 exhibited significantly positive (favourable) heterobeltiosis for grain weight under stress at both GS2 and GS3 stages, indicating that these hybrids can develop heavier grains than the best parent.

Regarding number of grains per panicle, 11, 16 and 10 crosses exhibited positive (favourable) heterobeltiosis, out of them 8, 10 and 8 crosses showed significance for heterobeltiosis under control, stress at GS2 and stress at GS3, respectively. On the other hand, 13, 9 and 14 crosses exhibited negative heterobeltiosis, out of them 8, 5 and 10 crosses showed significance for heterobeltiosis under control, GS2 and GS3, respectively. It's interesting to mention that a broad range was observed for heterobeltiosis manifested in this trait among crosses. This range was from –31.4 % (A-88005 x RTX82BDM499) to 45.6 % (A-1 X R-89022) under control, from –24.6 % (A-102 X R-89022) to 57.9 % (A-1 X V-112) under stress at GS2 and from –29.2 % (A-88005 X RTX82BDM499) to 46.8 % (A-1 X V-112) under stress at GS3. The later cross exhibited the greatest (favourable) heterobeltiosis for grains/panicle under water stress at both GS2 and GS3.

With respect to grain yield, all the hybrids showed positive heterobeltiosis, under control and stress at GS2 stage, out of them 17 and 20 crosses exhibited significant heterobeltiosis values under the same soil moisture regimes, respectively. While under stress at GS3 19 crosses showed significant and positive heterobeltiosis values and only 2 crosses had significant negative heterobeltiosis for grain yield under stress at GS3.

The range of heterobeltiosis for grain yield was from 0.7 % (A-88006 X RTX82BDM499) to 64.0 % (A-1 X R-89022) under control, from 0.4 % (A-102 X R-89022) to 47.5 % (A-88006 X R-89022) under stress at GS2 and from –8.6 % (A-102 X RTX82BDM499) to 92.7 % (A-88006 X R-89022) under stress at GS3.

In general, significant favourable heterosis above the better parent in this study was manifested in some hybrids for all studied traits. The existence of heterosis for different characters in grain sorghum crosses developed under either control or water stress conditions had been demonstrated by several authors. Blum (1970) found that heterosis in grain sorghum developed under drought conditions was manifested in earliness and plant height. Blum *et al* (1992) reported that sorghum hybrids subjected to drought stress were earlier compared with open-pollinated cultivars. El-Bakry (1998) found that grain sorghum hybrids were earlier and taller than their better parents.

Heterosis for leaf area per plant, leaf area index or leaf number per plant was not clearly seen by Blum (1970) and Blum *et al* (1990), whereas it was evident during the pre-heading stages in other studies (Gibson and Schertz 1977). El-Bakry (1998) reported that grain sorghum hybrids had smaller leaf area of the third leaf from the top of the plant than parents. Oosterom *et al* (1996) reported that the expression of heterosis for non-senescence as related to the stay-green trait was stable across experiments.

Blum (1970) found that heterosis in grain sorghum developed under drought conditions was manifested in number of kernels/panicle. Blum *et al* (1992) found that although sorghum hybrids subjected to drought stress produced more grains compared with open-pollinated cultivars, cultivars were less affected by water stress than hybrids. They attributed that to the superior physiological resistance to drought stress of these cultivars. Blum *et al* (1990) reported that significant heterosis was found for biomass, grain yield per plant and grain number per panicle. No heterosis occurred for harvest index, indicating that heterosis in grain yield was due to heterosis in biomass.

Results of heterosis in this study showed that some grain sorghum hybrids were earlier, taller, had heavier grains and higher grain yield than their respective parental lines under control as well as drought stress conditions.

## Analysis of variance

Mean squares of the 25 hybrids tested under each soil moisture regime were partitioned into males, females and male X female components

(Table 2).Under all soil moisture regimes, mean squares due to males and females in their respective crosses showed highly significant differences for *most traits evaluated, indicating that estimates of GCA effects were* significant ($P \leq 0.01$) for both parental males and females for all traits.

Contribution of the variation due to females to the total variation was greater than the contribution of the variation due to males for all traits . Mean squares due to females were greater than mean squares due to males by many folds ranging from 1.41 (grain yield) to 14.3 folds (50 % flowering) under control, from4.0 ( plant height) to 41.7 folds (50 % flowering) under stress at GS2 and from 2.3 (grains/panicle) to 27.3 folds (50 % flowering) under stress at GS3. This indicates that most of the total GCA variance was due to the females GCA variance.

Variation due to male x female interaction was also highly significant for all studied traits. This suggests that SCA effects were significant at the 0.01 level under all soil moisture conditions. Similarly, when hybrids X locations interaction mean squares (Table 2) were partitioned, highly significant male X location interactions were detected for most traits, indicating that GCA effects for males interacted significantly with locations at 0.01 level. The exceptions were plant height under control and 1000-grain weight under control and stress at GS2 where males did not interact significantly with locations.

Females X locations interactions were highly significant for all traits except for days to 50 % flowering under control (Table 2). This indicates that GCA effects of females interacted differently with locations. The interaction of males X females X locations was significant for all traits, under all soil moisture regimes. This reveals that the crosses between males x females (SCA effects) behaved somewhat differently from location to location for all traits under all irrigation regimes.

## General combining ability effects

Estimates of GCA effects obtained from the males and females in their crosses evaluated under each soil moisture regime are presented in Table (3). Concerning days to 50 % flowering GCA effects of the lines V-112 (male) and B-88006 (female) were negative (favourable) and significant under all soil moisture regimes. Positive GCA effects for flowering indicate a parental effect for hybrid lateness, while the negative GCA effects indicate hybrid earliness.

**Table 2.** Mean squares from combined analysis of variance for males, females, males X females and their interactions with locations under three soil moisture regimes in 2000.

| Source of variation | d.f | Mean squares<br>Days to 50 % flowering | Plant height | Leaf area | 1000 grain weight | Grains/ panicle | Grain yield/ plant |
|---|---|---|---|---|---|---|---|
| | | Control | | | | | |
| Males (M) | 4 | 22.5** | 5358.8** | 42096** | 17.1** | 3409462** | 2598** |
| Females(F) | 4 | 367.9** | 26401** | 91581** | 232.8** | 7362462** | 3663** |
| M x F | 16 | 10.0** | 1509.9** | 16930** | 22.2** | 934353** | 765** |
| M X $L^1$ | 4 | 4.5** | 3.9 | 194.7** | 6.5 | 280151** | 127** |
| F X $L^1$ | 4 | 1.04 | 24.0**. | 830.4** | 76.6** | 468998** | 982** |
| M X F X L | 16 | 2.8** | 56.9** | 305.8** | 13.1** | 574097** | 442** |
| Error | 96 | 0.64 | 6.2 | 52.4 | 3.1 | 74336 | 20.1 |
| | | Stress at GS2 | | | | | |
| Males (M) | 4 | 8.4** | 5573.5** | 21332** | 9.2** | 695260** | 407** |
| Females(F) | 4 | 350.4** | 22431** | 96040** | 165.4** | 5237262** | 1867** |
| M x F | 16 | 14.6** | 2007** | 18278** | 11.4** | 875936** | 373** |
| M X $L^1$ | 4 | 4.2** | 401.2** | 7132** | 0.8 | 474945** | 174** |
| F X $L^1$ | 4 | 3.3** | 111.6** | 1807** | 35.5** | 666631** | 167** |
| M X F X $L^1$ | 16 | 3.1** | 234.3** | 2868** | 14.7** | 562998** | 202** |
| Error | 96 | 0.5 | 8.6 | 359 | 1.8 | 37643 | 5.1 |
| | | Stress at GS3 | | | | | |
| Males (M) | 4 | 15.0** | 5668.2** | 30210** | 50.5** | 4142151** | 1254** |
| Females(F) | 4 | 409.2** | 24919** | 103119** | 251** | 9670522** | 3931** |
| M x F | 16 | 15.8** | 1786.6** | 17368** | 22.7** | 134144** | 618** |
| M X $L^1$ | 4 | 15.0** | 333.2** | 10442** | 24.3** | 424482** | 367** |
| F X $L^1$ | 4 | 3.2** | 324.5** | 1421** | 37.4** | 818344** | 1032** |
| M X F X $L^1$ | 16 | 4.2** | 128.9** | 3313** | 20.8** | 847824** | 294** |
| Error | 96 | 0.5 | 6.3 | 454.3 | 0.7 | 39417 | 9.6 |

*,** significant at 0.05 and 0.01 probability levels , respectively.
$L^1$ = Locations

Regarding the estimates of GCA effects for plant height, the lines R-90011, V-112 and RTX82BDM499 (as males) and B-102 and B-88005 (as females) showed positive and significant GCA effects, while R-89016 (male) and B-1, B-37 and B-88006 (females) showed significant and negative GCA effects under all soil moisture regimes. The highest positive GCA effect under all treatments was obtained from the female B-88005, while the lowest negative GCA effect was shown by the female B-88006. This indicates that the line B-88005 played an important role in increasing the height of all crosses involved and the line B-88006 is important for decreasing the plant height of the crosses.

**Table 3. General combining ability effects of 5 males and 5 female lines of grain sorghum combined over Assiut and Shandaweel locations for all studied *traits in 2000 season.***

| Parental line | Cont. | GS2 | GS3 | Cont. | GS2 | GS3 | Cont. | GS2 | GS3 |
|---|---|---|---|---|---|---|---|---|---|
| | Days to 50%heading | | | Plant height | | | Leaf area | | |
| Males: | | | | | | | | | |
| ICSR-89016 | 0.4** | -0.3* | -0.3 | -22.0** | -21.0** | -22.0** | -9.40** | -0.30 | 1.1 |
| ICSR-89022 | 1.2** | 0.60** | 0.9* | 0.60 | -4.20 ** | 0.60 | -8.70** | -13.7** | -6.3 |
| ICSR-90011 | -0.9** | 0.020 | 0.1 | 2.10 ** | 7.50 ** | 3.70** | -27.8** | 7.10** | -2.8 |
| ICSV-112 | -0.6** | -0.7 ** | -0.9* | 5.60 ** | 2.70 ** | 1.80** | -19.6** | -32.4** | -40** |
| RTX–82BDM | -0.08 | 0.40** | 0.3 | 13.8 ** | 15.0 ** | 15.8** | 65.5** | 39.4** | 48** |
| Females: | | | | | | | | | |
| ICSB-1 | 1.6** | 1.5** | 1.7** | -1.1* | -5.1** | -5.5** | -52.9** | -39** | -46** |
| ICSB-37 | 1.3** | 1.5** | 2.0** | -7.2** | -5.1** | -7.2** | 47.7** | 65.8** | 62.1** |
| ICSB-102 | 1.4** | 1.4** | 1.2** | 9.9** | 4.9** | 8.3** | 0.88 | 1.03 | 3.9 |
| ICSB-88005 | 1.8** | 1.5** | 1.5** | 40.2** | 40.7** | 41.9** | 61.8** | 43.3** | 51.4** |
| ICSB-88006 | -6.2** | -6.1** | -6.6** | -41.9** | -35.4** | -37.5** | -57.5** | -71.2** | -71** |
| S.E.gi | 0.14 | 0.13 | 0.46 | 0.45 | 0.53 | 0.45 | 1.3 | 3.46 | 3.9 |
| S.E.gi-gj | 0.19 | 0.18 | 0.65 | 0.63 | 0.75 | 0.63 | 1.84 | 4.9 | 5.5 |
| | 1000 grain weight | | | No. of grains / panicle | | | Grain yield/plant | | |
| Males: | | | | | | | | | |
| ICSR-89016 | -0.05 | -0.02 | -0.3* | 30.1 | -11.5 | 45.5 | 1.0 | 0.07 | 0.1 |
| ICSR-89022 | -0.37 | -0.42 | -0.2 | -202 ** | -249** | -276** | -5.5 ** | -6.5** | -5.7** |
| ICSR-90011 | -3.1 ** | -3.0** | -3.1** | 794 ** | 696** | 917** | 8.6 ** | 7.0** | 8.1** |
| ICSV-112 | 4.5 ** | 3.6** | 4.7** | -69.5 | -49.9 | -85.7 | 11.7** | 8.6** | 13.3** |
| RTX–82BDM | -1.01** | -0.25 | -1.2** | -552 ** | -385** | -602** | -16.0** | -9.1** | -16** |
| Females: | | | | | | | | | |
| ICSB-1 | 0.26 | -0.10 | -1.1** | 523 ** | 232** | 506** | 14.6** | 5.5** | 7.1** |
| ICSB-37 | -1.30** | -0.9 ** | -1.5** | -139 ** | -12.6 | -8.2 | -7.5 ** | -2.8** | -5.7** |
| ICSB-102 | -0.07 | 0.50 * | 0.4** | 81.8 | -6.8 | -47.8 | 2.5 ** | 1.5** | 2.1** |
| ICSB-88005 | 0.60** | 0.30 | 1.4** | -385.4** | -196** | -535** | -8.1 ** | -3.6** | -7.7** |
| ICSB-88006 | 0.40 | 0.20 | 0.9** | 80.8 | -16.2 | 85.8* | -1.6 * | -0.6 | 4.3** |
| S.E.gi | 0.30 | 0.24 | 0.15 | 49.7 | 35.4 | 36.2 | 0.82 | 0.41 | 0.56 |
| S.E.gi-gj | 0.45 | 0.34 | 0.21 | 70.3 | 50.1 | 51.2 | 1.1 | 0.58 | 0.80 |

***,** Significant at 0.05 and 0.01 probability levels, respectively.**

For leaf area the male, RTX82BDM499 and the females B-37 and B-88005 had the highest positive and significant GCA effects under all soil moisture regimes, but the male V-112 and the females B-1 and B-88006 had the highest negative and significant GCA effects, under all soil moisture regimes.

With regard to 1000-grain weight, the lines V-112 and B-88005 (under all soil moisture regimes), B-102 (under stress at GS2 and GS3) and B-88006 (under stress at GS3) had positive and significant GCA effects which would increase grain weight of hybrids. Other lines had either significant negative or non significant GCA effects on 1000-grain weight.

With respect to number of grains/panicle, the restorer R-90011 and the cms line B-1 had the highest significant and positive GCA effects (favourable) under all soil moisture regimes. But the males R-89022 and RTX82BDM499 and the females B-88005 had negative and significant GCA effects under all irrigation treatments.

For grain yield/plant, the male V-112 followed by R-90011 and the females B-1 and B-102 had positive and significant (favourable) GCA effects under all irrigation treatments, indicating that they are good general combiners for yield. The superiority of these lines in GCA effects for grain yield could be attributed mainly to their superiority in GCA effects for either 1000-grain weight or number of grains/panicle.

## Specific combining ability effects

Estimates of SCA effects for the $F_1$ hybrids tested under the three moisture regimes are presented in Table (4). The SCA effects for days to 50 % flowering showed that 7, 8 and 3 crosses under control, stress at GS2 and stress at GS3, respectively had significant and positive values. On the contrary 8, 10 and 0 crosses had significant negative SCA effects under the respective moisture regimes. The lowest significant negative (favourable) SCA effects for days to 50 % flowering were shown by the cross A-88005 X R-89022 followed by A-1 X V-112 under control, A-102 X R-89016 and A-88006 X R-90011 under stress at GS2 and A-37 X RTX82BDM449 and A-88006 X R-90011 under stress at GS3.

For plant height, 11, 8 and 12 crosses had positive and significant SCA effects and 9, 12 and 11 crosses showed negative and significant SCA effects under control,stress at GS2 and at GS3, respectively. The highest positive SCA effects were shown by the crosses A-37 X RTX82BDM499, A-1 X R-89016, A-88005 X R-89022 and A-88005 X R-90011 under all soil moisture regimes, A-88005 X RTX82BDM499 under control and stress at GS3, A-37 X V-112 under stress at both GS2 and GS3 and A-102 X R-90011 under stress at GS2 stage.

Significant and positive estimates of SCA effects for leaf area (LA) were obtained for 11, 12 and 10 crosses under control, stress at GS2 and GS3, respectively. The highest positive SCA effects were exhibited by the crosses A-1 X RTX82BDM499, A-1 X R-89016, A-102 X R-89022, A-88005 X R-89016, A-37 X R-90011, A-88006 X R-90011 and A-88006 X RTX82BDM499 under all irrigation treatments and A-37 X R-89016, A-88005 x R-90011 and A-88006 x R-89022 under stress at both GS2 and GS3.

**Table 4. Specific combining ability effects of 25 grain sorghum crosses tested *under 3 irrigation regimes (Data are combined over two* locations in 2000.**

| Crosses | Cont. | GS2 | GS3 | Cont. | GS2 | GS3 | Cont. | GS2 | GS3 |
|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | | | Plant height | | | Leaf area | | |
| 1-A-1 X R-89016 | 0.3 | 0.9** | 0.1 | 18** | 27.4** | 24.8** | 43.0** | 37.6** | 31.8** |
| 2-A-1 X R-89022 | 1.3** | -1.4** | 0.2 | 0.32 | -5.1** | 1.10 | -78.8** | -78.5** | -85.6** |
| 3-A-1 X R-90011 | -1.2** | 0.2 | -1.1 | 4.2** | -3.5** | 0.90 | -41.6** | -61.6** | -48.3** |
| 4-A-1 X V-112 | -1.3** | 0.7** | -0.2 | -0.10 | -1.2 | -4.5** | 10.8** | 20.8** | 15.8 |
| 5-A-1X RTX | 0.8** | -0.5 | 1.02* | -22.3** | -17.5** | -22.4** | 66.7** | 81.7** | 86.2** |
| 6-A-37 X R-89016 | -0.70* | -0.7** | -0.4 | -13.5** | -8.4** | -11.7** | 4.9 | 28.4** | 25.3** |
| 7-A-37 X R-89022 | 0.08 | -0.2 | -0.1 | -8.2** | -24.2** | -12.1** | 42.1** | 6.30 | 6.20 |
| 8-A-37 X R-90011 | 1.9** | 3.5** | 3.7** | -17.2** | -12.7** | -18.6** | 31.5** | 26.7** | 26.3** |
| 9-A-37 X V-112 | -0.30 | -1.4** | -1.4 | 5.9** | 8.7** | 7.7** | -32.3** | -10.5 | -11.8 |
| 10A-37X RTX | -0.9** | -1.1** | -1.8 | 32.9** | 36.6** | 34.8** | -46.3** | -50.9** | -46.1** |
| 11-A-102 X R-89016 | -0.9** | -1.6** | 0.25 | 3.6** | 6.6** | 6.8** | -3.1 | 28.2** | 13.5 |
| 12-A-102 X R-89022 | -0.3 | 1.2** | 0.30 | -0.50 | -8.4** | -2.0* | 37.7** | 21.3** | 35.2** |
| 13-A-102 X R-90011 | -0.6 | -1.3** | -1.01 | 4.9** | 8.1** | 6.9** | -55.7** | -47.3** | -50.6** |
| 14-A-102 X V-112 | 1.9** | 1.5** | 0.40 | 2.2* | 2.1 | 2.6** | 32.8** | 1.60 | 17.5* |
| 15-A-102X RTX | 0.02 | 0.3 | -1.0 | -10.2** | -8.4** | -14.3** | -11.8** | -3.8 | -15.4 |
| 16-A-88005 X R-89016 | 1.2** | 0.4 | 0.6 | -20.7** | -26.7** | -23.4** | 46.6** | 21.5** | 32.7** |
| 17-A-88005 X R-89022 | -2.1** | -1.0** | 1.6 | 9.4** | 17.4** | 10.5** | 14.2** | 8.80 | -3.9 |
| 18-A-88005 X R-90011 | 0.38 | -0.8** | -1.0 | 10.5** | 9.70** | 12.9** | -7.1* | 36.9** | 39.1** |
| 19-A-88005 X V-112 | -0.7* | 0.1 | -0.6 | -13.0** | -2.90* | -13.5** | -14.7** | -17.6* | -23.3** |
| 20-A-88005X RTX | 1.2** | 1.3** | 2.6** | 13.7** | 2.40* | 13.4** | -39.0** | -49.7** | -44.6** |
| 21-A-88006 X R-89016 | 0.18 | 1.1** | -0.6 | 12.7** | 1.10 | 3.5** | -91.5** | -116** | -103** |
| 22-A-88006 X R-89022 | 1.0 ** | 1.4** | 1.2 | -1.0 | 20.2** | 2.5* | -15.3** | 42.0** | 48.1** |
| 23-A-88006 X R-90011 | -0.5 | -1.6** | -1.5 | -2.4* | -1.50 | -2.2* | 72.9** | 45.3** | 33.7** |
| 24-A-88006 X V-112 | 0.4 | -0.9** | [illegible] | 4.9** | -6.7** | 7.7** | 3.40 | 5.6 | 1.70 |
| 25-A-88006X RTX | -1.1** | 0.01 | -0.8 | -14.2** | -13.1** | -11.5** | 30.4** | 22.8** | 19.9** |
| S.E. $_{sij}$ | 0.32 | 0.28 | 1.02 | 1.01 | 1.2 | 1.02 | 2.9 | 7.7 | 8.7 |
| S.E. $_{sij-skl}$ | 0.45 | 0.39 | 1.4 | 1.43 | 1.7 | 1.4 | 4.1 | 10.8 | 12.3 |
| | 1000 grain weight | | | Grains/panicle | | | Grain yield /plant | | |
| 1- A-1 X R-89016 | 1.5* | 0.1 | -0.8** | 104 | 3.60 | 320** | 7.5** | -1.8* | 2.0 |
| 2- A-1 X R-89022 | 0.8 | 0.4 | 1.4** | -263* | -89.4 | -411** | -3.8* | -0.40 | -2.7* |
| 3- A-1 X R-90011 | -0.8 | -0.8 | -0.5** | -33.5 | 186.3* | 235** | -4.4* | 2.3** | 2.7* |
| 4- A-1 X V-112 | 0.3 | 0.7 | 0.4** | 162 | 142.0 | 62.0 | 4.2* | 5.5** | 2.4 |
| 5- A-1X RTX | -1.8** | -0.4 | -0.5** | 30.4 | -242.5** | -206** | -3.4 | -5.5** | -4.5** |
| 6- A-37 X R-89016 | -1.0 | 0.6 | 1.2** | 267.8* | -318** | 170.3* | 1.8 | -5.8** | 7.5** |
| 7- A-37 X R-89022 | -1.0 | -1.8** | -1.7** | -20.0 | 110.4 | 10.8 | -2.8 | -1.40 | -3.6** |
| 8- A-37 X R-90011 | -1.9** | -0.4 | -2.9** | -857** | -534.3** | -725** | -26.4** | -13.2** | -24.5** |
| 9- A-37 X V-112 | -2.0** | 0.3 | 0.1 | 407** | 334.0** | 328.4** | 10.1** | 8.9** | 7.8** |
| 10- A-37X RTX | 4.3** | 1.3* | 3.2** | 202 | 398.0** | 216** | 17.4** | 11.6** | 12.8** |
| 11- A-102 X R-89016 | 1.2 | 1.1* | 0.4** | -449** | -454.4** | -242** | -7.3** | -6.7** | -4.7** |
| 12- A-102 X R-89022 | -0.8 | -0.2 | -1.0** | 308** | 425.4** | 548.4** | 1.8 | 6.8** | 4.2** |
| 13- A-102 X R-90011 | -0.5 | -0.4 | 1.7** | 419** | 200.7** | 124 | 12.9** | 2.7** | 9.4** |
| 14- A-102 X V-112 | -2.7** | -0.3 | -0.5** | -253* | 43.8 | -39.4 | -6.6** | 0.60 | -0.02 |
| 15- A-102X RTX | 2.1** | -0.01 | -0.6** | -25 | -215.5** | -390.8** | -0.9 | -3.5** | -8.9** |
| 16- A-88005 X R-89016 | -2.7** | -2.7** | -2.6** | 437** | 784.4** | 516.6** | 5.7** | 12.3** | 5.4** |
| 17- A-88005 X R-89022 | 2.1** | 2.7** | 23** | -41 | -284** | -273** | 5.1** | 0.30 | 0.50 |
| 18- A-88005 X R-90011 | -0.2 | 0.8 | 0.1 | 301** | -22.4 | 413.3** | 9.6** | 1.80 * | 11.5** |
| 19- A-88005 X V-112 | 0.4 | -1.2* | -0.6** | -195.5 | -221.4** | -254** | -5.6** | -9.0 ** | -9.8** |
| 20- A-88005X RTX | 0.3 | 0.3 | 0.8** | -501.4** | -256.3** | -403** | -14.8** | -5.5 ** | -7.6** |
| 21- A-88006 X R-89016 | 0.9 | 0.8 | 1.7** | -359.7** | -15.1 | -765** | -7.6** | 2.1* | -10.3** |
| 22- A-88006 X R-89022 | -0.7 | -1.1* | -0.9** | 16.0 | -162.4* | 124.4 | -0.3 | -5.4** | 1.5 |
| 23- A-88006 X R-90011 | 1.8** | 0.9 | 1.4** | 170.7 | 169.7* | -47 | 8.3** | 6.3** | 0.80 |
| 24- A-88006 X V-112 | 0.3 | 0.5 | 0.6** | 120.6 | -308.4** | -96.7 | -2.1 | -6.0** | -0.30 |
| 25- A-88006X RTX | -2.3** | -1.2* | -2.8** | 293.7** | 316.3** | 784** | 1.7 | 3.0** | 8.2** |

*, ** Significant at 0.05 and 0.01 probability levels, respectively.

For 1000-grain weight 5, 3 and 11 crosses showed significant positive SCA effects while 6, 5 and 12 crosses showed significant negative SCA effects under control, stress at GS2 and at GS3, respectively. The highest positive (favourable) SCA effects for grain weight was shown for the crosses A-88005 X R-89022, A-37 X RTX82BDM499 under all irrigation treatments and A-102 X RTX82BDM499 under control.

Estimates of SCA effects for number of grains/panicle were positive and significant in 7, 8 and 9 crosses and negative and significant in 6, 10 and 9 crosses under control, stress at GS2 and at GS3, respectively. The highest positive SCA effects were obtained from A-37 X V-112, A-102 X R-89022, A-88005 X R-89016 and A-88006 X RTX82BDM499 under all irrigation treatments, A-102 X R-90011 under control, A-37 X RTX82 BDM499 under stress at GS2 and A-88005 X R-90011 under stress at GS3.

With respect to grain yield, SCA effects were significant and positive for 9, 11 and 9 crosses and significant and negative for 8, 10 and 9 crosses under control, stress at GS2 and stress at GS3, respectively. The highest SCA effects for grain yield were obtained for the crosses A-37 X V-112 and A-37 X RTX82BDM499 under all soil moisture regimes, A-37 X V-112 and A-88005 X R-90011 under control and stress at GS3, and A-88006 X R-90011 under control and stress at GS2.

It is interesting to report that under any soil moisture regime the superiority of a hybrid regarding its SCA effect for grain yield was due to its superiority in SCA effects for one or more yield components.

## Components of genetic variance

Variance components estimates (Table 5) were appreciably larger for additive ($\sigma^2_A$) than for dominance ($\sigma^2_D$) variance for all the six studied traits under all irrigation regimes except for plant height under stress at GS3. Moreover, the magnitude of interaction variance for $\sigma^2_D$ X locations was markedly higher than for $\sigma^2_A$ X locations for most traits under all soil moisture regimes, indicating that dominance types of gene action was more affected by environment than additive types. These results are in agreement with those obtained by Chhina and Phul (1988) who reported that non-additive gene action was thought to be of major importance in the inheritance of grain yield and its components under irrigated and limited irrigation environments.

Degree of dominance a (Table 5) was partial ($a < 1$) under all soil-moisture regimes for 50 % flowering, under control and stress at GS2 for plant height and grains/panicle and under control and stress at GS3 for 1000-grain weight. Moreover, partial dominance was also exhibited for

**Table 5.** Estimates of additive ($\delta^2 A$) and dominance ($\delta^2 D$) variance, their interactions with locations, degree of dominance a , heritability ($h^2$) and selection gain (GA) for characters of grain sorghum hybrids under each soil moisture regime in the 2000 season.

| Variance components | Days to 50% flowering | Plant height | Leaf area | 1000-grain weight | Grains/ panicle | Grain yield/ Plant |
|---|---|---|---|---|---|---|
| **Control** | | | | | | |
| $\delta^2 A$ | 12.36 | 961.0 | 3313.5 | 4.95 | 310075 | 183.6 |
| $\delta^2 D$ | 1.2 | 242.0 | 2771 | 1.5 | 6004 | 53.8 |
| $\delta^2$ Ax L | 0.0 | -9.2 | 27.6 | 3.76 | -26603 | 57.0 |
| $\delta^2$ D x L | 0.72 | 16.9 | 84.4 | 3.3 | 166587 | 140.6 |
| $\delta^2 e$ | 0.1 | 1.03 | 8.7 | 0.5 | 1239 | 3.35 |
| a | 0.41 | 0.71 | 1.29 | 0.78 | 0.20 | 0.77 |
| $h^2$ (n) | 88.2 | 79.6 | 53.9 | 47.5 | 77.4 | 54.0 |
| GA(%) | 8.7 | 28.4 | 12.8 | 15.1 | 31.3 | 29.8 |
| **Stress at GS2** | | | | | | |
| $\delta^2 A$ | 10.9 | 798.1 | 2586.6 | 4.79 | 138835 | 53.06 |
| $\delta^2 D$ | 2.0 | 295.4 | 2568 | -0.5 | 52156 | 28.5 |
| $\delta^2$ Ax L | 0.08 | 2.9 | 213.5 | 0.5 | 1038.6 | -4.1 |
| $\delta^2$ D x L | 0.86 | 75.2 | 836 | 4.8 | 175118 | 65.6 |
| $\delta^2 e$ | 0.08 | 1.4 | 59.8 | 0.05 | 6274 | 0.85 |
| a | 0.61 | 0.86 | 1.41 | 0.0 | 0.28 | 1.04 |
| $h^2$ (n) | 81.0 | 70.4 | 45.1 | 64.0 | 48.7 | 46.1 |
| GA(%) | 7.8 | 31.2 | 12.8 | 16.2 | 23.5 | 19.8 |
| **Stress at GS3** | | | | | | |
| $\delta^2 A$ | 12.7 | 245.3 | 3111.4 | 7.8 | 466573 | 104.5 |
| $\delta^2 D$ | 2.0 | 276.3 | 2342.5 | 0.3 | -118946 | 54.0 |
| $\delta^2$ Ax L | 0.66 | 26.6 | 601.3 | 1.33 | -30188 | 56.0 |
| $\delta^2$ D x L | 1.2 | 40.8 | 953.0 | 6.7 | 269469 | 94.8 |
| $\delta^2 e$ | 0.08 | 1.05 | 75.7 | 0.1 | 6569.5 | 1.6 |
| a | 0.56 | 1.50 | 1.23 | 0.28 | 0.0 | 1.01 |
| $h^2$ (n) | 80.8 | 44.1 | 49.3 | 64.1 | 76.8 | 44.4 |
| GA(%) | 8.7 | 15.9 | 14.4 | 22.2 | 40.6 | 24.6 |

grain yield under control. Complete dominance of the higher parent (a = approximately 1) was shown by grain yield under stress at both GS2 and GS3 stages. Overdominance (a > 1) was manifested by leaf area under all irrigation regimes and by plant height under stress at GS3. No dominance (a = 0) was shown by 1000-grain weight under stress at GS2 and grains/panicle under stress at GS3.

## Heritability and selection gain

Narrow-sense heritability estimates (Table 5) ranged from 47.5 % for 1000 grain weight to 88.2 % for days to 50 % flowering under control, from 45.1 % for leaf area to 81.0 % for days to 50 % flowering under stress at GS2 and from 44.1 % for plant height to 80.8 % for 50 % flowering under stress at GS3. Narrow sense heritability for grain yield was of medium magnitude (54.0, 46.1 and 44.4 % under control, under stress at GS2 and stress at GS3, respectively).

It's concluded that heritability estimates in the narrow-sense under control were higher than those under stress at GS2 and GS3 for all studied traits except for 1000-grain weight. Similar to our results, some investigators found that heritability was decreased under stressed environments (Frey 1964, Subandi and Compton 1974, Ordas and Stucker 1977 and Asay and Johnson 1990).

The best genetic advance percentage (Table 5) could be obtained through practicing selection under optimum irrigation conditions for grain yield /plant (29.8 %), selection under stress conditions at GS2 stage for plant height (31.2 %) and selection under stress at GS3 for grains/panicle (40.6 %), 1000-grain weight (22.2 %) and leaf area (14.4 %).

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# وراثة بعض صفات الذرة الرفيعة للحبوب تحت ظروف مختلفة من الاجهاد المائى

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**هجنت خمسة سلالات عقيمة ذكريا من الذرة الرفيعة للحبوب مع خمسة سلالات معيدة للخصب في موسم ١٩٩٩ بمحطة بحوث الجيزة التابعة لمركز البحوث الزراعية و تم الحصول علي ٢٥ هجين $F_1$ . كانت الآباء تختلف في قدرتها علي تحمل الجفاف . في موسم ٢٠٠٠ تم تقييم العشرة آباء والـ ٢٥ هجين $F_1$ في تحارب حقلية زرعت في موقعين ( كلية الزراعة جامعة أسيوط ومحطة بحوث شندويل ) تحت ظروف الري الكامل (كنترول) و الجفاف في مرحلة ما قبل التزهير (GS2) و تحت ظروف الجفاف في مرحلة ما بعد التزهير (GS3) ، بهدف دراسة قوة الهجين و القدرة علي الائتلاف و**

نوع فعل الجين و القدرة علي التوريث لبعض صفات المحصول و الصفات الزراعية تحت ظروف مختلفة من الاجهاد الرطوبي الأرضي . وصلت قوة الهجين بالنسبة للأب الأحسن إلي أقصاها في صفة ارتفاع النبات يليها في ذلك صفة محصول الحبوب/النبات تحت كل ظروف الاجهاد المائي. وصلت قوة الهجين بالنسبة للأب الأحسن لمحصول الحبوب في بعض الهجن (A-88006 X R-89022) إلي ٤٧,٥ و ٩٢,٧ % تحت ظروف الجفاف في الـ GS2 و الـ GS3 ، علي التوالي.كانت السلالات المعيدة للخصب R-90011 , V-112 و السلالات عقيمة الذكر B-1, B-102 هي أحسن السلالات في قدرتها العامة علي الإئتلاف بالنسبة لمحصول الحبوب تحت كل ظروف الإجهاد الرطوبي . تم الحصول علي أحسن قيم لتأثيرات القدرة الخاصة علي الإئتلاف لمحصول الحبوب في الهجن A-37 X RTX ، A-37 X V-112 تحت كل ظروف الإجهاد و الهجين A-88005 X R-90011 تحت ظروف الكنترول و الإجهاد في مرحلة ما بعد التزهير و الهجين A-88006 x R-90011 تحت ظروف الكنترول و الإجهاد في مرحلة ما قبل التزهير. كان التباين من النوع المضيف ($\sigma^2_A$) أكبر بدرجة ملحوظة من التباين من نوع السيادة ($\sigma^2_D$) بالنسبة لكل الصفات المدروسة تحت كل معاملات الري ، ما عدا صفة ارتفاع النبات تحت ظروف الجفاف في مرحلة ما بعد التزهير، حيث كان فيها العكس صحيحا. وصلت قيمة درجة السيادة إلي أكبر من الواحد الصحيح (أي السيادة الفائقة) بالنسبة لمساحة الورقة تحت ظروف الإجهاد في مرحلتي الـGS2 و الـ GS3 و ارتفاع النبات تحت ظروف الإجهاد في مرحلة الـ GS3 . و كانت السيادة كاملة (درجة السيادة تساوي واحد صحيح ) بالنسبة لصفة محصول الحبوب تحت ظروف الإجهاد في مرحلتي الـ GS2 و الـ GS3 . كانت السيادة جزئية ( درجة السيادة أقل من الواحد و أكبر من الصفر ) بالنسبة لـ ٥٠ % تزهير تحت كل ظروف الإجهاد و ارتفاع النبات و عدد حبوب القنديل تحت ظروف الكنترول و الإجهاد في مرحلة الـ GS2 ووزن الألف حبة تحت ظروف الكنترول و الإجهاد في مرحلة الـ GS3 و محصول الحبوب تحت ظروف الكنترول. لم توجد أي سيادة (درجة السيادة تساوي صفر) في صفة وزن الألف حبة تحت ظروف الجفاف في الـ GS2 و عدد حبوب القنديل تحت ظروف الجفاف في الـ GS3 . كانت القدرة علي التوريث بمعناها الخاص أعلي تحت ظروف الكنترول عنها تحت ظروف الإجهاد بالنسبة لكل الصفات المدروسة ، ما عدا صفة وزن الألف حبة . أمكن الحصول علي أحسن قيم للتحسين الوراثي المتوقع بواسطة الإنتخاب تحت ظروف الري المثلي لصفة محصول الحبوب (٢٩,٨ %) و من الانتخاب تحت ظروف الإجهاد في مرحلة الـGS2 بالنسبة لصفة ارتفاع النبات (٣١,٢ %) ، و من الانتخاب تحت ظروف الإجهاد في مرحلة الـ GS3 بالنسبة لصفات عدد حبوب القنديل (٤٠,٦ %) ووزن الألف حبة (٢٢,٢ %) و مساحة الورقة (١٤,٤ %) .

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