# Genetic Behaviour of Some Agronomic Traits in Two Durum Wheat Crosses under Heat Stress

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## ABSTRACT

Parents ($P_1$&$P_2$), $F_1$, $F_2$ and first generation backcrosses ($BC_1$&$BC_2$) of two durum wheat crosses i.e., Bani Sweif 5 / Bani Sweif 3 ($C_1$) and Sohag 3 /KSU 18 ($C_2$), were grown in two experiments (normal and heat stress = late sowing). This study was conducted during the three successive growing seasons i.e., 2009/2010, 2010/2011 and 2011/2012 at the Experimental Farm of Shandaweel Agric. Res. Station, ARC, to estimate non-allelic interaction, scaling tests (A, B, C and D), coupled with six types of gene action in addition to determining the adequacy of genetic model controlling the genetic system of the inheritance of some economic traits. Days to heading, plant height, number of spikes / plant, number of kernels / spike, 100-kernel weight, biological and grain yields / plant were studied. Results indicated the presence of non-allelic interaction for the significant values in all traits of the two crosses and environments except number of spikes / plant and number of kernels / spike in the two environments for cross I, 100-kernel weight under heat stress for cross II in which the values did not reach the significance level.

Result revealed that additive – dominance model was inadequate for the inheritance of most studied traits of the two crosses and environment conditions. Meanwhile, the scaling tests indicated the presence of non-allelic epistatic gene effect for the remaining characters. Additive, additive x additive and additive x dominance gene effects were higher than the dominance and dominance x dominance gene effect, proving the important role of additive gene effects for most studied traits and selection in the $F_2$ population would be effective for improving of these characters to produce lines having high grain yield under heat stress.

$(H/D)^{0.5}$ exhibited different values < ±1.0 to > ± 1.0 according to cross, environment and characters, indicating the presence of partial dominance for all characters under normal and heat stress conditions in the two populations, except over-dominance were observed in the number of spikes /plant and number of kernels/spike under normal condition.

Broad sense heritability values were varied from moderate 41.73% for plant height to high 81.89% for 100-kernel weight in cross I under heat stress. Narrow sense heritability estimates were low for number of spikes/plant, number of kernels/spike and biological yield/plant in the cross I under normal condition. However, it was moderate for all traits for the two crosses and environments except days to heading under the two environments, 100 kernel weight under heat stress in cross I as well as plant height and 100 kernel weight under heat stress for cross II. From the previous results it cold be conclude that selection in segregation generated could be effective to produce high yielding ability lines under heat conditions.

**Key words: wheat, heat stress, genetic components, six generations.**

## INTRODUCTION

Durum wheat currently represents 8-10% of the wheat grown and produced worldwide (FAO STAT date, 2006). However, it is concentrated in relatively small geographical areas where it often plays a major role in the food security of urban population and in the livelihood and nutrition of urban communities. The productivity of durum wheat is often limited by an array of a biotic stresses that affect a successful growth and a complete grain filling. Heat stress, due to increased temperature, is an agricultural problem in many areas in the world (Wahid *et al.*, 2007).

High temperature during floral initiation and spikelets development (a period of several weeks preceding anthesis) reduced the potential number of grains, thus determining maximum yield potential. Heat stress during the post- anthesis, grain filling stage affects availability and translocation of photosynthates to the developing kernel, starch synthesis and deposition within the kernel, thus resulting in lower grain weight and altered grain quality (Bhullar & Jenner, 1985)

Generation mean analyses provides information on the relative importance of average effects of the genes (additive effects), dominance deviations, and effects due to non allelic genetic interactions, in determining genotypic values of the individuals and, consequently, mean genotypic values of families and generations. Generation mean analysis is a simple but useful technique for estimating gene effects for a polygenic trait, its greatest merit lying in the ability to estimate epistatic gene effects such as additive X additive, dominance X dominance and additive X dominance effects.

Since, genetic information obtained from multi generation are reliable compared with those based on one generation therefore, six populations ($P_1$, $P_2$, $F_1$, $F_2$, $BC_1$and $BC_2$) are considered the one which may be give detailed genetic information for the employed genotypes. High values of heritability and no significant epistatic effects were detected in the inheritance of heading date, plant height and 100 kernel weight (Bhatt, 1972; Edwards *et al.*, 1976 and Singh *et al.*, 1985). Khalifa *et al.*(1997) and Bayoumi *et al.* (2008) found that additive – dominance model were adequate for revealing the inheritance of grain yield and its components. With A, B, C and D. scaling tests, additive, dominance and epistatic effects were important for yield and its components characters. On the other hand, Pawar *et al.* (1988), El-Hennawy (1992) and Amawate and Behl (1995) revealed that the dominance gene effects were more important than additive one in most cases which showed presence of both types of gene effects. Result of Srivastava *et al.* (1992), Awaad (1996), Moshref (1996) and Sharma *et al.* (2003), indicated that both additive and non additive gene effects were predominant for most studied traits, though the non-additive gene effects were also important. This study aims to evaluate the genetic variations of a recombination inbred line populations for heat tolerance and determine the adequacy genetic model, types of gene action and heritability using six populations under normal and heat environments.

## MATERIALS AND METHODS

This study was carried out at the Experimental Farm of Shandaweel Agric. Res. Station, ARC., Egypt during the successive growing seasons of 2009/2010, 2010/2011, and 2011/2012. Four durum wheat cultivars (three local and one introduced) were chosen for this study on basis of their diversity of the studied traits (Table 1). In 2009/2010 season, two crosses were made among the parents to produce $F_1$ hybrid grains and designated as follows:

In 2010/2011 season, some $F_1$ plants of each cross were backed cross to both parents to produce the back crosses ($Bc_1$ and $Bc_2$). At the same time, some other $F_1$ plants were selfed to produce $F_2$ generation. Also, crosses were made to produce more $F_1$ grains. In the 2011/2012 season, the six populations, i.e., $P_1$, $P_2$, $F_1$, $F_2$, $Bc_1$ and $Bc_2$ of the two crosses were sown in two experiments in two sowing dates, ( Nov. 20 as normal and Dec. 20 as late sowing = heat stress) in a randomized complete blocks design with three replicates. Each replicate consisted of 20 grains in one row for each of the parents and $F_1$'s', 40 grains in two rows of each back cross and 80 grains in four rows for the $F_2$ population. Rows were 2.0 m long and 30 cm apart and 10 cm between plants. Recommended cultural practices for wheat production were adopted in all the growing season. Data were recorded on 5 competitive individual plants for non-segregate basis ($P_1$, $P_2$, and $F_1$) and 10 plants for $BC_1$ and $BC_2$ and 60 plants for $F_2$ population for each replicate as follows:

1 - Days to heading. 2 - Plant height (cm).
3– Number of spikes / plant. 4– Number of kernels / spike.
5– 100-kernel weight (gm). 6– Biological Yield / plant (gm).
7– Grain yield / plant (gm).

**Components the genetic variance:**

In the case of three– six parameters model where the absence of non-allelic interaction as indicated by non– significance of scale test, the genetic components of variance for each trait in the studied crosses were partitioned into additive (D), dominance (H) and environmental (E) genetic variances using formula as follows:

$E = 1/3\ (VP_1 + VP_2 + VF_1)$
$D = 4VF_2 - 2\ (VBc_1 + VBc_2)$ and
$H = 4(VF_2 - 1/2\ VD - E)$

$F_2$ plants were used to compute average degree of dominance $(H/D)^{0.5}$ and heritability in broad and narrow sense.

The A, B, C, and D scaling tests as outlined were applied to test the presence of non-allelic interaction as follows

$A = 2\bar{B}_1 - \bar{P}_1 - \bar{F}_1 \quad VA = 4V(\bar{B}_1) + V(\bar{P}) + V(\bar{F}1)$
$B = 2\bar{B}_2 - \bar{P}_2 - \bar{F}_1 \quad VB = 4V(\bar{B}_2) + V(\bar{P}_2) + V(\bar{F}1)$
$C = 4\bar{F}_2 - 2\bar{F}_1 - \bar{P}_1 - \bar{P}_2 \quad VC = 16\ V(\bar{F}_2) + 4V(\bar{F}_1) + V(\bar{P}_1) + V(\bar{P}_2)$
$D = 2\bar{F}_2 - \bar{B}_1 - \bar{B}_2 \quad VD = 4V\bar{F}_2 + V\bar{B}_1 + VB_2$

The analysis of the values of A, B, C and D should be equal zero within the limits of this standard error. The significance of any one of these scales are taken to indicate proceeded to compute the interaction types involved the six parameters genetic model of. Hayman (1958).

The significance of the genetic components were tested using "t" test

Where $\pm t$ = effect / (variance effect) $^{1/2.}$

potence ratio (P), was estimated using the following equation.

**Table 1: Pedigree and origin of the cultivars used in the two durum wheat crosses.**

| Cross | | Parent | Pedigree | Origin |
|---|---|---|---|---|
| Cross 1 | $P_1$ | Bani Sweif 5 | DIPPER-2/BUSHEN-3 | Egypt |
| | $P_2$ | Bani Sweif 3 | CORM "S"/ RUFO "S" | Egypt |
| Cross 2 | $P_1$ | SOhag 3 | MEXI "S" MGHA/51792// DURUM 6 | Egypt |
| | $P_2$ | KSU 18 | KSU 18 | Italian |

$P = (F_1 - M.P.) / 1/2 (P2 - P_1)$ where:

P: potence ratio of gene set. $F_1$: First generation mean.

$P_1$: the mean of the lower parent, $P_2$: the mean of the higher parent, and M.P: the mid-parent values = $1/2(P_1 + P_2)$.

Stress tolerance index (STI) for grain yield was computed according to Farshadfar, et al. (2001), as follow:

$STI = Yp \times Ys / (Yp)^2 \times 100$ where:

Yp = grain yield under normal conditions.

Ys = grain yield under stress conditions.

Broad–sense heritability ($H^2$) as estimated based on the following equations $H^2 = Vg / (Vg + Ve) \times 100$, where: $Ve = (Vp_1 + Vp_2 + VF_1)/3$,

$Vg = VF_2 - Ve$.

Narrow–sense heritability($h^2$) for $F_2$–generation was estimated as proposed by Warner (1955), $h^2 = 2VF_2 - (VB_1 + VB_2) / VF_2 \times 100$.

Expected genetic advance from selection was calculated as formula proposed using the selection differential (K) equal 2.06 for 5% selection intensity and narrow- sense heritability.

## RESULTS AND DISCUSSION

### I-Performance and potence ratio:

Average of the seven characters for P1, P2, F1, F2, BC1 and BC2 populations for two durum wheat crosses under the two environments are given in Tables (2&3). The analysis of variance indicated that there were significant difference between the studied generations in all characters under study and the two environmental conditions, except, number of spikes /plant and number of kernels/spike under the two environments, while plant height and 100 kernel weight under heat stress for cross I (Bani Sweif 5 X Bani Sweif 3), number of spikes/plant, 100-kernel weight and biological yield/plant under heat condition for cross I1 (Sohag 3 x KSU 18) and number of kernel/spikes under two environments for cross II. Significant differences for most characters under study in normal and heat stress conditions indicated the presence of sufficient genetic variability in the experimental materials for grain yield and other traits.

Data for means of six-populations showed that the F1 hybrids were higher than mid-parents and or higher parents in days to heading, plant height, number of spikes/plant, number of kernels/spike, 100-kernel weight, biological yield/plant and grain yield/plant for both crosses under the two environments, except days to heading under the two conditions for cross1I. The results indicated the presence of heterotic effects for these characters.

The potence ratio presented in Tables (2&3), its values ranged from less than one (0.14) for plant height under heat stress to more than one (14.17) for biological yield/plant under normal condition indicating the presence of partial dominance for plant height (0.14) under heat stress and 100-kernel weight (0.17) under normal condition in the cross 1, days to heading (0.88) and plant height (0.79) under normal condition in the cross I1. Over-dominance were detected for days to heading, number of spikes /plant, number of kernels /spike, biological yield/plant and grain yield/plant under the two environments for cross 1, plant height and 100-kernel weight under normal and stress conditions, respectively in the same cross. In the cross II, number of spikes /plant, number of kernels /spike, 100-kernel weight, biological yield/plant and grain yield /plant were over-dominance under the two environments, while days to heading and plant height were over-dominance under heat stress condition. These results are in line with those obtained by ketata et al. (1976), Moshref (1996), khalifa et al. (1997) and Farshadfar *et al.* (2008).

Stress tolerance index (STI %) for grain yield/plant showed that the first cross had higher values compared to the second cross, Table (3). The $F_1$ hybrid for cross I gave the highest value (77.14 %) of heat tolerance followed by $P_2$ and $F_2$ which had (76.52 and 76.49%) than $BC_2$, $BC_1$ and $P_1$ populations which had 76.41, 74.96 and 73.91% respectively, in cross I, while in cross II, $F_1$ hybrid had the highest heat tolerance (74.32%) followed by $P_1$ (73.79) and $P_2$ (71.74). These result indicated that selection in the segregation population for development grain yield/plant under heat condition could be effective to produce lines have high grain yield and high tolerance to heat stress. The same results were obtained by Kheiralla, *et al.* (1993) and Farshadfar *et al.* (2001).

### II-Gene effects:

Choice the most efficient breeding procedures depends, to large extent, on the knowledge of the genetic system controlling the characters to be selected, the estimates of various types of gene effects contributing to the genetic variability are presented in Tables (4&5). The results of A, B, C, and D scaling test for the two durum wheat crosses under both environments, revealed that significant of any of these tests indicates the presence of non-allelic gene interactions or epistasis on the scale of measurement used. Results of scaling test, showed that additive-dominance model are inadequate for explaining the inheritance of all studied traits and this would indicate the presence of non-allelic gene interaction in the two crosses under the two environments, except number of spikes/plant and number of kernels/spike under normal and heat stress, while under heat stress for 100 kernel weight in the first cross. However cross II showed insignificant for plant height and 100 kernels weight under heat stress, indicating the simple genetic variation controlling the inheritance of these traits in the two crosses.

Table 2: Means ± S.E for the six populations and potence ratio for days to heading, plant height, number of spikes/plant and number of kernels/spike of two durum wheat crosses under two environments.

| Characters | days to heading | | plant height (cm) | | number of spikes/plant | | number of kernels/spike | |
|---|---|---|---|---|---|---|---|---|
| Population | Normal | Heat | Normal | Heat | Normal | Heat | Normal | Heat |
| **Cross I** | | | | | | | | |
| $P_1$ | 81.93± 0.57 | 76.73±0.71 | 94.93±0.75 | 90.20±0.61 | 9.33±0.42 | 8.93±0.36 | 40.41±0.72 | 39.76±0.38 |
| $P_2$ | 95.33± 0.77 | 82.47±0.50 | 105.87±0.79 | 100.53±0.69 | 10.20±0.45 | 10.00±0.37 | 39.00±0.73 | 37.93±0.55 |
| $F_1$ | 96.73± 0.75 | 89.87±0.49 | 107.27±0.70 | 98.67±0.55 | 11.66±0.51 | 10.78±0.14 | 46.80±0.69 | 42.20±0.52 |
| $F_2$ | 88.97± 0.47 | 77.14±0.40 | 91.75±0.42 | 88.01±0.31 | 9.41±0.25 | 8.62±0.21 | 41.01±0.40 | 40.35±0.27 |
| $BC_1$ | 93.50± 0.77 | 79.43±0.59 | 103.53±0.67 | 93.17±0.52 | 9.97±0.42 | 9.23±0.33 | 43.02±0.67 | 39.01±0.44 |
| $BC_2$ | 91.00± 0.67 | 77.11±0.59 | 95.43±0.65 | 90.00±0.51 | 10.47±0.43 | 9.97±0.35 | 39.35±0.64 | 40.57±0.44 |
| potence ratio | 1.21 | 3.58 | 1.72 | 0.14 | 4.17 | 2.03 | 10.0 | 3.66 |
| L. S.D.0.05 | 7.63 | 2.71 | 6.65 | NS | NS | NS | NS | NS |
| **Cross II** | | | | | | | | |
| $P_1$ | 98.93±0.79 | 87.00±0.18 | 104.53±0.74 | 90.38±0.26 | 9.00±0.49 | 9.52±0.21 | 41.03±0.59 | 40.08±0.41 |
| $P_2$ | 94.00±0.68 | 80.93±0.23 | 100.67±0.70 | 87.50±0.33 | 9.93±0.46 | 8.70±0.21 | 41.83±0.57 | 36.06±0.39 |
| $F_1$ | 97.67±0.73 | 82.20±0.22 | 104.13±0.29 | 91.40±0.25 | 11.60±0.44 | 10.20±0.82 | 46.23±0.69 | 42.65±0.38 |
| $F_2$ | 98.65±0.39 | 77.20±0.12 | 98.80±0.44 | 88.44±0.29 | 9.55±0.27 | 7.90±0.11 | 42.08±0.34 | 43.30±0.20 |
| $BC_1$ | 92.97±0.64 | 87.25±0.19 | 105.27±0.72 | 90.98±0.40 | 8.97±0.42 | 8.86±0.18 | 40.02±0.56 | 40.58±0.34 |
| $BC_2$ | 91.80±0.61 | 80.23±0.20 | 103.77±0.70 | 87.80±0.42 | 10.10±0.54 | 8.90±0.18 | 40.00±0.54 | 44.03±0.33 |
| potence ratio | 0.88 | 4.62 | 0.79 | 1.71 | 4.53 | 1.73 | 11.00 | 2.72 |
| L. S.D.0.05 | 4.26 | 3.80 | 3.86 | 3.80 | 1.99 | NS | NS | NS |

**Table3: Means ± S.E for the six populations, potence ratio and stress tolerance index (STI) for 100-kernel weight, Biological yield/plant and grain yield/plant for two durum wheat crosses.**

| Characters | 100-kernel weight | | Biological yield/plant | | grain yield/plant | | |
|---|---|---|---|---|---|---|---|
| **Population** | **Normal** | **Heat** | **Normal** | **Heat** | **Normal** | **Heat** | **STI%** |
| **Cross I** | | | | | | | |
| $P_1$ | 5.28±0.09 | 5.05±0.06 | 95.29±0.26 | 88.73±0.72 | 20.93±0.72 | 15.47±0.70 | 73.91 |
| $P_2$ | 4.56±0.09 | 4.68±0.12 | 96.21±0.81 | 75.61±0.82 | 23.00±0.76 | 17.60±0.58 | 76.52 |
| $F_1$ | 5.98±0.08 | 5.13±0.09 | 102.27±1.18 | 90.73±0.98 | 27.13±0.66 | 20.93±0.49 | 77.14 |
| $F_2$ | 5.24±0.05 | 5.00±0.08 | 104.21±0.52 | 76.12±0.46 | 21.53±0.39 | 16.47±0.32 | 76.49 |
| $BC_1$ | 5.29±0.08 | 5.01±0.14 | 83.25±0.93 | 80.92±0.73 | 21.93±0.64 | 16.44±0.52 | 74.96 |
| $BC_2$ | 5.27±0.08 | 4.84±0.09 | 83.00±0.80 | 83.93±0.75 | 23.07±0.61 | 17.63±0.50 | 76.41 |
| **potence ratio** | 0.17 | 1.50 | 14.17 | 1.30 | 3.60 | 4.13 | ------- |
| **L. S. D.0.05** | 0.48 | NS | 7.36 | 6.22 | 4.32 | 2.96 | ------- |
| **Cross II** | | | | | | | |
| $P_1$ | 5.47±0.08 | 4.84±0.14 | 94.27±1.54 | 80.07±0.62 | 22.13±0.76 | 16.33±0.24 | 73.79 |
| $P_2$ | 5.33±0.09 | 4.42±0.12 | 92.99±1.30 | 68.32±0.54 | 19.75±0.64 | 14.17±1.02 | 71.74 |
| $F_1$ | 5.97±0.06 | 4.91±0.12 | 98.80±0.97 | 82.45±0.52 | 29.13±0.60 | 21.65±0.26 | 74.32 |
| $F_2$ | 5.19±0.05 | 4.60±0.09 | 94.21±0.74 | 70.21±0.32 | 20.39±0.21 | 15.64±0.14 | 69.85 |
| $BC_1$ | 5.51±0.08 | 4.46±0.14 | 90.77±1.22 | 82.51±0.58 | 21.90±0.59 | 14.96±0.23 | 68.36 |
| $BC_2$ | 5.36±0.08 | 4.35±0.15 | 84.27±1.16 | 74.35±0.46 | 21.77±0.63 | 13.93±0.22 | 63.99 |
| **potence ratio** | 2.17 | 1.33 | 8.08 | 1.15 | 6.88 | 8.82 | ------- |
| **L. S. D.0.05** | 0.46 | NS | 8.93 | NS | 4.81 | 3.17 | -------- |

These results may be taken as an evidence for the failure of simple genetic model to ascertain the genetic variation for these characters in the corresponding crosses. Therefore, the six parameters model was applied for these characters in order to assess the digenic interaction types controlling the genetic variations. These results were in agreement with those of Sirvastava *et al.*(1992), Hassan (1993), Tammam (2005), Abd El-Mageed (2005), El-Sayed and El-Shaarawy (2006) and El-Aref *et al.*(2011).

The mean parameters (m) for all studied attributes of the two crosses and environments which reflect the contribution due to the over all mean plus the locus effects and interaction of the fixed loci were significant. Additive gene effect (d) was positive and significant for days to heading, number of spikes/ plant and grain yield under heat stress, 100 kernel weight under normal condition for cross II and only grain yield/plant under heat for cross I, while positive and negative insignificant for all other characters of the two crosses under both environment conditions. These results indicated that potentiality of improving the performance of these traits using the pedigree selection program may be more effective, El-Sayed and El-Shaarawy (2006).

The estimated of dominance gene action (h) in cross I was positive and significant for plant height, 100 kernel weight and grain yield/plant under normal condition, biological yield/plant under heat stress, while it was negative and significant were obtained by plant height under heat stress and biological yield/plant, under normal environment. Meanwhile in the cross II, positive or negative significant dominance gene effects were found to be involved in the inheritance of plant height and biological yield/plant, under both normal and heat stress, 100 kernel weight and grain yield/plant under normal condition. These results indicated the importance gene effects in inheritance of these traits. On the other hand, significant additive (d) and dominance (h) components indicated that both additive and dominance gene effects were important in the inheritance of these characters. Also, selection desirable characters may be practiced in early generations but it would be effective in the late ones. Similar results were obtained by Hendawy (2003), El-Sayed and El-Shaarawy (2006).

Estimates of epistatic gene effects: additive x additive (I), additive x dominance (J) and dominance x dominance (L) are presented in Table (4&5). Significant estimates of epistatic gene effects for one or more of these three types of epistatic gene effects for some studied traits were detected. Regarding to the additive x additive (i) type of epistatic gene effects were positive and significant in the biological and grain yield/plant under normal environment in cross 1, indicated that two traits had increasing gene and selection for the development of these traits could be effective. Meanwhile, it was negative and significant in case of days to heading under two environments in cross I, days to heading and biological yield/plant under normal environment and number of spikes/plant under both normal and heat stress in the second cross.

On the other hand most traits were insignificant and positive or negative for two crosses and environments, these results indicated that the materials used in this study have increasing alleles for these characters and selection to improve it could be effective.

Data concerning the epistatic gene effects, additive x dominance (j) in Tables (4 & 5) had positive and significant for days to heading and plant height under normal conditions in the cross I and days to heading under heat stress for cross II, while it was significant and negative for biological yield/plant in cross I, number of spikes /plant and number of kernels/spike in cross II under heat stress. These results showed that the inheritance of these traits were effective by the duplication effect of epistatic genes.

The dominance x dominance (l) gene interaction (Tables 4&5) were differed according to crosses and environments, where days to heading under heat stress, biological yield/plant and grain yield/plant under normal conditions in cross I, days to heading under normal, biological and grain yield/plant under heat stress in cross II were positive and significant, while days to heading under heat stress and biological yield/plant under heat and normal environments respectively, were negative and significant. However, other traits under study for the two crosses did. not reach the significance level. Positive and significant results confirm the important role of dominance x dominance gene interaction in the genetic system controlling these results were reported by Srivastava *et al.* (1992), Tammam (2005) El-Sayed and El-Shaarawy (2006). The absolute relative magnitude of the epistatic effects to the mean effects was somewhat variable depending on the cross and the studied traits. Generally, the absolute magnitude of the epistatic effects were larger than additive or dominance effects. Therefore, it could be concluded that homozygous x homozygous and heterozygous x heterozygous non-allelic interactions were more important than the heterozygous x heterozygous interaction in the inheritance of most studied traits. The study further revealed the epistatic gene effects were important as additive and dominance gene effects for most of the studied traits. The failure in detecting epistatic gene effects based on the generation mean analysis does not necessarily indicate that non-allelic interactions play no role in the determination of phenotypic value.

**Table 4: Scaling test and six genetic parameters of non-allelic gene interaction for morpho-physiological all studied traits in durum wheat cross I under normal and heat stress.**

| Characters | | Scaling test | | | | genetic parameters | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | m | d | h | I | J | L |
| Days to heading | N | 8.33± 9.26 | -10.07± 8.47 | 25.15*± 19.94 | 71.19± 10.91 | 98.97*± 4.68 | 2.50± 5.62 | -18.78± 22.10 | -26.88*± 21.83 | 9.20*± 5.92 | 26.61± 30.07 |
| | H | -7.73± 7.26 | -18.13*± 7.03 | 9.63± 4.04 | 17.75*± 3.02 | 87.14*± 3.97 | 2.33± 4.58 | -25.23± 18.50 | -35.49*± 18.33 | 5.20± 4.88 | 61.36*± 24.76 |
| Plant height | N | -6.07± 2.90 | -11.33± 2.86 | -48.33*± 4.24 | -15.47± 0.34 | 91.75*± 4.15 | 8.10± 5.17 | 37.80*± 19.86 | 30.93± 19.57 | 13.57*± 5.58 | -13.53± 27.39 |
| | H | 0.47± 2.55 | -9.27*± 2.55 | 8.97± 3.70 | 8.89± 2.72 | 98.01*± 3.14 | -0.8± 3.97 | -21.97*± 15.10 | -17.77± 14.84 | 4.87± 4.35 | 26.57± 20.98 |
| Nmber of spikes/plant | N | -3.87± 2.30 | 0.00± 2.12 | -5.09± 3.35 | -0.61± 2.47 | 9.41*± 2.56 | -1.90± 3.32 | -1.50± 12.43 | 3.06± 12.21 | 1.23± 3.52 | -1.07± 17.40 |
| | H | -2.60± 2.04 | 0.13± 2.07 | -6.39± 3.03 | -1.96± 2.23 | 8.62**± 2.13 | -0.73± 2.62 | 5.22± 10.15 | 3.92± 10.00 | -0.10± 2.81 | -1.45± 13.96 |
| Number of kernels/spike | N | 0.24± 2.88 | -8.50± 2.84 | -8.98± 4.17 | -0.36± 3.08 | 41.01*± 3.99 | 3.67± 5.09 | 7.81± 19.24 | 0.71± 18.95 | 2.96± 5.47 | 7.55± 26.75 |
| | H | -2.12± 2.32 | -0.83± 2.42 | -0.71± 1.04 | 1.12± 0.73 | 40.35*± 2.57 | -1.56± 3.14 | 1.11± 13.16 | -2.24± 12.94 | -2.47± 3.65 | 5.19± 18.17 |
| 100-kernelweight | N | 1.03± 0.96 | 0.29*± 0.94 | 1.17± 3.46 | -0.08± 2.52 | 5.24*± 0.48 | 0.01± 0.59 | 0.21*± 2.29 | 0.15± 2.25 | -0.35± 0.64 | -1.47± 3.14 |
| | H | 1.00± 1.11 | -0.10± 1.01 | 1.41± 1.34 | 0.25± 1.15 | 5.15*± 0.79 | 0.36± 0.90 | -0.64± 3.65 | -0.51± 3.63 | 0.18± 0.93 | -0.39± 4.86 |
| Biological yield/plant | N | -13.07*± 3.42 | -32.47*± 3.22 | 20.81± 4.84 | 42.17*± 3.54 | 104.21*± 2.30 | 0.25± 6.75 | -77.83*± 25.62 | -84.35*± 25.10 | 0.70± 7.13 | 147.89*± 25.80 |
| | H | -4.51± 0.41 | -11.60± 0.40 | -41.33*± 0.49 | -12.61± 0.27 | 76.12*± 4.61 | -3.02± 5.73 | 33.78*± 22.14 | 25.22± 21.71 | -9.58*± 6.11 | -9.11± 3.69 |
| Grain yield/plant | N | -7.27± 3.04 | -2.13± 3.08 | -13.28*± 4.51 | -1.94± 3.29 | 21.53*± 3.94 | -1.13± 4.86 | 12.45*± 8.82 | 3.88*± 8.53 | 0.30± 5.28 | 5.52*± 25.89 |
| | H | 2.35*± 2.60 | -1.13± 2.53 | 1.95± 3.74 | 0.36± 2.76 | 18.47*± 3.24 | 1.31*± 4.07 | 1.17± 15.53 | -0.73± 15.31 | 0.88± 4.43 | -0.49± 21.44 |

**Table 5: Scaling test and six genetic parameters of non-allelic gene interaction for morpho-physiological all studied traits in durum wheat cross II under normal and heat stress.**

| Characters | | Scaling test | | | | genetic parameters | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | m | d | H | I | J | L |
| Days to heading | N | -10.66*± 2.86 | -8.07± 2.76 | 6.33± 4.13 | 12.53*± 3.03 | 98.65*± 3.90 | 1.17± 4.88 | -23.86*± 18.74 | -1.30*± 18.41 | 43.79± 5.28 | 15.23*± 25.95 |
| | H | 10.30*± 2.38 | 2.33± 1.59 | 8.15± 2.30 | -2.24± 1.70 | 82.62*± 1.22 | 7.02*± 1.53 | -2.29± 5.86 | 4.48± 5.77 | 3.99*± 1.63 | -17.11*± 8.10 |
| Plant height | N | 5.74± 3.00 | -1.12± 2.98 | -18.26*± 4.40 | -11.44± 3.23 | 98.80*± 4.44 | 1.50± 5.52 | 24.41*± 21.29 | 22.88± 20.93 | -0.43± 5.87 | -27.50± 29.41 |
| | H | 3.06± 2.16 | -6.18± 2.23 | -6.92± 3.46 | -1.90± 2.57 | 88.44*± 2.92 | 3.18± 3.21 | 6.26± 13.38 | 3.80± 13.31 | 1.74± 3.35 | -0.68± 1.75 |
| Number of spikes/plant | N | -3.59± 2.29 | -0.40*± 2.33 | -3.93± 3.40 | 3.03*± 2.52 | 9.55**± 2.69 | -1.13± 3.34 | 2.08± 1.22 | -0.06± 12.68 | -0.66± 3.59 | 4.05± 1.70 |
| | H | 2.82*± 1.51 | -1.92± 1.45 | -3.02*± 2.23 | -1.96± 1.64 | 7.90*± 1.14 | -0.04*± 1.41 | 7.01± 5.46 | 3.92± 5.36 | -2.45*± 1.52 | -4.82± 7.53 |
| Number of kernels/spike | N | -7.84*± 2.65 | -7.66± 2.62 | -7.28± 3.86 | 4.11± 2.83 | 42.08*± 3.40 | 0.01± 4.26 | -0.68± 16.43 | -8.22*± 16.04 | 0.11± 4.54 | 23.72± 22.65 |
| | H | 2.54± 2.07 | 5.33± 2.04 | 11.67*± 2.99 | 1.99± 2.20 | 43.30*± 2.05 | -3.45± 2.58 | 0.60± 0.96 | -3.98*± 1.06 | -5.46*± 0.49 | -3.79± 2.02 |
| 100-kernelweight | N | 0.72*± 1.14 | 0.28± 0.92 | 0.02± 0.96 | -0.49± 1.4 | 5.19*± 0.49 | 0.15*± 0.6 | 0.55± 2.32 | 0.98± 9.69 | 0.08± 2.81 | -1.98± 1.37 |
| | H | -0.41± 1.24 | -1.05± 1.32 | -0.68± 1.98 | 0.39± 2.45 | 4.60*± 0.95 | 0.11± 1.10 | -0.50± 4.42 | -0.78± 4.38 | -0.10± 1.15 | 2.24± 5.91 |
| Biological yield/plant | N | -11.53± 3.88 | -23.25*± 3.76 | 31.98*± 5.62 | 33.38*± 4.18 | 104.21*± 7.42 | 6.50± 9.21 | -61.59*± 35.36 | -66.76*± 34.94 | 0.29± 4.38 | -45.31*± 21.44 |
| | H | 8.50*± 2.68 | 7.93*± 2.41 | -12.45*± 3.73 | -14.44± 2.76 | 70.21*± 3.24 | 6.16± 4.07 | -27.14*± 15.52 | 28.88± 15.31 | -3.37± 5.14 | 13.60*± 2.52 |
| Grain yield/plant | N | -.5.06± 2.76 | -6.32*± 2.79 | -9.16± 4.06 | 1.11± 2.99 | 22.39*± 3.81 | 0.130± 4.76 | 6.68*± 1.24 | -2.22± 17.96 | -0.37± 5.14 | 13.60± 2.52 |
| | H | -1.66± 1.69 | -5.09*± 1.67 | -1.97± 2.50 | 2.39± 1.84 | 15.64*± 1.45 | 1.03*± 1.76 | -3.82± 6.89 | -4.79± 6.78 | -0.35± 1.88 | 11.54*± 9.44 |

**Table 6: Genetic variance, broad ($H^2$) and narrow ($h^2$) sense heritabilities and expected genetic advance (G.S) for seven characters in the cross I under normal and heat stress.**

| Genetic parameter | | genetic variance | | | $(H/D)^{0.5}$ | Heritabilites | | G.S |
|---|---|---|---|---|---|---|---|---|
| Characters | | D | H | E | | $H^2$ | $h^2$ | |
| Days to heading | N | 24.20 | 9.33 | 7.44 | 0.62 | 66.0 | 55.34 | 5.33 |
| | H | 20.95 | 1.60 | 4.87 | 0.28 | 69.08 | 66.54 | 5.44 |
| Plant height | N | 15.60 | 4.36 | 8.36 | 0.53 | 51.54 | 45.22 | 3.87 |
| | H | 7.79 | 0.82 | 5.73 | 0.32 | 41.73 | 39.64 | 2.56 |
| Nmber of spikes/plant | N | 4.28 | 4.83 | 3.22 | 1.06 | 50.69 | 32.57 | 1.72 |
| | H | 4.34 | 1.44 | 2.00 | 0.58 | 55.83 | 47.90 | 2.10 |
| Number of kernels/spike | N | 12.00 | 8.71 | 7.78 | 2.95 | 51.23 | 37.59 | 0.85 |
| | H | 7.00 | 1.75 | 3.62 | 0.50 | 52.07 | 46.30 | 2.62 |
| 100-kernelweight | N | 0.22 | 0.06 | 0.10 | 0.54 | 54.87 | 47.83 | 0.47 |
| | H | 0.86 | 0.31 | 0.11 | 0.60 | 81.89 | 69.35 | 1.12 |
| Biological yield/plant | N | 20.99 | 13.40 | 14.15 | 0.80 | 49.45 | 37.49 | 4.09 |
| | H | 19.19 | 3.40 | 10.79 | 0.42 | 49.19 | 45.15 | 4.29 |
| Grain yield/plant | N | 14.92 | 1.24 | 7.78 | 0.29 | 49.96 | 47.97 | 3.90 |
| | H | 9.02 | 2.87 | 5.29 | 0.56 | 49.70 | 42.87 | 2.86 |

**Table 7: Genetic variance, broad ($H^2$) and narrow ($h^2$) sense heritabilities and expected genetic advance (G.S) for seven characters in the cross II under normal and heat stress.**

| Genetic parameter | | Genetic variance | | | $(H/D)^{0.5}$ | heritabilites | | G.S |
|---|---|---|---|---|---|---|---|---|
| Characters | | D | H | E | | $H^2$ | $h^2$ | |
| Days to heading | N | 13.29 | 1.75 | 8.15 | 0.36 | 46.49 | 43.62 | 3.51 |
| | H | 1.34 | 0.64 | 0.67 | 0.69 | 55.13 | 44.52 | 1.12 |
| Plant height | N | 17.94 | 7.19 | 8.97 | 0.63 | 54.55 | 45.44 | 4.16 |
| | H | 13.44 | 0.70 | 1.61 | 0.23 | 81.10 | 79.04 | 0.75 |
| Nmber of spikes/plant | N | 6.66 | 2.68 | 3.25 | 0.63 | 55.17 | 45.93 | 2.55 |
| | H | 1.22 | 0.09 | 0.67 | 0.28 | 48.72 | 46.92 | 1.10 |
| Number of kernels/spike | N | 9.99 | 3.48 | 5.69 | 0.59 | 50.75 | 43.21 | 3.03 |
| | H | 3.44 | 0.61 | 2.33 | 0.42 | 44.54 | 40.93 | 1.73 |
| 100-kernelweight | N | 0.23 | 0.10 | 0.10 | 0.66 | 58.76 | 48.37 | 0.49 |
| | H | 1.20 | 0.27 | 0.23 | 0.47 | 74.07 | 66.67 | 1.30 |
| Biological yield/plant | N | 50.76 | 18.60 | 25.08 | 0.61 | 54.49 | 46.05 | 7.04 |
| | H | 8.86 | 5.00 | 4.82 | 0.75 | 54.09 | 42.17 | 2.82 |
| Grain yield/plant | N | 0.23 | 0.10 | 0.10 | 0.49 | 58.76 | 48.37 | 2.05 |
| | H | 2.20 | 0.28 | 0.93 | 0.36 | 55.71 | 52.38 | 1.56 |

Nighawan *et al.* (1969) reported the importance of all the three types of gene action. On the other hand Ketata *et al.* (1976) postulated non- additive gene action of sizable amount for grain yield in wheat.

**III-Genetic variance of three– parameters model:**

The assessment of genetic variance, additive (D) and dominance (H) gene effects in Tables (6 & 7), revealed that additive genetic variance was higher than dominance one in the days to heading, plant height, number of spikes/plant, number of kernels/spike, 100-kernel weight, biological and grain yield/plant, in the two crosses and environments under study, indicated that the additive gene effects play the main role in the inheritance of these traits and using selection in early segregating generations could be effective to isolate lines characterized by high grain yield under heat stress. Similar results were reported by Singh *et al.* (1985), El-Hennawy (1992), khieralla *et al.* (1992), Aboshosha and Hammad (2009) and El-Aref *et al.* (2011).

The average degree of dominance $(H/D)^{0.5}$ given in Tables (6&7) revealed that partial dominance gene effects was presented for all characters under study for the two crosses and environments except number of spike/plant and number of kernels/spike under normal condition in cross I. These result indicated that the genetic system of these traits under the two environments are controlling by additive and non-additive gene effects. Similar results were reported by kherilla *et al.* (1992), kherilla *et al.* (1997), El-Hag (2006), Farshadfar *et al.* (2008), Aboshosha and Hammad (2009), Khattab (2009) and El-Aref *et al.* (2011).

**Heritability and Genetic Advance:**

Heritability estimate indicates the progress from selection for plant characters is relatively easy or difficult to make in breeding program. Plant breeders, through experience, can perhaps rate a series of their response to selection. Heritability gave a numerical description of this concept. Assessment of heritability of various traits is of considerable important in crop improvement program, for example, to predict response to selection, Nyguist (1991).

Heritability estimates depending on the magnitudes of its genetic variance components of additive (D) and dominance (H) are found in Tables (6&7). In this respect broad sense heritability was higher than that of narrow sense in all studied characters for the two crosses and environments. Broad sense heritability values were varied from moderate 41.73% for plant height to high 81.89% for 100-kernel weight in cross I under heat stress, indicating that superior genotypes for these characters in that cross could be identified from its phenotypic expression, and illustrate the importance of phenotypic selection for improvement these traits (Awaad, 1996).

Narrow sense heritability estimates were low for number of spikes/plant (32.57%), number of kernels/spike (37.59%) and biological yield/plant (37.49%) in the cross I under normal condition. While it was moderate for all traits under two crosses and environment except days to heading (55.34 and 66.54%) under the two environments,100 kernel weight (69.35%) under heat stress in cross I as well as plant height (79.04%) and 100 kernel weight (66.67%) under heat stress for cross II. These revealed also that genetic variance was mostly attributed to the additive effects of gene for the other studied traits. This confirmed the previous results by mean of gene action estimates of additive genetic portion, which was mostly predominant. These results were harmony with those obtained by Hamada (2003), Hendaway (2003), El-Sayed and El-Shaarawy (2006), and El-Aref *et al.* (2011).

The expected genetic advance (G.S) as percentage of the $F_2$ mean depends mainly on the values of narrow sense heritability for the studied characters is presented in Table (6&7). Moderate to high genetic for all characters under two crosses and environment except, 100 kernel weight under two crosses and environments, number of spikes/plant and number of kernels/spike under normal in cross I and heat stress in cross II, plant height and grain yield/plant under heat stress in cross I. Moderate to high for most characters under two crosses and environments. These results may suggest that selection in $F_2$ population would be effective to improve these characters in early generations of wheat breeding under normal and heat stress condition. Similar finding were in line with Hassan (1993), El-Sayed and El-Shaarawy (2006), and El-Aref *et al.* (2011).

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## الملخص العربى

# السلوك الوراثى لبعض الصفات المحصولية فى هجينين من قمح المكرونة تحت ظروف الاجهاد الحرارى

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أجريت هذه الدراسة بالمزرعة البحثية لمحطة بحوث شندويل- مركز البحوث الزراعية- مصر، أثناء المواسم الزراعية ٢٠٠٩/٢٠١٠، ٢٠١٠/٢٠١١، ٢٠١١/٢٠١٢ بغرض دراسة طبيعة الفعل الجيني ونظام التحكم الو راثي والموديل الو راثي الملائم و التنبؤ بالتراكيب الو راثية المبشرة وذلك لسبع صفات اقتصادية لمحصول القمح مستخدما نظام الستة عشائر (الآباء- الجيل الأول- الجيل الثاني والهجن الرجعية) وذلك في هجينين من قمح الخبز هما:

١- بني سويف ٥/ بني سويف ٣ ٢- سوهاج ٣/KSU I8

- أوضحت النتائج أن الموديل الو راثي(اضافه- سيادة) كان ملائما لمعظم الصفات التى درست للعشيرتين والبيئتين. بينما أشار تحليل اختبار المقياس إلي وجود تأثير للتفاعلات الغير أليلية في باقي الصفات، وان التأثيرات التفاعلية المضيفة x المضيفة والمضيفة x السائدة كانت معظمها اكبر من التأثيرات للجينات السائدة والتفاعل بين السيادة x السيادة مؤكداً علي أهمية دور تأثير الجينات المضيفة في وراثة هذه الصفات وان إجراء الانتخاب في عشائر الجيل الثاني يمكن أن يكون مؤثرا في تحسين هذه الصفات وإنتاج سلالات عالية المحصول ومتحملة للحرارة.
- اظهر معامل درجة السيادة وجود سيادة جزئية لغالبيةالصفات تحت الظروف العادية والاجهاد الحرارى وكانت هناك سيادة فائقة لصفتى عدد السنابل على النبات و عدد حبوب السنبلة تحت الظروف العادية.
- تباينت تقديرات درجة التوريث بالمعنى الواسع من متوسطة ٤١,٧٣% كما في محصول الحبوب/ النبات في الهجين الاول تحت ظروف الاجهاد الحرارى الى مرتفعة ٨١,٨٩% لصفة وزن ١٠٠حبة فى الهجين الاول تحت ظروف الاجهاد الحرارى. بينما درجة التوريث بالمعنى الضيق منخفضة لصفة عدد السنابل/ النبات وعدد الحبوب بالسنبلة والمحصول البيولوجى/النبات فى العشيرة الاولى تحت الظروف العادية. وكانت متوسطة لكل الصفات تحت الدراسة فى الهجينين والبيئتين ماعدا تاريخ طرد السنابل تحت ظروف البيئتين وصفة وزن ١٠٠ حبة تحت ظروف الاجهاد الحرارى فى الهجين الاول وكذالك طول النبات وزن ١٠٠ حبة تحت ظروف الاجهاد الحرارى فى الهجين الثاني.

- تقديرات التقدم الوراثي المتوقع كانت معظمها منخفضة ولكن كانت عالية لصفات طول النبات في كل من الهجين الأول والثاني تحت الظروف البيئية تحت الدراسة، المحصول البيولوجي تحت ظروف كلا البيئتين، عدد حبوب السنبلة في الهجين الأول والثاني تحت ظروف البيئتين، محصول الحبوب/ النبات فـي الهجـين الأول وفتـرة امتلاء الحبوب في الهجين الثاني تحت ظروف كلا البيئتين. من النتائج السابقة يتضح أن استخدام الانتخاب في الأجيال الانعزالية لهذه لصفات تحت الظروف البيئية المستخدمة في الدراسة يمكن أن يكـون مفيـداً لإنتـاج سلالات مرتفعة فى المحصول البيولوجى ومحصول الحبوب وذات عدد حبوب مرتفع بالـسنبلة ومبكـرة فـي النضج تحت ظروف الحرارة المرتفعة.