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# COMBINING ABILITY IN DURUM WHEAT ( *TRITICUM DURUM* L. ) UNDER HEAT STRESS

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**ABSTRACT:** ***The present study was conducted at El-mattana Agric. Res. Stn. During 2004/2005, 2005/2006 and 2006/2007 seasons. Six durum wheat genotypes namely: Beni-Suef 1, Sohag 3 , Line 1, Line 2, Line 3 and Line 4 were crossed in a half diallel cross with all possible combinations, to study the general and specific combining ability and genetic control for high temperature tolerance of parents and their $F_1$ subscript crosses for days to heading, days to physiological maturity, duration of grain filing period, grain production rate, number of spikes pre plant, number of kernels/ spike , 1000 kernel weight, grain yield per plant and heat susceptibility index for yield and its components. Results revealed that mean squares due to genotypes as well as parents and their $F_1$ crosses and the parents vs. $F_1$ crosses were highly significant under both planting dates for all studied characters. Heat susceptibility index indicated that $P_2$ and $P_3$ were heat tolerant, which had "S" value less than one in grain yield and its components. Meanwhile, $P_1$ and $P_4$ were the sensitive parents (S= 1.13 and 1.05). Mean squares of both general and specific combining ability were significant or highly significant for all studied characteristics, indicating the presence of both additive and non additive types of gene effects in the genetic system controlling these characteristics in the parents. High ratio of GCA/SCA mean squares were obtained for all the studied characteristics. These results confirm the importance of additive effects in the inheritance of these characteristics.***

***Keywords:*** ***Wheat, Combining ability, heat tolerance, Sowing dates.***

## INTRODUCTION

**Wheat is one of the major cereal crops in Egypt. National wheat production is insufficient to meet the local consumption according to the higher increase of population, so that wheat receives the high attention of plant breeders. In this respect, plant breeders need knowledge about genetic system controlling the inheritance of traits in view (Moshref,1996 ; knobel *et al*.,1997; Abdel-Wahed,2001 and Abdel-Hameed,2002) found no association between heterosis and genetic diversity in a seven- parents diallel crosses of spring wheat. The expression of heterosis was due, in part, to genetic diversity, but was unpredictable and also dependent on factors not elucidated by their study. Heterosis values relative to mid-parent in wheat have been studied by many researchers (Afiah, 1999 and El-Shami *et al*., 1996).**

**Combining ability analysis provides a guideline to the breeder in selecting the elite parents and desirable cross combinations to be used in the formulation of systematic breeding program for the improvement of the quantitative characteristies like yield and yield components (Hunt *et al*.,1991and Abdel-Karim,1998). Combining ability gives an indication of the relative magnitudes of additive and non - additive genetic effects, (Bhuller *et al*.,1998 and El-Borhamy ,1995). The main objectives of this study were to estimate general and specific combining ability effects for studied characteristics and heat susceptibility index for grain yield and its components.**

## MATERIALS AND METHODS

**The present study was conducted during the three wheat growing seasons 2004/2005, 2005/2006 and 2006/2007 at El-Mattana Agricultural Research Station, Agric. Res. Center, Egypt. Six diverse durum wheat genotypes (*Triticum durum*, L.) differed in characteristics were crossed in all possible combinations, excluding reciprocals. Name and pedigree of these parents are shown in Table 1. The six parents plus $F_1$ crosses were evaluated in a randomized complete block design with four replicates under recommended planting date ($20^{th}$ of November ) and planting date ($20^{th}$ of December ), which resulted in exposing the plants to heat stress, especially during grain filling period (Table 2) Each genotype of the parents and 15 $F_1$ crosses were grown in a single row of 3m long, 30cm apart between rows and the plants were spaced 15cm within row. The recommended package of cultural practice was followed. Data were recorded on ten randomly selected plants per row in each of the four replications. Data recorded were days to heading, number of days to physiological maturity, duration of grain filing period, grain production rate, number of spikes Per plant, (S/P), number of kernel per spike (K/S), 1000 - kernel weight (KW) and grain yield per plant (GY/P).**

**Table (1): The name and pedigree of the six parents.**

| No. | Parents | Pedigree |
|---|---|---|
| 1 | Beni-Swuef 1 | JO''S''/AA''S''//FG=BITTERN''S'' |
| 2 | Sohage3 | MEXI''S''/MGHA/51792//DURUM6 |
| 3 | Line#1 | BCR/LKS-4 |
| 4 | Line#2 | JABBUL/5GDOVZ512/CIT//RUFF/ FG/4/BY*2/TOB//AA/3/TEL |
| 5 | Line#3 | =CRONOS |
| 6 | Line#4 | BOOMER-24/AJAIA-9//ACO89 |

**Combining ability analysis was performed according to Griffing (1956) using method 2 (Half diallel set + Parents), model 1(Fixed effects for genotypes).**

**The heat susceptibility index for each entry was computed according to Fischer and Maurer (1978).**

## RESULTS AND DISCUSSION

### Analysis of variance

**The analysis of variance for all the characteristics of the six parents and the 15 $F_1$ crosses grown under recommended and late planting dates are presented in Table (2). Results revealed that mean squares due to genotypes as well as parents and their $F_1$ crosses and the parents vs. $F_1$ crosses were highly significant under both planting dates, indicating the wide diversity among the parental materials used in the present study.**

**Mean squares of both general and specific combining ability were significant ($p \leq 0.05$) or highly significant ($p \leq 0.01$) for all characteristics studied. This indicated the presence of both additive and non - additive types of gene effects in genetic system controlling these characteristics in the parents.**

**High ratio of GCA/SCA mean squares were obtained for all characteristics studied except for grain yield per plant in the late planting date (Table2). These results confirm the importance of additive gene effects in the inheritance of these characteristics. These results are in agreement with those obtained by Esmail (2007) and Hendawy *et al* (2007).**

### General combining ability (GCA):

**The estimate of general combining ability effects of the six durum wheat parents for all characteristics studied under recommended and late planting dates are presented in Table (3).**

**Line #2 and Line #3 showed negative and significant values of general combining ability (gi) effects for heading and physiological maturity dates under both planting dates, while Line #1 showed a negative and significant values of general combining ability (gi) effects in the late planting date for days to physiological maturity.**

**Line #1 and Line #4 showed negative and significant values of general combining ability (gi) effects under both planting dates for grain filling period.**

**Line #2 showed positive and significant values of (gi) effects under both planting dates for grain production rate. Also, Sohag 3 showed positive and significant values of (gi) effects in the late planting date for days to heading, days to maturity and grain production rate.**

**Table 2**

**Table 2**

**Table 3**

**Table 3**

**Beni-Swuef 1 showed positive and significant values of (gi) effects under both planting dates, while Line #1 showed positive and significant values of (gi) effects in the late planting date for number of kernels per spike.**

**Line #2 showed positive and significant values of (gi) effects under both planting dates for grain yield per plant and 1000-kernel weight.**

**High positive values of general combining ability effects would be of interest for yield and yield components, while for earliness high negative values would be useful from the plant breeder point of view. It is of interest to mention that, line2 which prove to be good general for grain yield per plant under the two sowing dates was found to be good general combiner for number of spikes per plant, 1000 – kernel weight and grain production rate. However, line3 proved to be poor general combiner for grain yield per plant under the two sowing dates, but proved to be good general combiner for number of spikes per plant.**

## Specific combining ability (SCA):

**Specific combining ability effects (Sij) of the 15 $F_1$ crosses for characteristics studied in the recommended ant late planting date are presented in Table (4). Cross (Sohag 3 x Line #2) recorded the highest negative and significant values of (Sij) effects in the recommended planting date, while cross (Line #2 x Line #3) revealed the highest negative and significant values of (Sij) effects in the late planting date for number of days to heading.**

**Cross (Line #2 x Line #4) showed the highest negative and significant values of (Sij) effects in the recommended planting date, while cross (Sohag 3 x Line #4) showed the highest negative and significant values of (Sij) effects in the late planting date for days to physiological maturity.**

**Cross (Beni-Swuef 1x Line #1) showed the highest negative and significant values of (Sij) effects in the recommended planting date, while cross(Line #1 x Line #2) showed the highest negative and significant values of (Sij) effects in the late planting date for grain filling period.**

**Cross(Line #1 x Line #2) recorded the highest positive and significant values of (Sij) effects in the recommended planting date, and cross(Line #1 x Line #3) showed the highest positive and significant values of (Sij) effects in the late planting date for grain production rate.**

**Cross(Line #2 x Line #4) showed the highest positive and significant values of (Sij) effects in the recommended planting date, and cross(Line #1 x Line #3) showed the highest positive and significant values of (Sij) effects in the late planting date for number of spikes pre plant.**

**Cross (Beni-Swuf 1x Line #4) showed the highest positive and significant values of (Sij) effects in the recommended planting date. Cross(Line #1 x Line #3) showed the highest positive and significant values of (Sij) effects in the late planting date for number of kernels per spike.**

**Table 4**

**Table 4**

**Cross (Line #2 x Line #4) showed the highest positive and significant values of (Sij) effects in the late planting date for 1000-kernel weight.**

**For grain yield per plant, cross(Line #1 x Line #2) showed the highest positive and significant values of (Sij) effects in the recommended planting date, and (Beni-Swuf 1x Line #4) recorded the highest positive and significant values of (Sij) effects in the recommended planting date and late planting date for 1000-kernel weight and for grain yield per plant, respectively.**

**The results obtained herein concerning general and specific combining ability effects could indicate that, the excellent hybrid combinations between the parents of high X low general combining effects i.e. high X high and low X low, consequently, it could be concluded that general combining ability effects of the parental lines were generally unrelated to the specific combining ability effects of their respective crosses.**

## Heat susceptibility index:

**With respect to susceptibility index for number of spikes pre plant which is presented in Table (5), results were clear that all the parents were heat tolerant. The most tolerant $F_1$ crosses which had S less than one were ($P_1$x$P_4$), ($P_2$x$P_3$) and ($P_2$x$P_6$).**

**With regard to susceptibility index "S" for number of kernels per spike in Table (5) results indicated that Beni-Swuef 1 ($P_1$), Sohag 3, ($P_2$), Line #2 ($P_4$) and Line #4 ($P_6$) were heat stress tolerant, which had "S" less than one. Meanwhile, Line #1 (P3) and Line #3 (P5) were the most susceptible parents (S= 1.18 and 1.37), respectively. The most tolerant $F_1$ crosses were ($P_1$x$P_2$), ($P_1$x$P_3$), ($P_1$x$P_5$), ($P_2$x$P_3$), ($P_3$x$P_5$), ($P_3$x$P_6$) and ($P_5$x$P_6$). The results showed that four out of seven crosses, including Line #1 ($P_3$) as a common parent, showed "S" values less than one. This indicates that the tolerant parent ($P_3$) transmitted genes controlling tolerance heat stress to its hybrids.**

**Concerning susceptibility index for 1000-kernel weight in Table (5) results revealed that Beni-Swuef 1 ($P_1$), Sohag 3 ($P_2$), Line #3 ($P_5$) and Line #4 ($P_5$) were relatively heat tolerant, while Line #1($P_3$) and Line #2 ($P_4$) were susceptible. The most tolerant $F_1$ crosses were ($P_1$x$P_3$), ($P_1$x$P_4$), ($P_2$x$P_4$), ($P_2$x$P_5$), ($P_3$x$P_4$), ($P_3$x$P_5$), ($P_3$x$P_6$) and ($P_4$x$P_6$) which had S values less than one, four out of these eight tolerant crosses involving Line #1 ($P_3$) as a common parent. This indicates that Line #1 ($P_3$) possess heat tolerance genes and it could be useful in breeding programs for such stress.**

**Low stress susceptibility index "S" (S<1) is synonymous to higher stress tolerance (Fischer and Maurer,1978). Application of the susceptibility index based on grain yield, Table (5), showed that Line #1 ($P_3$), Line #3 ($P_5$) , Line#4 ($P_6$) and Line #2 ($P_4$) were relatively stress tolerant, while Beni-Swuef 1, Sohag 3 were susceptible. The most tolerant $F_1$ crosses were ($P_1$x$P_3$), (P1xP5), ($P_1$x$P_6$), ($P_2$x$P_3$), ($P_2$x$P_5$), ($P_2$x$P_6$) and ($P_3$x$P_6$).**

**Table (5): The heat susceptibility index values of grain yield and its components for each parents and crosses in 2005/2006 season.**

| Genotypes | Susceptibility index ( S ) | | | |
|---|---|---|---|---|
| Parents | #S/P | #K/S | 1000-KW | GY/P |
| P1 | 0.80 | 0.76 | 0.69 | 1.13 |
| P2 | 0.93 | 0.75 | 0.81 | 0.87 |
| P3 | 0.73 | 1.18 | 1.38 | 0.40 |
| P4 | 0.78 | 0.63 | 1.01 | 1.05 |
| P5 | 0.67 | 1.37 | 0.90 | 0.70 |
| P6 | 0.62 | 0.74 | 0.99 | 0.78 |
| Crosses | -------- | --------- | --------- | --------- |
| P1xP2 | 1.20 | 0.61 | 1.14 | 1.30 |
| P1xP3 | 1.03 | 0.50 | 0.99 | 0.68 |
| P1xP4 | 0.83 | 1.36 | 0.69 | 1.17 |
| P1xP5 | 1.00 | 0.71 | 1.00 | 0.63 |
| P1xP6 | 1.09 | 1.64 | 1.01 | 0.80 |
| P2xP3 | 0.95 | 0.99 | 1.16 | 0.86 |
| P2xP4 | 1.21 | 1.56 | 0.88 | 1.25 |
| P2xP5 | 1.05 | 1.31 | 0.83 | 0.33 |
| P2xP6 | 0.98 | 1.14 | 1.19 | 0.32 |
| P3xP4 | 1.10 | 1.09 | 0.93 | 1.46 |
| P3xP5 | 1.05 | 0.65 | 0.85 | 1.04 |
| P3xP6 | 1.05 | 0.99 | 0.83 | 0.86 |
| P4xP5 | 1.15 | 1.38 | 1.26 | 1.19 |
| P4xP6 | 1.17 | 1.06 | 0.75 | 1.19 |
| P5xP6 | 1.23 | 0.62 | 1.15 | 1.40 |

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# القدرة الائتلافية في قمح الديورم تحت ظروف التقسية الحرارية

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## الملخص العربي

أجريت هذه الدراسة بمحطة بحوث المطاعنة خلال المواسم ٢٠٠٤/٢٠٠٥ ، ٢٠٠٥/٢٠٠٦ و ٢٠٠٦/٢٠٠٧ . وقد تم إجراء التهجين الدائري بين ستة آباء من قمح الديورم بكل الطرق الممكنة ماعدا الهجن العكسية. وكانت هذه الآباء هي بني سويف١ ، سوهاج٣ ، سلالة١ ، سلالة٢ ، سلالة٣ و سلالة٤ وتمت زراعة هذه التهجينات في ميعادين للزراعة هما ٢٠ نوفمبر ، ٢٠ ديسمبر وذلك لدراسة القدرة العامة والخاصة على الائتلاف والنظام الوراثي الذي يحكم سلوك الآباء وهجن الجيل الأول لصفات عدد أيام كل من طرد السنابل والنضج الفسيولوجي ، فترة امتلاء الحبوب ، معدل امتلاء الحبة ، عدد السنابل للنبات، عدد حبوب السنبلة ، وزن الألف حبة ووزن محصول النبات وتقدير معامل الحساسية للحرارة لمحصول الحبوب ومكوناته. وقد أظهرت النتائج أن التباين الراجع إلى التراكيب الوراثية والآباء وهجنها بالإضافة للتفاعل بين الآباء وهجنها كان عالي المعنوية تحت ميعادي الزراعة لجميع الصفات تحت الدراسة. أشارت النتائج إلى أن تأخير الزراعة أدي إلى انخفاض قيم المتوسطات لكل الصفات تحت الدراسة لكل من الآباء وهجنها مقارنة بالميعاد الأمثل. وقد تبين أن تأخير الزراعة قد أدى إلى انخفاض قيم كل الصفات للآباء وهجنها. وقد كان الأب الثاني والثالث متحملين للحرارة العالية حيث كان معامل الحساسية (S) أقل من واحد لصفة محصول الحبوب ومكوناته ، بينما الأب الأول والرابع كانا ، إلى حد ما ، حساسين ( S= 1.13 و 1.05 ). وكانت مربعات القيم لكل من القدرة الائتلافية العامة والخاصة معنويا أو عالي المعنوية لكل الصفات تحت الدراسة وهذا يشير إلى أثر كل من الفعل الجيني المضيف والسيادي في النظام الوراثي الذي يحكم هذه الصفات في الآباء. إن ارتفاع قيمة القدرة الائتلافية العامة إلى الخاصة لكل الصفات المدروسة يؤكد أهمية الأثر الجيني المضيف في وراثة هذه الصفات.

**Table (2): Analysis of variance of the studied characteristies for six parents and 15 $F_1$ diallel crosses under recommended planting date (D1) and late planting date (D2).**

| Source of variance | d.f | MS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | DH | | DM | | GFP | | GPR | |
| | | D1 | D2 | D1 | D2 | D1 | D2 | D1 | D2 |
| Reps ( R) | 3 | 0.06 | 0.54 | 1.47 | 0.52 | 2.01 | 1.09 | 0.004 | 0.005 |
| Genotypes(G) | 20 | 116.09** | 69.19** | 77.64** | 41.71** | 52.67** | 35.37** | 0.358** | 0.146** |
| Parents (P) | 5 | 89.86** | 50.08** | 110.64** | 14.17** | 11.14** | 19.67** | 0.174** | 0.078** |
| Crosses (C ) | 14 | 112.64** | 52.85** | 60.32** | 32.59** | 68.54** | 42.81** | 0.351** | 0.140** |
| P X C | 1 | 296.43** | 393.60** | 155.14 | 307.22** | 38.14** | 9.64** | 1.36** | 0.565** |
| Error | 60 | 0.32 | 0.34 | 0.55 | 0.59 | 0.72 | 0.95 | 0.002 | 0.004 |
| GCA | 5 | 57.87** | 28.82** | 49.00** | 16.90** | 18.00** | 12.62** | 0.100** | 0.027** |
| SCA | 15 | 19.40** | 13.46** | 9.55** | 8.27** | 11.56** | 7.58** | 0.086** | 0.040** |
| Error | | 0.079 | 0.085 | 0.136 | 0.148 | 0.180 | 0.237 | 0.0005 | 0.0009 |
| GCA/SCA | | 2.98 | 2.14 | 5.13 | 2.04 | 1.56 | 1.67 | 1.16 | 0.67 |

** significant at 0.01 level of probability.

DH : Days to heading. DM : Days to maturity. GFP : Grain filing period.
GPR : Grain production rate. GCA : General combining ability. SCA : Specific combining ability.

Table (2): cont.

| source of variance | d.f | MS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | S/P | | K/S | | 1000-KW | | GY/P | |
| | | D1 | D2 | D1 | D2 | D1 | D2 | D1 | D2 |
| Reps ( R) | 3 | 0.87 | 0.55 | 15.85 | 9.21 | 0.12 | 7.82 | 2.80 | 0.58 |
| Genotypes(G) | 20 | 21.95** | 5.31** | 514.88** | 458.80** | 127.31** | 93.94** | 545.15** | 68.70** |
| Parents (P) | 5 | 11.50** | 7.88** | 378.50** | 387.77** | 255.75** | 184.90** | 430.79** | 60.40** |
| Crosses (C ) | 14 | 22.36** | 2.99** | 509.10** | 481.67** | 64.38** | 52.39** | 498.17** | 48.20** |
| P X C | 1 | 68.75** | 25.03** | 1277.7** | 493.73** | 366.05** | 220.82** | 1774.8** | 397.31** |
| Error | 60 | 1.14 | 0.65 | 9.29 | 9.04 | 4.16 | 3.74 | 2.91 | 2.75 |
| GCA | 5 | 8.10** | 2.52** | 197.78** | 194.72** | 65.40** | 52.30** | 184.60** | 13.83** |
| SCA | 15 | 4.62** | 0.93 | 105.70** | 88.03** | 20.64** | 13.88** | 120.19** | 18.29** |
| Error | | 0.286 | 0.163 | 2.32 | 2.259 | 1.039 | 0.935 | 0.727 | 0.688 |
| GCA/SCA | | 1.76 | 2.70 | 1.87 | 2.21 | 3.17 | 3.77 | 1.54 | 0.76 |

** significant at 0.01 level of probability.

S/P : Number of spikes per plant. K/S : Number of kernels per spike. 1000-KW : 1000-Kernel weight.

GY/P : Grain yield per plant. GCA : General combining ability. SCA : Specific combining ability.

**Table (3): Estimates of general combining ability effects of six durum wheat for the studied characteristics under recommended planting date (D1) and late planting date(D2).**

| Genotype | | DH | | DM | | GFP | | GPR | |
|---|---|---|---|---|---|---|---|---|---|
| | | General combining ability effects | | | | | | | |
| Parents | | D1 | D2 | D1 | D2 | D1 | D2 | D1 | D2 |
| P1 | Beni-Suef 1 | 2.167** | 1.240** | 4.000** | 2.406** | 1.083** | 1.146** | -0.028** | -0.040** |
| P2 | Sohag 3 | 1.042** | 2.052** | 1.594** | 0.250* | 0.552** | -1.792** | -0.051** | 0.056** |
| P3 | Line #1 | 2.104** | 0.865** | -0.313* | 0.500** | -1.979** | -0.354* | -0.011 | -0.010 |
| P4 | Line #2 | -1.896** | -1.948** | -1.844** | -1.688** | 0.021 | 0.240 | 0.214** | 0.072** |
| P5 | Line #3 | -4.583** | -2.729** | -2.875** | -1.250** | 1.865** | 1.583** | -0.113** | -0.081** |
| P6 | Line #4 | 1.167** | 0.521** | -0.563** | -0.219 | -1.542** | -0.823** | -0.011 | 0.004 |
| S.E.(gi) | | 0.091 | 0.094 | 0.119 | 0.124 | 0.137 | 0.157 | 0.007 | 0.010 |
| L.S.D. (gi) $_{0.05}$ | | 0.182 | 0.188 | 0.239 | 0.248 | 0.274 | 0.315 | 0.015 | 0.020 |
| L.S.D. (gi) $_{0.01}$ | | 0.242 | 0.250 | 0.318 | 0.330 | 0.364 | 0.418 | 0.019 | 0.026 |
| S.E.(gi-gi) | | 0.141 | 0.146 | 0.185 | 0.192 | 0.212 | 0.244 | 0.011 | 0.015 |

*,** significant at 0.05 and 0.01 levels of probability, respectively.
DH : Days to heading. DM : Days to maturity.
GFP : Grain filing period. GPR : Grain production rate.

Table (3): cont.

| Genotype | | S/P | | K/S | | 1000-KW | | GY/P | |
|---|---|---|---|---|---|---|---|---|---|
| | | General combining ability effects | | | | | | | |
| Parents | | D1 | D2 | D1 | D2 | D1 | D2 | D1 | D2 |
| P1 | Beni-Suef 1 | -0.750** | -0.167 | 8.823** | 8.469** | -0.764* | 0.123 | 0.084 | 0.047 |
| P2 | Sohag 3 | -0.781** | -0.854** | -1.646** | -1.344** | -0.543 | -0.289 | -1.272** | -0.006 |
| P3 | Line #1 | -0.625** | -0.104 | 0.792 | 1.563** | 1.558** | 0.234 | -3.088** | -0.962** |
| P4 | Line #2 | 1.750** | 0.802** | -6.177** | -6.438** | 4.048** | 3.947** | 9.484** | 2.503** |
| P5 | Line #3 | 0.625** | 0.396** | -2.052** | -2.063** | 0.293 | 0.102 | -3.194** | -1.106** |
| P6 | Line #4 | -0.219 | -0.073 | 0.260 | -0.188 | -4.593** | -4.117** | -2.016** | -0.475 |
| S.E.(gi) | | 0.173 | 0.130 | 0.492 | 0.485 | 0.329 | 0.312 | 0.275 | 0.268 |
| L.S.D. (gi) $_{0.05}$ | | 0.345 | 0.261 | 0.984 | 0.970 | 0.658 | 0.624 | 0.551 | 0.536 |
| L.S.D. (gi) $_{0.01}$ | | 0.459 | 0.346 | 1.308 | 1.291 | 0.875 | 0.830 | 0.732 | 0.712 |
| S.E.(gi-gj) | | 0.267 | 0.202 | 0.762 | 0.752 | 0.510 | 0.483 | 0.427 | 0.415 |

** significant at 0.05 and 0.01 levels of probability, respectively.
S/P : Number of spikes per plant. K/S : Number of kernels per spike.
1000-KW : 1000-Kernel weight. GY/P : Grain yield per plant.

**Table (4): Estimates of specific combining ability effects for the studied characteristics of 15$F_1$ diallel crosses, under recommended planting date (D1) and late planting date (D2).**

| Cross | | DH | | DM | | GFP | | GPR | |
|---|---|---|---|---|---|---|---|---|---|
| | | Specific combining ability effects | | | | | | | |
| | | D1 | D2 | D1 | D2 | D1 | D2 | D1 | D2 |
| 1 | 1x2 | 0.70** | 1.41** | 0.80* | 2.99** | -0.36 | 1.60** | 0.10** | -0.16** |
| 2 | 1x3 | 4.38** | 3.85** | 0.71* | 1.99** | -4.33** | -1.84** | 0.05* | 0.13** |
| 3 | 1x4 | 1.63** | -0.59* | 0.74* | 1.`92** | -1.08** | 2.57** | -0.05* | -0.13** |
| 4 | 1x5 | -2.68** | -1.31** | 2.77** | 2.74** | 5.08** | 3.97** | -0.30** | -0.20** |
| 5 | 1x6 | -0.68** | 0.69** | 1.21** | 0.71* | 2.48** | -0.12 | 0.09** | 0.24** |
| 6 | 2x3 | 5.76** | 3.29** | 0.86* | 0.89* | -2.30** | -2.40** | 0.16** | 0.22** |
| 7 | 2x4 | -3.24** | 1.60** | 0.64 | 0.83* | 1.70** | -0.75 | 0.11** | 0.11** |
| 8 | 2x5 | -1.30** | 1.88** | 1.92** | 0.39 | 4.11** | -1.59** | -0.16** | 0.18** |
| 9 | 2x6 | -0.05 | -0.37 | -2.14** | -1.39** | -0.99* | -0.93* | -0.25** | 0.00 |
| 10 | 3x4 | 3.95** | 4.29** | 1.05** | 0.08 | -3.02** | -4.18** | 0.49** | 0.21** |
| 11 | 3x5 | 3.38** | 2.32** | 4.33** | 0.39 | 0.39 | -2.03** | 0.28** | 0.25** |
| 12 | 3x6 | 5.63** | 4.32** | 5.52** | 5.36** | -1.71** | 1.13* | 0.00 | -0.11** |
| 13 | 4x5 | 0.38 | -1.37** | -0.39 | 0.58 | -1.86** | 1.63** | 0.02 | -0.09** |
| 14 | 4x6 | 1.88** | 1.88** | -2.70** | -0.45 | -3.71** | -2.21** | 0.27** | 0.18** |
| 15 | 5x6 | -1.93** | -1.34** | -2.42** | 1.11 | -0.80* | 1.94** | 0.40** | -0.03 |
| S.E.(sij) | | 0.25 | 0.26 | 0.33 | 0.34 | 0.38 | 0.43 | 0.02 | 0.03 |
| L.S.D. $(sij)_{0.05}$ | | 0.50 | 0.52 | 0.66 | 0.68 | 0.75 | 0.86 | 0.04 | 0.05 |
| L.S.D. $(sij)_{0.01}$ | | 0.66 | 0.69 | 0.87 | 0.91 | 1.00 | 1.15 | 0.05 | 0.07 |
| S.E. sij-sik | | 0.37 | 0.39 | 0.49 | 0.51 | 0.56 | 0.64 | 0.03 | 0.04 |
| S.E. sij-skl | | 0.34 | 0.36 | 0.45 | 0.47 | 0.52 | 0.60 | 0.03 | 0.04 |

*,** significant at 0.05 and 0.01 levels probability, respectively.
DH : Days to heading. DM : Days to maturity.
GFP : Grain filing period. GPR : Grain production rate.

Table (4): cont.

| Crosses | | S/P | | K/S | | 1000-KW | | GY/P | |
|---|---|---|---|---|---|---|---|---|---|
| | | Specific combining ability effects | | | | | | | |
| | | D1 | D2 | D1 | D2 | D1 | D2 | D1 | D2 |
| 1 | 1x2 | 1.10* | -0.74* | 3.16* | 7.63** | 2.93** | 0.38 | 4.44** | -3.28** |
| 2 | 1x3 | -1.05* | -1.24** | -9.78** | -3.28* | 1.50 | 1.68 | -1.81* | 2.67** |
| 3 | 1x4 | -3.18** | -0.65 | -4.56** | -8.53** | -3.99** | -2.12* | -2.66** | -1.29 |
| 4 | 1x5 | -0.30 | -0.49 | 7.31** | 10.09** | -3.14** | -3.31** | -10.88** | -3.61** |
| 5 | 1x6 | -0.21 | -1.02** | 16.00** | 0.97 | 6.73** | 5.04** | 7.09** | 7.54** |
| 6 | 2x3 | 0.23 | 0.70 | -2.06 | -2.47 | 5.47** | 4.12** | 4.92** | 3.70** |
| 7 | 2x4 | 2.10** | -0.21 | 0.41 | -5.47* | -1.92* | -1.30 | 7.77** | 2.44** |
| 8 | 2x5 | -1.02* | -0.55 | -9.97** | -11.59** | 0.61 | 1.92* | -4.50** | 4.42** |
| 9 | 2x6 | -0.18 | 0.42 | 5.72** | 3.03 | -2.46** | -3.48** | -11.53** | -1.21 |
| 10 | 3x4 | 1.95** | 0.04 | 9.97** | 7.38** | -2.66** | -1.02 | 16.06** | 1.77* |
| 11 | 3x5 | 2.57** | 0.70 | 14.34** | 17.00** | -0.59 | 0.28 | 14.19** | 6.38** |
| 12 | 3x6 | 0.17 | -0.58 | 15.03** | 12.13** | 2.34* | 2.09* | -3.06** | -1.88* |
| 13 | 4x5 | 1.70** | -0.46 | 2.81* | -1.00 | 4.88** | 1.38 | -0.18 | -0.94 |
| 14 | 4x6 | 2.79** | 0.01 | -5.00** | -3.13* | 6.01** | 7.12** | 6.19** | 2.78** |
| 15 | 5x6 | 1.92** | -1.08** | -6.38** | 0.25 | 4.07** | 2.60** | 17.59** | 1.16 |
| S.E.(sij) | | 0.47 | 0.36 | 1.35 | 1.33 | 0.90 | 0.86 | 0.76 | 0.74 |
| L.S.D. $(sij)_{0.05}$ | | 0.95 | 0.72 | 2.70 | 2.67 | 1.81 | 1.71 | 1.51 | 1.47 |
| L.S.D. $(sij)_{0.01}$ | | 1.26 | 0.95 | 3.59 | 3.54 | 2.40 | 2.28 | 2.01 | 1.96 |
| S.E. sij-sik | | 0.71 | 0.53 | 2.02 | 1.99 | 1.35 | 1.28 | 1.13 | 1.10 |
| S.E. sij-skl | | 0.65 | 0.49 | 1.87 | 1.84 | 1.25 | 1.18 | 1.04 | 1.02 |

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

S/P : Number of spikes per plant. K/S : Number of kernels per spike.

1000-KW : 1000-Kernel weight. GY/P : Grain yield per plant.

**Table ( 2 ): Analysis of variance of the studied characteristies for six parents and 15 $F_1$ diallel crosses under recommended planting date (D1) and late planting date (D2).**

| Source of variance | d.f | MS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | DH | | DM | | GFP | | GPR | |
| | | D1 | D2 | D1 | D2 | D1 | D2 | D1 | D2 |
| **Reps ( R)** | 3 | 0.06 | 0.54 | 1.47 | 0.52 | 2.01 | 1.09 | 0.004 | 0.005 |
| **Genotypes(G)** | 20 | 116.09** | 69.19** | 77.64** | 41.71** | 52.67** | 35.37** | 0.358** | 0.146** |
| **Parents (P)** | 5 | 89.86** | 50.08** | 110.64** | 14.17** | 11.14** | 19.67** | 0.174** | 0.078** |
| **Crosses (C )** | 14 | 112.64** | 52.85** | 60.32** | 32.59** | 68.54** | 42.81** | 0.351** | 0.140** |
| **P X C** | 1 | 296.43** | 393.60** | 155.14 | 307.22** | 38.14** | 9.64** | 1.36** | 0.565** |
| **Error** | 60 | 0.32 | 0.34 | 0.55 | 0.59 | 0.72 | 0.95 | 0.002 | 0.004 |
| **GCA** | 5 | 57.87** | 28.82** | 49.00** | 16.90** | 18.00** | 12.62** | 0.100** | 0.027** |
| **SCA** | 15 | 19.40** | 13.46** | 9.55** | 8.27** | 11.56** | 7.58** | 0.086** | 0.040** |
| **Error** | | 0.079 | 0.085 | 0.136 | 0.148 | 0.180 | 0.237 | 0.0005 | 0.0009 |
| **GCA/SCA** | | 2.98 | 2.14 | 5.13 | 2.04 | 1.56 | 1.67 | 1.16 | 0.67 |

**** significant at 0.01 level of probability.**

DH : Days to heading. DM : Days to maturity. GFP : Grain filing period.

GPR : Grain production rate. GCA : General combining ability. SCA : Specific combining ability.

**Table (2): cont, d.**

| source of variance | d.f | MS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | S/P | | K/S | | 1000-KW | | GY/P | |
| | | D1 | D2 | D1 | D2 | D1 | D2 | D1 | D2 |
| **Reps ( R)** | **3** | 0.87 | 0.55 | 15.85 | 9.21 | 0.12 | 7.82 | 2.80 | 0.58 |
| **Genotypes(G)** | **20** | 21.95** | 5.31** | 514.88** | 458.80** | 127.31** | 93.94** | 545.15** | 68.70** |
| **Parents (P)** | **5** | 11.50** | 7.88** | 378.50** | 387.77** | 255.75** | 184.90** | 430.79** | 60.40** |
| **Crosses (C )** | **14** | 22.36** | 2.99** | 509.10** | 481.67** | 64.38** | 52.39** | 498.17** | 48.20** |
| **P X C** | **1** | 68.75** | 25.03** | 1277.7** | 493.73** | 366.05** | 220.82** | 1774.8** | 397.31** |
| **Error** | **60** | 1.14 | 0.65 | 9.29 | 9.04 | 4.16 | 3.74 | 2.91 | 2.75 |
| **GCA** | **5** | 8.10** | 2.52** | 197.78** | 194.72** | 65.40** | 52.30** | 184.60** | 13.83** |
| **SCA** | **15** | 4.62** | 0.93 | 105.70** | 88.03** | 20.64** | 13.88** | 120.19** | 18.29** |
| **Error** | | 0.286 | 0.163 | 2.32 | 2.259 | 1.039 | 0.935 | 0.727 | 0.688 |
| **GCA/SCA** | | 1.76 | 2.70 | 1.87 | 2.21 | 3.17 | 3.77 | 1.54 | 0.76 |

**** significant at 0.01 level of probability.**

S/P : Number of spikes per plant. K/S : Number of kernels per spike. 1000-KW : 1000-Kernel weight.

GY/P : Grain yield per plant. GCA : General combining ability. SCA : Specific combining ability.

**Table (3): Estimates of general combining ability effects of six durum wheat for the studied characteristics under recommended planting date (D1) and late planting date(D2).**

| Genotype | | DH | | DM | | GFP | | GPR | |
|---|---|---|---|---|---|---|---|---|---|
| | | General combining ability effects | | | | | | | |
| Parents | | D1 | D2 | D1 | D2 | D1 | D2 | D1 | D2 |
| P1 | Beni-Suef 1 | 2.167** | 1.240** | 4.000** | 2.406** | 1.083** | 1.146** | -0.028** | -0.040** |
| P2 | Sohag 3 | 1.042** | 2.052** | 1.594** | 0.250* | 0.552** | -1.792** | -0.051** | 0.056** |
| P3 | Line #1 | 2.104** | 0.865** | -0.313* | 0.500** | -1.979** | -0.354* | -0.011 | -0.010 |
| P4 | Line #2 | -1.896** | -1.948** | -1.844** | -1.688** | 0.021 | 0.240 | 0.214** | 0.072** |
| P5 | Line #3 | -4.583** | -2.729** | -2.875** | -1.250** | 1.865** | 1.583** | -0.113** | -0.081** |
| P6 | Line #4 | 1.167** | 0.521** | -0.563** | -0.219 | -1.542** | -0.823** | -0.011 | 0.004 |
| S.E.(gi) | | 0.091 | 0.094 | 0.119 | 0.124 | 0.137 | 0.157 | 0.007 | 0.010 |
| L.S.D. (gi) $_{0.05}$ | | 0.182 | 0.188 | 0.239 | 0.248 | 0.274 | 0.315 | 0.015 | 0.020 |
| L.S.D. (gi) $_{0.01}$ | | 0.242 | 0.250 | 0.318 | 0.330 | 0.364 | 0.418 | 0.019 | 0.026 |
| S.E.(gi-gi) | | 0.141 | 0.146 | 0.185 | 0.192 | 0.212 | 0.244 | 0.011 | 0.015 |

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

DH : Days to heading. DM : Days to maturity.

GFP : Grain filing period. GPR : Grain production rate.

**Table (3): cont, d .**

| Genotype | | S/P | | K/S | | 1000-KW | | GY/P | |
|---|---|---|---|---|---|---|---|---|---|
| | | General combining ability effects | | | | | | | |
| Parents | | D1 | D2 | D1 | D2 | D1 | D2 | D1 | D2 |
| P1 | Beni-Suef 1 | -0.750** | -0.167 | 8.823** | 8.469** | -0.764* | 0.123 | 0.084 | 0.047 |
| P2 | Sohag 3 | -0.781** | -0.854** | -1.646** | -1.344** | -0.543 | -0.289 | -1.272** | -0.006 |
| P3 | Line #1 | -0.625** | -0.104 | 0.792 | 1.563** | 1.558** | 0.234 | -3.088** | -0.962** |
| P4 | Line #2 | 1.750** | 0.802** | -6.177** | -6.438** | 4.048** | 3.947** | 9.484** | 2.503** |
| P5 | Line #3 | 0.625** | 0.396** | -2.052** | -2.063** | 0.293 | 0.102 | -3.194** | -1.106** |
| P6 | Line #4 | -0.219 | -0.073 | 0.260 | -0.188 | -4.593** | -4.117** | -2.016** | -0.475 |
| S.E.(gi) | | 0.173 | 0.130 | 0.492 | 0.485 | 0.329 | 0.312 | 0.275 | 0.268 |
| L.S.D. (gi) $_{0.05}$ | | 0.345 | 0.261 | 0.984 | 0.970 | 0.658 | 0.624 | 0.551 | 0.536 |
| L.S.D. (gi) $_{0.01}$ | | 0.459 | 0.346 | 1.308 | 1.291 | 0.875 | 0.830 | 0.732 | 0.712 |
| S.E.(gi-gj) | | 0.267 | 0.202 | 0.762 | 0.752 | 0.510 | 0.483 | 0.427 | 0.415 |

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

S/P : Number of spikes per plant. K/S : Number of kernels per spike.

1000-KW : 1000-Kernel weight. GY/P : Grain yield per plant.

**Table (4): Estimates of specific combining ability effects for the studied characteristics of $15F_1$ diallel crosses, under recommended planting date (D1) and late planting date (D2).**

| Cross | | DH | | DM | | GFP | | GPR | |
|---|---|---|---|---|---|---|---|---|---|
| | | Specific combining ability effects | | | | | | | |
| | | D1 | D2 | D1 | D2 | D1 | D2 | D1 | D2 |
| 1 | 1x2 | 0.70** | 1.41** | 0.80* | 2.99** | -0.36 | 1.60** | 0.10** | -0.16** |
| 2 | 1x3 | 4.38** | 3.85** | 0.71* | 1.99** | -4.33** | -1.84** | 0.05* | 0.13** |
| 3 | 1x4 | 1.63** | -0.59* | 0.74* | 1.`92** | -1.08** | 2.57** | -0.05* | -0.13** |
| 4 | 1x5 | -2.68** | -1.31** | 2.77** | 2.74** | 5.08** | 3.97** | -0.30** | -0.20** |
| 5 | 1x6 | -0.68** | 0.69** | 1.21** | 0.71* | 2.48** | -0.12 | 0.09** | 0.24** |
| 6 | 2x3 | 5.76** | 3.29** | 0.86* | 0.89* | -2.30** | -2.40** | 0.16** | 0.22** |
| 7 | 2x4 | -3.24** | 1.60** | 0.64 | 0.83* | 1.70** | -0.75 | 0.11** | 0.11** |
| 8 | 2x5 | -1.30** | 1.88** | 1.92** | 0.39 | 4.11** | -1.59** | -0.16** | 0.18** |
| 9 | 2x6 | -0.05 | -0.37 | -2.14** | -1.39** | -0.99* | -0.93* | -0.25** | 0.00 |
| 10 | 3x4 | 3.95** | 4.29** | 1.05** | 0.08 | -3.02** | -4.18** | 0.49** | 0.21** |
| 11 | 3x5 | 3.38** | 2.32** | 4.33** | 0.39 | 0.39 | -2.03** | 0.28** | 0.25** |
| 12 | 3x6 | 5.63** | 4.32** | 5.52** | 5.36** | -1.71** | 1.13* | 0.00 | -0.11** |
| 13 | 4x5 | 0.38 | -1.37** | -0.39 | 0.58 | -1.86** | 1.63** | 0.02 | -0.09** |
| 14 | 4x6 | 1.88** | 1.88** | -2.70** | -0.45 | -3.71** | -2.21** | 0.27** | 0.18** |
| 15 | 5x6 | -1.93** | -1.34** | -2.42** | 1.11 | -0.80* | 1.94** | 0.40** | -0.03 |
| S.E.(sij) | | 0.25 | 0.26 | 0.33 | 0.34 | 0.38 | 0.43 | 0.02 | 0.03 |
| L.S.D. $(sij)_{0.05}$ | | 0.50 | 0.52 | 0.66 | 0.68 | 0.75 | 0.86 | 0.04 | 0.05 |
| L.S.D. $(sij)_{0.01}$ | | 0.66 | 0.69 | 0.87 | 0.91 | 1.00 | 1.15 | 0.05 | 0.07 |
| S.E. sij-sik | | 0.37 | 0.39 | 0.49 | 0.51 | 0.56 | 0.64 | 0.03 | 0.04 |
| S.E. sij-skl | | 0.34 | 0.36 | 0.45 | 0.47 | 0.52 | 0.60 | 0.03 | 0.04 |

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

DH : Days to heading. DM : Days to maturity.

GFP : Grain filing period. GPR : Grain production rate.

**Table (4): cont, d .**

| Crosses | | S/P | | K/S | | 1000-KW | | GY/P | |
|---|---|---|---|---|---|---|---|---|---|
| | | Specific combining ability effects | | | | | | | |
| | | D1 | D2 | D1 | D2 | D1 | D2 | D1 | D2 |
| 1 | 1x2 | 1.10* | -0.74* | 3.16* | 7.63** | 2.93** | 0.38 | 4.44** | -3.28** |
| 2 | 1x3 | -1.05* | -1.24** | -9.78** | -3.28* | 1.50 | 1.68 | -1.81* | 2.67** |
| 3 | 1x4 | -3.18** | -0.65 | -4.56** | -8.53** | -3.99** | -2.12* | -2.66** | -1.29 |
| 4 | 1x5 | -0.30 | -0.49 | 7.31** | 10.09** | -3.14** | -3.31** | -10.88** | -3.61** |
| 5 | 1x6 | -0.21 | -1.02** | 16.00** | 0.97 | 6.73** | 5.04** | 7.09** | 7.54** |
| 6 | 2x3 | 0.23 | 0.70 | -2.06 | -2.47 | 5.47** | 4.12** | 4.92** | 3.70** |
| 7 | 2x4 | 2.10** | -0.21 | 0.41 | -5.47* | -1.92* | -1.30 | 7.77** | 2.44** |
| 8 | 2x5 | -1.02* | -0.55 | -9.97** | -11.59** | 0.61 | 1.92* | -4.50** | 4.42** |
| 9 | 2x6 | -0.18 | 0.42 | 5.72** | 3.03 | -2.46** | -3.48** | -11.53** | -1.21 |
| 10 | 3x4 | 1.95** | 0.04 | 9.97** | 7.38** | -2.66** | -1.02 | 16.06** | 1.77* |
| 11 | 3x5 | 2.57** | 0.70 | 14.34** | 17.00** | -0.59 | 0.28 | 14.19** | 6.38** |
| 12 | 3x6 | 0.17 | -0.58 | 15.03** | 12.13** | 2.34* | 2.09* | -3.06** | -1.88* |
| 13 | 4x5 | 1.70** | -0.46 | 2.81* | -1.00 | 4.88** | 1.38 | -0.18 | -0.94 |
| 14 | 4x6 | 2.79** | 0.01 | -5.00** | -3.13* | 6.01** | 7.12** | 6.19** | 2.78** |
| 15 | 5x6 | 1.92** | -1.08** | -6.38** | 0.25 | 4.07** | 2.60** | 17.59** | 1.16 |
| S.E.(sij) | | 0.47 | 0.36 | 1.35 | 1.33 | 0.90 | 0.86 | 0.76 | 0.74 |
| L.S.D. $(sij)_{0.05}$ | | 0.95 | 0.72 | 2.70 | 2.67 | 1.81 | 1.71 | 1.51 | 1.47 |
| L.S.D. $(sij)_{0.01}$ | | 1.26 | 0.95 | 3.59 | 3.54 | 2.40 | 2.28 | 2.01 | 1.96 |
| S.E. sij-sik | | 0.71 | 0.53 | 2.02 | 1.99 | 1.35 | 1.28 | 1.13 | 1.10 |
| S.E. sij-skl | | 0.65 | 0.49 | 1.87 | 1.84 | 1.25 | 1.18 | 1.04 | 1.02 |

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

S/P : Number of spikes per plant. K/S : Number of kernels per spike.

1000-KW : 1000-Kernel weight. GY/P : Grain yield per plant.