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# COMBINING ABILITY AND MODE OF GENE ACTION FOR EARLINESS, YIELD AND SOME YIELD ATTRIBUTES OF BREAD WHEAT (*Triticum aestivum* L.) GENOTYPES GROWN ON DIFFERENT SOWING DATES

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## ABSTRACT

Six parents of bread wheat were crossed using half-diallel cross method in 2011/2012 growing season. The six parents and their 15 $F_1$ crosses were sown in a randomized complete block design experiment in 2012/2013 season on the three sowing dates at the Experimental Farm of the Faculty of Agriculture, Zagazig University, to estimate each of mean performance, combining ability and gene action for days to heading and maturity, plant height, No. of grains/spike, 1000 grain weight and grain weight. Analysis of variance revealed that mean squares due to genotypes, parents and $F_1$ crosses, were highly significant for all studied characters. Highly significant mean squares due to Parents *vs.* $F_1$'s for all these traits, indicating heterotic patterns. The overall average of genotypes were 81.57, 84.53 and 73.93 days to heading; 140.98, 136.78 and 132.35 days to maturity; 94.05, 90.64 and 81.34cm for plant height; 60.45, 62.65 and 46.41 for number of grains/spike; 56.84, 57.41 and 48.49g for 1000 grain weight and 22.74, 29.60 and 19.54g for grain weight/plant on the early, normal and late sowing dates, respectively. Late sowing date (heat stress) ceased reduction for days to heading (12.54%) and maturity (6.12%), plant height (13.51%), No. of grains/spike (25.92%), 1000-grain weight (15.54%) and grain weight (33.99%) compared with 2nd sowing date (favorable). The parental wheat cultivar Sids12 and $F_1$ crosses Gemmeiza 9 × Misr1, Gemmeiza 9 × Line1 and Line1 × Misr2 exhibited Heat susceptibility index (HIS) values less than unity, hence these genotypes were considered as more tolerant to late sowing (heat stress) as regards their grain weight/plant. The mean squares due to both general (GCA) and specific (SCA) combining abilities were highly significant for all studied characters. The ratio of GCA variance to SCA variance was above one for earliness and plant height, while it was less than unity for No. of grains/spike, 1000 grain weight and grain weight/plant on the three sowing dates. Narrow-sense heritability was estimated to be 67.01, 72.56 and 65.85% for days to heading; 64.86, 67.65 and 61.49% for days to maturity; 53.14, 76.36 and 45.31% for plant height; 18.54, 19.66 and 18.38% for number of grains/spike; 15.0, 12.14 and 17.5% for 1000-grain weight and 17.0, 20.0 and 8.05% for grain weight/plant on the early, normal and late sowing dates, respectively. Graphical analysis revealed additive gene action with partial dominance for days to heading, days to maturity on the three sowing dates and plant height on the normal sowing date. Negative intercepts of regression lines indicated non-additive gene action with over dominance for plant height on the early and the late sowing dates, number of grains/spike, 1000-grain weight and grain weight/plant on the three sowing dates.

**Key words:** Bread wheat, diallel cross, genetic components, sowing dates, heat stress.

## INTRODUCTION

Wheat is the first strategic crop grown during the winter season. It is the staple food for about third of the world population due to its multiple uses, wider adaptation and high nutritive values. It occupies a vital position in agriculture policies of Egypt. Variation in the weather condition among and within growing seasons is one of the most important constrains affecting yield potential (Murungu and Madanzi, 2010).

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Global climate models predict an increase in mean ambient temperatures between 1.8 and 5.8°C by the end of this century (IPCC, 2007). In Egypt, heat stress after anthesis is the major grain yield limiting factor in wheat (*Triticum aestivum* L.). Delayed sowing increases the chance of the crop being exposed to heat stress, particularly on the vulnerable pre-flowering growth stages. Menshawy, 2005 and Ali 2011 reported under Egypt condition several advantages for earliness in wheat. Accordingly, the early wheat genotypes are highly needed to fit in new crop intensive rotation as sowing cotton after wheat and sowing wheat after harvesting shorter duration vegetable crops, *etc.*, furthermore, the early cultivars are preferable to escape from drought, heat, pests and other stress injuries that occur on the end of the growing season.

The optimum temperature for wheat anthesis and grain filling ranges from 12 to 22°C. Wheat genotypes are very sensitive to high temperature (Slafer and Satorre, 1999). Heat stress during the reproductive phase is more harmful than during the vegetative phase due to the direct effect on grain number and dry weight (Wollenweber *et al.,* 2003). Hence, temperature of 30°C, during floret formation, may cause complete sterility (Saini *et al.,* 1983). Additionally, when temperature are elevated between anthesis to grain maturity, grain yield is reduced because of the reduced time to capture resources. Lobell *et al.* (2005) reported in Mexico, that wheat yield decreased by 10% for every 1°C increase in night-time temperature, but the same increase in day-time temperature had no significant effect. Night temperature >20°C can reduce spikelet fertility with a concomitant reduction in grain number and size (Prasad *et al.*, 2008). Heat tolerance can be improved by selecting and developing wheat genotypes with heat resistance. Wheat pre-breeding and breeding may be based on secondary traits like membrane stability, photosynthetic rate and grain yield under heat stress (Farooq *et al.*, 2011). Dias and Lidon (2010) reported that, a high potential grain yield associated to a higher grain filling rate, under high temperature, might be an advantage of the *Triticum* genotypes in response of grain yield to high temperature, on the end of the life cycle of the plants.

The concept of combining ability is becoming increasingly important in plant breeding. It is especially useful in connection with "testing" procedures, in which it is desired to study and compare the performance of lines in hybrid combination, Griffing (1956). Developmental patterns of wheat are essential for improving adaption and yield potential. Improvement of wheat genotypes regarding each of days to heading, days to maturity, plant height, No. of grains/spike, 1000 grain weight and grain yield potential is largely depends on the knowledge of relative amount of genetic components, mode of gene action and the presence of non-allelic interaction of both traits in the plant material under investigation. Diallel cross technique as advocated by Hayman (1954 a,b) and Jinks (1954) was used to estimate the necessary genetic information on plant characters of self-fertilized crops like wheat in $F_1$ generation, Akram *et al.* (2008) reported that the additive genetic component was more imperative for genetic manipulation of number of days to heading, proposing the possibility of selection in the early generation ($F_1$). However, Simultaneous additive and dominance gene effects were involved in the inheritance of grain yield with more contribution to over dominance effect (Badieh *et al.*, 2012). The operative of over dominace was observed for the expression of number of days to maturity (Akram *et al.*, 2008) and grain yield (Gurmani *et al.*, 2007).

The present study was undertaken to generate information regarding the relative amount of genetic components and mode of gene action operative for number of days to heading, days to maturity, plant height, No. of grains/spike, 1000 grain weight and grain yield of 6×6 diallel cross. Information derived may be effectively exploited in developing and formulating breeding program for the evolution of early and high weighting wheat varieties on the early and late sowing dates (heat stress).

## MATERIALS AND METHODS

The present study was carried out on the Experimental Farm, Faculty of Agriculture, Zagazig University, Egypt, during the two successive growing seasons of 2011/2012 and 2012/2013. Six diverse bread wheat genotypes (Misr 1, Misr 2, Sids 12, Gemmeiza 9, Line 1 and Line 2) were selected on the basis of their differences in earliness and their promising of yield related traits. The pedigree and origin of the used genotypes are shown in Table 1. These parental wheat genotypes were sown on three sowing dates (2nd , 22nd November and 12th December 2011) in order to facilitate hybridization. The six parental genotypes were crossed during February/March 2012 in all possible combinations, excluding reciprocals to produce $F_1$ crosses.

In 2011/2012 season the seeds of the $F_1$ hybrids along with their six parents were sown on three sowing dates *i.e.*, early (2nd November), optimum , (22nd November) and late (12th December) sowing dates in the three adjacent experiments using a randomized complete block design with three replications. In all experiments, each cross was planted in a plot of five rows of 3 m length (2 rows for each parent and 1 row for the $F_1$ cross). Inter row and inter plant distances were kept on 20 cm and 10 cm, respectively. All recommended cultural practices for wheat production and inputs like irrigation, manuring and weed control, were kept uniform for all entries from sowing till harvesting to minimize environmental variation to the maximum extent. The meteorological data for monthly average during 2012/2013 growing season are presented in Table 2.

For data collection, ten-guarded plants for each parent and cross were tagged on random in each replication and data was recorded for days to heading, days to maturity, plant height, No. of grains/spike, 1000-grain weight and grain weight/ plant.

The collected data were subjected to analysis of variance as proposed by Steel *et al.* (1997) for determining validity in case wheat significant differences among mean values of genotypes were found. Estimation of both general (GCA) and specific (SCA) combining abilities were computed according to Griffing (1956) designated as method 2, model 1 for the studied characters. The traits showing significant genotypes differences were analyzed using diallel analysis technique as described by Hayman (1954 a,b) and Jinks (1954). The derived parameters were also calculated from the following formulae:

(a) $(H_1/D)^{0.5}$: The average degree of dominance.

(b) $(H_2/4H_1)$: Refer to the proportion of genes with positive and negative effects in the genetic constitution of parental genotypes.

(c) $KD/KR = (4DH_1)^{0.5} + F/ (4DH_1)^{0.5} - F$.

This ratio refers to the proportion of dominance and recessive genes in the studied parents.

Heritability in narrow ($T_n$) sense was calculated according to Mather and Jinks (1982) using the following equation.

$$T_n = \frac{\frac{1}{2}D + \frac{1}{2}H_1 - \frac{1}{2}H_2 - \frac{1}{2}F}{\frac{1}{2}D + \frac{1}{2}H_1 - \frac{1}{4}H_2 - \frac{1}{2}F + E}$$

**Table 1. Pedigree and origin of the 6 parental bread wheat genotypes**

| No. | Genotype | Pedigree | Origin |
|---|---|---|---|
| 1 | Misr 1 | OASIS/KAUZ//4*PASTOR.CMss00Y01881T-050M-030Y-030M-030WGY-33M-0Y-0S | Egypt |
| 2 | Misr 2 | SKAUZ / BAV92. CMss96M03611S-1M-0105Y-010M-010SY-8M-0Y-0S. | Egypt |
| 3 | Gemmeiza 9 | ALD "S" HUAC "S" // CMH74A.630/5XCGM4583-5GM-1GM-0GM | Egypt |
| 4 | Sids 12 | BUC//7C/ALD/5/MAYA74/ON//1160-147/3/BB/GLL/4/HAT" S"/S/MAYA-VUL//CMH74A.630/4*SX.SD7096-4SD-1SD-1SD-OSD | Egypt |
| 5 | Line 1 | Sakha 93/Sids6 CGZ(16)GM-2GM-OGM | Egypt |
| 6 | Line 2 | Giza 168/Sids7 CGZ(7)4GM-2GM.OGM | Egypt |

**Table 2. Meteorological data for monthly average during 2012/2013 growing season**

| 2012/2013 | Temp. (°C) | | | Humidity (%) | | |
|---|---|---|---|---|---|---|
| | High | Low | Avg. | High | Low | Avg. |
| November | 26 | 17 | 21 | 84 | 36 | 62 |
| December | 20 | 12 | 16 | 71 | 32 | 54 |
| January | 19 | 10 | 15 | 74 | 30 | 54 |
| February | 21 | 12 | 16 | 73 | 23 | 50 |
| March | 26 | 14 | 20 | 71 | 16 | 43 |
| April | 27 | 15 | 21 | 72 | 17 | 45 |
| May | 33 | 20 | 27 | 72 | 13 | 42 |

Graphic representation of the variance Vr (variance of the crosses involving a particular parents or variance of each array) and Wr (covariance between parents and their offspring, which Wr is covariance of the array with non-recurring parents) were done. The values of Wr were plotted against the corresponding values of Vr to produce Wr/Vr graph.

The reduction percentage of means due to early or late sowing for all studied traits was calculated as [(mean value of optimum sowing trait - mean value of early or late sowing trait) / mean value of optimum sowing trait] x 100.

The heat susceptibility index (HSI) was used as a measure of late sowing tolerance in terms of minimization of the reduction in grain yield caused by unfavorable versus favorable environments. (HSI) was calculated for each genotype according to the formula of Fischer and Maurer (1978).

$HSI = (1 - Y_{LS} / Y_{OS}) / (1- (X_{LS} / X_{OS})$

Where;

$Y_{LS}$ = mean of grain yield of a genotype in late sowing experiment.

$Y_{OS}$ = mean of grain yield of a genotype in optimum sowing experiment.

$X_{LS}$ = mean of all genotypes in late sowing.

$X_{OS}$=mean of all genotypes in optimum sowing.

## RESULTS AND DISCUSSION

### Analysis of Variance

The results of analysis of variance (Table 3) revealed that, mean squares due to genotypes, parents and $F_1$ crosses for days to heading and maturity, plant height, No. of grains/spike, 1000- grain weight and grain weight/plant on the three sowing dates were highly significant ($P<0.01$), indicating the presence of adequate genetic variability in the used genetic material. These results are in agreement with the findings of Gashaw *et al.* (2007), Anwar *et al.* (2009) and Rizkalla *et al.* (2012), who reported high variability for different characters among wheat genotypes using diallel cross. Moreover, mean squares due to Parents *Vs.* Crosses (P *vs.* C) were highly significant for all traits on the three sowing dates, indicating that mean performance of crosses was different with parents, revealed to attainability of heterosis for these traits in the studied genotypes. The genotypic mean squares on the late sowing were higher for days to heading and No. of grains/spike and lower for days to maturity and 1000- grain weight on the early sowing, and for plant height and grain weight/plant on normal sowing date as compared to other sowing dates.

### Mean Performance

Generally, all studied traits were severely decreased on the third sowing dates when compared with the first and the second sowing dates, showing that delay in wheat sowing reduced these characters drastically due to terminal high temperature which reduced season length and higher risk of disease attacks. While sowing on the second date (favorable) increased all studied characters. These results are in well agreement with those of, Hamam and Khaled (2009), Hozayn and Abd El-Monem (2010) and Ali (2011), who reported that delayed sowing date caused marked reduction in biological and economic yields, through reduction in spike length and yield, spike grain weight, No of spikes per square meter and 1000-grain weight.

For days to 50% heading (Table 4), average heading of wheat genotypes was significantly reduced on the early sowing date (81.57 days) and the late sowing (73.93 days) as compared to normal (84.53 days). This trait showed 3.50% and 12.54% reduction due to the early and the late sowing dates when compared with normal sowing, respectively. These results are in line with those reported by Hamam and Khaled (2009), who found that the number of days to heading on late sowing was reduced by 9 days, and with those of Hakim *et al.* (2012) and Laghari *et al.* (2012) who reposed reductions of 14-19% and 11.09%, respectively duo to late sowing for this trait.

The local wheat cultivar Sids 12 was the earliest one on the three sowing dates ($S_1$=80.00, $S_2$ = 80.75 and $S_3$ = 70.50 days). The good level of heading on the first sowing date was pronounced in Sids 12, Line 1 and Misr 1, which was reflected in the performance of their $F_1$, crosses Sids 12 × Misr 1 (79.33 days) and followed by Line 2 × Line 1 (80.00 days). Meantime, Sids 12 × Gemmeiza 9 and Sids 12 × Line 2 were the earliest ones on the second and the third sowing dates (81.00 and 69.33 days, respectively). Whereas, the wheat cultivar Gemmeiza 9 (83.33 days) was the latest, as well as their $F_1$ cross Gemmeiza 9×Line 1 and Gemmeiza 9

**Table 3. Mean squares of 6 parents and $F_1$ progenies of bread wheat for earliness, yield and some yield attributes on the three sowing dates**

| Source of variation | df | Days to heading | | | Days to maturity | | | Plant height (cm) | | | No. of grains / spike | | | 1000-grain weight (g) | | | Grain weight/plant (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 |
| Replicates | 2 | 0.05 | 0.36 | 0.07 | 0.78 | 1.21 | 1.44 | 0.01 | 0.56 | 0.21 | 0.05 | 0.05 | 3.90 | 0.52 | 0.46 | 0.44 | 0.51 | 1.97 | 0.03 |
| Genotypes | 20 | 4.34** | 11.07** | 19.65** | 11.12** | 4.14** | 4.55** | 23.64** | 34.84** | 23.66** | 17.07** | 18.27** | 19.26** | 9.47** | 6.86** | 3.66** | 5.68** | 9.48** | 4.08** |
| Parents (P) | 5 | 7.17** | 21.16** | 33.93** | 23.43** | 6.93** | 7.52** | 27.19** | 47.91** | 18.76** | 9.21** | 10.28** | 12.69** | 4.43** | 5.21** | 0.83** | 4.49** | 7.59** | 2.37** |
| Crosses (C) | 14 | 3.63** | 8.04** | 15.80** | 7.47** | 3.36** | 3.17** | 23.86** | 31.43** | 25.79** | 19.54** | 20.76** | 21.40** | 1.48** | 1.17** | 4.51** | 4.70** | 8.91** | 4.19** |
| P. vs. C. | 1 | 0.13** | 3.06** | 2.15** | 0.57** | 1.24** | 8.93** | 2.72** | 17.20** | 18.48** | 21.87** | 23.26** | 22.08** | 146.53** | 94.78** | 5.86** | 25.27** | 26.91** | 11.00** |
| Error | 40 | 0.31 | 0.37 | 0.40 | 0.43 | 0.39 | 0.51 | 0.46 | 0.84 | 0.47 | 1.15 | 1.06 | 0.62 | 0.61 | 1.10 | 0.64 | 1.30 | 1.71 | 0.62 |

*and**=significant on 0.05 and 0.01 levels of probability, respectively.

$S_1$=Early sowing (2nd November), $S_2$= Normal sowing (22nd November) and $S_3$= Late sowing (12th December).

**Table 4. Mean performance of six bread wheat parents and their $F_1$ progenies for earliness, yield and some yield attributes on the three sowing dates and heat susceptibility index for grain weight/plant**

| Genotypes | Days to heading | | | Days to maturity | | | Plant height (cm) | | | No. of grains/spike | | | 1000-grain weight (g) | | | Grain weight (g/plant) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | HSI |
| **Sids12 (P1)** | 80.00 | 80.75 | 70.50 | 136.33 | 134.67 | 130.33 | 89.98 | 87.34 | 79.67 | 61.54 | 63.85 | 48.24 | 56.67 | 56.91 | 49.67 | 19.58 | 25.76 | 18.91 | 0.78 |
| **Gemmeiza9 (P2)** | 83.33 | 83.33 | 74.75 | 139.00 | 137.00 | 134.00 | 92.00 | 86.84 | 80.07 | 61.51 | 63.68 | 46.98 | 54.83 | 56.09 | 48.84 | 22.49 | 29.54 | 18.10 | 1.14 |
| **Line2 (P3)** | 82.67 | 84.83 | 70.47 | 141.33 | 136.00 | 132.33 | 95.65 | 88.50 | 82.15 | 59.34 | 61.65 | 46.35 | 54.23 | 54.34 | 49.00 | 21.38 | 28.10 | 17.80 | 1.08 |
| **Misr1 (P4)** | 80.00 | 85.08 | 75.50 | 142.33 | 139.00 | 133.00 | 91.33 | 86.59 | 80.96 | 58.72 | 60.70 | 44.29 | 53.71 | 56.54 | 48.33 | 22.45 | 29.49 | 19.62 | 0.99 |
| **Line1 (P5)** | 80.33 | 87.11 | 79.36 | 141.67 | 137.33 | 133.00 | 97.53 | 96.03 | 85.93 | 57.00 | 58.98 | 42.68 | 53.83 | 53.53 | 48.53 | 23.00 | 30.20 | 20.15 | 0.98 |
| **Misr2 (P6)** | 82.67 | 88.17 | 74.75 | 144.33 | 138.00 | 135.00 | 95.81 | 93.57 | 84.40 | 59.00 | 61.31 | 44.35 | 53.29 | 55.41 | 49.49 | 21.53 | 28.29 | 18.70 | 1.00 |
| **P1 × P2** | 81.67 | 81.00 | 72.33 | 139.00 | 135.33 | 131.33 | 88.49 | 89.71 | 78.19 | 65.70 | 67.94 | 51.32 | 59.00 | 59.00 | 48.33 | 23.74 | 31.16 | 21.09 | 0.95 |
| **P1 × P3** | 81.67 | 82.33 | 69.33 | 141.33 | 135.33 | 131.00 | 92.33 | 88.00 | 78.62 | 61.00 | 63.31 | 47.25 | 57.08 | 58.33 | 49.33 | 25.16 | 33.01 | 20.21 | 1.14 |
| **P1 × P4** | 79.33 | 84.80 | 73.00 | 140.33 | 137.00 | 132.00 | 90.67 | 88.00 | 77.27 | 56.73 | 58.71 | 42.05 | 58.67 | 58.37 | 48.33 | 22.47 | 29.51 | 19.94 | 0.95 |
| **P1 × P5** | 81.00 | 83.33 | 75.00 | 137.00 | 135.33 | 129.33 | 93.77 | 96.00 | 85.00 | 61.51 | 63.82 | 48.03 | 57.33 | 57.67 | 46.41 | 24.30 | 31.89 | 18.55 | 1.23 |
| **P1 × P6** | 82.33 | 84.50 | 72.33 | 141.00 | 137.67 | 132.33 | 95.54 | 90.00 | 83.30 | 61.70 | 63.68 | 47.79 | 57.36 | 58.50 | 49.30 | 22.15 | 29.10 | 19.18 | 1.00 |
| **P2 × P3** | 82.00 | 84.08 | 70.00 | 142.00 | 135.33 | 131.67 | 96.25 | 88.10 | 83.45 | 59.00 | 61.31 | 44.55 | 58.63 | 58.33 | 47.82 | 24.88 | 32.64 | 19.37 | 1.20 |
| **P2 × P4** | 81.33 | 86.00 | 73.67 | 142.00 | 137.67 | 131.67 | 91.27 | 88.04 | 80.44 | 62.33 | 64.64 | 48.25 | 58.78 | 58.30 | 49.67 | 22.33 | 29.33 | 21.55 | 0.78 |
| **P2 × P5** | 83.33 | 83.00 | 75.67 | 140.67 | 136.33 | 132.67 | 98.79 | 96.78 | 82.42 | 62.53 | 64.84 | 47.79 | 57.94 | 58.16 | 49.63 | 21.63 | 28.42 | 21.84 | 0.68 |
| **P2 × P6** | 83.33 | 83.00 | 73.75 | 140.33 | 136.33 | 133.00 | 94.50 | 90.73 | 80.95 | 58.63 | 60.94 | 44.92 | 57.67 | 56.75 | 48.54 | 20.81 | 27.35 | 18.02 | 1.00 |
| **P3 × P4** | 81.67 | 84.50 | 73.67 | 141.00 | 136.67 | 132.67 | 98.50 | 86.00 | 79.13 | 62.23 | 64.54 | 48.32 | 57.54 | 59.16 | 46.45 | 24.26 | 30.50 | 18.96 | 1.11 |
| **P3 × P5** | 80.00 | 85.00 | 78.67 | 142.00 | 137.00 | 132.67 | 95.67 | 95.15 | 79.30 | 60.60 | 62.91 | 47.22 | 57.10 | 58.44 | 49.53 | 22.22 | 29.19 | 19.90 | 0.94 |
| **P3 × P6** | 82.00 | 86.00 | 75.33 | 142.33 | 137.67 | 132.67 | 95.00 | 93.00 | 79.23 | 60.00 | 62.31 | 45.92 | 57.00 | 57.49 | 49.79 | 23.00 | 30.20 | 20.63 | 0.93 |
| **P4 × P5** | 80.33 | 85.00 | 75.10 | 140.67 | 136.33 | 132.33 | 95.40 | 91.31 | 84.96 | 56.93 | 58.91 | 42.85 | 58.33 | 58.15 | 46.85 | 23.56 | 30.93 | 18.76 | 1.16 |
| **P4 × P6** | 82.00 | 86.33 | 74.33 | 142.33 | 138.67 | 133.67 | 92.16 | 90.69 | 77.00 | 58.83 | 60.81 | 44.49 | 57.49 | 58.67 | 47.05 | 22.61 | 29.69 | 18.42 | 1.12 |
| **P5 × P6** | 82.00 | 87.00 | 75.00 | 143.67 | 137.67 | 132.67 | 94.33 | 93.00 | 85.69 | 64.60 | 66.91 | 51.09 | 57.10 | 57.45 | 47.47 | 24.01 | 27.22 | 20.67 | 0.71 |
| **Mean** | 81.57 | 84.53 | 73.93 | 140.98 | 136.78 | 132.35 | 94.05 | 90.64 | 81.34 | 60.45 | 62.65 | 46.41 | 56.84 | 57.41 | 48.49 | 22.74 | 29.60 | 19.54 | 1.00 |
| **Reduction (%)** | 3.50 | | 12.54 | - | | 6.12 | - | | 13.51 | 3.51 | | 25.92 | 0.99 | | 15.54 | 23.18 | | 33.99 | |
| **LSD $_{0.05}$ (G)** | 0.93 | 1.00 | 1.04 | 1.08 | 1.03 | 1.18 | 1.13 | 1.51 | 1.13 | 1.77 | 1.70 | 1.30 | 1.28 | 1.73 | 1.32 | 1.88 | 2.16 | 1.30 | 0.18 |
| **LSD $_{0.05}$ (S)** | | 0.21 | | | 0.23 | | | 0.27 | | | 0.34 | | | 0.31 | | | 0.39 | | |
| **LSD$_{0.05}$ (G × S)** | | 0.96 | | | 1.07 | | | 1.24 | | | 1.56 | | | 1.42 | | | 1.77 | | |

$S_1$=Early sowing (2[nd] November), $S_2$= Normal sowing (22[nd] November) and $S_3$= Late sowing (12[th] December) - HSI = Heat susceptibility index

× Misr 2 (83.33 days) on the first sowing date. In this situation, the wheat cultivar Misr2 was the latest on the second sowing dates (88.17 days) as well as their $F_1$ cross line 1 × Misr 2 (87.00 days). Also, the genotype Line 1 (79.36 days) was the latest as well as their $F_1$ cross Line 2 × Line 1 (78.67 days) on third sowing date. These results suggest that genes controlling the early heading have been transferred from the parents to their $F_1$ progenies. Therefore, these genotypes are promising ones for the early heading.

Mean performance of days to maturity was significantly reduced due to late sowing date (132.35 days), while it was higher on the first sowing (140.98 days) but it was reduced on normal sowing to (136.78 days). The reduction of 6.12% was observed due to the late sowing when compared to the normal sowing date. Similar results were obtained by El-Shamarka *et al.* (2009), Laghari *et al.* (2012) and Phadnawis and Saini (1992). In the late sowing, the wheat variety should be short duration that may escape from high temperature on the grain filling stage. The good level of earliness pronounced in Sids 12 ($S_1$ = 136.33, $S_2$ = 134.67 and $S_3$ = 130.33 days) was reflected in the performance of their $F_1$ crosses (Sids 12 × Line 1), (Sids 12 × Gemmeiza 9), (Sids 12 × Line 2) on the three sowing dates. These results indicated that genes controlling earliness in maturity have been transmitted from the parents to the progenies. The above results might suggest that these crosses are the promising ones for isolating new early maturity genotypes. On the light of these results, the most desired wheat genotype in heading and maturity was Sids 12 and their $F_1$ crosses (Sids 12 × Line 1) and (Sids 12 × Gemmeiza 9) on the three sowing dates.

Data presented in Table 4 show that delay sowing date reduced plant height for all parents and $F_1$ crosses. Overall mean, reduction of 13.51% was recorded due to late sowing when compared to normal sowing date. Shorter plant height on late sowing was due to shorter growing period, while the early sowing date had the better environmental conditions especially the temperature and solar radiation which resulted in taller plants. These results are in well agreement with those obtained by Shahzad *et al.* (2002), Tahir *et al.* (2009) and Ali (2011). Also, Laghari *et al.* (2012) recorded reduction (32.54%) in plant height of wheat genotypes due to the late sowing and high temperature. Wheat cultivar Misr1 was the shortest parent on normal sowing date (86.59 cm) and Sids12 (89.98 cm) on the early and the late (79.67 cm) sowing dates. Also, the $F_1$ crosses, Sids 12 × Gemmeiza 9 (88.49 cm) on the early sowing, Line 2 × Misr 1 (86.0 cm) on normal sowing and Misr 1×Misr 2 (77.0 cm) on the late sowing, were shorter wheat crosses. On the other hand, Line1 was the tallest one among the parents on the three sowing dates and their $F_1$ crosses, *i.e.* Gemmeiza 9 × Line 1 on normal and early sowing, and Line 1 × Misr 2 on the late sowing date. These results reveal that plant height was more heritable character. These results indicate that genes controlling plant height were transmitted from the parents to the $F_1$ progenies.

Number of grains/spike showed significant reduction with the early and the late sowing compared to the normal sowing (Table 4), it recorded 3.51% and 25.92% reduction due to the early and the late sowing when compared to the 2nd (favorable) sowing date, respectively. It is evident that, the highest No. of grains/spike was recorded on normal sowing (62.65) followed by the early sowing (60.45) and late sowing (46.41). Less number of grains/spike in the 3rd sowing date was due to less production of photosyntheesis due to shorter growing period. These results are in accordance with those reported by Shahzad *et al.* (2002), Tahir *et al.* (2009) and Hozayn and Abd El-Monem (2010). Both local wheat cultivars Sids 12 and Gemmeiza 9 produced the greatest number of grains/spike as well as the $F_1$ crosses (Sids 12 × Gemmeiza 9), (Line 1 × Misr 2) and (Line 2 × Misr 1) on the three sowing dates, these genotypes are the promising ones for number of grains/ spike. These results suggested that the above genotypes could be used for isolating new recombinants with greater number of grains /spike. Furthermore, on the three sowing dates, the lowest mean number of grains /spike were recorded by both parental genotypes Line1 and Misr1 as well as $F_1$ crosses, (Sids 12 × Misr 1), (Misr 1× Line 1) and (Misr 1 × Misr 2).

Mean of 1000-grain weight was significantly reduced on late sowing (48.49g) and the early sowing date (56.84g) as compared to normal sowing (57.41g). The wheat cultivar Sids 12 had the highest values on the three sowing dates ($S_1$ = 56.67, $S_2$ = 56.91 and $S_3$ = 49.67g). For $F_1$ crosses, it ranged from 57.0 in Line 2 × Misr 2 to 59.0 in Sids 12 × Gemmeiza 9 on the 1st sowing date, from 57.45 in Line 1 × Misr 2 to 59.16 in Line 2 × Misr 1 on the 2nd sowing date and from 46.41 in Sids12×Line1 to 49.79 in Line 2 × Misr 2 on the 3rd sowing date.

However, 1000-grain weight was drastically decreased with late sowing, because late sown crop is on higher risk of disease attacks, drought and high temperature shocks. Reduction in this trait was 0.99 and 15.54% due to the early and delay in sowing dates compared with 2nd sowing date, respectively. These findings are strongly supported by those of Tahir *et al.* (2009), Hamam and Khaled (2009), Hozayn and Abd El-Monem (2010), Ali (2011) and Laghari *et al.* (2012).

Data presented in Table 4, show that grain weight/plant of bread wheat genotypes was significantly decreased with the early (23.18%) and late (33.99%) sowing dates. The parental wheat genotype Line1 had the highest mean values of grain weight/plant on the three sowing dates (23.00, 30.20 and 20.15g, respectively), as well as $F_1$ cross Sids 12 × Line 2 on the first and the second sowing dates (25.16 and 33.01, respectively) and Gemmeiza 9 × Line 1 (21.84g) on the third sowing date. On the other hand, the genotype Sids12 gave the less mean values of grain weight on the early and the normal sowing dates (19.58 and 25.76 respectively) and Line2 (17.80g) on late date, as well as the $F_1$ cross Gemmeiza 9 × Misr 2 on the three sowing dates (20.81, 27.35 and 18.02g, respectively).

It is of interest to report that late sowing date reduced each of days to heading (12.54%) and maturity (6.12%), plant height (13.51%), No. of grains/spike (25.92%), 1000-grain weight (15.54%) and grain weight (33.99%) compared with the 2nd (favorable) sowing date. These results are in well agreement with those of Hozayn and Abd El-Monem (2010), they reported that delayed sowing caused marked reduction in biological and economic yields, through reduction in the spike length, spike grain weight, No. of spike /$m^2$ and 1000-grain weight. Hamam and Khaled (2009) reported that higher 1000-grain weight and days to heading are the two important traits which could be considered as potential selection criteria for yield under heat stress. Heat stress reduces plant photosynthetic capacity through metabolic limitations and oxidative damage to chloroplasts, with concomitant reductions in dry matter accumulation and grain yield (Farooq *et al.* 2011). Heat stress after anthesis reduced the grain growth rate (12%) and grain growth period (30%) compared with optimum conditions (Modhej *et al.*, 2011).

## Heat Susceptibility Index (HSI)

The heat susceptibility index (HSI) values were calculated for determining the stress tolerance of wheat genotypes based on minimization of yield, losses duo to late sowing compared to optimum sowing date. The wheat genotypes showing HSI values less than 1.0 (HSI < 1) are more tolerant to heat stresses while those with values above 1.0 are sensitive to heat stress. The heat susceptibility index for grain weight/plant was highly significant tolerance values (HSI < 1) for parents and $F_1$ crosses.

Therefore, the parental wheat cultivar Sids 12 (0.78) and $F_1$ crosses Gemmeiza 9 × Misr 1 (0.78), Gemmeiza 9×Line 1 (0.68) and Line 1 × Misr 2 (0.71) exhibited HSI values less than unity, hence these genotypes were considered as more tolerant to late sowing (heat stress) as regards to their grain weight/plant (Table 4). Furthermore, the genotypes showing HSI values near 1.0 are moderate to late sowing, in this respect, parental wheat genotype Line1 (0.98) and $F_1$ crosses Sids 12 × Gemmeiza 9 (0.95), Line 2 × Line 1 (0.94) and Line 2 × Misr 2 (0.93) had HSI values near one. On the other side, Gemmeiza 9 (1.14), Misr 2 (1.0), Line 2 (1.08) and $F_1$ crosses Sids 12× Line 2 (1.14), Sids 12 × Line 1 (1.23), Gemmeiza 9× Line 2 (1.20) and Misr 1×Line 1 (1.16) had HSI values equal or more than 1.0, they were classified as susceptibility to late sowing. Various investigators stated similar results by Abdel-Nour (2011), Abd-Allah and Amin (2013) and Hamam (2013), they recorded a wide range of response to late sowing tolerance in wheat genotypes.

## General and Specific Combining Abilities

Analysis of variance of general (GCA) and specific (SCA) combining abilities for all studied traits are presented in Table 5. The results showed that mean squares of GCA and SCA were highly significant for days to heading and maturity, plant height, No. of grains/spike, 1000 grain weight and grain weight/plant on three sowing dates, suggesting the importance of both additive and non-additive gene effects in the expression of these characters. The ratio of GCA/SCA variances were more than unity for days to heading and maturity and plant height, indicating the major role of additive gene effects in controlling the genetic mechanism of these characters and giving additional evidence that selection should be effective in the early segregating generations. In contrast, the ratio of variance GCA to variance SCA was below one for No. of grains/spike, 1000 grain weight and grain yield, this emphasized that, non-additive gene action was the prevailed type in controlling these characters; consequently, hybrid breeding system would be the most efficient method for improving these characters. Similar results recorded by El-Moselhy (2009). Estimates of general combining ability effects (gi) for all studied traits on the three sowing dates are shown in Table 6. The results indicate that, Sids12 showed negative and highly significant general combining ability effects for days to 50% heading, days to maturity and plant height on the three sowing dates, as well as, it had positive and highly significant GCA effects for No. of grains/spike on the three sowing dates and 1000- grain weight on the early sowing. These results indicate that this genotype could be the best candidate as one of the parental genotypes to improve any of these traits.

Moreover, Gemmeiza 9 was the best combiner for days to 50% heading on normal (-1.0) and the late sowing (-0.32), days to maturity on the early (-0.61) and on the normal sowing (-0.31), plant height on the three sowing dates (-0.63, -0.93 and -0.47, respectively), No. of grains / spike on the three sowing dates (1.01, 1.06 and 0.74, respectively) and 1000-grain weight on the early sowing date. Line 2 had negative and highly significant GCA effects for days to 50% heading on the 3rd sowing date, days to maturity on the 2nd sowing date and plant height on the 2nd and the 3rd sowing dates. While, Misr1 showed negative and highly significant GCA effects for days to 50% heading on the 1st sowing date and plant height on the three sowing dates. Concerning, Line1, it had negative and highly significant GCA effects for days to 50% heading on the 1st sowing date. These parents are considered to be good general combiners and can be used in breeding programs for improving these characters. It is important to mention that general combining ability effects differed in their magnitude and significance from one environment to another.

The SCA effects on the different sowing dates for all studied characters are given in Table ,6. For days to heading, negative and significant SCA effects were registered by (Sids 12 × Misr 1), (Gemmeiza 9 × Line 2) and (Line 2 × Line 1) on the 1st sowing date, (Sids 12 × Gemmeiza 9), (Gemmeiza 9 × Line 1), (Gemmeiza 9 × Misr 2) and (Misr 1 × Line 1) on the 2nd sowing time and (Sids 12 × Line 2), (Gemmeiza 9 × Line 2), (Misr 1 × Line 1) and (Line 1 × Misr 2) on the 3rd sowing time, involved on general combiner parent.

Regarding days to maturity, negative and significant SCA effects were recorded by the crosses (Sids 12 × Line 1), (Gemmeiza 9 × Line 1), (Line 2 × Misr 1) and (Misr 1 × Line 1) on the early sowing date. Moreover F1 crosses (Sids 12 × Line 1), (Gemmeiza 9 × Misr 2) and (Misr 1 × Line 1) had negative and significant SCA effects on the normal sowing date, also $F_1$ crosses (Gemmeiza 9 × Line 2) and (Gemmeiza 9 × Misr 1) on the late sowing date. Therefore, the abovementioned crosses are considered to be the promising for the early maturity improvement. Negative and significant SCA effects for earliness characters were also recorded by Rizkalla *et al.* (2012) and Abd-Allah and Amin (2013).

The SCA effects (Table 6) for plant height were negative and highly significant in the cross combinations (Sids 12 × Gemmeiza 9), (Sids 12 × Line 2), (Gemmeiza 9 × Misr 1), (Line 2 × Line 1), (Line 2 × Misr 2), (Misr 1 × Misr 2) and (Line 1 × Misr 2) on the 1st sowing date, (Sids 12 × Misr 2), (Line 2 × Misr1) and (Line 1×Misr 2) on the 2nd sowing date. Also, seven out fifteen crosses (Sids 12 × Gemmeiza 9), (Sids 12 × Line 2), (Sids 12 × Misr 1), (Gemmeiza 9 × Line 1), (Line 2 × Line1), (Line 2 × Misr 2) and (Misr × Misr 2) had negative and highly significant SCA effects on the third sowing date.

Positive and highly significant SCA effects for number of grains/spike (Table 6) in the cross combinations (Sids 12 × Gemmeiza 9), (Gemmeiza 9 × Misr 1), (Gemmeiza 9 × Line 1), (Line 2 × Misr 1) and (Line 1 × Misr 2) on the three sowing dates; also in the cross combinations (Sids 12 × Line 1) and (Line 2 × Line 1) on the late sowing. Similar results recorded by Sedek (2009).

For 1000-grain weight (Table 6), positive and highly significant SCA effects were found in all crosses on the 1st sowing date except, (Sids 12×Line 2), (Sids 12 × Line 1) and (Sids 12 × Misr 2), also, $F_1$ crosses (Gemmeiza 9 × Line 1),

**Table 5. Mean squares of general (GCA) and specific combining ability (SCA) for earliness, yield and some yield attributes on the three sowing dates**

| Source of variation | df | Days to heading | | | Days to maturity | | | Plant height (cm) | | | No. of grains/ spike | | | 1000-grain weight (g) | | | Grain weight/plant (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 |
| GCA | 5 | 12.83** | 34.33** | 56.49** | 32.53** | 12.28** | 12.51** | 56.06** | 109.65** | 45.17** | 14.73** | 16.46** | 16.35** | 5.29** | 4.62** | 2.87** | 2.63** | 5.69** | 1.70** |
| SCA | 15 | 1.51** | 3.32** | 7.37** | 3.98** | 1.43** | 1.90** | 12.83** | 9.90** | 16.50** | 17.85** | 18.87** | 20.23** | 10.86** | 7.60** | 3.92** | 6.69** | 10.75** | 4.87** |
| Error | 40 | 0.31 | 0.37 | 0.40 | 0.43 | 0.39 | 0.51 | 0.46 | 0.84 | 0.47 | 1.15 | 1.06 | 0.62 | 0.61 | 1.10 | 0.64 | 1.30 | 1.71 | 0.62 |
| $\sigma^2$ GCA/ $\sigma^2$ SCA | | 8.52 | 10.34 | 7.66 | 8.18 | 8.57 | 6.60 | 4.37 | 11.07 | 2.74 | 0.83 | 0.87 | 0.81 | 0.49 | 0.61 | 0.73 | 0.39 | 0.53 | 0.35 |

*and**=significant on 0.05 and 0.01 levels of probability, respectively. $S_1$=Early (2nd November), $S_2$= Normal (22nd November) and $S_3$= Late (12th December)

Table 6. Estimates of general (GCA) and specific (SCA) combining ability effects of the bread wheat genotypes for earliness, yield and some yield attributes on the three sowing dates

| Genotypes | Days to heading | | | Days to maturity | | | Plant height (cm) | | | No. of grains/ spike | | | 1000-grain weight (g) | | | Grain weight/plant (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 |
| | | | | | | | | | GCA | | | | | | | | | |
| Sids 12 (P1) | -0.63** | -1.78** | -1.81** | -1.94** | -0.93** | -1.22** | -2.20** | -1.01** | -0.96** | 0.82** | 0.82** | 1.00** | 0.61** | 0.48 | 0.20 | -0.28 | -0.12 | -0.001 |
| Gemmeiza 9 (P2) | 0.92** | -1.00** | -0.32* | -0.61** | -0.31* | 0.24 | -0.63** | -0.93** | -0.47* | 1.01** | 1.06** | 0.74** | 0.48* | 0.11 | 0.28 | -0.10 | 0.10 | 0.16 |
| Line 2 (P3) | 0.21 | -0.02 | -1.20** | 0.56** | -0.43* | -0.14 | 1.34** | -0.90** | -0.67** | -0.21 | -0.11 | 0.13 | -0.26 | -0.18 | 0.18 | 0.39 | 0.57 | -0.26 |
| Misr 1 (P4) | -0.79** | 0.64** | 0.41* | 0.51** | 0.86** | 0.24 | -0.96** | -2.15** | -1.08** | -1.08** | -1.20** | -1.30** | 0.05 | 0.48 | -0.55* | 0.12 | 0.22 | 0.01 |
| Line 1 (P5) | -0.46** | 0.73** | 2.58** | 0.06 | -0.01 | -0.10 | 1.84** | 3.73** | 2.48** | -0.37 | -0.41 | -0.32 | -0.30 | -0.62** | -0.31 | 0.32 | 0.11 | 0.40 |
| Misr 2 (P6) | 0.75** | 1.43** | 0.34* | 1.43** | 0.82** | 0.99** | 0.60** | 1.26** | 0.70** | -0.17 | -0.16 | -0.25 | -0.58** | -0.27 | 0.21 | -0.44 | -0.88** | -0.31 |
| $SE_{(gi-gj)}$ | 0.16 | 0.18 | 0.18 | 0.19 | 0.18 | 0.21 | 0.20 | 0.26 | 0.20 | 0.31 | 0.30 | 0.23 | 0.22 | 0.30 | 0.23 | 0.33 | 0.38 | 0.23 |
| | | | | | | | | | SCA | | | | | | | | | |
| P1 x P2 | -0.20 | -0.75* | 0.54 | 0.57 | -0.21 | -0.03 | -2.73** | 1.01* | -1.72** | 3.42** | 3.41** | 3.17** | 1.07** | 1.01 | -0.63 | 1.38* | 1.59* | 1.39** |
| P1 x P3 | 0.51 | -0.40 | -1.59** | 1.74** | -0.08 | 0.01 | -0.86* | -0.73 | -1.09** | -0.07 | -0.05 | -0.29 | -0.12 | 0.63 | 0.46 | 2.31** | 2.96** | 0.94* |
| P1 x P4 | -0.82** | 1.42** | 0.48 | 0.78* | 0.29 | 0.64 | -0.22 | 0.53 | -2.03** | -3.46** | -3.57** | -4.07** | 1.17** | 0.00 | 0.20 | -0.12 | -0.18 | 0.39 |
| P1 x P5 | 0.51* | -0.15 | 0.30 | -2.10** | -0.50 | -1.70 | 0.08 | 2.64** | 2.14** | 0.61 | 0.74 | 0.93* | 0.18 | 0.40 | -1.97** | 1.52* | 2.31** | -1.39** |
| P1 x P6 | 0.64* | 0.32 | -0.13 | 0.53 | 1.00** | 0.22 | 3.08** | -0.89* | 2.22** | 0.60 | 0.36 | 0.62 | 0.49 | 0.88 | 0.40 | 0.13 | 0.51 | -0.06 |
| P2 x P3 | -0.70* | 0.56 | -2.41** | 1.07** | -0.71* | -0.78* | 1.49** | -0.71 | 3.25** | -2.25** | -2.29** | -2.73** | 1.57** | 1.00 | -1.13** | 1.85** | 2.37** | -0.07 |
| P2 x P4 | -0.36 | 1.83** | -0.35 | 1.11** | 0.33 | -1.15** | -1.19** | 0.48 | 0.66 | 1.95** | 2.13** | 2.40** | 1.42** | 0.30 | 1.45** | -0.43 | -0.59 | 1.84** |
| P2 x P5 | 1.30** | -1.26** | -0.52 | 0.24 | -0.13 | 0.18 | 3.54** | 3.34** | -0.93* | 1.45* | 1.54** | 0.96* | 0.93* | 1.26* | 1.18** | -1.32* | -1.38* | 1.73** |
| P2 x P6 | 0.10 | -1.97** | -0.20 | -1.47** | -0.96** | -0.57 | 0.48 | -0.24 | -0.62 | -2.65** | -2.60** | -1.98** | 0.93* | -0.49 | -0.44 | -1.39* | -1.47* | -1.38** |
| P3 x P4 | 0.68* | -0.65* | 0.53 | -1.05** | -0.54 | 0.22 | 4.07** | -1.58** | -0.46 | 3.07** | 3.20** | 3.07** | 0.92* | 1.45* | -1.67** | 1.01 | 0.12 | -0.33 |
| P3 x P5 | -1.32** | -0.24 | 3.35** | 0.40 | 0.67* | 0.55 | -1.56** | 1.68** | -3.85** | 0.73 | 0.77 | 0.99* | 0.82* | 1.83** | 1.17** | -1.23* | -1.09 | 0.22 |
| P3 x P6 | -0.53 | 0.06 | 2.26** | -0.64* | 0.50 | -0.53 | -0.99** | 2.00** | -2.14** | -0.07 | -0.07 | -0.38 | 1.00* | 0.54 | 0.90* | 0.32 | 0.91 | 1.66** |
| P4 x P5 | 0.01 | -0.90** | -1.82** | -0.89* | -1.29** | -0.15 | 0.47 | -0.90 | 2.22** | -2.06** | -2.14** | -1.94** | 1.75** | 0.88 | -0.77 | 0.38 | 1.00 | -1.19** |
| P4 x P6 | 0.47 | -0.26 | -0.35 | -0.60 | 0.21 | 0.10 | -1.53** | 0.95 | -3.95** | -0.36 | -0.48 | -0.38 | 1.19** | 1.05* | -1.10* | 0.20 | 0.76 | -0.82* |
| P5 X P6 | 0.14 | 0.31 | -1.85** | 1.20** | 0.08 | -0.57 | -2.15** | -2.63** | 1.17** | 4.70** | 4.82** | 5.24** | 1.14** | 0.93 | -0.92* | 1.40* | -1.61* | 1.03* |
| $SE_{(Sij-Sji)}$ | 0.32 | 0.35 | 0.36 | 0.38 | 0.36 | 0.41 | 0.39 | 0.53 | 0.40 | 0.62 | 0.60 | 0.45 | 0.45 | 0.61 | 0.46 | 0.66 | 0.75 | 0.46 |

*and**=significant on 0.05 and 0.01 levels of probability, respectively.

$S_1$=Early sowing (2nd November), $S_2$= Normal sowing (22nd November) and $S_3$= Late sowing (12th December).

(Line 2 × Misr 1), (Line 2 × Line 1) and (Misr 1 × Misr 2) had positive and significant SCA effects on the 2nd sowing date as well as (Gemmeiza 9 × Misr 1), (Gemmeiza 9 × Line 1), (Line 2 × Line 1) and (Line2×Misr2) on the 3rd sowing date. These crosses could be employed in breeding program for improving this trait in bread wheat. Similar results were recorded by El-Moselhy (2009), Sedek (2009) and Rizkalla *et al.* (2012).

Estimates of SCA effects for grain weight/ plant on the three sowing dates are illustrated in Table 6. The results display that positive and significant SCA effects were detected in five crosses out of 15 $F_1$'s *i.e.*, cross combinations (Sids 12 × Gemmeiza 9), (Sids 12 × Line 2), (Sids 12 × Line 1), (Gemmeiza 9 × Line 2) and (Line 1 × Misr 2) on the 1st sowing date. Whereas, on the 2nd sowing date the crosses (Sids 12 × Gemmeiza 9), (Sids 12 × Line 2), (Sids 12 × Line 1) and (Gemmeiza 9 × Line 2) manifested positive and significant SCA effects. Furthermore, on the 3rd sowing date, positive and significant SCA effects have been registered by six crosses out of 15 $F_1$'s *i.e.,* (Sids 12 × Gemmeiza 9), (Sids 12 × Line 2), (Sids 12 × Misr 1), (Gemmeiza 9 × Misr 2), (Gemmeiza 9 × Line 1), (Line 2 × Line 1), (Line 2 × Misr 2) and (Line 1 × Misr 2). In general, the above crosses seemed to be good $F_1$ cross combinations for increasing wheat grain yield.

## Mode of Gene Action

Data presented in Table 7 show significant value of additive (D) gene effects for days to heading and days to maturity, plant height, No. of grain/spike on the three sowing dates and 1000- grain weight on the 1st and the 2nd sowing dates. Meantime significant values of dominance ($H_1$ and $H_2$) were detected on the three sowing dates for all studied characters, revealing the importance of both additive and non-additive gene action in the inheritance all these traits.

The additive genetic effects (D) seemed to be more than the non-additive gene effect ($H_1$ and $H_2$) for days to heading and days to maturity on the three sowing dates and plant height on the normal sowing date, it means that due to the presence of additive variance selection for these traits could be practiced in the early generations. These results are in accordance with the finding of Akram *et al.* (2008), Sedek (2009) and Hussain *et al.* (2013).

However the dominance gene effects ($H_1$ and $H_2$) were more than the additive gene effects (D) for No. of grains/spike, 1000- grain weight and grain weight on the three sowing dates and plant height on the 1st and the 3rd sowing dates, showing that these characters are controlled by dominance gene action and could be improved through hybrid breeding method.

The dominance component ($H_1$) was more than ($H_2$) one, for all traits on the three sowing dates, showing that dominance and recessive genes were un-equally distributed in the parents. These results are confirmed by the value of [$H_2$/ $4H_1$] which was less than its maximum value (0.25) and ranged from 0.17 for grain weight/plant on the 2nd sowing date to 0.24 for plant height on the 1st sowing date F which indicates the relative frequency of dominant and recessive alleles in the parents was found to be positive and insignificant for days to 50% for heading, days to maturity, No. of grains/spike and grain weight on the three sowing dates, plant height on the1st sowing and 1000- grain weight on the 1st and the 2nd sowing dates, indicating that parental genotypes contained more dominant alleles than the recessive ones respective whether they increase or decrease mean performance of the abovementioned characters, respectively and it was supported by the ratio of KD/KR, which was greater than unity for these traits.

Negative (F) values were observed for plant height on the 2nd and the 3th sowing dates and 1000- grains weight on the 3rd sowing date, showing the importance of recessive alleles in these characters, which was supported by low value of KD/KR than unity for these traits.

The sum of dominant alleles in heterozygous phase over all loci, as indicated by ($h^2$), was positive for all studied traits on the three sowing dates, except the1st sowing for days to 50% heading, showing that dominant genes controlling these characters were mainly due to heterozygosity of loci.

Environmental component of variation (E) was found to be insignificant for all studied traits except days to maturity on the three sowing dates, revealing unimportant role of environmental factors in determining these traits.

**Table 7. Additive (D), dominance (H) genetic variances and their derived parameters for earliness, yield and some yield attributes on the three sowing dates**

| Genetic Component | Days to heading | | | Days to maturity | | | Plant height(cm) | | | No. of grains/spike | | | 1000-grain weight (g) | | | Grain weight/plant (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 |
| **Genetic Parameters** | | | | | | | | | | | | | | | | | | |
| D | 2.29** | 6.93** | 11.18** | 7.66** | 2.17** | 2.32** | 8.92** | 15.69** | 6.10** | 2.70* | 3.09* | 3.97** | 1.275** | 1.380** | 0.065 | 1.078 | 1.96 | 0.59 |
| $H_1$ | 1.88** | 4.42** | 10.03* | 5.29** | 1.70** | 1.83** | 17.01** | 12.88** | 22.05** | 22.94** | 24.45** | 26.87** | 8.891** | 5.987** | 4.645** | 7.906** | 14.32** | 5.99** |
| $H_2$ | 1.66** | 3.63* | 8.88* | 4.58** | 1.36** | 1.70** | 16.32** | 10.96** | 19.86** | 21.33** | 22.57** | 24.22** | 8.281** | 5.603** | 4.421** | 6.107** | 9.67** | 5.25** |
| F | 0.41 | 2.26 | 3.29 | 3.60 | 0.49 | 0.51 | 0.02 | -1.86 | -0.18 | 1.72 | 2.03 | 3.78 | 1.082 | 1.279 | -0.300 | 2.411 | 5.12 | 1.06 |
| $h^2$ | -0.03 | 0.59 | 0.39 | 0.04** | 0.19 | 1.83** | 0.51 | 3.56 | 3.91 | 4.52* | 4.84* | 4.63 | 31.546** | 20.278** | 1.149 | 5.225** | 5.50* | 2.27** |
| E | 0.10 | 0.12 | 0.13 | 0.15** | 0.14** | 0.19** | 0.15 | 0.28 | 0.15 | 0.37 | 0.34 | 0.26 | 0.200 | 0.356 | 0.211 | 0.420 | 0.57 | 0.20 |
| **Derived Parameters** | | | | | | | | | | | | | | | | | | |
| $[H_1/D]^{0.5}$ | 0.91 | 0.80 | 0.95 | 0.83 | 0.89 | 0.89 | 1.38 | 0.91 | 1.90 | 2.91 | 2.81 | 2.60 | 2.640 | 2.083 | 8.399 | 2.708 | 2.70 | 3.18 |
| $[H_2/4H_1]$ | 0.22 | 0.21 | 0.22 | 0.22 | 0.20 | 0.23 | 0.24 | 0.21 | 0.23 | 0.23 | 0.23 | 0.23 | 0.233 | 0.234 | 0.239 | 0.193 | 0.17 | 0.22 |
| $[h_2/H_2]$ | -0.02 | 0.16 | 0.04 | 0.01 | 0.14 | 1.08 | 0.03 | 0.33 | 0.20 | 0.21 | 0.21 | 0.19 | 3.809 | 3.619 | 0.260 | 0.856 | 0.57 | 0.43 |
| [KD / KR] | 1.22 | 1.51 | 1.37 | 1.79 | 1.29 | 1.28 | 1.00 | 0.88 | 0.98 | 1.25 | 1.27 | 1.45 | 1.383 | 1.572 | 0.571 | 2.407 | 2.87 | 1.79 |
| $T_{(n)}$ | 67.01 | 72.56 | 65.86 | 64.86 | 67.65 | 61.49 | 53.14 | 76.36 | 45.31 | 18.54 | 19.66 | 18.38 | 15.0 | 12.14 | 17.5 | 17.0 | 20.0 | 8.05 |

*and**=significant on 0.05 and 0.01 levels of probability, respectively.

$S_1$=Early sowing (2nd November), $S_2$= Normal sowing (22nd November) and $S_3$= Late sowing (12th December)

The degree of dominance $(H_1/D)^{0.5}$ was more than unity for plant height on the 1st and the 3rd sowing dates, No. of grains/spike, 1000- grain weight and grain weight on the three sowing dates, confirming the importance of over-dominance gene action in controlling the inheritance of these characters. Similar findings were reported by (Awaad, 2005; Ismail, 2006; Al-Naggar *et al.*, 2007).

In contrast, the degree of dominance was less than unity for days to 50% heading and days to maturity on the three sowing dates and plant height on the 2nd sowing date, indicating the presence of partial dominance for these traits in these cases, which was confirmed from the regression line, which cuts the Wr axis above the origin. Preponderance of partial dominance for these traits reveal the importance of the early generation selection, which would be helpful in future breeding of wheat cultivars. Similar finding was reported by Akram *et al.* (2008).

The proportions of genes with positive and negative effects in the parents as indicated by $(H_2/4H_1)$ were near to theoretical value (0.25) for all studied traits on the three sowing dates, suggesting symmetrical distribution of positive and negative alleles among the parental genotypes.

The proportion of dominant and recessive genes in the parents (KD/KR) were more than unity on the three sowing dates for days to 50% heading, days to maturity, No. of grains/spike and grain yield on the three sowing dates, plant height on the1st sowing date and 1000-grains weight on the 1st and the 2nd sowing dates, suggesting that dominance genes were more frequent than the recessive ones in the parental genetic make-up. Meanwhile, recessive genes were more important in each of plant height on the 2nd and the 3rd sowing dates and 1000-grain weight on the 3rd sowing dates.

Narrow sense heritability estimates recorded high values on the three sowing dates for days to 50% heading (67.01, 72.56 and 65.86, respectively), days to maturity (64.86, 67.65 and 61.49, respectively) and moderate to high for plant height (53.14, 76.36 and 45.31, respectively).

In this connection, moderate to high narrow sense heritability estimates were recorded for days to heading (Menshawy, 2005; Koumber and El-Beially 2005 ; El-Marakby *et al.*, 2007). This suggest that days to heading is an important attribute contributing towards weight and direct selection can be practiced in the early segregation generation.

Low narrow sense heritability estimates were reported on the three sowing dates for No. of grains/ spike (18.54, 19.66 and 18.38%, respectively), 1000-grain weight (15.0, 12.14 and 17.5%, respectively), and grain weight/plant (17.0, 20.0 and 8.05%, respectively). Indicating that non-additive genetic effects controlling the inheritance of these traits. Narrow sense heritability measures the magnitude of additive variation, which is mainly responsible for changing the genetic composition of the population *via* selection (Dabholkar, 1992). The low value of narrow sense heritability for grain yield suggests that progress in selection will be inherently slow. All these results for genetic components by Hayman method are in well agreement with those obtained by diallel analysis by Griffing's method.

## Graphical Analysis

Hayman graphical analysis was conducted to evaluate the genetic relationship among the parents. The position of regression line on Vr-Wr graph provides information about the average degree of dominance (Singh and Chaudhary, 1995).

The deviation of the regression line from unit slope was found non-significant for days to 50% heading (Fig. 1) on the three sowing dates; this indicates the absence of non-allelic interactions. The regression line intercepts the covariance-axis above the origin showing additive type of gene action with partial dominance.

The regression lines on the three sowing dates for earliness characters intercepts Wr-axis above the point of origin, showing additive type of gene action with partial dominance controlling the genetic mechanism of these characters. These results are supported by genetic component, which indicates that additive gene action is the prevailed type in the genetics of earliness characters. Similar finding was reported by Ahmad *et al.* (2011) and Abd Allah and Amin (2013). The distribution of parental genotypes along the regression lines for days to 50% heading on the three sowing showed that genotype Sids 12 and Line1 possessed the most recessive genes, Misr 2 had most dominant genes, Line 2 and Gemmeiza 9 possessed 50:50 recessive to dominant genes on the early sowing date. On the normal sowing date, genotypes Line1, Misr 2 and Sids 12 possessed the most recessive genes, whereas, Misr 1 being the nearest supposedly had most of the dominant genes and Line 2 possessed 50:50 recessive to dominant genes. With respect to the late sowing, Line 2 possessed the most recessive genes being far away from the origin. Misr 1, Misr 2, and Line 1 had maximum number of recessive genes for this character.

For days to maturity, the regression coefficients were significant from zero, but not from unity on the three sowing dates. This trait is controlled by additive type of gene action with partial dominance as the regression line cuts the Wr-axis above the origin. Similar finding was reported by Sami-Ullah *et al.* (2010) and Abd-Allah and Amin (2013). Fig. 2 shows that most of the parental forms are closely clustered around the regression line, which proves that the genetic system that controls days to maturity is mainly additive. Distribution of array points on the regression line suggesting that genotypes Sids 12 and Line 1 possessed the most recessive genes, while Misr 1 and Line 2 cumulates the most dominant genes and Misr 2 possessed 50:50 recessive to dominant genes on the early sowing date. On the normal sowing, genotypes Sids 12 and Misr1 possessed the most recessive genes, and Line 1, Line 2, Misr 2 and Gemmeiza 9 had recessive and dominant genes in about equal proportions. Additionally, on the late sowing date, Line1 was far from the origin, it possessed the most recessive genes, while genotypes Misr 1 and Line 2 possessed an excess of dominant genes over recessive. Cultivars Gemmeiza 9, Misr 2 and Sids 12 possessed 50:50 recessive to dominant genes. Fig. 3 illustrates Wr/Vr relationship for plant height on the three sowing dates. Regression coefficients show significant variation from zero but not from unity on the early and the normal sowing dates and obviously indicates the non-existence of epistasis effects.

The regression line cuts Wr-axis below point of origin on the early and the late sowing dates. Showing the major role of over dominance gene action in the genetics of plant height. But we should also consider the regression line cut the Wr-axis above the origin on the normal sowing date for this trait.

The pattern of distribution of parental genotypes along the regression line for plant height (Fig. 3), indicates that Gemmeiza 9 possessed the most recessive genes, while genotypes Misr 2, Line1 and Line 2 being closer to origin contain most of the dominant genes, but Sids 12 possessed 70:25 recessive to dominant genes on the early sowing date. Genotypes Line 2 had the most recessive genes, while Misr 2 and Line1 had most dominant genes on the 2$^{nd}$ sowing date. Cultivars Sids 12 and Misr 2 had the highest proportion of recessive alleles, while genotype Line 2 carry maximum dominant genes, Line1 possessed 50:50 recessive to dominant genes on the late sowing date.

Figs. (4, 5 and 6) illustrate Wr/Vr relationship for No. of grains/spike, 1000-grain weight and grain weight/plant on the three sowing dates. Regression coefficients show significant variation from zero and unite slope on the early and the normal sowing dates for 1000-grain weight and non-significant variation for 1000-grain weight on late sowing date and grain weight/plant on the three sowing dates.

Number of grains/spike, 1000-grain weight and grain weight/plant on the three sowing dates were inherited by over dominance as the regression line intersected the covariance axis below the point of origin in the negative region [intercept = a<0 (negative)], suggests that selection for desirable transgressive segregates would not be possible through selection in the early generations. Similar finding were reported by Ahmad *et al.* (2011), Rabbani *et al.* (2011), Khodadadi *et al.* (2012) as well as Abd-Allah and Amin (2013).

Dispersion of parents around the regression line for No. of grains/spike (Fig.4) showed that genotypes Line1 had the most recessive genes, while Line2 exhibited most dominant genes and Sids 12 possessed 75:25 recessive to dominant genes on the three sowing dates.

The graphical representation of 1000-grain weight on the early sowing date Fig. 5, indicates that Misr1 contains maximum number of recessive genes for this trait and Sids 12 contributed most of the dominant alleles since it was the closest to the origin, while genotype Line 2, Gemmeiza 9 and Line 1 were situated on the middle of the regression line; this indicates contribution of both dominant and recessive alleles by the parents on the early sowing date.

Moreover, on the normal sowing date for 1000-grain weight Line1, which was furthest from the origin contributed most of the recessive alleles, and Misr1, Gemmeiza9 and Sids12 had most dominant genes. On the late sowing date,

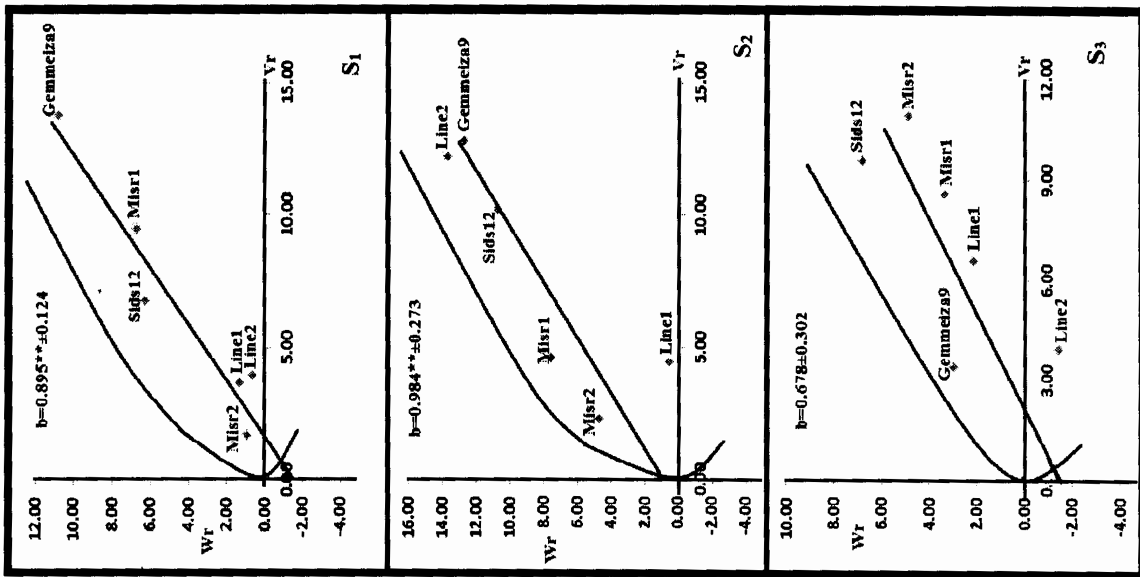


Fig.3 Wr/Vr graph for plant height (cm)

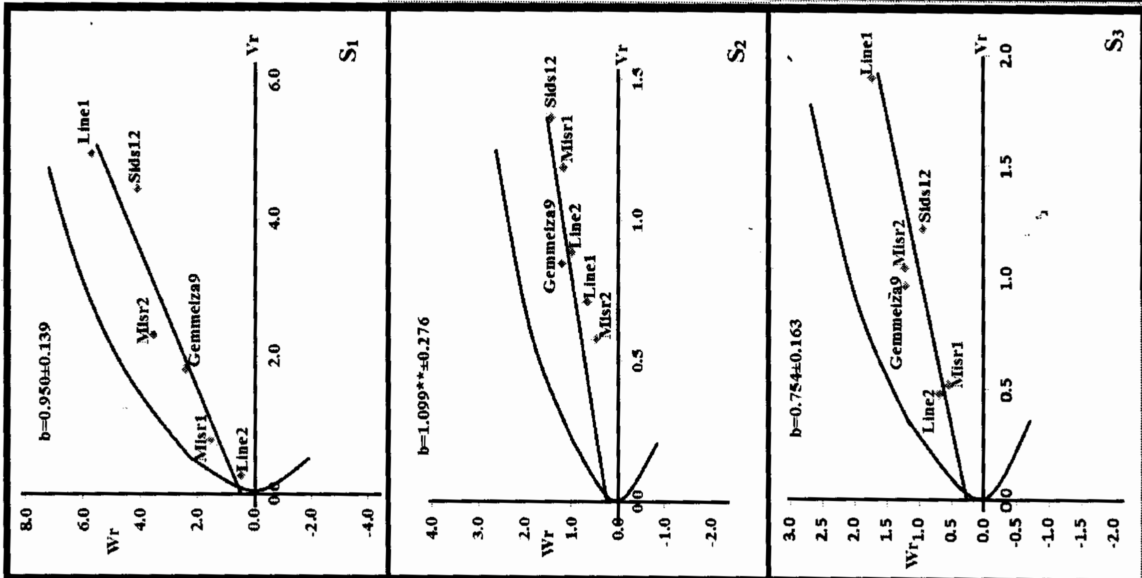


Fig.2 Wr/Vr graph for days to maturity

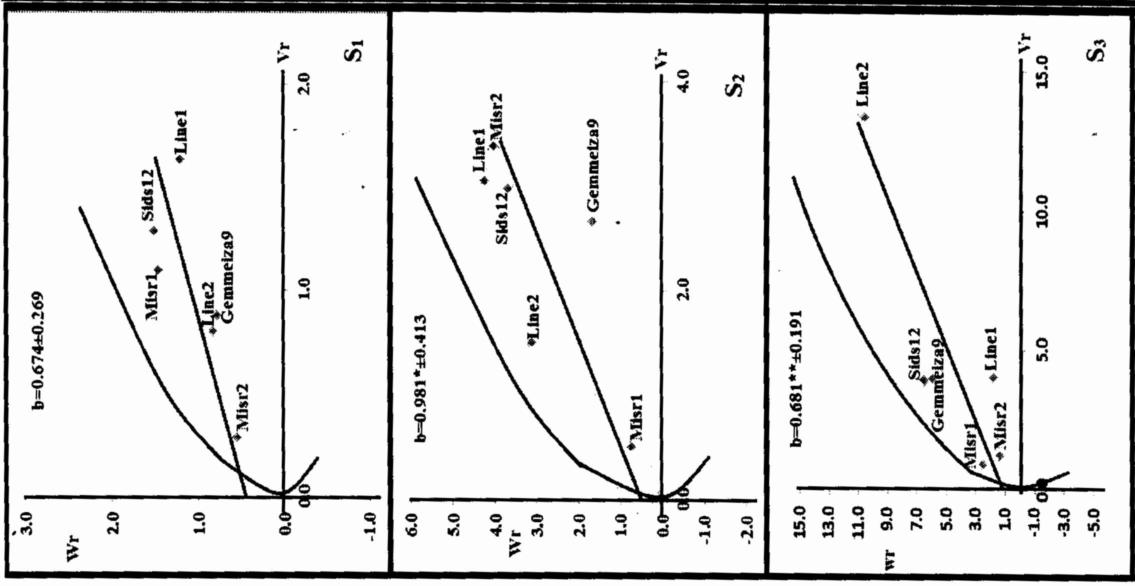


Fig.1 Wr/Vr graph for days to heading

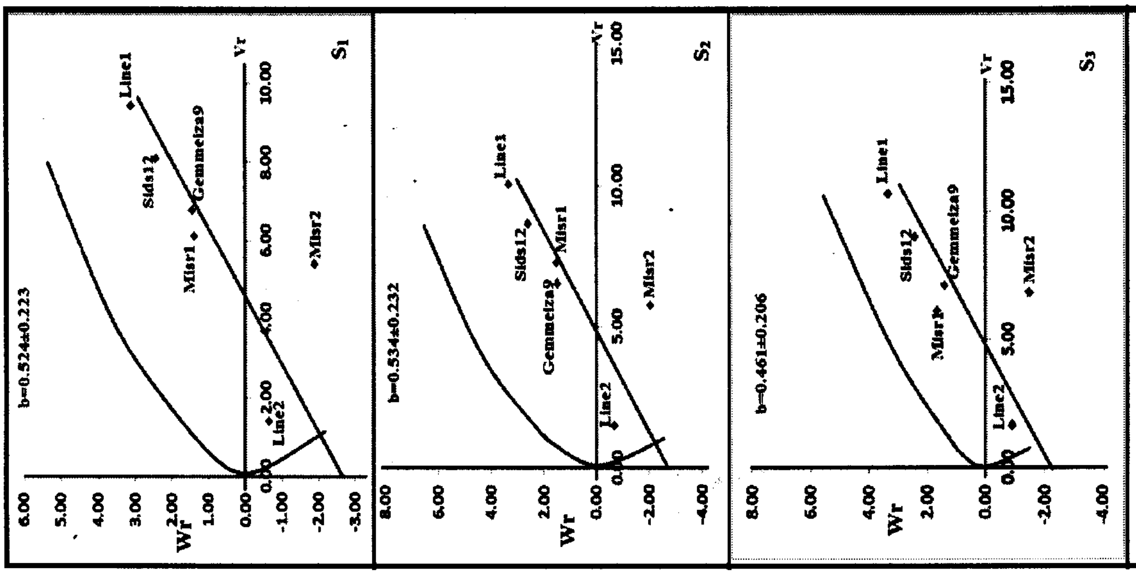


Fig.4 Wr/Vr graph for number of grains/spike

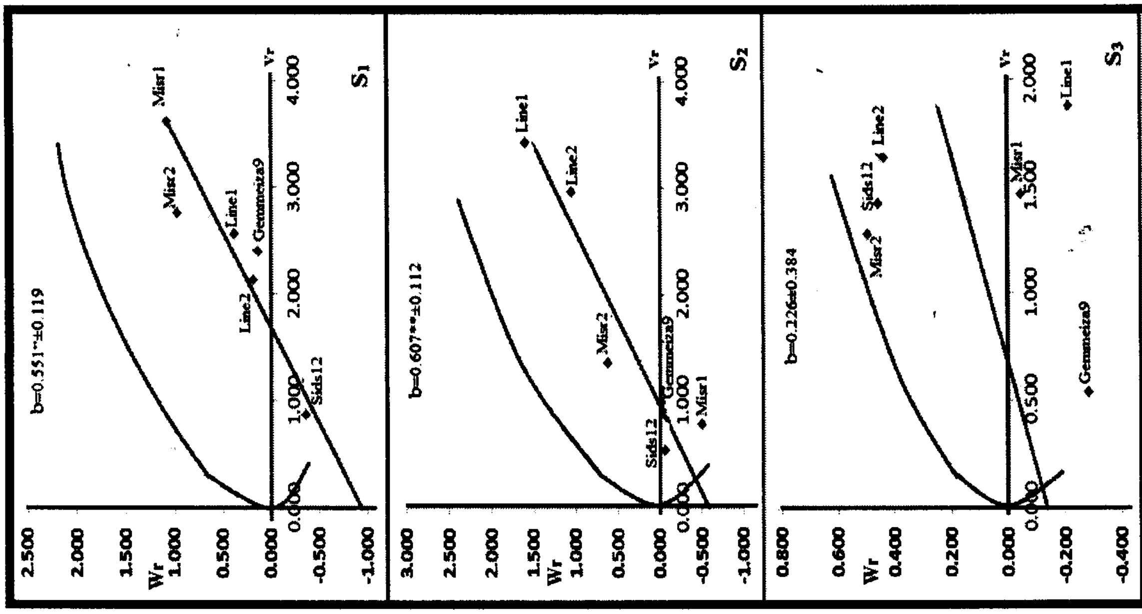


Fig. 5 Wr/Vr graph for 1000 grain weight (g)

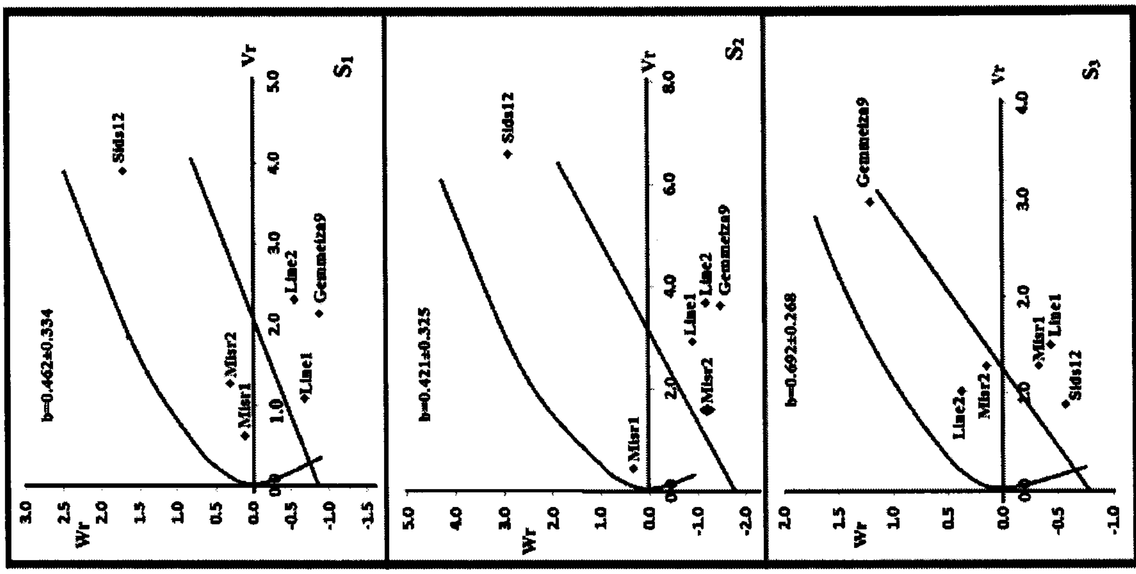


Fig. 6 Wr/Vr for grainweight/plant

genotypes Misr2, Sids12 and Line2 which were on the furthest end of regression line, contributed the recessive genes, while Gemmeiza9 was clustered near the origin of the slope suggesting important contribution of dominant alleles.

Distribution of array points along regression line for grain weight/plant (Fig. 6) revealed that on the early and the normal sowing dates, Sids12 shared the maximum recessive alleles, while, parents Misr 1, Misr 2 and Line1 being cluster in the first quadrate had maximum dominant genes. Subsequently, on the late sowing date, Gemmeiza 9 according to its array, which is far away from the origin, had the highest quantity of recessive genes, while, other parents Line1, Misr 2, Misr 1, Line 2 and Sids12 had most dominant genes on the 3rd sowing date for grain weight/plant.

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# القدرة على الإئتلاف ونظام الفعل الجينى لصفات التبكير، المحصول و مكوناته لبعض التراكيب الوراثية فى قمح الخبز تحت مواعيد زراعة مختلفة

**إيمـــان عبدالله - محمد محمد عبدالحميد على - محمد عبدالسلام طه يس - عبد الحميد حسن سالم**

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فى تجربة بنظام الدياليل ٦×٦ أجريت هذه الدراسة بالمزرعة التجريبية بكلية الزراعة - جامعة الزقازيق خلال الموسم الشتوى لأعوام ٢٠١٢/٢٠١١ و٢٠١٣/٢٠١٢، بهدف دراسة القدرة على الائتلاف والفعل الجينى المتحكم فى وراثة صفات التبكير والمحصول ومكوناته فى قمح الخبز وذلك تحت ثلاث مواعيد زراعة (٢ نوفمبر، ٢٢ نوفمبر و١٢ ديسمبر)، حيث أظهرت النتائج وجود اختلافات عالية المعنوية بين التراكيب الوراثية للقمح تحت الدراسة لصفات التبكير والمحصول ومكوناته مما يشير إلى وجود اختلافات وراثية كافية لإجراء التحليلات الوراثية، وكان المتوسط العام لصفة عدد الأيام حتى طرد السنابل (٨١,٥٧ ، ٨٤,٥٣ و ٧٣,٩٣ يوم)، عدد الأيام حتى النضج (١٤٠,٩٨ ، ١٣٦,٧٨ و١٣٢,٣٥يوم )، ارتفاع النبات (٩٤,٠٥ ، ٩٠,٦٤ و٨١,٣٤سم)،عدد حبوب السنبلة (٦٠,٤٥، ٦٢,٦٥ و٤٦,٤١)، وزن ١٠٠٠ حبة (٥٧,٤١، ٥٦,٨٤ و٤٨,٤٩ جم) ومحصول الحبوب/النبات (٢٢,٧٤ ، ٢٩,٦٠، و١٩,٥٤ جم) تحت ميعاد الزراعة المبكر، الامثل والمتأخر، على التوالي، كان مقدار الانخفاض نتيجة التأخير فى ميعاد الزراعة (الإجهاد الحرارى) بنسبة ١٢,٥٤% لصفة عدد الأيام حتى طرد السنابل ، ٦,١٢% لعدد الأيام حتى النضج، ١٣,٥١% لارتفاع النبات، ٢٥,٩٢% لعدد حبوب السنبلة، ١٥,٥٤% لوزن ١٠٠٠ حبة و٣٣,٩٩% لمحصول الحبوب/ النبات مقارنة بميعاد الزراعة الأمثل، أظهرت التراكيب الوراثية سدس١٢ والهجن جميزة ٩ × مصر١، جميزة ٩ × السلالة ١، والسلالة١ × مصر٢ قيم منخفضة لدليل الحساسية للحرارة (HSI) (٠,٧٨ ، ٠,٧٨، ٠,٦٨ و ٠,٧١ على التوالي) مما يشير إلى أهميتها فى تحمل الإجهاد الحرارى، كان التباين الراجع إلى القدرة العامة والخاصة على التآلف عالى المعنوية لجميع الصفات تحت الدراسة وكانت نسبة القدرة على التآلف أكبر من الوحدة بالنسبة لصفات التبكير وارتفاع النبات مما يوضح أهمية الفعل الجينى المضيف فى وراثة تلك الصفات، بينما كانت أقل من الوحدة فى صفات عدد حبوب/السنبلة، وزن ١٠٠٠ حبة ومحصول الحبوب/النبات مما يوضح أهمية الفعل الجينى غير المضيف، تراوحت كفاءة التوريث بالمعنى الخاص بين (٦٧,٠١ ، ٧٢,٥٦ و ٦٥,٨٦%) لصفة عدد الأيام حتى الطرد، (٦٧,٦٥ ، ٦٤,٨٦ و٦١,٤٩%) لصفة عدد الأيام حتى النضج، (٥٣,٤٤ ، ٧٦,٣٦ و٤٥,٣١%) لصفة ارتفاع النبات، (١٨,٥٤ ، ١٩,٦٦ و١٨,٣٨%) لصفة عدد حبوب /السنبلة، (١٥,٠، ١٢,١٤ و١٧,٥%) لصفة وزن ١٠٠٠ حبة و (١٧,٠، ٢٠,٠ و٨,٠٥%) لصفة محصول الحبوب/النبات، قطع خط الإنحدار محور Wr أعلى نقطة الأصل لصفات التبكير تحت مواعيد الزراعة الثلاثة وصفة ارتفاع النبات تحت ميعاد الزراعة الثانى، بينما قطع خط الإنحدار محور Wr أسفل نقطة الأصل لصفات ارتفاع النبات تحت ميعادى الزراعة الأول والثالث وصفة عدد حبوب السنبلة و وزن ١٠٠٠ حبة ومحصول حبوب النبات تحت مواعيد الزارعة الثلاثة.

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**المحكمـــــون:**

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