Asian Journal of Crop Science

ISSN 1994-7879

science alert
http://www.scialert.net

ANSInet
an open access publisher
http://ansinet.com

Asian Journal of Crop Science 5 (1): 14-23, 2013
ISSN 1994-7879 / DOI: 10.3923/ajcs.2013.14.23

Gene Action and Combining Ability in a Six Parent Diallel Cross of Wheat

M.M. Adel and E.A. Ali
Department of Agronomy, Faculty of Agriculture, Assiut University, Assiut, Egypt

Corresponding Author: M.M. Adel, Department of Agronomy, Faculty of Agriculture, Assiut University, Assiut, Egypt

ABSTRACT

The present study was carried out during 2008/2009 and 2009/2010 to obtain information about the performance of wheat genotypes, gene action and asses the combining ability of parental genotypes and their F_1's under Libyan conditions by using diallel fashion. The analysis of variance revealed that mean squares due to genotypes were highly significant for all studied characters indicating wide diversity among the parental materials used in the present study. Giza 165 variety had the highest number of spikes/plant, spikes weight/plant and grain yield/plant compared with the other parents. Crosses (Sakha 69×Sakha 8) and (Sakha 69×Giza 165) gave the highest grain yield/plant compared with the other F_1 crosses. Mean squares due to both general (GCA) and specific (SCA) combining abilities were highly significant for all studied traits, except SCA for plant height and GCA for No. of spikelets/spike. These results indicated that presence both of additive and non-additive types of gene action in the genetic system controlling the studied traits. The ratio of $\Sigma g_i^2/\Sigma s_{ij}^2$ variance was less than unity for all studied traits, suggesting that non-additive gene effects were more important than the additive ones in the expression of these traits. The regression analysis for days to heading, number of tillers and number of spikes/plant revealed that positive intercepts of Wr/Vr regression line supported an additive gene action with partial dominance and the selection in early generation may be fruitful for these traits. On the other hand, the regression analysis for plant height, spikes weight and grain yield/plant revealed that negative intercepts of Wr/Vr regression line supported an over dominance gene action and the selection in early generation may be unfruitful for these traits.

Key words: Bread wheat, combining ability, diallel analysis, wheat traits inheritance

INTRODUCTION

For a systemic and successful hybridization program a through understanding of genetic inheritance of important economic traits must be achieved. Information on the genetic structure of a set of parents and mode of gene action governing yield and its attributes could be useful in designing suitable breeding procedures. For genetic studies various workers had used different biometrical methods but amongst them the approach of Hayman (1954) and Mather and Jinks (1971) had been followed frequently. Genetic analysis of some economic traits showed different pattern of inheritance. Ahmed *et al.* (2011) reported that partial dominance with additive gene effects was important for days to heading. Khan and Habib (2003) and Ahmed *et al.* (2011) concluded that spikes and grain weight were governed by over dominance type of gene action. The combining ability analysis helps in classifying the parents in terms of their hybrid performance and in gaining greater understanding of the nature of quantitatively inherited trait (Ahmed *et al.*, 2011; Ahmed, 2003; Abd El-Aty and El-Borhamy, 2007).

Wheat is the most important cereal crop in Egypt and Libya, but, both of Libya and Egypt import a large quantity of wheat yearly. Therefore, increasing wheat production is an important goal to reduce the gap between production and consumption. This can be achieved by developing high yielding varieties, application of improved agronomic technique and cultivating wheat in newly reclaimed soils. Scarcity of water and sandy soils are prevalent in Libya, so you must evaluate and determine the best varieties in terms of General Combining Ability (GCA) must be done under conditions that will be the cultivation of improved varieties which could result from the selection in which hybrids are produced from hybridization among these varieties.

Therefore, the objectives of this investigation were to obtain information about the performance of wheat genotypes, gene action and asses the combining ability of parental genotypes and their F_1 under Libyan conditions by using diallel fashion.

MATERIALS AND METHODS

The present investigation was carried out during 2008/2009 and 2009/2010 seasons at the Experimental Farm, Department of Plant Production in EL-Kufra City, Garyounis University, Libya. The soil texture of the experimental site was sandy, comprising of 91.4% sand, 5.6% silt and 3.0% clay, with pH of 7.7 and EC 1.2 dS m^{-1}.

Genetic materials: The genetic materials used in this study were six parents (Debeira, Giza 168, Sakha 69, Sids 4, Sakha 8 and Giza 165) and their F_1 which are presented in Table 1.

The genotypes were crossed in half diallel fashion during 2008/2009 season to obtain the F_1 seeds. The F_1 seeds of all crosses with their parents were planted in the field during 2009/2010 season for evaluation in a Randomized Complete Block Design (RCBD) with three replications. The experimental unit was single row of 3 m long. Inter-plant and inter-row distances were 10 and 30 cm, respectively. All other treatments were kept constant for the whole experiment.

Studied traits: Ten plants from each row were randomly selected for recording data on the studied traits (days to heading, plant height (cm), number of tillers/plant, number of spikes/plant, number of spikelet/main spike, weight of spikes/plant (g) and weight of grain/plant (g).

Statistical analysis: Data were analyzed statistically using analysis of variance technique (Steel and Torrie, 1984) and significant differences at $p \leq 0.05$ among the genotypes were further analyzed using diallel analysis techniques (Hayman, 1954). Combing ability analysis was performed according to Griffing, 1956, Method 2, Model 1. Analysis of components of genetic performed by using method of Jinkes (1954), Hayman (1954) and Mather and Jinks (1971).

Table 1: Pedigree and the origin of the varieties

Variety	Pedigree	Origin
Debeira	HD2172	Sudan
Giza 168	MIL/Buc/Seri CM93046-8M-04-0M-2Y-0B	Egypt
Sakha 69	Inia/RL4220//7C/Yr"S"CM15430-25-65-05-05	Egypt
Sids 4	Maya"S"/Mon "S"/CMH74.A592/3/Giza175-2	Egypt
Sakha 8	CN067//SN64/KLRE/3/8156PK-3418-65-05-05	Egypt
Giza 165	OMC no/Mfd//Mon"S"CM43339-C-1Y-1M-24-0B	Egypt

Information about gene action was inferred by plotting the covariance (Wr) of each array against its variance (Vr). The slope and position of the regression line fitted to the array points within the limiting parabola indicated the degree of dominance and the presence or absence of gene interaction.

Array variances and co-variances were used to draw a regression line within the limiting parabola. The distance between the origin and the point where the regression line cut the Wr-axis provides a measure of average degree of dominance are:

- **Partial dominance:** When the intercept is positive
- **Complete dominance:** When the line passed through the origin
- **Over dominance:** When the intercept is negative
- **No dominance:** When the regression line touched parabola limits

RESULTS AND DISCUSSION

Performance of wheat genotypes: The analysis of variance (Table 2) revealed that mean squares due to genotypes were highly significant for all the studied characters indicating wide diversity among the parental materials used in the present study.

The average number of days from planting to heading (Table 3) for the parents ranged from 79.6 for Sids 4 (P_4) to 104.7 days for Giza 168 (P_2), with an average of 95.4 days.

The average number of days to heading for F_1 crosses ranged from 88.3 for ($P_3 \times P_4$) cross to 101.3 days for ($P_5 \times P_6$) cross, with an average of 93.3 days. Dhanda and Sethi (2002) and Dencic *et al.* (2000) found that days to heading were different significantly among wheat genotypes under different conditions. Giza 165 variety had the highest number of spikes/plant, Spikes weight/plant and grain yield/ plant compared with the other parents. In the F1 crosses, ($P_3 \times P_5$) and ($P_3 \times P_6$) crosses gave the highest grain yield compared with the other crosses. Parent Sids 4 gave the lowest values for all studied traits except number of spikelets in the main spike. This results in harmony with results which obtained by Moustafa (2009), Inamullah *et al.* (2006), Ahmed *et al.* (2011) and Saleh (2011).

Combining ability: The analysis of variance for all studied characters of the eight parents and their 15 F_1 crosses are presented in Table 2. Results indicated that mean squares due to both general (GCA) and specific (SCA) combining abilities were highly significant for all studied characters, except SCA for plant height and GCA for No. of spikelets/spike. These results indicated the presence of both additive and non-additive types of gene effects in the genetic system controlling these characters. The ratio of $\Sigma g_i^2/\Sigma s_{ij}^2$ variance was less than unity for all studied traits,

Table 2: Mean squares for yield and its attributes of six parental genotypes and their F_1's

SOV	df	Days to heading	Plant height (cm)	No. of tillers/plant	No. of spikes/plant	No. of spikelets/spike	Weight spikes/plant	Weight grains/plant
Replicates	2	0.59	21.97	53.48	0.53	1.94	2.54	18.04
Genotypes	20	106.88**	35.54**	24.80**	19.42**	1.64**	304.31**	126.35**
GCA	5	278.39**	62.91*	45.65**	35.35**	0.11	315.78**	173.01**
SCA	15	49.72**	26.41	17.85**	14.12**	2.15**	300.49**	110.80**
Error	40	0.47	14.25	2.37	2.36	0.42	7.51	8.61
$\sum g_i^2/\sum s_{ij}^2$		0.71	0.50	0.35	0.35	0.02	0.13	0.20

*,**Significant at $p \leq 0.05$ and $p \leq 0.01$, respectively, GCA: General combing ability, SCA: Specific combining ability

Table 3: Performance of wheat genotypes

Genotypes	Days to heading	Plant height (cm)	No. of Tillers/plant	No. of spikes/ plant	No. of spikelets/spike	Weight spikes/pant (g)	Weight grains/plant
Parents							
Debeira	104.30	99.80	16.80	14.30	21.80	39.60	27.50
Giza 168	104.70	101.90	15.80	13.40	23.40	37.80	25.30
Sakha 69	93.00	104.70	15.80	14.10	22.20	40.20	26.70
Sids 4	79.60	96.90	9.90	8.20	23.20	33.60	24.80
Sakha 8	90.70	103.10	16.60	14.50	22.60	46.70	32.20
Giza 165	100.30	103.90	16.10	14.60	22.30	51.80	37.30
Crosses							
$P_1 \times P_2$	90.70	100.60	16.20	13.90	22.10	51.10	33.60
$P_1 \times P_3$	92.30	102.70	12.80	10.50	22.40	38.60	25.30
$P_1 \times P_4$	91.30	100.10	14.80	11.60	23.40	54.40	35.10
$P_1 \times P_5$	94.30	96.00	15.90	11.70	22.30	45.10	29.70
$P_1 \times P_6$	100.70	103.60	17.70	14.00	22.20	57.30	37.90
$P_2 \times P_3$	93.60	98.90	15.00	11.90	22.10	37.50	23.20
$P_2 \times P_4$	89.70	99.20	12.60	10.60	23.30	44.60	28.70
$P_2 \times P_5$	89.00	100.70	16.10	14.30	23.10	40.20	25.30
$P_2 \times P_6$	95.00	100.50	15.50	12.90	22.10	48.80	32.00
$P_3 \times P_4$	88.30	105.20	17.10	14.50	21.10	55.20	39.90
$P_3 \times P_5$	91.70	103.80	21.90	18.50	22.40	72.50	46.70
$P_3 \times P_6$	98.30	111.90	22.50	13.00	23.20	70.20	45.60
$P_4 \times P_5$	90.30	104.10	12.70	9.90	21.30	49.00	35.10
$P_4 \times P_6$	93.30	98.40	12.60	11.10	24.10	50.60	35.00
$P_5 \times P_6$	101.30	103.50	15.40	11.80	22.20	49.50	33.20
$LSD_{0.05}$	0.98	7.36	2.35	2.38	1.09	3.94	4.48

suggesting that non-additive gene effects were more important than the additive ones in the expression of these traits. These results are in agreement with those reported by Talbert *et al.* (2001), El-Borhamy (2004), Ahmed (2003), Ismail *et al.* (2006) and Moustafa (2009).

Estimates of GCA and SCA effects are presented in Table 4. The parental genotypes Sids 4 (P4), Sakha 8 (P_5) and Sakha 69 (P_3) showed significant and negative GCA effects for days to heading, Therefore, they could be considered good combiners for earliness, with respect to SCA effects, there are five crosses ($P_1 \times P_2$, $P_1 \times P_3$, $P_1 \times P_5$, $P_2 \times P_5$ and $P_2 \times P_6$) showed negative and significant SCA effects and they could be considered the most promising crosses for improving earliness in these material.

About the plant height, Parent Sids 4 (P4) showed negative and significant GCA effect, therefore, it is considered a good source for reduce plant height. On the other hand, for improving plant height and increasing both of number of tillers and number of spikes/plant, the parental Sakha 69 consider a good combiner for these traits because of it showed positive and significant GCA effect for these traits.

To improve the spikes and grain weight in plants, the parental Giza 165 is considered best for this task because it showed the highest positive and significant GCA (5.23 and 3.81, respectively) for these traits among all parental genotypes and is ranked second parent No.3 (Sakh 69).

The most promising crosses for improving the spikes and grain weight/plant were ($P_3 \times P_5$) and ($P_3 \times P_6$), because its gave the highest positive significant SCA for the above-mentioned traits. Results obtained from this study agree with results obtained by Khan *et al.* (1985), Kashif and Khan (2008), Moustafa (2009) and Abd El-Aty and El-Borhamy (2007).

Table 4: GCA and SCA for wheat genotypes

Genotypes	Days to heading	Plant height (cm)	No. of tillers/plant	No. of spikes/plant	No. of spikelets/spike	Weight spikes/plant (g)	Weight grains/plant
GCA							
Debeira	2.56*	-1.23	0.11	- 0.18	-0.05	- 1.48*	- 1.37*
Giza 168	1.22*	-1.16	-0.34	- 0.16	0.04	- 5.05*	- 4.28*
Sakha 69	-0.90*	2.31*	1.67*	1.34*	-0.04	2.02*	0.80
Sids 4	-5.65*	-1.59*	-2.55*	- 2.19*	0.01	- 2.15*	0.25
Sakha 8	-1.19*	0.13	0.67*	0.45	-0.06	1.44*	0.80
Giza 165	3.97*	1.54*	0.75*	0.74*	0.11	5.23*	3.81*
SE	0.13	0.70	0.29	0.29	0.24	0.51	0.55
SCA							
$P_1 \times P_2$	-7.05*	1.36	0.70	1.16	0.86*	9.35*	6.97*
$P_1 \times P_3$	-3.26*	-0.32	-4.38*	- 3.72*	-0.19	- 10.26*	- 6.55*
$P_1 \times P_4$	0.49	0.99	1.50*	0.83	0.71*	9.73*	3.62*
$P_1 \times P_5$	-0.96*	-4.76*	-0.62	- 1.65*	0.17	- 3.13*	- 2.27*
$P_1 \times P_6$	0.20	1.36	1.14	0.35	-0.24	5.23*	2.89*
$P_2 \times P_3$	-0.59	-4.11*	-1.72*	- 2.35*	-0.12	- 7.80*	- 5.82*
$P_2 \times P_4$	0.16	0.05	-0.24	- 0.12	0.82*	3.46*	0.13
$P_2 \times P_5$	-4.96*	-0.19	0.28	0.91	-0.16	- 4.49*	- 3.74*
$P_2 \times P_6$	-4.13*	-1.74	-0.56	- 0.83	-0.44	0.33	- 0.05
$P_3 \times P_4$	0.95*	2.47	2.63*	2.29*	0.84*	7.04*	6.26*
$P_3 \times P_5$	-0.17	-0.54	4.16*	3.59*	0.69*	20.74*	12.56*
$P_3 \times P_6$	1.33*	6.19*	4.65*	3.52*	-0.45	14.68*	8.44*
$P_4 \times P_5$	3.24*	3.62*	-1.14	- 1.42*	-0.10	1.41	1.48
$P_4 \times P_6$	1.08*	-3.47*	-1.32*	- 0.58	0.57	- 0.74	- 1.59
$P_5 \times P_6$	4.62*	-0.07	-1.73*	- 2.44*	1.57*	- 5.47*	- 4.00*
SE	0.29	1.59	0.65	0.65	0.59	1.16	1.24

*Significant at $p \leq 0.05$

Regression analysis (Vr/Wr graph)

Days to heading: The regression analysis for days to heading (Fig. 1) revealed that positive intercepts of Wr/Vr regression line supported an additive gene action with partial dominance. This result suggests that the selection in early generation may be fruitful. Varieties Sakha 69 and Giza 165 possessed maximum dominant genes being nearest to the origin, while varieties Giza 168 and Debeira possessed maximum recessive genes being farthest from the origin. It means that genotypes Sakh 69 and Giza 165 are efficient for taking minimum time to reach the heading stage when used in hybrid condition.

On the other hand, varieties Giza 168 and Debeira with more recessive genes took maximum days to heading. The rest parents (Sids 4 and Sakha 8) possessed equal proportion of dominant and recessive genes. The estimated regression line was not deviated significantly from the unit slope; this suggests the absence of non allelic interaction. Similar results for different genotypes were obtained by Ahmed *et al.* (2011).

Plant height: The regression analysis for plant height (Fig. 2) revealed that negative intercepts of Wr/Vr regression line supported an overdominance gene action. This results suggests that the selection in early generation may be unfruitful. Variety Giza 168 possessed maximum dominant

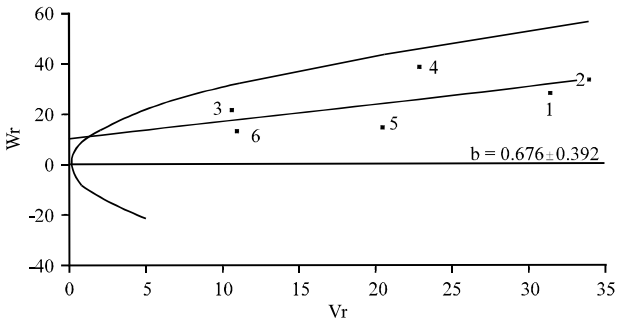

Fig. 1: Vr/Wr graph for days to heading, 1: Debeira, 2: Giza 168, 3: Sakha 69, 4: Sids 4, 5: Sakha 8, 6: Giza 165, b: Coefficient of regression

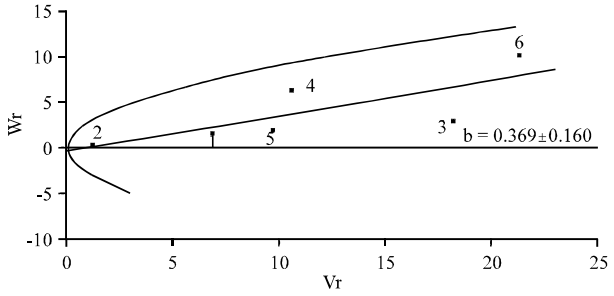

Fig. 2: Vr/Wr graph for plant height, 1: Debeira, 2: Giza 168, 3: Sakha 69, 4: Sids 4, 5: Sakha 8, 6: Giza 165, b: Coefficient of regression

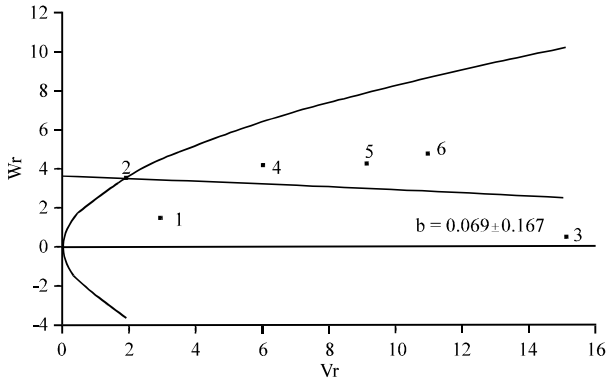

Fig. 3: Vr/Wr graph for number of tillers/plant, 1: Debeira, 2: Giza 168, 3: Sakha 69, 4: Sids 4, 5: Sakha 8, 6: Giza 165, b: Coefficient of regression

genes being nearest to the origin, while variety Giza 165 possessed maximum recessive genes being farthest from the origin. The estimated regression line was deviated significantly from the unit slope; this suggests the presence of non allelic interaction.

Number of tillers/plant: From Vr/Wr graph (Fig. 3), it was evident that regression line cut the Wr-axis above the origin revealing additive and partial dominance type of gene action. Epistasis was presence as the regression line deviate significantly from unit slope. Parents Debeira and

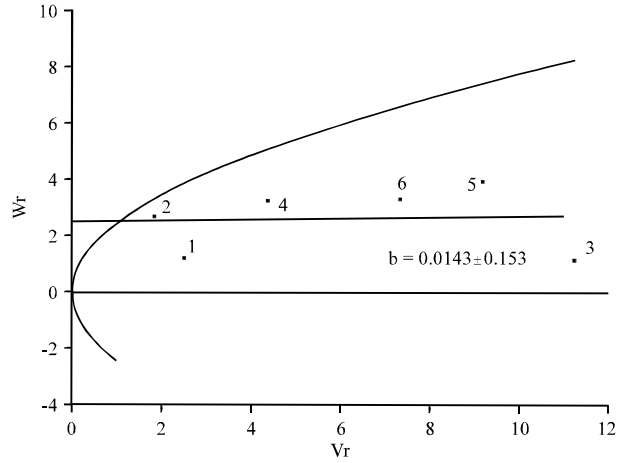

Fig. 4: Vr/Wr graph for number of spikes/plant, 1: Debeira, 2: Giza 168, 3: Sakha 69, 4: Sids 4, 5: Sakha 8, 6: Giza 165, b: Coefficient of regression

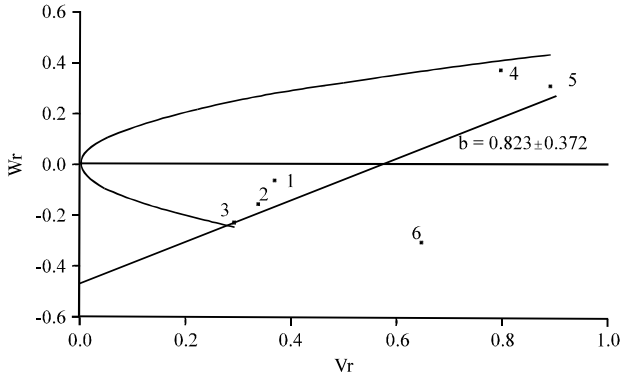

Fig. 5: Vr/Wr graph for number of spikelets/spike, 1: Debeira, 2: Giza 168, 3: Sakha 69, 4: Sids 4, 5: Sakha 8, 6: Giza 165, b: Coefficient of regression

Giza 168 possessed maximum dominant genes being closest to the origin, whereas the parent Sakha 69 had maximum recessive genes being father from the origin. Due to the additive shown by these traits, the selection in the early generation would be fruitful.

Number of spikes/plant: From Vr/Wr graph (Fig. 4), observed that regression line intercepts the Wr-axis on the positive side of the origin, so, this indicates the additive with partial dominance type of gene action. Varieties Giza 168 and Debeira possessed maximum dominant genes being closest to the origin whereas the parent Sakha 69 had maximum recessive genes being father from the origin.

The regression line deviate significantly from unit slope, this indicates that present of non-allelic interactions. According to the pattern of inheritance for number of spikes/plant the selection in the early generation would be fruitful. These results are in line with Khan and Habib (2003) and Ahmed *et al.* (2011) who found that the same pattern of inheritance in different wheat genotypes.

Number of spikelets/spike: The regression analysis for plant height (Fig. 5) revealed that negative intercepts of Wr/Vr regression line supported an over dominance gene action. This result

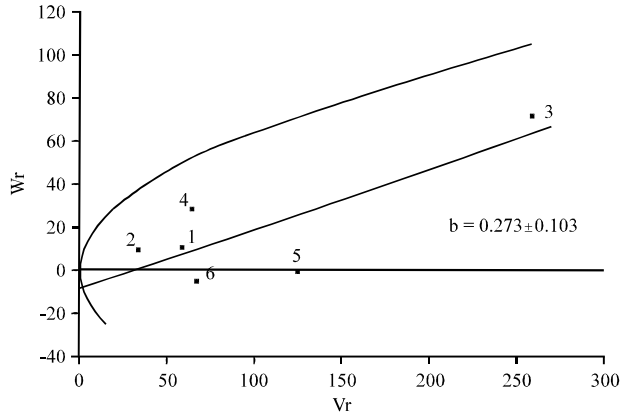

Fig. 6: Vr/Wr graph for weight of spikes/plant, 1: Debeira, 2: Giza 168, 3: Sakha 69, 4: Sids 4, 5: Sakha 8, 6: Giza 165, b: Coefficient of regression

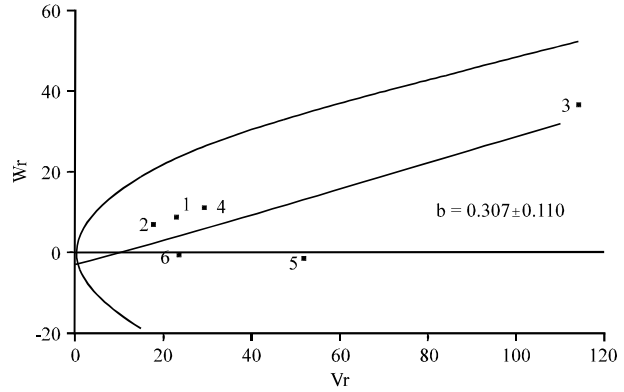

Fig. 7: Vr/Wr graph for grain yield/plant, 1: Debeira, 2: Giza 168, 3: Sakha 69, 4: Sids 4, 5: Sakha 8, 6: Giza 165, b: Coefficient of regression

suggests that the selection in early generation may be unfruitful. Variety Sakha 69 possessed maximum dominant genes being nearest to the origin, while variety Sakha 8 possessed maximum recessive genes being farthest from the origin. The estimated regression line was not deviated significantly from the unit slope; this suggests the absence of non allelic interaction.

Weight of spikes/plant: The results in Fig. 6 revealed that regression line intercepts the Wr-axis on the negative side of the origin and thus indicates over dominance type of gene action. As the regression line deviate significantly from unit slope, there seems present of non-allelic interactions. The distribution of varietal points on the regression line demonstrated that variety Giza 165 possessed mostly dominant genes while variety Sakha 69 had preponderance of recessive alleles. This trait seems difficult to fix and the progress in selection will be inherently slow. This results is agree with Inamullah *et al.* (2006), Ansari (2003), Mann *et al.* (1995), Khan and Habib (2003) and Ahmed *et al.* (2011) who found the same pattern of inheritance of this traits in different another wheat genotypes.

Grain yield/plant: From results in Fig. 7 we observed that regression line intercepts the Wr-axis on the negative side of the origin, so, this indicates the over dominance type of gene action.

Varieties Giza 165 and Giza 168 possessed maximum dominant genes being closest to the origin whereas the parent Sakha 69 had maximum recessive genes being father from the origin. The regression line deviate significantly from unit slope, this indicates that present of non-allelic interactions. According, to the pattern of haritance for grain yield/plant seems to difficult to fix and the progress in selection will be inherently slow. This results in harmony with results obtained by Khan and Habib (2003) and Ahmed *et al.* (2011).

CONCLUSION

Variety Giza 165 had the highest number of spikes/plant, Spikes weight/plant and grain yield/plant compared with the other parents and it is consider the best combiner to improve the spikes and grain weight in plants , because it showed the highest positive and significant GCA.

REFERENCES

Abd El-Aty, M.S.M. and H.S. El-Borhamy, 2007. Estimates of combining ability and susceptibility index in wheat diallel crosses under stress and normal irrigation treatments. Proceedings of the 13th Australasian Plant Breeding Conference, May 27, 2007, Giza, Egypt, pp: 651-680.

Ahmed, A.A., 2003. Diallel analysis and stability of yield and yield components in bread wheat (*Triticum aestivum* L. em. Thell). M.Sc. Thesis, Faculity Agricutre Assiut University, Egypt.

Ahmed, F., K. Saleem, A. Latif, K. Hakim, K. Ayub and N. Akhtar, 2011. Genetics of yield and related traits in bread wheat over different planting dates using diallel analysis. Afr. J. Agric. Res., 6: 1564-1571.

Ansari, B.A., 2003. Diallel analysis of yield and yield components in wheat. Ph.D. Thesis, Sindh Agriculture University, Tandojam.

Dencic, S., R. Kastori, B. Kobiljski and B. Duggan, 2000. Evaluation of grain yield and its components in wheat cultivars and landraces under near optimal and drought conditions. Euphytica, 113: 43-52.

Dhanda, S.S. and G.S. Sethi, 2002. Tolerance to drought stress among selected Indian wheat cultivars. J. Agric. Sci., 139: 319-326.

El-Borhamy, H.S., 2004. Genetic analysis of some drought and yield related characters in spring wheat varieties (*Triticum aestivum* L. em. Thell). J. Agric. Sci. Mansoura Univ., 29: 3719-3729.

Griffing, B., 1956. Concept of general and specific combining ability in relation to diallel crossing systems. Aust. J. Biol. Sci., 9: 463-493.

Hayman, B.I., 1954. The theory and analysis of diallel crosses. Genetics, 39: 789-809.

Inamullah, H.A., F. Mohammad, S. Din, G. Hassan and R. Gul, 2006. Diallel analysis of the inheritance pattern of agronomic traits of bread wheat. Pak. J. Bot., 38: 1169-1175.

Ismail, A.A., T.A. Ahmed, M.B. Tawfils and E.M.A. Khalifa, 2006. Gene action and combining ability analysis of diallel crosses in bread wheat under moisture stress and non-stress conditions. Assiut J. Agric. Sci., 37: 17-33.

Jinkes, J.L., 1954. The analysis of continuous variation in a diallel cross of *Nicotiana rustica* varieties. Genetics, 39: 767-789.

Kashif, M. and A.S. Khan, 2008. Combining ability studies for some yield contributing traits of bread wheat under normal and late sowing conditions. Pak. J. Agic. Sci., 45: 44-49.

Khan, A.S. and I. Habib, 2003. Gene action in a five parent diallel cross of spring wheat (*Triticum aestivum* L.). Pak. J. Biol. Sci., 6: 1945-1948.

Khan, N.I., M.A. Bajwa and A.G. Asi, 1985. Combining ability study in a diallel cross of five wheat varieties. Pak. J. Agric., Res., 6: 248-251.

Mann, M.S., S.N. Sharma and V.K. Bhatnagar, 1995. Combining ability and nature of gene effects for grain yield and harvest index in macaroni wheat. Crop Improv., 22: 65-68.

Mather, K. and J.L. Jinks, 1971. Biometrical Genetics. 2nd Edn., Chapman and Hall Ltd., London.

Moustafa, M.M., 2009. Inheritance and selection for some agronomic traits in wheat under water stress conditions. M.Sc. Thesis, Faculity of Agriculture Assiut University, Egypt.

Saleh, S.H., 2011. Performance, correlation and path coefficient analysis for grain yield and its related traits in diallel crosses of bread wheat under normal irrigation and drought conditions. World J. Agric. Sci., 7: 270-279.

Steel, R.G.D. and J.H. Torrie, 1984. Principles and Procedures of Statistics. McGraw Hill Book Co. Inc., New York.

Talbert, L.E., S.P. Lanning, R.L. Murphy and J.M. Martin, 2001. Grain fill duration in twelve hard red spring wheat crosses: Genetic variation and association with other agronomic traits. Crop Sci., 41: 1390-1395.