J. Plant Production, Mansoura Univ., Vol. 7(12):1535 -1541, 2016

Combining Ability for Earliness, Agronomic and Leaf and Stem Rusts Resistance Traits in F_1 And F_2 Bread Wheat Diallel Crosses

Farhat, W. Z. E and M. A. H. Darwish
Wheat Research Department, Field Crops Research Institute, ARC, Egypt
wayosha@yahoo.com

ABSTRACT

Six bread wheat parents and their diallel F1 (in 2012/13 season) and F2's (in 2013/14 season) hybrids were evaluated to estimate combining ability for earliness, agronomic and leaf and stem rusts resistance traits. The parents were Gemmeiza 9, Sids 12, Misr 1, Misr 2, Sids 1 and Cham 4. The studied characters were: number of days to heading and maturity, grain filling period and rate, plant height, number of spikes plant-1, number of kernels spike-1, 100 kernel weight, grain yield plant-1, leaf and stem rusts resistance in the F1 hybrids; and plant height, number of spikes plant-1, number of kernels spike-1, 100 kernel weight, grain yield plant-1, leaf and stem rusts resistance in the F2 hybrids. The variances due to genotypes, parents, crosses and parents vs crosses were significant for most characters, reflecting sufficient genetic variability. According to the mean squares due to the general and specific combining ability, the additive and nonadditive gene effects were involved in the expression of most studied traits and the additive genetic effects were more important. Heterotic effects were revealed for leaf rust and stem rust resistance in F2. Misr 1 and Sids 1 were the highest parents in mean performance and best good combiners for grain yield plant-1 in the two seasons. The highest grain yield plant-1 was detected in Misr 2 x Sids 1 F1 cross and in Misr 2 x Sids 1, Misr 1 x Sids 1 and Gemmeiza 9 x Sids 1 F2 crosses. The best F1 and F2 cross for grain yield plant-1, leaf rust and stem rusts resistance was Misr 2 x Sids 1. Except Sids 1, the parents were resistant or moderately resistant to leaf rust, while Gemmeiza 9, Sids 12 and Sids 1 were the most resistant parents to stem rust resistance in the two seasons. The most F1 crosses were resistant to leaf rust and sensitive or moderately sensitive for stem rust resistance.

Keywords: Diallel, wheat, combining ability, rust resistance.

INTODUCTION

Bread wheat (*Triticum aestivum* L.) is the most strategic cereal crop in Egypt and in many parts of the world. Wheat leaf and stem rusts caused by *Puccinia triticina* and *Puccinia graminis* f.sp. *tritici*, respectively, are globally important fungal diseases of wheat that cause significant grain yield losses. Breeding for wheat rusts resistance is still the most economic and desirable method for controlling the disease.

The diallel is a genetic-statistical methodology that assists in the selection of parents, based on their combining ability and produce promising segregating populations. More over, the diallel methodology was used in wheat by many reseachers like Abd El-Lateef (2014); Kumar *et al*. (2016) and Saeed *et al*. (2016).

Earlier studies revealed that both general (GCA) and specific (SAC) combining abilities were involved for earliness, yield and yield component characters (Abd El-Lateef, 2014 and Saeed *et al*., 2016). Most of these studies revealed that a large part of total genetic variability for yield and its components was associated with the GCA effects, a measure of additive genetic variance. Significant genotypic differences for agronomic traits have been reported in wheat (Akram *et al*., 2011; Abd El-Lateef, 2014 and Saeed *et al*., 2016). Many studies were conducted to study the inheritance of stem rust resistance (El-Sayed, 2011; Ashmawy *et al*., 2013 and Hermas and El-Sawi, 2015) and leaf rust resistance (Ahamed *et al*., 2004 and Boulot and Gad-Alla, 2007).

This study was undertaken to determine combining ability for some earliness, agronomic characters and leaf and stem rusts resistance in some wheat genotypes, and to select suitable parents for hybridization and suitable crosses for crop improvement programme.

MATERIALS AND METHODS

The present study was carried out at Sakha Agricultural Research station, Kafr Elsheikh, Eygpt (31° 5' 12" North, 30° 56' 49" East) during the three successive seasons 2011/2012, 2012/2013 and 2013/2014.

Fifteen F_1 and F_2 hybrids were generated from six Parents (Table 1), selected based on their leaf and stem rusts reactions, following a half-diallel mating design. Crosses were made during the 2011/2012 season. The parents and their F_1 crosses were sown on 28, November 2012. In addition, the parents and their F_2 hybrids were sown on 30, November 2013. The recommended cultural practices for wheat production were applied at the proper time. The experiment was surrounded by mixed wheat genotypes which were highly sensitive to leaf and stem rusts as a spreader. The average minimum and maximum temperature was 11.39 ^{0}C and 22.53 ^{0}C during 2012/2013 season and 11.08 ^{0}C and 22.38 ^{0}C during 2013/2014 season, respectively.

Table 1. Names and pedigree of the used parents.

No	Genotypes	Cross name and pedigree
P_1	Gemmeiza 9	Ald "S"/ Huac// Cmh74A .630/ Sx BUC//7C/ALD/5/MAYA74/ON//II60.147/3/B
P_2	Sids 12	B/GLL/4/CHAT"S"/6/MAYA/VUL//CMH74 A.630/4*SX
P_3	Misr 1	OASIS/SKAUZ//4*BCN/3/2*PASTOR
P_4	Misr 2	SKAUZ/BAV92
P_5	Sids 1	HD2172/PAVON"S"//1158.57/MAYA74"S"
P_6	Sham 4	FLK/HORK

In the two seasons, a randomized complete block design with three replications was used. For F_1, the experimental plots of each parent and cross consisted of one row of 2 meters long, 25 cm apart and plants within rows were 20 cm spaced. In each row, data were taken on five random competitive plants. For F_2, the plot of each parent and cross consisted of six rows of 2 meters long, 25 cm apart and plants within rows were 20 cm spaced. In each parent and cross, data were taken on fifty random competitive plants.

The studied characters were: plant height (PH, cm), number of spikes per plant (SP^{-1}), number of kernels per spike (KS^{-1}), 100-kernel weight (100KW, g), grain yield (GY, g), Leaf (LR) and stem (SR) rusts resistance in F_1 and F_2, in addition: the number of days to heading (DH, days) and maturity (DM, days), grain filling period (GFP, days as the number of days from heading to maturity) and grain filling rate (GFR, g day^{-1} calculated from GY divided by GFP) in F_2 only. Rusts reaction were recorded under field conditions at Sakha Agric. Res. Station as it is considered as a hot spot for rust diseases, according to the scale of Stubbes *et al*. (1986). For the quantitative analysis, field response was converted into an average coefficient of the infection according to the methods of Stubbes *et al*. (1986) and modified by Shehab El-Din *et al*. (1996).

The data obtained for each trait were analyzed on plot mean basis. An ordinary analysis of variance was firstly performed for F_1 and F_2 diallel set as presented by Snedecor and Cochran (1980). Genotypes were subdivided to their components, i.e. parents, crosses and parents vs crosses. The LSD test at 5 % according to Steel and Torrie (1980) was used for comparison of the mean performance of the different parents and hybrids separately. The effects of genotypes were assumed to be fixed.

General (g_i) and specific (s_{ij}) combining ability variances and effects were estimated according to Griffing (1956) method 2 model 1. The relative importance of general and specific combining ability on progeny performance was estimated according to Baker (1978).

All statistical analysis was performed using the Genes software (Cruz, 2006) and the statistical routines available in Microsoft EXCEL (2016).

RESULTS AND DISCUSSION

1) Analysis of variance

a) F_1 Diallel

Data in Table 2 showed that mean squares of the studied characters for the genotypes, parents, crosses and parents vs. crosses were significant (0.01 or 0.05 probability), except genotypes, parents and crosses for SP^{-1}; crosses and parents vs crosses for PH and GFP; crosses for 100KW; and parent vs crosses for DH, DM, GY, LR and SR. These results indicated that there was genetic variability among the 21 genotypes (six parents and 15 F_1 crosses) for most studied characters, which is considered adequate for further biometrical assessment. Heterotic effects were revealed for SP^{-1} and 100KW as a result of the significance of parents vs. crosses mean squares. These results were in harmony with those of EL-Hawary (2010), Abd El-Lateef (2014) and Saeed *et al*. (2016),

Based on the significance of the F-test, the sum of squares for genotypes was partitioned into sum of squares for general (GCA) and specific (SCA) combining ability, according to method 2, model 1، proposed by Griffing (1956) (Table 2).

SCA mean square values were significant (0.01 or 0.05 probability) for all characters, except 100KW, suggesting that additive gene effects were expressed for studied characters. However, SCA mean squares were significant (0.01 or 0.05 probability) only for DH, GFR, KS^{-1}, GY, LR and SR, indicating that nonadditive gene effects were involved in the expression for these traits. These results suggest the possibility of obtaining new genotypes of segregating populations from crosses among the tested parents.

Baker (1978) suggested that the progeny performances could be predicted using the ratio of combining ability variance components. The closer this ratio to unity, the greater the predictability based on GCA alone. The ratio of GCA/SCA was less than and close to unity (larger than 0.80) for all studied traits, except 100KW (0.67), indicating that the additive genetic effects were more important and played the major role.

Table 2. Mean squares for the parents and their F_1 hybrids as well as general (GCA) and specific (SCA) combining ability and their ratio for all studied traits in season 2012/2013.

SOV	df	Days to heading	Days to maturity	Plant height (cm)	Grain Filling Period (days)	Grain Filling Rate (g days^{-1})	No. of spikes plant^{-1}	No. of Kernels Spike^{-1}	100 Kernel Weight	Grain Yield Plant^{-1} (g)	Leaf Rust	Stem Rust
Replication	2	12.25**	3.00	43.25	13.09*	0.01*	10.73	279.71*	0.07	42.18**	97.86	690.54
Genotypes (G)	20	23.34**	12.24**	57.18**	9.08*	0.08**	35.52	297.70**	0.98**	206.43**	1188.61**	2048.97**
Parents (P)	5	62.21**	25.79**	68.89**	24.48**	0.10**	56.59	580.95**	1.86**	210.96**	2322.17**	2081.71**
Crosses (C)	14	11.01**	8.28*	50.56	4.12	0.07**	26.44	185.56*	0.57	198.52**	847.61**	2107.35**
P vs.C	1	1.54	0.00	91.43	1.44	0.13	57.32**	451.47	2.22**	294.52	294.79	1068.03
Error	40	1.74	2.45	15.34	3.94	0.00	20.17	66.66	0.37	4.57	120.74	250.44
Total	62	9.05	5.63	29.74	5.89	0.03	24.82	148.06	0.56	70.90	464.48	844.81
GCA	5	74.28**	42.92**	161.94**	15.98**	0.16**	74.87*	725.71**	0.98	460.1*7	2991.54**	6434.38**
SCA	15	6.36**	2.02	22.26	6.77	0.06**	22.41	155.03*	0.98	121.85*	587.64**	587.17*
GCA/SCA		0.96	0.98	0.94	0.83	0.85	0.87	0.90	0.67	0.88	0.91	0.96
CV %		1.31	1.04	3.64	4.03	4.44	20.26	11.15	15.85	4.30	106.40	50.96

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

b) F_2 Diallel

Table 3 show the mean squares of the studied characters for the genotypes, parents, crosses and parents vs. crosses as well as general and specific combining ability in F_2. Genotypes, parents and crosses had significant (0.01 or 0.05 probability) variances for all characters, indicating that there was genetic variability which considered adequate for further biometrical assessment. Heterotic effects were revealed for LR and SR as a result of the significance of parents vs. crosses mean square.

Gi and sij mean square values were significant (0.01 or 0.05 probability) for all characters, except sij for 100KW, suggesting that additive and nonadditive gene effects were expressed for characters and the possibility of obtaining new genotypes from segregating populations from crosses among the tested parents.

The ratio of GCA/SCA was close and less than unity (larger than 0.80) for all studied traits, indicating that the additive genetic effects were more important and played the major role. Similar findings were also observed by Kumar *et al*. (2016) for most traits. Jag *et al*. (2003) observed that days to heading and maturity were regulated by additive gene action.

Information of general (GCA) and specific (SCA) combining ability variances indicated the types of gene action influencing various traits enables the plant breeder to evaluate parental entries and select the best breeding system (Obi, 2013). Values of GCA indicate the importance of genes with predominantly additive effects and enable to select new inbred lines in advanced generations. Nonadditive gene effects correspond to SCA effects.

Table 3. Mean squares for the parents and their F_2 hybrids as well as general (GCA) and specific (SCA) combining ability and their ratio for all studied traits in season 2013/2014.

SOV	df	Plant height (cm)	No. of spikes plant^{-1}	No. of Kernels Spike^{-1}	100 Kernel Weight	Grain Yield Plant^{-1} (g)	Leaf Rust	Stem Rust
Replication	2	31.61**	1.66	222.18**	0.10	246.50**	38.35*	44.61*
Genotypes (G)	20	142.72**	30.24**	117.20**	0.41**	138.55**	398.93**	161.03**
Parents (P)	5	331.51**	59.30**	251.60**	0.92**	246.15**	1301.38**	349.45**
Crosses (C)	14	82.10**	20.29**	66.13**	0.22*	97.40**	92.54**	98.01**
P v s .C	1	47.35	24.33	160.11	0.44	176.74	176.12*	101.31*
Error	40	5.13	1.88	11.49	0.09	12.45	8.69	10.85
Total	62	50.37	11.02	52.39	0.19	60.68	135.53	60.38
GCA	5	497.51**	105.94**	269.08**	6.49**	2228.31**	5670.38**	2291.84**
SCA	15	24.45**	5.01*	66.57**	1.65	542.74**	2308.19**	928.86**
GCA/SCA		0.98	0.98	0.89	0.89	0.89	0.83	0.83
CV %		1.96	7.48	6.12	7.35	10.33	34.50	47.99

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

2) Mean Performance

a) F_1 Diallel

The mean performances of the studied characters for the six parents and their F1 are presented in Table 4. For parents, Cham4 was the latest in days to DH and DM and the shortest parent. Whereas, Sids 12 was the earliest one for DH and Sids 12 and Misr 1 were the earliest parents for DM. Meanwhile, Sids 1 and Misr 2 were the tallest parents. The longest GFP belonged to Sids 12, while the shortest GFP were showed by Gemmeiza 9 and Misr 1. Sids 12 revealed the highest KS-1, while Sids 1 and Cham 4 had the lowest KS-1. The highest 100KW was shown by Misr 2, Sids 12 and Gemmeiza 9, while Misr 1 showed the lowest value. In addition, the highest and lowest parents for GY plant-1 were Misr 2 and Gemmeiza 9, respectively. Sids 1 was the most sensitive parent for LR, whereas the other parents were resistant or moderately resistant. Moreover, Gemmeiza 9, Sids 12 and Sids 1 were the most resistant parents for SR, while the rest ones were the most sensitive.

Table 4. Means of parents and their F_1 hybrids for all studied traits in season 2012/2013.

Genotype	Days to heading (day)	Days to maturity (day)	Plant height (cm)	Grain Filling Period (days)	Grain Filling Rate	No. of spikes plant^{-1}	No. of Kernels Spike^{-1}	100 Kernel Weight	Grain Yield Plant^{-1}	Leaf Rust	Stem Rust
					Parents						
Gemmeiza 9 (P1)	103.67	150.00	108.33	46.33	0.76	21.17	85.42	4.04	34.95	2.02	1.35
Sids 12 (P_2)	92.44	147.00	105.00	54.56	0.87	16.04	100.00	4.09	47.45	0.05	1.62
Misr 1 (P_3)	99.33	146.67	101.67	47.33	1.27	26.30	72.57	2.10	59.87	0.37	60.00
Misr 2 (P_4)	100.33	150.33	110.00	50.00	0.91	26.12	79.18	4.20	45.42	0.05	40.00
Sids 1 (P_5)	101.33	151.00	110.00	49.67	0.98	27.61	63.16	3.33	48.87	70.00	0.95
Cham 4 (P_6)	105.67	154.67	98.33	49.00	0.83	24.84	64.60	3.53	40.84	10.00	43.33
Mean of Parents	100.46	149.94	105.56	49.48	0.94	23.68	77.49	3.55	46.23	13.75	24.54
LSD 0.05	2.64	1.93	10.06	2.58	0.06	12.06	7.71	0.89	3.96	19.54	16.65
					F_1 Hybrids						
P_1 x P_2	100.00	147.67	108.33	47.67	0.88	19.20	80.80	4.64	41.65	0.47	2.13
P_1 x P_3	102.00	149.33	103.33	47.33	1.04	20.47	61.33	3.98	49.01	0.05	20.00
P_1 x P_4	102.33	150.67	115.00	48.33	0.71	21.18	74.00	3.56	34.19	0.05	36.67
P_1 x P_5	99.33	149.33	113.33	50.00	0.91	19.49	71.53	3.45	45.67	43.33	2.02
P_1 x P_6	104.67	153.33	108.33	48.67	0.89	24.87	79.40	3.76	43.27	15.33	20.00
P_2 x P_3	97.67	148.33	105.00	50.67	1.13	19.93	62.47	4.35	57.23	0.05	60.00
P_2 x P_4	98.67	148.33	108.33	49.67	1.16	15.43	85.07	4.40	57.49	0.05	50.00
P_2 x P_5	100.67	147.67	108.33	47.00	1.25	20.07	82.09	4.16	58.56	0.05	5.01
P_2 x P_6	101.44	151.33	101.67	49.89	1.26	24.78	74.50	3.87	62.72	23.33	60.00
P_3 x P_4	100.67	150.33	106.67	49.67	0.96	18.25	73.30	3.98	47.64	0.10	70.00
P_3 x P_5	99.07	149.00	105.00	49.93	1.05	23.67	62.45	3.96	52.59	0.10	12.00
P_3 x P_6	102.00	151.00	106.67	49.00	1.03	22.73	69.96	4.49	50.24	0.05	73.33
P_4 x P_5	98.67	149.67	116.67	51.00	1.26	24.33	61.40	3.07	64.12	0.05	10.00
P_4 x P_6	102.00	151.33	108.33	49.33	1.00	26.28	67.71	3.52	49.55	1.37	63.33
P_5 x P_6	102.95	152.00	108.33	49.05	1.05	22.85	67.40	4.27	51.36	50.00	20.33
Mean of F_1	100.81	149.96	108.22	49.15	1.04	21.57	71.56	3.96	51.02	8.96	33.66
$LSD_{0.05}$	2.16	2.84	5.43	3.68	0.08	6.05	15.47	1.11	3.16	18.13	30.05

For F_1 hybrids, Gemmeiza 9 x Cham 4 was the latest one for DH and DM, while Sids 12 x Misr 1, Sids 12 x Misr 2, Misr 1 x Sids 1 and Misr 2 x Sids 1 were the earliest in DH and Gemmeiza 9 X Sids 12 was the earliest in DM. The shortest cross was Sids 12 x Cham 4 and the tallest ones were Misr 2 x Sids 1, Gemmeiza 9 x Misr 2 and Gemmeiza 9 x Sids 1. The longest GFP was shown by crosses Misr 2 x Sids 1, Sids 12 x Misr 1 and Gemmeiza 9 x Sids 1 and the shortest GFP by Sids 12 x Sids 1 and the most crosses. The highest and lowest GFR revealed in cross Misr 2 x Sids 1 and Gemmeiza 9 x Misr 2, respectively. The crosses Misr 2 x Cham 4, Misr 2 x Sids 1 and Sids 12 x Cham 4 had the highest SP^{-1} and the cross Sids 12 x Misr 2 was *vice versa*. The highest KS^{-1} was shortest by crosses Sids 12 x Misr 2, while Gemmeiza 9 x Misr 1 and Misr 2 x Sids 1 showed the opposite trend. The heaviest 100KW were detected in cross Gemmeiza 9 x Sids 12, while cross Misr 2 x Sids 1 was *vice versa*. The highest and lowest GY plant^{-1} were detected in crosses Misr 2 x Sids 1 and Gemmeiza 9 x Misr 2, respectively. The result of LR revealed that Sids 1 x Cham 4, Gemmeiza 9 x Sids 1, Sids 12 x Cham 4 and Gemmeiza 9 x Cham 4 were the most sensitive crosses, while the other crosses were resistant. All crosses were sensitive or moderately sensitive for SR, except Gemmeiza 9 x Sids 1, Gemmeiza 9 x Sids 12 and Sids 12 x Sids 1.

On average, parents and F_1 hybrids showed no differences for DH and DM. The average of hybrids was greater than that of the parents for PH, GFR and GY plant^{-1}, and less for SP^{-1}. In general, the F_1 crosses were more resistant than parents for LR and sensitive for SR.

b) F_2 Diallel

The mean performances of the studied characters for the six parents and their F_2's are presented in Table 5. For parents, Cham 4 had the shortest plants and lowest KS^{-1}, 100KW and GY. In addition, Sids 12 had the lowest SP^{-1} and highest KS^{-1} and GY. Sids 1 revealed the highest plant height, SP^{-1} and GY. Except Sids 1 and Cham 4, the parents were resistant for LR. Gemmeiza 9, Sids 12, and Sids 12 were the most resistant for SR, but the remaining parents were vice versa.

Table 5. Means of parents and their F_2 hybrids for all studied traits in season 2013/2014.

Genotype	Plant height (cm)	No. of spikes plant^{-1}	No. of Kernels Spike^{-1}	100 Kernel Weight	Grain Yield Plant^{-1}	Leaf Rust	Stem Rust
Parents							
Gemmeiza 9 (P_1)	120.40	15.32	60.39	3.85	31.69	0.20	0.27
Sids 12 (P_2)	108.23	9.92	67.67	4.29	28.23	0.22	0.91
Misr 1 (P_3)	112.30	20.22	57.29	4.08	38.53	0.23	27.03
Misr 2 (P_4)	121.50	17.53	64.22	4.12	34.53	0.32	8.51
Sids 1 (P_5)	125.57	22.90	56.59	3.97	40.66	52.20	0.69
Sham 4 (P_6)	97.10	18.01	41.30	2.75	15.47	13.97	15.80
Mean of Parents	114.18	17.32	57.91	3.84	31.52	11.19	8.87
LSD 0.05	1.87	2.18	5.88	0.36	6.46	5.00	5.97
F_2 Hybrids							
$P_1 \times P_2$	111.56	13.64	52.33	3.89	32.22	5.14	1.54
$P_1 \times P_3$	116.30	18.15	53.43	4.18	36.88	2.85	6.10
$P_1 \times P_4$	122.30	17.51	50.07	4.00	31.70	3.33	5.35
$P_1 \times P_5$	119.73	19.95	47.73	4.02	41.92	18.39	2.10
$P_1 \times P_6$	109.77	20.55	49.67	3.43	25.58	14.45	3.63
$P_2 \times P_3$	109.63	16.00	55.55	4.47	36.27	3.29	6.68
$P_2 \times P_4$	114.67	14.91	59.01	4.18	33.78	2.15	7.05
$P_2 \times P_5$	116.33	16.65	57.23	4.06	36.89	6.69	3.77
$P_2 \times P_6$	105.97	18.61	56.26	3.77	33.44	4.24	2.90
$P_3 \times P_4$	121.13	19.44	61.37	4.11	37.92	1.97	24.79
$P_3 \times P_5$	120.43	22.09	50.88	4.30	43.14	4.48	3.70
$P_3 \times P_6$	113.98	21.99	48.22	3.79	33.08	9.34	10.98
$P_4 \times P_5$	124.50	20.84	62.33	4.45	46.52	9.57	3.56
$P_4 \times P_6$	118.03	18.33	58.80	3.87	26.70	8.20	6.06
$P_5 \times P_6$	117.20	21.68	52.84	3.91	32.32	18.22	2.71
Mean of F_2	116.10	18.69	54.38	4.03	35.22	7.49	6.06
$LSD_{0.05}$	4.32	2.32	5.77	0.54	5.74	5.18	5.66

For F_2 hybrids, Misr 2 x Sids 1 and Gemmeiza 9 x Misr 2 were the tallest crosses, while Sids 12 x Cham 4 was the shortest one. The crosses Misr 1 x Sids 1, Misr 1 x Cham 4, Misr 2 x Sids 1 and Gemmeiza 9 x Cham 4 had the highest SP^{-1}, while Gemmeiza 9 x Sids 12 and Sids 12 x Misr 2 were *vice versa*. The highest KS^{-1} recorded to Misr 2 x Sids 1, while Gemmeiza 9 x Sids 1 and Misr 1 x Cham 4 showed the opposite trend. The heaviest 100 kernel weight were detected in Sids 12 x Misr 1 and Misr 2 x Sids 1, while crosses Gemmeiza 9 x Cham 4 and Misr 1 x Cham 4 were *vice versa*. The highest and lowest GY were detected in crosses Misr 2 x Sids 1, Gemmeiza 9 x Sids 1 and Misr 1 x Sids 1 and crosses Gemmeiza 9 x Cham 4 and Misr 2 x Cham 4, respectively. The results of leaf rust resistance revealed that Sids 1 x Cham 4, Gemmeiza 9 x Sids 1 and Cham 4 were the most sensitive crosses, while the other crosses were resistant or moderately resistant. Misr 1 x Misr 2 was the most sensitive for stem rust, while the remaining crosses were resistant or moderately resistant.

The average of F_2 hybrids was higher than the parents for all characters, except for KS^{-1} and LR.

3) Combining Ability

a) F_1 Diallel

Table 6 illustrate the estimates of the general (g_i) and specific (s_{ij}) combining ability effects of the parents and their F_1 hybrids, respectively for the studied characters.

For DH, DM, GFP, PH, LR and SR, the lower g_i effects correspond to superior parents, while the other characters were *vice versa*. Significant and negative g_i effects were assessed for Sids 12 for DH and DM; Misr 1 for DM and PH; Sids 12, Misr 1 and Misr 2 for LR; and Gemmeiza 9 and Sids 1 for SR. Whereas, best parents for the remining characters correspond to the higher gi. Significant and positive gi effects were showed by Sids 12, Misr 1 and Sids 1 for GFR and Sids 12 for KS^{-1} and 100KW.

Table 6. Estimates of the general (g_i) and specific (s_{ii} and s_{ij}) combining ability effects for the studied characters assessed in six wheat parents and their F_1 hybrids and the standard error (SE) in season 2012/2013.

Genotype/ Combining Ability	Days to heading (day)	Days to maturity (day)	Plant height (cm)	Grain Filling Period (days)	Grain Filling Rate	No. of spikes $plant^{-1}$	No. of Kernels $Spike^{-1}$	100 Kernel Weight	Grain Yield $plant^{-1}$	Leaf Rust	Stem Rust
					Parents						
Gemmeiza 9 (P_1)	1.34**	0.08	1.60	-1.25*	-0.14**	-0.96	3.14	0.07	-7.99**	-1.13	-16.73**
Sids 12 (P_2)	-2.70**	-1.54**	-1.32	1.16*	0.04**	-2.96*	9.02**	0.33*	3.12**	-6.03*	-4.62
Misr 1 (P_3)	-0.61	-1.04*	-2.78*	-0.43	0.08**	0.31	-4.77	-0.24	3.61**	-8.90**	17.25**
Misr 2 (P_4)	-0.25	0.17	2.85*	0.41	-0.02	0.31	0.88	0.00	-0.47	-8.82**	11.58*
Sids 1 (P_5)	-0.20	.	2.43*	0.20	0.05**	1.30	-5.20*	-0.17	2.81**	20.16**	-20.76**
Cham 4 (P_6)	2.43**	2.33**	-2.78*	-0.09	-0.02	2.00	-3.08	0.01	-1.09*	4.72	13.29**
SE (g_i)	0.25	0.29	0.73	0.37	0.01	0.84	1.52	0.11	0.40	2.05	2.95
SE (g_i-g_j)	0.38	0.45	1.13	0.57	0.01	1.30	2.36	0.18	0.62	3.17	4.57
					Hybrids						
P_1 x P_2	0.66	-0.83	0.60	-1.49	-0.03	0.95	-4.61	0.39	-3.14*	-2.70	-7.57
P_1 x P_3	0.57	0.34	-2.95	-0.23	0.08**	-1.05	-10.29*	0.31	3.73**	-0.25	-11.57
P_1 x P_4	0.53	0.46	3.10	-0.07	-0.14**	-0.35	-3.28	-0.36	-7.01**	-0.33	10.77
P_1 x P_5	-2.51**	-0.70	1.85	1.81	-0.01	-3.03	0.34	-0.29	1.19	13.98*	8.46
P_1 x P_6	0.19	0.96	2.05	0.77	0.04	1.65	6.08	-0.16	2.69*	1.41	-7.61
P_2 x P_3	0.27	0.96	1.64	0.69	-0.01	0.42	-15.04*	0.41	0.85	4.65	16.32
P_2 x P_4	0.91	-0.24	-0.65	-1.15	0.12**	-4.09	1.91	0.22	5.18**	4.57	11.99
P_2 x P_5	2.86**	-0.74	-0.24	-3.61**	0.14**	-0.44	5.02	0.15	2.98**	-24.40**	-0.65
P_2 x P_6	1.01	0.59	-1.70	-0.42	0.22**	3.57	-4.70	-0.32	11.03**	14.31*	20.28*
P_3 x P_4	0.82	1.26	-0.86	0.44	-0.11**	-4.54**	3.93	0.37	-5.16**	7.50	10.12
P_3 x P_5	-0.82	0.09	-2.11	0.91	-0.09**	-0.11	-0.84	0.53	-3.49**	-21.48**	-15.54
P_3 x P_6	-0.53	-0.24	4.76	0.28	-0.05	-1.74	4.54	0.88*	-1.93	-6.10	11.75
P_4 x P_5	-1.60*	-0.45	3.93	1.14	0.22**	0.55**	-7.54	-0.61	12.13**	-21.61**	-11.87
P_4 x P_6	-0.89	-1.12	0.80	-0.23	0.04	1.80	-3.35	-0.33	1.46	-4.86	7.41
P_5 x P_6	0.02	-0.29	1.22	-0.30	0.01	-2.62	2.42	0.58	-0.01	14.79*	-3.24
SE (S_{ij})	0.68	0.80	2.00	1.02	0.02	2.30	4.18	0.31	1.09	5.62	8.10
SE (S_{ij}-S_{ik})	1.01	1.20	2.99	1.52	0.03	3.43	6.24	0.47	1.63	8.39	12.08
SE (S_{ij}-S_{kl})	0.93	1.11	2.77	1.40	0.03	3.18	5.77	0.43	1.51	7.77	11.19

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

On the other hand, undesired parents were Gemmeiza 9, Sids 12, Sids 1 and Cham 4, which had significant and negative gi effects for, GFR, SP-1, KS-1 and GY, respectively. In addition, significant positive gi was detected by Gemmeiza 9 and Cham 4 for DH; Cham 4 for DM; Misr 2 and Sids 1 for PH; Sids 12 for GFP; Sha, 4 for LR; and Misr 1, Misr 2 and Cham 4 for SR.

Similar results in regards to yield per plant of wheat for sij among F_1 hybrids have also been reported (Koumber, and El-Gammaal., 2012).

The best F_1 crosses were Gemmeiza 9 x Sids 1 and Misr 2 x Sids 1 for DM; Sids 12 x Sids 1 for GFP; and Sids 12 x Sids 1, Misr 1 x Sids 1 and Misr 2 x Sids 1 for LR, which had significant negative s_{ij}. Corresponding to significant and positive s_{ij}, effects, the best F_1 crosses were Gemmeiza 9 x Misr 1, Sids 12 x Misr 2, Sids 12 x Sids 1, Sids 12 x Cham 4 for GFR; Misr 1 x Cham 4 for 100KW; and Gemmeiza 9 x Misr 1, Gemmeiza 9 x Cham 4, Sids 12 x Misr 2, Sids 12 x Misr Sids 1, Sids 12 x Cham 4 and Misr 2 x Sids 1 for GY. Although no F_1 cross had significant and negative s_{ij} effects, the best crosses were Gemmeiza 9 x Sids 12, Sids 12 x Sids 1 and Misr 2 x Cham 4 for DM; Gemmeiza 9 x Misr 1 and Misr 1 x Sids 1 for PH; and Misr 1 x Sids 1, Misr 2 x Sids 1 and Gemmeiza 9 x Misr 1 for SR.

On the contrary, the worst F_1 hybrids were Gemmeiza 9 x Misr 2, Misr 1 x Misr 2, Misr 1 x Sids 1 for GFR; Misr 1 x Misr 2 for SP-1; Gemmeiza 9 x Misr 1, Sids 12 x Misr 1 for KS-1; and Gemmeiza 9 x Sids 12, Misr 1 x Misr 2, Misr 1 x Sids 1 for GY, which had significant and negative s_{ij} effects. The same trend corresponds with significant and positive s_{ij} effects in crosses Sids 12 x Sids 1 for DH; Gemmeiza 9 x Sids 1, Sids 12 x Cham 4, Sids 1 x Cham 4 for LR; and Sids 12 x Cham 4 for SR.

b) F_2 Diallel

Table 7 shows the estimates of the general (gi) and specific (sij) combining ability effects of the parents and their F_2 hybrids for the studied characters.

For PH, LR and SR, the lower g_i effects correspond to superior parents, while the remaining characters were *vice versa*. Significant and negative g_i effects were detected for Sids 12 and Cham 4 for PH; Gemmeiza 9, Sids 12, Misr 1 and Misr 2 for LR; and Gemmeiza 9, Sids 12 and Sids 1 for SR. Significant and positive g_i effects were observed in Misr 2, Sids 1 and

Cham 4 for SP^{-1}; Sids 12 and Misr 2 for KS^{-1}; and Misr 1 for 100KW.

On the other hand, undesired parents were Gemmeiza 9 and Sids 12 for SP^{-1}; Gemmeiza 9 and Cham 4 for KS^{-1}; and Cham 4 for 100KW and GY, which had significant and negative g_i effects. Also, significant and positive g_i effects were detected by Gemmeiza 9, Misr 2 and Sids 1 for PH; Sids 1 and Cham 4 for LR; and Misr 1 and Misr 2 for SR.

The best F_2 crosses were Sids 12 x Sids 1, Misr 1 x Sids 1 and Misr 2 x Cham 4 for LR; and Gemmeiza 9 x Misr 1, Sids 12 x Misr 1, Misr 1 x Sids 1 and Cham 4 and Misr 2 x Cham 4 for SR, which had significant and negative s_{ij} effects. According to the significant and positive s_{ij} effects, the best crosses were Gemmeiza 9 x Cham 4 and Sids 12 x Cham 4 for SP^{-1}; Misr 2 x Cham 4 for KS_{-1}; and Sids 12 x Cham 4 and Misr 2 x Sids 1 for GY.

On the contrary, the inferior F_2 hybrids were Gemmeiza 9 x Sids 12, Misr 2 and Sids 1 and Sids 12 x Misr 2 for KS^{-1}, which had significant and negative s_{ij} effects. The same trend corresponds with significant and positive s_{ij} effects in Misr 1 x Cham 4, Misr 2 x Cham 4 and Sids 1 x Cham 4 for PH; Gemmeiza 9 x Sids 12 and Cham 4 and Sids 12 x Misr 1 for LR; and Sids 12 x Sids 1 and Misr 1 x Misr 2 for SR.

Table 7. Estimates of the general (g_i) and specific (s_{ij}) combining ability effects for the studied characters assessed in six wheat parents and their F_2 hybrids and the standard errors (SE) in season 2013/2014.

Genotype/Combining Ability	Plant height (cm)	No. of spikes plant^{-1}	No. of Kernels Spike^{-1}	100 Kernel Weight	Grain Yield plant^{-1}	Leaf Rust	Stem Rust
			Parents				
Gemmeiza 9 (P_1)	1.45*	-0.96*	-1.71*	-0.07	-0.93	-1.91*	-3.60**
Sids 12 (P_2)	-4.28**	-3.55**	3.50**	0.14	-1.26	-4.73**	-3.04**
Misr 1 (P_3)	-0.35	1.25**	-0.46	0.15*	3.15**	-4.68**	7.28**
Misr 2 (P_4)	4.34**	-0.25	4.04**	0.13	0.82	-4.24**	1.97*
Sids 1 (P_5)	5.06**	2.37**	-0.44	0.11	5.37**	12.74**	-3.85**
Cham 4 (P_6)	-6.22**	1.14**	-4.92**	-0.44**	-7.14**	2.82**	1.23
SE (g_i)	0.42	0.26	0.63	0.06	0.66	0.55	0.61
SE (g_i-g_j)	0.65	0.40	0.98	0.08	1.02	0.85	0.95
			F_2 Hybrids				
P_1 x P_2	-1.16	-0.15	-4.85*	-0.154	0.25	3.23*	1.31
P_1 x P_3	-0.35	-0.45	0.22	0.131	0.50	0.89	-4.45*
P_1 x P_4	0.96	0.42	-7.64**	-0.024	-2.35	0.93	0.11
P_1 x P_5	-2.32	0.24	-5.50**	0.018	3.32	-0.99	2.69
P_1 x P_6	-1.02	2.07**	0.91	-0.023	-0.51	4.99**	-0.87
P_2 x P_3	-1.29	0.00	-2.87	0.208	0.22	4.15*	-4.43*
P_2 x P_4	-0.95	0.42	-3.92*	-0.057	0.07	2.58	1.25
P_2 x P_5	0.00	-0.46	-1.21	-0.160	-1.39	-9.86**	3.80*
P_2 x P_6	0.91	2.73**	2.29	0.097	7.67**	-2.39	-2.15
P_3 x P_4	1.59	0.14	2.40	-0.144	-0.21	2.35	8.67**
P_3 x P_5	0.17	0.18	-3.61	0.068	0.46	-12.13**	-6.59**
P_3 x P_6	4.99**	1.30	-1.79	0.110	2.90	2.65	-4.40*
P_4 x P_5	-0.45	0.42	3.35	0.238	6.17**	-7.47**	-1.42
P_4 x P_6	4.35**	-0.85	4.29*	0.214	-1.14	1.08	-4.00*
P_5 x P_6	2.81*	-0.12	2.81	0.274	-0.08	-5.89**	-1.53
SE (S_{ij}-S_{ik})	1.16	0.70	1.74	0.15	1.81	1.51	1.69
SE (S_{ij}-S_{kl})	1.73	1.05	2.59	0.22	2.69	2.25	2.52
SE (S_{ij}-S_{ik})	1.60	0.97	2.40	0.207	2.49	2.08	2.33

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

In this respect, many researchers detected good general and specific combiners according to their circumstances (EL-Hawary, 2006; Abd El-Lateef 2014; Kumar *et al*., 2016 and Saeed *et al*., 2016). The crosses with high s_{ij} effects for grain yield and resistant to leaf and stem rusts like Misr 1 x Sids 1 are suggested to be utilized for development of higher yielding and leaf and stem rusts resistant lines. The good general combiners like Misr 1 and Sids 1 may be used for varietal improvement through the recurrent selection; inter-mating and bi-parental mating in F_2 generation of promising crosses consisting good x good general combiners. This may lead in the fixation of both additive and non-additive components while making improvement in grain yield and its attributes (Singh *et al*., 2011; Zaazaa and El-Hashash, 2012 and Kumar *et al*., 2016).

REFERENCES

Abd El-Lateef, M. A. H. (2014). Molecular and Genetic Characterization of Some Bread Wheat (*Triticum aestivum* L.) Genotypes Under Water Stress Conditions. M.Sc. thesis, Kafrelsheikh Univ., Egypt.

Ahamed, M. L; S. S. Singh, J. B. Sharma and R. B. Ram (2004). Evaluation of inheritance to leaf rust in wheat using area under disease progress curve. Hereditas 141: 323-327.

Akram, Z; S. U. Ajmal; K. S. Khan; R. Qureshi and M. Zubair (2011). Combining ability estimates of some yield and quality related traits in spring wheat (*Triticum aestivum*). Pak. j. bot., 43(1): 221-231.

Ashmawy, M.A., W.M. EL-Oraby, M. Nazim and A.A. Shahin (2013). Effect of stem rust infection on grain yield and yield components of some wheat cultivars in Egypt. ESci Journal Plant Pathology. 2 (03): 171-178

Baker, R.J. 1978. Issues in diallel analysis. Crop Sci. 18:533–536.

Boulot, O.A. and A.M. Gad-Alla (2007). Inheritance of adult plant resistance to leaf rust in five Egyptian bread wheat cultivars. J. Agric. Sci., Mansoura Univ. 6: 4355-4366.

Cruz, C.D. (2006). Programa Genes: aplicativo computacional em genética e estatística. Viçosa: UFV, p 648.

Darwish, M.A.H. (2007). Genetic studies on some physiological and agronomic characters for some bread wheat crosses. M.Sc. thesis, Kafr EL-Shekh, Univ., Egypt.

El Sayed, O.A. (2011). Studies on stem rust disease of wheat in Egypt. MSc. Thesis, Faculty of Agric., Mansoura University, Egypt.

El-Hawary, M.N.A. (2006). Breeding for drought tolerance in bread wheat. M.Sc. Thesis, Fac. of Agric, Mansouera Univ., Egypt.

El-Hawary, M.N.A. (2010). Breeding for stress tolerance in some bread wheat. Ph. D. Thesis, Fac. of Agric, Mansoura Univ., Egypt.

EXCEL (2016). Microsoft EXCEL Computer user's guide.

Griffing B (1956). A generalised treatment of the use of diallel crosses in quantitative inheritance. Heredity 10: 31-50.

Hermas, Gamalat A. and S.A. El-Sawi (2015). Inheritance of stem rust resistance and some yield components in crosses from five Egyptian wheat cultivars. Egypt. J. Plant Breed. 19(1): 71 – 87.

Jag, S., L. Khant and R.P. Singh (2003). Winter and spring wheat: An analysis of combining ability. Cereal Research Com., 31: 347-354.

Koumber, R.M. and A.A. El-Gammaal (2012). Inheritance and Gene Action for Yield and Its Attributes in Three Bread Wheat Crosses (*Triticum aestivum* L.). World J. of Agric. Sci., 8: 156-162.

Kumar. J.; S.K. Singh; L. Singh; A. Kumar; Anurag; Sanjay k. Singh and M. Kumar (2016). Estimates of general and specific combining ability for grain yield and other physiological characters in bread wheat under late sown condition. Res. Environ. Life Sci., 9(7): 784-789.

Obi, I.U. (2013). Post graduate lecture notes on diallel crosses and analyses. Department of Crop Production and Landscape Management, Ebonyi State Varsity, Abakaliki. Unpublished.

Saeed, M.; I. H. Khalil; D. Nayab and M. Tanveer (2016). Combining ability and heritability for yield traits in wheat (*Triticum aestivum* L.). Pakistan J. of Agric. Sci., 53 (3): 1-7.

Shehab El-Din, T. M.; M. M. EL-Shami and A. H. Abd El Latif (1996). Qualitative and quantitative genetic studies on *Triticum aestivum*: *Puccinia recondita* interaction. J. Agric. Sci. Mansoura Univ. 21(11): 3769-3778.

Singh, H., S.N. Sharma and R.S. Sain (2011). Combining Ability for Some Quantitative Characters in Hexaploid Wheat (*Triticum aestivum* L. em. Thell). Proceedings of 4th International Crop Science Congress, Brisbane, 26 September-1 October 2004.

Snedecor, G.W. and W.G. Cochran (1980). Statistical Methods. Seventh Edition. Ames Iowa: The Iowa State University Press.

Steel, R.G.D. and J.H. Torrie, (1980). Principle and Procedures of Statistics: A Biochemical Approach. 2nd Ed., McGraw-Hill Book Company Inc., New York, USA.

Stubbes, R. W.; J. M. Prescott; E.E. Saari and H. J. Dubin (1986). Cereal disease methodology manual. Centrol International de Majormiento de Maiz Y Trigo (CIMMYT). Mixico PP.222.

Zaazaa, E.I., M.A. Hager and E.F. El-Hashash (2012). Genetical Analysis of Some Quantitative Traits in Wheat Using Six Parameters Genetic Model. J. of Agric. Sci., 12: 456-462.

القدرة على التآلف لصفات التبكير والصفات الزراعية ومقاومة صدأ الأوراق وصدأ الساق في هجن الجيل الأول والثاني من قمح الخبز

وليد ذكي اليماني فرحات و محمد عبد الكريم حسن درويش
قسم بحوث القمح ـ معهد بحوث المحاصيل الحقلية ـ مركز البحوث الزراعية ـ مصر

تم تقييم ستة آباء من القمح وهجنها التبادلية في الجيل الأول (موسم ٢٠١١/١٢) والجيل الثاني (موسم ٢٠١٢/١٣) وتقدير تباينات وتأثيرات القدرة على الائتلاف، الموديل الأول، النموذج الثاني. وكانت الآباء تحت الدراسة هي: جميزة ٩، سدس ١٢، مصر ١، مصر ٢، سدس ١ وشام ٤. في حين كانت الصفات المدروسة هي: عدد الأيام حتى طرد السنابل والنضج الفسيولوجي، طول فترة الامتلاء، معدل الامتلاء، طول النبات، عدد سنابل النبات، عدد حبوب السنبلة، وزن ١٠٠ حبة، محصول الحبوب للنبات، صدأ الأوراق وصدأ الساق في الجيل الأول، وطول النبات، عدد السنابل للنبات، عدد حبوب السنبلة، وزن ١٠٠ حبة، محصول الحبوب للنبات، صدأ الأوراق وصدأ الساق في الجيل الثاني. وكانت تباينات التراكيب الوراثية، والآباء، والهجن وتفاعل الآباء مع الهجن معنوية في الجيل الأول والثاني لمعظم الصفات مما يشير لوجود قدر كافي من الاختلافات الوراثية. وتبعا لنتائج متوسطات مربعات القدرة العامة والخاصة على التآلف، كانت التأثيرات الوراثية مكونة من التأثيرات الوراثية المضيفة وغير المضيفة مع تأثير أكبر للتباينات المضيفة. وأظهرت النتائج تأثيرات قوة الهجين لصفتي مقاومة صدأ الأوراق ومقاومة صدأ الساق في هجن الجيل الثاني. كانت أفضل الآباء لمتوسطات محصول النبات والقدرة العامة على التآلف هي مصر ١ وسدس ١ في موسمي الزراعة. وأعطت هجن مصر ٢ x سدس ١ في الجيل الأول وهجن مصر ٢ x سدس ١، مصر ١ x سدس ١ وجميزة ٩ x سدس ١ في الجيل الثاني أعلى المتوسطات لمحصول النبات من الحبوب. وكان الهجين مصر ٢ x سدس ١ أفضل الهجن في الجيل الأول والثاني لمحصول الحبوب للنبات ومقاومة صدأ الأوراق وصدأ الساق. باستثناء سدس ١، كانت الآباء مقاومة أو متوسطة المقاومة لصدأ الأوراق، بينما كانت جميزة ٩، سدس ١٢ وسدس ١ الأكثر مقاومة لصدأ الساق في موسمي الزراعة. كانت معظم هجن الجيل الأول مقاومة لصدأ الأوراق وحساسة أو متوسطة التحمل لصدأ الساق.