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Breeding for some Agronomic and Quality Characters in Bread Wheat

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ABSTRACT

To improve agronomic and quality in bread wheat, this experiment was performed in 2015/16 and 2016/17 seasons at Sakha Agricultural Research Station, Egypt to study performance of ten bread wheat (*Triticum aestivum* L.) genotypes (Giza 171, Sakha 95, Gemmeiza 12, Shandweel 1, Sids 12, Sids 14, Misr 3, Line 1, Line 2 and Line 3) and their forty-five F_1 crosses were evaluated for sixteen agronomic and grain quality characters. The mean squares for genotypes, parents, crosses, parents vs. crosses, general and specific combining ability were significant for most studied characters. The ratio of general and specific combining ability was more than unity for all characters and both additive and non-additive gene effects were important in controlling the studied characters with more importance for additive effects. The best performance was detected in Sakha 95, Sids 14 and Shandweel 1 for grain yield plant^{-1}, all parents except for Sids 12 and Giza 171 and Shandweel 1 for yellow rust, Line 1 for stem rust and Gemmeiza 12 and Sids 12 for dry gluten. The best combiners were Sakha 95, Sids 14, Giza 171 and Misr 3 for grain yield plant^{-1} and Giza 171, Sakha 95, Gemmeiza 12 and Shandweel 1 for wet and dry gluten. Grain yield plant^{-1} had positive significant correlation with grain filling rate, plant height, number of spikes plant^{-1} and kernel weight. The correlation of dry gluten was significant and positive with wet gluten and negative with hydration capacity percentage. Path coefficient analysis showed that the highest positive direct effect on grain yield plant^{-1} was obtained by grain filling period, wet gluten, days to maturity and days to heading. On the other hand, the highest negative direct effect was detected by dry gluten, hydration capacity percentage and days to anthesis. The highest positive direct effect on dry gluten was obtained by wet gluten, grain filling rate and days to maturity. Meanwhile, the highest negative direct effect on dry gluten was obtained by grain yield plant^{-1}, hydration capacity percentage and days to anthesis. Using stepwise regression, days to heading, grain filling period and rate, kernel weight, yellow rust resistance and electrical conductivity had justified the maximum of grain yield plant^{-1} changes. Number of kernels spike^{-1}, wet gluten and hydration capacity percentage had justified the maximum of dry gluten changes. Giza 171 × Misr 3, Line 1 × Line 3, Sids 12 × Misr 3, Giza 171 × Line 2, Sakha 95 × Shandweel 1, Sakha 95 × Gemmeiza 12 and Shandweel 1 × Misr 3 crosses had high yield potentiality and resistance to yellow rust and moderately susceptible to stem rust, consequently these crosses will be favorable in wheat breeding programs. Sakha 95 × Gemmeiza 12 and Sids 12 × Misr 3 were the best crosses for dry gluten and will be promising in breeding for wheat grain quality.

Keywords: Diallel, bread wheat, *Triticum aestivum*, grain quality, combining ability, heterosis, path analysis, stepwise regression.

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) plays an important role in the national Egyptian diet. The genetic improvement of wheat genotypes for high yield potential, resistance to biotic and abiotic stresses and high grain quality is a dire need in Egypt. The potentiality of any genotype to be used as a parent in hybridization depends on its *per se* performance and the its performance of F1 hybrid derived from it and its own general combining ability effect.

In Egypt, wheat infected by three rusts i.e. stem, or black rust caused by *Puccinia graminis* Pers. f. sp. *tritici* Eriks. & Henn, leaf, or brown rust (P. *triticina* Eriks) and stripe, or yellow, rust (P. *striiformis* f. sp. *tritici*). Effective breeding procedures start from choice of rusts resistant parental lines in addition to their yield potentiality, then the resulting crosses with having resistant genotypes are considered and promoted to the advanced generations.

According to Guzman *et al*. (2016), wheat quality is a wide concept and are defined differently by the different stakeholders of the wheat chain. In the spring bread wheat program, wheat quality analysis/selection is mainly performed in two stages i.e., evaluation of the parental lines and advanced lines in elite yield trials. For this reason, annually, all the lines that are part of the crossing block are characterized for the above-mentioned quality characters.

Recent investigations were carried out to investigate the ability of wheat genotypes to combine well and produce promising segregants in succeeding generation for earliness, yield and its components, rusts resistance and grain quality characters (Kumar and Kerkhi, 2015; Ahmad *et al*., 2016; Farhat and Darwish, 2016; Saeed *et al*., 2016; Qabil, 2017; Thomas *et al.*, 2017 and Bhumika *et al.,* 2018).

Heterosis in wheat crosses for earliness, as well as yield and its components and grain quality characters were investigated by Ahmad *et al.* (2016); Maich *et al.* (2017); Yadav (2017) and Ranjitha *et al.* (2018). They concluded that the values of heterosis over the mid and better parents varied from positive to negative and from significant to insignificant for the studied characters.

According to previous studies, there are many characters contribute to the grain yield in wheat, like earliness characters, plant height, yield components, rusts resistance and grain quality (Abd El-Mohsen and Abd El-Shafi, 2014). Several investigations have been performed to exhibit factors responsible for grain quality in wheat (Amiri *et al*., 2018 and Lindeque *et al*., 2018). Moreover, the relationship pattern of grain yield and quality with other traits varies in different sets of genotypes and growth environments. The correlation coefficient, multivariate methods like path coefficient and stepwise regression may give more sufficient information about the relationship of grain yield and quality with other agronomic and quality traits (Rharrabti and Elhani, 2014; Drikvand *et al*., 2013).

Therefore, the objectives of this study were to: (1) Investigate ten bread wheat genotypes and their F1 crosses, (2) Determine the heterosis, combining ability estimates for agronomic and grain quality characters, (3) Determine some relationships affecting grain yield and quality, (4) Select suitable parents for hybridization and wheat improvement, and (5) Obtain promising high yielding crosses with a relatively satisfactory grain quality.

MATERIALS AND METHODS

A- Studied genotypes and layout

This study was performed during 2015/16 and 2016/17 seasons at the experimental farm and the lab of Seed Technology Res. Sec. of Sakha Agricultural Research Station, Kafr El-Sheikh, Agricultural Research Center (ARC), Egypt (31° 5' 12" North, 30° 56' 49" East). Ten bread wheat (*Triticum aestivum* L.) cultivars and lines were used as parents. Most of these are new promising cultivars and lines. However, the names and pedigrees of these parents are shown in Table 1.

Table 1. Genotypes names and pedigree of the used bread wheat parents.

Name	Pedigree
Giza 171	SAKHA 93/GEMMEIZA 9 S.6-1GZ-4GZ-1GZ-2GZ-0S
Sakha 95	PASTOR // SITE / MO /3/ CHEN / AEGILOPS SQUARROSA (TAUS) // BCN /4/ WBLL1. CMA01Y00158S-040POY-040M-030ZTM-040SY-26M-0Y-0SY-0S.
Gemmeiza 12	OTUS/3/SARA/THB//VEE CMSS97Y00227S-5y-010M-010Y-010M-2Y-1M-0Y-OGM
Shandweel 1	SITE/MO/4/NAC/TH.AC//3*PVN/3/MIRLO/BUC CMSS93B00567S-72Y-010M-010Y-010M-3Y-0M-0HTY-0SH
Sids 12	BUC//7C/ALD/5/MAYA74/ON//1160.147/3/BB/GLL/4/CHAT"S"/6/MAYA/VUL//CMH74A.630/4*SX SD7096-4SD-1SD-1SD-0SD
Sids 14	Bow"s"/Vee"s"//Bow's'/Tsi/3/BANI SUEF 1 SD293-1SD-2SD-4SD-0SD
Misr 3*	ATTILA*2/PBW65*2/KACHU CMSS06Y00582T-099TOPM-099Y-099ZTM-099Y-099M-10WGY-0B-0EGY
Line 1	CHEN/AEGILOPS SQUARROSA(TAUS)//BCN/3/2* KAUZ/4/GEN*2 //BUC/ FLK /3/ BUCHIN. S.16280-020S-015S-4S-0S
Line 2	WBLL1*2/4/BABAX/LR42//BABA×/3/BABX/LR42//BABAX. CMSS06Y00885T-099TOPM-099Y-099ZTM-099NJ-099NJ-26WGY-0B-0EGY
Line 3	BAJ1/3/KIRITATI//ATTILA*2/PASTOR. CMSS07Y00288S-0B-099Y-099M-099Y-1M-0WGY-0EGY

*** Misr 3 still under registration.**

The ten parents were crosses in all possible combinations excluding reciprocals to produce their hybrid seeds in season 2015/16. Then, the ten parents and their 45 F1's were planted on 24, November 2016 in a randomized complete block design with three replications. Each replicate included 55 rows. Each genotype was represented by a single row, 2 m long, 30 cm apart and the plants were spaced 20 cm apart within the rows. All cultural practices were applied according to the recommendations of the ARC for the region. The average of minimum and maximum temperatures were 14.0 0C and 21.9 0C during 2016/17 season, respectively.

B- Studied characters

The data of studied characters were recorded on five randomly chosen guarded plants per row in each replicate and classified into:

1- **Agronomic characters include:** number of days to heading (DH) and maturity (DM), grain filling period (GFP, in days and equal to the number of days from anthesis to maturity) and grain filling rate (GFR) in g plant-1 days-1 and equal to grain yield plant-1 divided by GFP), plant height (PH, cm), number of spikes plant-1 (SP), number of kernels spike-1 (KS), 100-kernel weight (KW, g), grain yield plant-1 (GY, g.) and yellow (YR) and stem (SR) rusts. Stem and yellow rusts were recorded under field condition, then the 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).

2- **Quality characters** were estimated using seed samples taken randomly in bulk from each genotype and grounded to fine powder to pass through 2 mm mesh. Wet (WG) and dry (DG) gluten percentage were determined by hand-washing weighted meal sample according to the standard method (Pleshkov,1976) until starch was not detected in the washing water, then dried and weighed in gram then. The hydration capacity percentage (HC) of gluten was estimated as (wet gluten – dry gluten) × 100 / dry gluten. Electrical conductivity (EC) of leached from 50 seed weight and soaked in 250 ml of distilled water for 24 h was measured in µ-mhos using conductivity meter, were estimated under optimum conditions according to the international rules (I.S.T.A, 1993). Relative density (RD) of seeds was calculated as in Karmer and Twigg (1962).

C- The statistical and biometrical analyses:

The data were analyzed on the mean of the five plants in each replication. The analysis of variance was done for the parents and their crosses according to Snedecor and Cochran (1980). Genotypes were divided to parents, crosses and parents vs. crosses. The LSD test at 5 % according to Steel *et al.* (1997) was used for comparison the mean performance of genotypes. The effects of genotypes were assumed to be fixed. General (GCA) and specific (SCA) combining ability effects were calculated using Griffing (1956) method 2 model 1. The relative importance of GCA and SCA was calculated according to Hung and Holland (2012) as follows:

K2GCA/K2SCA = (Ms GCA – Ms e / (p +2)) / (Ms SCA – Ms e). Where Ms = mean squares of each item, P = No. of parents and K2 = the fixed effect of each item. Better parent heterosis was calculated following the method of Falconer and Mackay (1996). T-test was used to test the significance of heterosis and made using standard error for better parent = $\pm\sqrt{2Ms\ e / r}$, where, Ms e is error mean square and r is the number of replications and the t obtained was tested against the tabular t-value at error degree of freedom. The above statistical analysis was performed using the statistical routines available in Microsoft EXCEL (2016).

Simple correlation was worked for all genotypes according to Steel *et al.* (1997). Path coefficient analysis was performed using phenotypic correlation coefficients and grain yield and dry gluten were considered as effects, while the rest studied characters considered as cause. Direct and indirect effects of the studied characters on grain yield and dry gluten were performed according to Dewey and Lu (1959) using the Genes software (Cruz, 2016). Stepwise regression was calculated according to Draper and Smith (1981) using Minitab software (Ver 18) to detect the most important characters (independent variables) significantly contributed to grain yield and dry gluten (dependent variable) characters.

RESULTS AND DISCUSSION

A- Analysis of variances

1- Agronomic characters

The mean squares (Table 2) were significant (0.01 or 0.05 probability) among genotypes, parents, crosses, and parents vs. crosses for the agronomic characters, except parents for SR and parents vs. crosses for DH, GFP, KS, GY, YR and SR. In addition, coefficient of variation estimates ranged from 1.0 % for DM to 128.6 % for YR, reflecting the ability to perform effective selection for yellow rust. The significance of source of variation due to genotypes containing parents and their hybrids were also detected in most previous studied as in Kumar and Kerkhi, (2015); Ahmad *et al.* (2016); Farhat and Darwish (2016); Saeed *et al.* (2016); Qabil (2017); Thomas *et al.* (2017) and Bhumika *et al.* (2018).

2- Grain quality characters

The results in Table 3 showed that seed density had not any significant for genotypes, parents, crosses and parents vs crosses, so there is no need to proceed further because no detectable differences were contributed by the parents to their offspring. Furthermore, the mean squares sources of variations for the other grain quality characters were significant (0.01 or 0.05 probability), except parents vs. crosses for the hydration capacity percentage. These results reflect the variation among the parents and crosses and confirm that genetic potential is crucial to obtain high grain quality wheat genotypes (Bagulho *et al*., 2015). In general, these results are in the same trend with those of Ahmad *et al.* (2016); Maich *et al.* (2017); Ranjitha *et al.* (2018).

Table 2. Mean squares and coefficient of variation for the studied agronomic characters.

SOV	df	Days to heading	Days to anthesis	Days to maturity	Grain filling period (day)	Grain filling rate (g plant^{-1} day^{-1})	Plant height (cm)
Reps	2	16.52**	4.49	13.47**	2.96	0.01	75.15**
Entry	54	15.57**	17.44**	15.04**	6.50**	0.08**	65.98**
Parents (P)	9	27.80**	20.90**	17.35**	9.24**	0.12**	144.54**
Crosses (C)	44	12.06**	15.35**	13.85**	5.99**	0.07**	50.15**
P vs C	1	59.68	78.22*	46.59*	4.07	0.03**	55.23*
Error	108	2.03	1.98	2.21	2.41	0.01	8.48
Total	164						
CV		1.4	1.2	1.0	3.8	9.0	2.6
SOV	df	No. of spikes plant^{-1}	No. of kernels spike^{-1}	100-kernel weight	Grain yield plant^{-1}	Yellow rust	Stem rust
Reps	2	18.36**	31.27	0.02	11.42	16.13	154.00**
Entry	54	26.26**	113.71**	0.33**	136.19**	138.47**	47.86**
Parents (P)	9	62.61**	161.94**	0.63**	168.01**	35.34**	54.31
Crosses (C)	44	17.15**	105.44**	0.23**	132.22**	161.91**	47.55**
P vs C	1	99.70*	43.70	1.68*	24.60	35.16	3.54
Error	108	3.50	14.47	0.06	23.03	16.38	19.80
Total	164						
CV		9.2	4.3	5.5	9.3	128.6	77.2

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

Table 3. Mean squares and coefficient of variation for the studied grain quality characters.

SOV	df	Relative density	Germination %	Electrical conductivity	Wet gluten %	Dry gluten %	Hydration %
Reps	2	0.001	16.39	0.03	0.79	6.71**	3201.73**
Entry	54	0.01	29.67**	0.59**	69.48**	22.45**	3874.12**
Parents (P)	9	0.01	40.59*	0.93**	30.90**	16.35**	2769.89**
Crosses (C)	44	0.01	23.07*	0.51**	68.85**	22.15**	4159.43**
P vs C	1	0.00	222.00*	1.46*	444.08**	90.66*	1258.61
Error	108	0.01	14.61	0.04	0.86	0.28	235.16
Total	164						
CV		9.3	4.0	7.7	3.7	5.3	9.8

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

B- Means performance

1- Agronomic characters

The wheat breeder preferred the low values of days to heading, anthesis and maturity, grain filling period and yellow and stem rusts resistance. The earliest parents (Table 4) for days to heading were Sids12, Line 2 and Giza 171 with values of 95, 99.7 and 102 days, respectively without significant differences. Where the latest parents were Sids 14 and Misr 3 with values of 106.3 and 104.3 days. In addition, Sids 12 (106.3 days) and Sids 14 (116.3 days) were the earliest and latest parents for days to anthesis, respectively. The shortest periods of maturity were detected in Line 1 (149.3 days), Sids 12 (150 days) and Sakha 95 (151.7 days), while the longest periods were observed in Shandweel 1 (157 days) and Sids 14 (155.3). Line 1, Sakha 95 and Sids 14 with values of 38, 39 and 39 days showed the shortest periods to grain filling, while the rest parents showed the longest periods without significant differences and ranges from 40.7 to 43.7 days.

The lowest rate of grain filling belonged to Sids 12 and Line 1 with 0.89 and 1.03 g d^{-1} $plant^{-1}$, while the highest values belonged to Sakha 95 and Sids 14 with 1.56 and 1.51 g d^{-1} $plant^{-1}$. The shortest parents were Misr 3, Line 2, line 1 and Sids 12 with values of 103.3, 105, 108.3 and 108.3 cm, respectively, where the tallest parents were Giza 171 and Sids 14 with 123.3 cm. The highest and lowest number of spikes $plant^{-1}$ belonged to Sakha 95 (29.2 spikes) and Sids 12 (11.4), respectively. Estimate of 101.1 kernels were detected in Sids 12 as the highest parent for number of kernels $spike^{-1}$, where Line 1, Line 3 and Line 2 had 75.1, 80.8 and 81.2 kernels $spike^{-1}$, respectively and were the lowest parents. The lightest weight of 100 kernels were observed in Gemmeiza 12 (3.58 g), Shandweel 1 (3.75 g), Misr 3 (3.85 g), Sids 12 (4.09 g) and Line 1 (4.10 g), while the heaviest weight was observed in Giza 171 (4.97 g), Line 3 (4.74 g), Sids 14 (4.65 g) and Sakha 95 (4.47 g), respectively. Sakha 95, Sids 14 and Shandweel 1 had the highest grain yield $plant^{-1}$ (60.9, 58.9 and 56.2 g, respectively), while Sids 12 (38.8 g) and Line 1 (39.3 g) had the lowest ones. For yellow rust, Sids 12 was susceptible with value of 10, as well as Giza 171 and Shandweel 1 with values of 6.67 and 2.40, respectively were moderately susceptible, while the rest parents were tolerant or moderately tolerant with values 0.05 to 0.40. For stem rust, Line 1 (0.17 was the most tolerant parent, as well as Line 3 (13.33), Giza 171 (10), Sakha 95 (8.33), Line 2 (7.33) and Sids 12 (6) were the most susceptible, where the rest parents were moderately susceptible (1.73 to 7.33).

The means of the forty-five crosses were slightly higher than the means of the ten parents for all agronomic characters, except for grain filling period and number of spikes $plant^{-1}$. The lowest values for days to heading were detected in four crosses and were between 99.3 and 101.3 days, while the highest values ranged from 106 to 107.7 days in ten crosses. Three crosses were the earliest ones for days to anthesis with values of 108.3 to 110.7 days, while the latest crosses had values between 116.7 and 119 days in seven crosses. The shortest periods of maturity were between 150 and 152.3 days in nine crosses, while the highest values were between 156.7 and 159 days in seven crosses. The shortest and longest periods of grain filling were in the range of 36.67 to 39 days and 41.67 to 44 days in eight crosses, respectively. The lowest rates of grain filling were 0.85 to 1.02 g $plant^{-1}$ day^{-1} in four crosses, while the highest rates were 1.34 to 1.53 g $plant^{-1}$ day^{-1} in twenty crosses. The studied crosses differed in plant height and the lowest values were detected in eight crosses and were 106.7 to 110 cm, while the highest values detected in twelve crosses and were 118.3 and 121.7 cm. The lowest values of number of spikes $plant^{-1}$ belonged to Sids 12 × Line 1 (13.13 spikes) and Sids 12 × Line 2 (14.4 spikes) and Giza 171 × Sids 12 (15.43 spikes), while the highest values were 26.37 spikes in Sakha 95 × Sids 14 and 24.72 spikes in Sakha 95 × Line 1. The lowest number of the kernel $spikes^{-1}$ were showed in Sids 12 × Line 3 with 70.75 kernels and Giza 171 × Line 1 with 75.27 kernels, while the highest values ranged from 92.44 to 98.03 kernels in thirteen crosses. The lightest 100 kernel weights were observed in seven crosses and ranged from 3.81 to 4.16 g, while the heaviest values were 4.68 to 5.04 g in fourteen crosses. Moreover, the lowest grain yield $plant^{-1}$ were showed in Sids 12 × Line 3, Gemmeiza 12 × Shandweel 1, Giza 171 × Line 3 and Gemmeiza 12 × Line 1 and were 33.81 to 41.09 g, while the highest estimates were reported in eleven crosses and were in the range of 57.06 and 65.03 g. The most susceptible crosses for yellow rust were Shandweel 1 × Sids 12, Sids 12 × Sids 14 and Sids 12 × Line 1, while the rest crosses were moderately susceptible, moderately tolerant or tolerant. The most susceptible crosses for stem rust were Sids 14 × Line 2 followed by Sakha 95 × Line 3 and Giza 171 × Line 3 and, while the rest forty-three crosses were susceptible or moderately susceptible.

Generally, the previous investigations reported exitance of variation within the studied parents and crosses allowing to determine the best and worst genotypes (Ahmad *et al.*, 2016; Farhat and Darwish, 2016; Saeed *et al.*, 2016; Qabil, 2017; Thomas *et al.*, 2017 and Bhumika *et al.,* 2018).

2- Grain quality characters

The parents (Table 4 and 5) differed insignificantly for relative density and their values ranged from 1.18 to 1.29 gcm^{-3}. The parents Sids 14 (88 %), Shandweel 1 (89 %), Misr 3 (90.7 %) and Gemmeiza 12 (93.3 %) showed the lowest germination %, while the rest six parents were vice versa. The lowest electrical conductivities were 1.98 to 2.27 μ-mhos in Sakha 95, Sids 12 and Line 3, while the highest values were 3.19 to 3.61 μ-mhos in Line 1, Misr 3, Giza 171 and Sids 14. In addition, Misr 3, Line 2 and Sids 14 with wet gluten of 22.4, 24.8 and 25 %, respectively were the lowest parents and Sakha 95 differed significantly with value of 27 %, while the rest six parents showed the highest estimates without significant differences and ranges from 29.3 to 31.6 %. The values of 8.53 to 8.99 % were the lowest dry gluten and belonged to Sakha 95, Misr 3 and Line 2, while the highest values were 14.17 % in Gemmeiza 12 and 14.04 % in Sids 12.

Table 4. Means performance of the parents and their F_1 crosses for the studied agronomic characters.

Genotypes	Days to heading	Days to anthesis	Days to maturity	Grain filling period (day)	Grain filling rate (g plant^{-1} day^{-1})	Plant height (cm)	No. of spikes plant^{-1}	No. of kernels spike^{-1}	100-kernel weight (g)	Grain yield plant^{-1} (g)	Yellow rust	Stem rust
Parents												
Giza 171	102.0	111.7	153.0	41.3	1.24	123.3	20.7	84.4	4.97	51.2	6.67	10.00
Sakha 95	103.0	112.7	151.7	39.0	1.56	115.0	29.2	83.3	4.47	60.9	0.17	8.33
Gemmeiza 12	103.7	113.3	154.3	41.0	1.16	111.7	22.9	91.0	3.58	47.7	0.05	1.87
Shandweel 1	102.3	114.0	157.0	43.0	1.31	113.3	22.8	90.9	3.75	56.2	2.40	2.87
Sids 12	95.0	106.3	150.0	43.7	0.89	108.3	11.4	101.1	4.09	38.8	10.00	6.00
Sids 14	106.3	116.3	155.3	39.0	1.51	123.3	23.6	84.4	4.65	58.9	1.60	1.73
Misr 3	104.3	114.0	154.7	40.7	1.21	103.3	23.3	91.5	3.85	49.3	0.05	2.87
Line 1	102.3	111.3	149.3	38.0	1.03	108.3	18.7	75.1	4.10	39.3	0.30	0.17
Line 2	99.7	111.3	152.3	41.0	1.27	105.0	24.2	81.2	4.37	51.8	0.05	7.33
Line 3	103.0	113.7	154.3	40.7	1.35	116.7	22.3	80.7	4.74	54.9	0.40	13.33
Mean of parents	102.2	112.5	153.2	40.7	1.25	112.8	21.9	86.4	4.26	50.9	2.17	5.45
$LSD_{0.05}$ for parents	2.5	2.0	2.0	2.4	0.15	5.3	3.4	7.8	0.53	5.4	1.46	8.13
F_1 Hybris												
Giza 171 × Sakha 95	101.0	111.3	151.7	40.3	1.44	116.7	21.3	86.8	4.95	57.8	1.60	11.67
Giza 171 × Gemmeiza 12	103.0	114.0	155.7	41.7	1.41	118.3	20.7	85.5	4.58	58.7	2.40	6.67
Giza 171 × Shandweel 1	102.3	114.0	155.3	41.3	1.20	116.7	20.5	84.6	5.04	49.9	9.33	5.00
Giza 171 × Sids 12	103.3	114.7	156.3	41.7	1.34	111.7	15.4	93.3	4.76	55.6	10.67	10.67
Giza 171 × Sids 14	104.7	116.0	157.3	41.3	1.36	121.7	20.9	90.6	4.72	56.4	10.67	3.00
Giza 171 × Misr 3	102.0	112.0	156.0	44.0	1.48	116.7	20.8	94.6	4.93	65.0	0.05	5.67
Giza 171 × Line 1	103.0	113.3	154.3	41.0	1.22	120.0	18.6	75.3	4.76	50.1	0.80	4.00
Giza 171 × Line 2	102.3	113.3	156.3	43.0	1.36	113.3	20.9	89.4	4.75	58.6	0.17	6.67
Giza 171 × Line 3	103.7	114.7	155.3	40.7	0.97	118.3	20.4	80.9	4.68	39.6	1.07	15.00
Sakha 95 × Gemmeiza 12	102.3	112.7	152.0	39.3	1.46	113.3	21.3	93.3	4.37	57.4	0.05	2.53
Sakha 95 × Shandweel 1	102.7	113.3	154.3	41.0	1.41	111.7	20.7	96.6	4.82	58.0	0.80	2.87
Sakha 95 × Sids 12	99.3	108.3	150.0	41.7	1.44	111.7	17.8	85.2	4.54	59.9	9.33	7.33
Sakha 95 × Sids 14	104.0	115.0	153.7	38.7	1.53	118.3	26.4	84.9	4.50	59.3	1.60	11.67
Sakha 95 × Misr 3	105.0	115.3	156.3	41.0	1.16	106.7	20.2	89.3	4.62	47.7	0.05	8.33
Sakha 95 × Line 1	105.0	114.3	151.0	36.7	1.21	115.0	17.6	82.8	4.41	44.3	0.05	4.67
Sakha 95 × Line 2	102.3	113.7	153.3	39.7	1.28	111.7	24.7	88.5	4.55	50.8	0.05	5.67
Sakha 95 × Line 3	102.3	112.0	151.7	39.7	1.42	118.3	20.6	84.6	4.92	56.5	0.30	15.00
Gemmeiza 12 × Shandweel 1	103.3	114.0	153.3	39.3	0.95	110.0	17.7	88.7	3.99	37.2	0.55	3.67
Gemmeiza 12 × Sids 12	104.3	114.3	154.3	40.0	1.13	110.0	19.5	96.4	4.15	45.3	3.20	1.73
Gemmeiza 12 × Sids 14	107.0	116.3	155.0	38.7	1.24	118.3	18.6	80.4	4.45	48.0	0.80	1.87
Gemmeiza 12 × Misr 3	106.0	116.0	155.7	39.7	1.38	111.7	18.4	87.7	4.40	54.7	0.05	2.87
Gemmeiza 12 × Line 1	106.7	116.7	154.7	38.0	1.08	108.3	17.5	88.8	4.02	41.1	0.17	2.40
Gemmeiza 12 × Line 2	103.0	112.3	152.0	39.7	1.28	111.7	17.3	85.4	4.48	51.0	0.05	3.53
Gemmeiza 12 × Line 3	107.0	117.0	156.7	39.7	1.40	115.0	22.7	77.5	4.55	55.6	0.55	4.67
Shandweel 1 × Sids 12	106.3	117.0	158.0	41.0	1.07	111.7	21.9	83.6	3.81	43.5	43.33	1.87
Shandweel 1 × Sids 14	107.7	119.0	159.0	40.0	1.15	120.0	20.6	84.3	4.34	46.2	7.33	2.73
Shandweel 1 × Misr 3	101.7	113.0	156.0	43.0	1.33	118.3	20.0	92.7	4.16	57.1	0.05	2.73
Shandweel 1 × Line 1	102.7	114.7	154.7	40.0	1.22	106.7	19.2	83.6	4.28	48.8	1.20	2.73
Shandweel 1 × Line 2	101.7	112.0	155.0	43.0	1.14	113.3	19.5	92.4	4.43	49.3	0.05	2.87
Shandweel 1 × Line 3	106.7	118.3	157.0	38.7	1.29	116.7	21.4	85.2	3.99	50.0	2.53	2.67
Sids 12 × Sids 14	104.0	115.0	155.0	40.0	1.29	121.7	21.6	88.4	4.44	51.5	18.33	5.00
Sids 12 × Misr 3	101.0	110.7	151.3	40.7	1.45	115.0	21.0	98.0	4.49	59.0	0.30	8.33
Sids 12 × Line 1	101.3	109.7	151.0	41.3	1.02	110.0	13.1	97.0	4.71	42.3	11.33	2.73
Sids 12 × Line 2	101.7	113.0	153.3	40.3	1.27	106.7	14.4	97.7	4.59	51.4	0.82	4.67
Sids 12 × Line 3	105.3	116.0	155.7	39.7	0.85	110.0	17.7	70.7	3.98	33.8	6.00	9.67
Sids 14 × Misr 3	107.0	118.3	157.7	39.3	1.40	121.7	20.6	93.7	4.62	55.1	0.55	5.00
Sd 14 × Line 1	103.3	114.0	152.7	38.7	1.43	116.7	18.9	94.1	4.56	55.4	0.67	5.67
Sd 14 × Line 2	103.0	113.7	152.7	39.0	1.34	115.0	19.3	87.6	4.80	52.4	0.05	18.33
Sd 14 × Line 3	107.3	118.3	158.3	40.0	1.41	116.7	20.5	85.9	4.48	56.5	4.00	4.67
Misr 3 × Line 1	103.0	112.0	152.3	40.3	1.25	111.7	18.1	86.6	4.50	50.5	0.05	1.87
Misr 3 × Line 2	102.7	113.0	154.7	41.7	1.23	111.7	20.5	85.0	4.50	51.2	0.05	4.00
Misr 3 × Line 3	106.3	116.0	156.0	40.0	1.33	118.3	22.5	84.6	4.79	53.4	0.05	5.00
Line 1 × Line 2	103.0	114.0	153.0	39.0	1.43	113.3	19.3	88.7	4.57	55.8	0.05	5.67
Line 1 × Line 3	103.0	114.3	154.3	40.0	1.50	113.3	22.1	82.3	4.71	60.0	0.28	5.67
Line 2 × Line 3	103.3	114.7	156.0	41.3	1.30	111.7	22.4	93.2	4.59	53.8	0.05	13.33
Mean of F_1	103.73	114.3	154.6	40.3	1.29	114.3	19.9	87.7	4.52	51.9	3.4	5.83
LSD 0.05 for F_1	2.25	2.4	2.5	2.6	0.20	4.7	3.0	5.9	0.37	8.3	7.2	7.18
Mean of all genotypes	103.44	113.9	154.3	40.4	1.28	114.1	20.3	87.5	4.47	51.7	3.1	5.76
$LSD_{0.05}$ for all genotypes	2.30	2.3	2.4	2.5	0.19	4.7	3.0	6.2	0.40	7.8	6.5	7.20

The lowest hydration capacity percentage of gluten were 117.9 to 127 and detected in Gemmeiza 12, Line 3, Sids 12 and Giza 171, in addition Sakha 95 was the highest one with 216.3.

Table 5. Mean performance of the parents and their F_1 crosses for the studied grain quality characters.

Genotypes	Relative density	Germination %	Electrical conductivity ($\mu mhosg^{-1}$)	Wet gluten %	Dry gluten %	Hydration %
			Parents			
Giza 171	1.25	96.0	3.24	29.3	12.94	127.0
Sakha 95	1.34	96.0	1.98	27.0	8.53	216.3
Gemmeiza 12	1.32	93.3	2.67	30.8	14.17	117.9
Shandweel 1	1.24	89.3	2.84	29.9	11.87	152.3
Sids 12	1.18	94.7	2.10	31.6	14.04	126.7
Sids 14	1.26	88.0	3.19	25.0	9.55	163.9
Misr 3	1.26	90.7	3.36	22.4	8.72	157.5
Line 1	1.29	94.7	3.61	31.6	13.30	138.9
Line 2	1.25	98.7	2.74	24.8	8.98	176.3
Line 3	1.24	98.7	2.27	29.6	13.33	122.7
Mean of parents	1.26	94.0	2.80	28.2	11.54	149.9
$LSD_{0.05}$ for parents	-	6.5	0.65	2.7	0.74	19.6
			F1 Hybris			
Giza 171 × Sakha 95	1.29	94.7	2.57	27.4	11.50	139.1
Giza 171 × Gemmeiza 12	1.27	93.3	3.04	22.7	8.61	164.6
Giza 171 × Shandweel 1	1.27	89.3	2.71	19.5	9.55	105.0
Giza 171 × Sids 12	1.33	89.3	2.69	30.5	14.97	105.3
Giza 171 × Sids 14	1.25	94.7	2.29	22.4	7.87	184.5
Giza 171 × Misr 3	1.37	98.7	2.64	26.0	9.63	170.8
Giza 171 × Line 1	1.29	98.7	2.83	28.0	7.97	251.5
Giza 171 × Line 2	1.35	94.7	2.99	19.4	9.57	102.7
Giza 171 × Line 3	1.28	98.7	2.68	30.0	13.67	119.2
Sakha 95 × Gemmeiza 12	1.25	98.7	2.43	30.1	14.14	113.4
Sakha 95 × Shandweel 1	1.24	98.7	2.28	23.2	6.10	285.2
Sakha 95 × Sids 12	1.30	98.7	2.07	27.5	10.93	152.7
Sakha 95 × Sids 14	1.28	96.0	2.28	29.8	11.67	156.0
Sakha 95 × Misr 3	1.21	100.0	2.64	26.6	10.84	145.9
Sakha 95 × Line 1	1.24	97.3	2.56	27.6	11.28	145.0
Sakha 95 × Line 2	1.19	97.3	3.21	28.3	12.63	123.8
Sakha 95 × Line 3	1.27	90.7	2.10	26.9	9.70	177.8
Gemmeiza 12 × Shandweel 1	1.26	98.7	2.78	30.6	12.80	139.0
Gemmeiza 12 × Sids 12	1.30	100.0	2.73	28.3	13.07	116.6
Gemmeiza 12 × Sids 14	1.24	100.0	2.43	26.4	11.86	122.7
Gemmeiza 12 × Misr 3	1.32	98.7	2.82	27.2	10.73	153.7
Gemmeiza 12 × Line 1	1.26	98.7	2.95	23.3	10.59	120.1
Gemmeiza 12 × Line 2	1.39	97.3	2.21	29.3	12.90	127.8
Gemmeiza 12 × Line 3	1.27	98.7	1.98	22.7	8.14	179.3
Shandweel 1 × Sids 12	1.23	97.3	4.04	28.0	10.93	156.9
Shandweel 1 × Sids 14	1.22	98.7	2.38	25.8	11.20	130.2
Shandweel 1 × Misr 3	1.25	98.7	2.62	20.8	6.93	200.8
Shandweel 1 × Line 1	1.25	98.7	2.71	24.9	9.83	153.3
Shandweel 1 × Line 2	1.02	100.0	2.24	21.5	8.13	164.8
Shandweel 1 × Line 3	1.24	98.7	2.67	25.7	10.00	157.0
Sids 12 × Sids 14	1.25	97.3	1.99	26.9	12.60	114.3
Sids 12 × Misr 3	1.27	96.0	2.54	27.6	13.02	112.2
Sids 12 × Line 1	1.29	98.7	3.30	26.4	11.35	132.7
Sids 12 × Line 2	1.22	96.0	2.86	15.7	5.68	176.6
Sids 12 × Line 3	1.17	98.7	2.85	16.2	5.30	206.1
Sids 14 × Misr 3	1.24	97.3	2.15	24.5	9.80	149.8
Sd 14 × Line 1	1.30	90.7	1.88	15.8	5.59	184.6
Sd 14 × Line 2	1.36	98.7	2.45	13.4	4.90	172.9
Sd 14 × Line 3	1.26	96.0	2.16	15.2	5.48	179.0
Misr 3 × Line 1	1.24	98.7	2.78	18.7	7.04	165.7
Misr 3 × Line 2	1.42	97.3	2.01	21.6	7.87	174.9
Misr 3 × Line 3	1.42	96.0	2.44	21.2	7.30	191.0
Line 1 × Line 2	1.37	93.3	2.55	16.3	5.77	183.4
Line 1 × Line 3	1.25	98.7	2.60	21.1	7.73	173.8
Line 2 × Line 3	1.28	98.7	1.93	16.6	5.79	187.8
Mean of F_1	1.27	97.0	2.56	23.9	9.62	157.1
LSD 0.05 for F_1	-	6.2	0.22	1.2	0.83	24.9
Mean of all genotypes	1.27	96.5	2.6	24.7	9.97	155.8
$LSD_{0.05}$ for all genotypes	-	6.2	0.3	1.5	0.86	24.8

The means of the forty-five crosses were slightly lower than the means of the ten parents for all grain quality characters, except for germination % and hydration capacity percentage of gluten. The crosses (Table 4 and 5) differed insignificantly for relative density and their values ranged from 1.02 to 1.42 gcm-3. Six crosses were the lowest ones for germination % and showed 89.3 to 93.3 %, while thirty-six crosses showed the highest percentages with 96 – 100 %. The lowest electrical conductivities were 1.88 to 2.1 µ-mhos in seven crosses, while the highest value was 4.04 µ-mhos in Shandweel 1 × Sids 12.

Moreover, Sids 14 × Line 2 with wet gluten of 13.4% were the lowest cross, while the highest estimates range from 29.8 to 30.6 % in Gemmeiza 12 x Shandweel 1, Giza 171 × Sids 12, Sakha 95 × Gemmeiza 12, Giza 171 × Line 3 and Sakha 95 × Sids 14. The values of 4.90 to 5.79 % were the lowest dry gluten and detected in Sids 14 × Line 2, Sids 12 × Line 3, Sids 14 × Line 3, Sids 14 × Line 1 and Sids 12 × Line 2, while the highest values were detected in Giza 171 × Sids 12 (14.97 %) and Sakha 95 × Gemmeiza 12 (14.14 %). The lowest hydration capacity percentage of gluten were 102.7 to 123.8 % and detected in eleven crosses, in addition Sakha 95 x Shandweel 1 was the highest cross with 285.2 %. These results are supported by Ahmad *et al.* (2016); Maich *et al.* (2017); Amiri *et al.* (2018) and Ranjitha *et al.* (2018) who concluded that the change in wheat quality is caused by genetic background.

C- Combining ability

1- Analysis of variance

The obtained results in Table 6 revealed significant (0.01 or 0.05 probability probability) general (GCA) and specific (SCA) combining ability mean squares for all studied characters, with the exception of SCA for grain filling period and stem rust; and GCA for germination %. These results indicate the importance of both additive and non-additive genetic variance in controlling the expression of the studied traits. As in this study, significant mean squares of general and specific combining ability for most agronomic and grain quality characters were obtained by Ahmad *et al.* (2016); Farhat and Darwish (2016); Maich *et al.* (2017) and Ranjitha *et al.* (2018).

Information of general and specific combining ability, indicate the types of gene action influencing various characters and enable the plant breeder to evaluate parental entries and select the best breeding system. The mean squares of GCA were higher than of those for SCA for all characters under the study, except for germination %, indicating that improvement the studied characters would be more effective using some of the present parents and crosses. These results were in harmony with those of Farhat and Darwish (2016) for DH, DM and PH, and Verma *et al.* (2016) for PH, GFP and gluten content.

The ratios of GCA/SCA (Table 6) were more than unity for all characters. These results indicate the importance of additive and non-additive effects in determining the performance of these characters and the additive gene effects predominantly control these characters and consequently the selection based on the accumulation of additive effects would be more effective in early segregated generations. Similar findings were also observed by Kumar and Kerkhi (2015); Farhat and Darwish (2016); and Mandal and Madhuri (2016) for DH, DM, GFP, GFR, PH, SP, KS, GY, and SR. Where, different results were detected by Kumar and Kerkhi (2015); Mandal and Madhuri (2016); and Verma *et al.* (2016) for DH, DM, GFP, PH, SP, KS, KW, GY and gluten content.

Table 6. Mean squares for general (GCA) and specific (SCA) combining ability and GCA/SCA ratio for the studied characters.

SOV	df	Days to heading	Days to anthesis	Days to maturity	Grain filling period (day)	Grain filling rate (g plant^{-1} day^{-1})	Plant height
Entry	54	15.57**	17.44**	15.04**	6.5**	0.08**	65.98**
GCA	9	47.3**	51.6**	52.03**	22.81**	0.18**	261.39**
SCA	45	9.22**	10.61**	7.65**	3.24	0.06**	26.89**
Error	108	0.7	0.66	0.74	0.80	0.00	2.83
GCA/SCA		5.53	5.18	7.52	-	3.23	10.85
SOV	df	No. of spikes plant^{-1}	No. of kernels spike^{-1}	100-kernel weight	Grain yield plant^{-1}	Yellow rust	Stem rust
Entry	54	26.26**	113.71**	0.33**	136.19**	138.47**	47.86**
GCA	9	80.87**	227.58**	1.12**	254.34**	377.66**	158.36**
SCA	45	15.33**	90.94**	0.17**	112.56**	90.63**	25.77
Error	108	1.17	4.82	0.02	7.68	5.46	6.60
GCA/SCA		5.70	2.64	7.57	2.42	4.43	-
SOV	df	Germination %	Electrical conductivity	Wet gluten %	Dry gluten %	Hydration %	
Entry	54	29.67**	0.59**	69.48**	22.45**	3874.12**	
GCA	9	24.18	0.97**	136.86**	41.81**	4494.79**	
SCA	45	30.77**	0.52**	56**	18.58**	3749.99**	
Error	108	4.87	0.01	0.29	0.09	78.39	
GCA/SCA		-	1.92	2.46	2.26	1.22	

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

2- General combining ability effects

Wheat breeders are interested to get significant negative GCA for days to heading, anthesis and maturity, grain filling period, plant height and yellow and stem rusts resistance and significant positive effects for grain filling rate, grain yield and its components.

a- Agronomic characters

Results in Table 7 showed that Giza 171 was good combiner for DH and DA with significant negative GCA and for KW and GY and had significant positive GCA. Moreover, the significant GCA effects of Sakha 95 were negative for DH, DA, DM, GFP and YR and positive for GFR, SP, KW and GY with preferred combination for these characters. Gemmeiza 12 was superior combiner for PH, YR and SR and had significant negative GCA. Shandweel 1 was preferable combiner only for SR with negative and significant GCA. Sids 12 was desirable combiner for DH, DA, DM and PH since had significant negative GCA and for KS and had significant positive GCA. Sids 14 was preferable combiner for GFP and had GCA with significant negative values and for GFR, SP and GY with significant positive GCA. Negative and significant GCA with good combinations were detected in Misr 3 for PH and YR, while the good combinations with positive significant were observed for SP, KW and GY. Significant and negative GCA effects were reported in Line 1 for DA, DM, GFP, PH, YR and SR and considered preferred combiner for these characters. Line 2 showed desirable combination for DH, DA, DM, PH and YR and had negative and significant GCA. Line 3 was preferable combiner only for SR and SP with significant negative and positive GCA, respectively.

Table 7. Estimates of general combining ability effects of the parents for the studied agronomic characters.

Parents	Days to heading	Days to anthesis	Days to maturity	Grain filling period	Grain filling rate	Plant height	No. of spikes plant^{-1}	No. of kernels spike^{-1}	100-kernel weight	Grain yield plant^{-1}	Yellow rust	Stem rust
Giza 171	-0.71*	-0.54*	0.56*	1.11**	0.01	3.78**	-0.16	-1.02	0.33**	2.11*	1.29	2.08*
Sakha 95	-0.66*	-0.99**	-1.69**	-0.70*	0.12**	-0.11	2.19**	-0.28	0.12*	3.70**	-1.70*	1.92*
Gemmeiza 12	1.01**	0.57*	0.03	-0.53	-0.03	-1.22*	-0.27	0.32	-0.25**	-2.04*	-2.23**	-2.48**
Shandweel 1	0.15	0.84**	1.59**	0.74*	-0.06*	-0.25	0.37	0.95	-0.23**	-1.38	2.95**	-2.54**
Sids 12	-1.77**	-1.82**	-1.05**	0.77*	-0.12**	-2.47**	-3.15**	4.20**	-0.13**	-4.07**	7.39**	0.05
Sids 14	1.90**	2.09**	1.20**	-0.89**	0.09**	5.17**	0.97**	-0.27	0.09	2.48**	1.05	-0.16
Misr 3	0.46	0.09	0.64*	0.55	0.03	-1.36*	0.47	2.75**	-0.04	1.94*	-2.78**	-1.15
Line 1	-0.18	-0.63*	-1.74**	-1.12**	-0.05*	-1.92**	-1.75**	-2.72**	-0.04	-3.51**	-1.62*	-2.30**
Line 2	-1.29**	-0.91**	-0.55*	0.36	0.01	-3.03**	0.33	0.70	0.07	0.74	-2.77**	1.34
Line 3	1.09**	1.29**	1.01**	-0.28	0.01	1.42*	1.0**	-4.64**	0.08	0.02	-1.58*	3.25**
LSD0.05 (gi-gj)	0.67	0.66	0.70	0.73	0.05	1.36	0.87	1.78	0.11	2.24	1.89	2.08

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

Whereas, Giza 171 was worse combiner for DM, GFP, and PH with significant positive GCA and for SR with significant positive GCA. Significant and positive GCA effects for DH and DA and negative for KW and GY were detected by Sakha 95 and Gemmeiza 12 and were undesirable combiners for these characters. Shandweel 1 was bad combiner for DA, DM, GFP and YR with positive and significant GCA and for GFR and KW with negative and significant GCA. Sids 12, was inferior combiner for GFP and YR since had significant positive GCA and for GFR, SP, KW and GY and had significant negative GCA. Sids 14 was poor combiner for DH, DA, DM and PH and had GCA with significant positive values. Misr 3 was undesirable combiner only for DM with positive significant GCA. Significant and negative GCA effects were reported in Line 1 for GFR, SP, KS and GY and considered poor combiner for these characters. Line 2 did not show any undesirable positive GCA. Line 3 was inferior combiner for DH, DA, DM, GFP, PH and SR with significant and positive GCA and for KS with significant negative GCA.

In conclusion, Sakha 95 was the best parent in nine and one characters with desirable and undesirable significant GCA, respectively. While, Shandweel 1 and Line 3 showed the opposite trend with one and two desirable and six and seven undesirable significant GCA, respectively. It is noticeable that Line 1, Sids 12 had undesirable general combining ability for seven characters. For grain yield plant-1, Sakha 95, Sids 14, Giza 171 and Misr 3 were the best parents with the highest significant and positive general combining abilities, while Sids 12, Line 1 and Gemmeiza 12 were the worst parents. Generally, these results are in line with previous studies where GCA for the studied traits varied between significant and insignificant and between positive and negative for the studied parental lines (Ahmad *et al.*, 2016; Farhat and Darwish, 2016; Saeed *et al.*, 2016; Qabil, 2017; Thomas *et al.*, 2017).

b- Grain quality characters

It could be noticed from data in Table 8 that Giza 171 (Table 8) was the inferior parent for germination % with significant positive GCA, while the rest parents did not have any significant values and Sids 14 and Shandweel 1 showed negative values. Sakha 95, Sids 14 and Linea 3 were the best parents for electrical conductivity with significant and negative GCA, while Giza 171, Shandweel 1 and Line 1 were vice versa. For wet and dry gluten, Giza 171, Sakha 95, Gemmeiza 12 and Shandweel 1 were the best parents with significant and positive GCA, except dry gluten in Shandweel, while the rest parents showed the opposite trend. Sakha 95, Shandweel 1, Misr 3, Line 1 and Line 3 were the best parents significant and positive GCA, while Giza 171, Gemmeiza 12 and Sids 12 were the worst parents with significant negative GCA. These results were in line with the previous studies for wheat grain quality which differed in their combining ability among the parental lines (Kumar and Kerkhi, 2015 and Verma *et al.*, 2016).

Table 8. Estimates of general combining ability effects of the parents for the studied quality characters.

Parents	Germination %	Electrical conductivity	Wet gluten %	Dry gluten %	Hydration %
Giza 171	-1.42*	0.19**	1.05**	0.80**	-9.76**
Sakha 95	0.24	-0.21**	2.46**	0.51**	13.15**
Gemmeiza 12	0.80	0.01	2.52**	1.79**	-20.06**
Shandweel 1	-0.31	0.12**	0.66**	-0.04	6.91*
Sids 12	0.02	0.05	1.52**	1.35**	-15.60**
Sids 14	-1.31	-0.18**	-1.81**	-0.80**	0.67
Misr 3	0.13	0.06	-1.08**	-0.76**	5.51*
Line 1	0.13	0.23**	-0.55**	-0.49**	6.17*
Line 2	0.80	-0.06	-3.35**	-1.54**	4.46
Line 3	0.91	-0.22**	-1.43**	-0.83**	8.55**
LSD0.05 (gi-gj)	1.79	0.09	0.43	0.25	7.16

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

3- Specific combining ability effects

a- Agronomic characters

Days to heading data (Table 9) showed desirable significant SCA effects only in Shandweel 1 × Misr 3 and Sids 14 × Line 1. Significant and negative SCA effects for days to anthesis were reported by Sakha 95 × Sids 12, Sakha 95 × Line 3, Shandweel 1 × Misr 3, Shandweel 1 × Line 2 and Sids 12 × Line 1. Desirable significant and negative SCA were reached by Sakha 95 × Line 3, Gemmeiza 12 × Shandweel 1, Gemmeiza 12 × Line 2, Sids 12 × Misr 3 and Sids 14 × Line 2. There were eight crosses possessed desirably significant SCA effects for grain filling rate and the most superior crosses were Sids 12 × Misr 3, Line 1 × Line 2 and Line 1 × Line 3. Significant positive SCA effects were detected in Giza 171 × Sids 12, Sakha 95 × Misr 3, Shandweel 1 × Line 1 and Sids 14 × Line 3.

Table 9. Estimates of specific combining ability effects for the studied F_1 crosses for the studied agronomic characters.

Crosses	Days to heading	Days to anthesis	Days to maturity	Grain filling rate	Plant height	No. of spikes plant^{-1}	No. of kernels spike^{-1}	100-kernel weight	Grain yield plant^{-1}	Yellow rust
Giza 171 × Sakha 95	-1.08	-1.06	-1.53	0.03	-1.06	-0.94	0.67	0.03	0.24	-1.13
Giza 171 × Gemmeiza 12	-0.74	0.05	0.74	0.15*	1.72	0.90	-1.23	0.04	6.89*	0.19
Giza 171 × Shandweel 1	-0.55	-0.23	-1.14	-0.03	-0.92	0.05	-2.79	0.48**	-2.59	1.95
Giza 171 × Sids 12	2.37*	3.11**	2.49*	0.16*	-3.70*	-1.52	2.63	0.08	5.85*	-1.16
Giza 171 × Sids 14	0.04	0.52	1.24	-0.02	-1.34	-0.16	4.42	-0.16	0.12	5.18*
Giza 171 × Misr 3	-1.19	-1.48	0.47	0.15*	0.19	0.18	5.39*	0.17	9.26**	-1.61
Giza 171 × Line 1	0.45	0.58	1.19	-0.02	4.08*	0.25	-8.45**	0.00	-0.18	-2.02
Giza 171 × Line 2	0.90	0.86	1.99*	0.06	-1.48	0.49	2.29	-0.12	4.02	-1.50
Giza 171 × Line 3	-0.16	-0.01	-0.56	-0.33**	-0.92	-0.70	-0.90	-0.20	-14.2**	-1.79
Sakha 95 × Gemmeiza 12	-1.46	-0.84	-0.67	0.10	0.61	-0.89	5.83*	0.03	4.05	0.83
Sakha 95 × Shandweel 1	-0.27	-0.45	0.11	0.08	-2.03	-2.11	8.46**	0.46**	3.99	-3.59
Sakha 95 × Sids 12	-1.69	-2.78**	-1.59	0.16*	0.19	-1.52	-6.19*	0.08	8.54**	0.50
Sakha 95 × Sids 14	-0.69	-0.03	-0.17	0.04	-0.78	2.96*	-1.98	-0.17	1.37	-0.89
Sakha 95 × Misr 3	1.76*	2.30*	3.05**	-0.27**	-5.92**	-2.69*	-0.63	0.06	-9.68**	1.38
Sakha 95 × Line 1	2.4*	2.02*	0.11	-0.13	2.97	-3.10*	-1.64	-0.15	-7.65*	0.23
Sakha 95 × Line 2	0.84	1.63	1.24	-0.12	0.74	1.96	0.61	-0.11	-5.37	1.37
Sakha 95 × Line 3	-1.55	-2.23*	-1.98*	0.02	2.97	-2.87*	2.04	0.25	1.02	0.44
Gemmeiza 12 × Shandweel 1	-1.27	-1.34	-2.62**	-0.24**	-2.59	-2.61*	-0.06	0.01	-11.09**	-3.32
Gemmeiza 12 × Sids 12	1.65	1.66	1.02	0.01	-0.37	2.61*	4.38	0.06	-0.26	-5.11*
Gemmeiza 12 × Sids 14	0.65	-0.26	-0.56	-0.10	0.33	-2.35*	-7.08**	0.14	-4.11	-1.17
Gemmeiza 12 × Misr 3	1.09	1.41	0.66	0.11	0.19	-2.04	-2.80	0.22	3.12	1.90
Gemmeiza 12 × Line 1	2.40*	2.8**	2.05*	-0.11	-2.59	-0.70	3.78	-0.16	-5.08	0.86
Gemmeiza 12 × Line 2	-0.16	-1.26	-1.81*	0.03	1.86	-3.04*	-3.03	0.19	0.55	1.89
Gemmeiza 12 × Line 3	1.45	1.22	1.30	0.15*	0.74	1.74	-5.65*	0.25	5.92*	1.21
Shandweel 1 × Sids 12	4.51**	4.05**	3.13**	-0.03	0.33	4.44**	-8.99**	-0.30*	-2.73	29.85**
Shandweel 1 × Sids 14	2.17*	2.13*	1.88*	-0.16*	1.02	-0.96	-3.88	0.02	-6.67*	0.19
Shandweel 1 × Misr 3	-2.38*	-1.87*	-0.56	0.07	5.88**	-1.10	1.56	-0.04	4.78	-3.27
Shandweel 1 × Line 1	-0.74	0.52	0.49	0.05	-5.23**	0.36	-2.06	0.09	1.94	-3.28
Shandweel 1 × Line 2	-0.63	-1.87*	-0.37	-0.09	2.55	-1.45	3.33	0.13	-1.79	-3.28
Shandweel 1 × Line 3	1.98*	2.27*	0.08	0.06	1.44	-0.25	1.43	-0.33*	-0.38	-1.98
Sids 12 × Sids 14	0.42	0.80	0.52	0.04	4.91*	3.48**	-2.96	0.01	1.41	6.75*
Sids 12 × Misr 3	-1.13	-1.53	-2.59**	0.26**	4.77*	3.37**	3.61	0.19	9.38**	-7.46**
Sids 12 × Line 1	-0.16	-1.81*	-0.53	-0.08	0.33	-2.23	8.07**	0.41*	-1.84	2.41
Sids 12 × Line 2	1.29	1.80*	0.61	0.10	-1.89	-3.03*	5.33*	0.18	3.00	-6.96*
Sids 12 × Line 3	2.56**	2.61**	1.38	-0.31**	-3.01	-0.44	-16.28**	-0.45**	-13.85**	-2.96
Sids 14 × Misr 3	1.20	2.22*	1.49	0.00	3.80*	-1.09	3.78	0.10	-1.04	-0.87
Sd 14 × Line 1	-1.83*	-1.39	-1.12	0.11	-0.64	-0.62	9.64**	0.04	4.68	-1.91
Sd 14 × Line 2	-1.05	-1.45	-2.31*	-0.04	-1.20	-2.29*	-0.30	0.18	-2.55	-1.38
Sd 14 × Line 3	0.90	1.02	1.80*	0.03	-3.98*	-1.75	3.32	-0.16	2.31	1.39
Misr 3 × Line 1	-0.71	-1.39	-0.89	0.00	0.88	-0.91	-0.94	0.11	0.38	1.30
Misr 3 × Line 2	0.06	-0.12	0.24	-0.09	1.99	-0.55	-5.94*	0.00	-3.24	2.45
Misr 3 × Line 3	1.34	0.69	0.02	0.01	4.22*	0.74	-1.00	0.27	-0.32	1.26
Line 1 × Line 2	1.04	1.61	0.97	0.20*	4.22*	0.44	3.25	0.07	6.87*	1.29
Line 1 × Line 3	-1.35	-0.26	0.74	0.26**	-0.23	2.58*	2.22	0.19	11.75**	0.34
Line 2 × Line 3	0.09	0.36	1.22	0.01	-0.78	0.86	9.69**	-0.03	1.36	1.25
L.S.D.05(sij-sik)	0.34	2.18	2.31	0.18	4.51	2.90	5.89	0.38	7.44	6.27
L.S.D.05(sij-skl)	0.76	2.08	2.20	0.17	4.30	2.76	5.62	0.36	7.09	5.98

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

The most superior and desirable crosses for SP were Giza 171 × Misr 3, Sakha 95 × Gemmeiza 12, Sakha 95 × Shandweel 1, Sids 12 × Line 1, Sids 12 × Line 2, Sids 14 × Line 1 and Line 2 × Line 3. Significant and positive SCA effects were detected in seven crosses for No. of kernels spike^{-1}. Giza 171 × Shandweel 1, Sakha 95 × Shandweel 1 and Sids 12 × Line 1 were the best crosses with significant positive SCA effects for 100-kernel weight. The preferable significant SCA for grain yield were observed in Giza 171 × Gemmeiza 12, Giza 171 × Sids 12, Giza 171 × Misr 3, Sakha 95 × Sids 12, Gemmeiza 12 × Line 3, Sids 12 × Misr 3, Line 1 × Line 2 and Line × Line 3. The crosses Gemmeiza 12 × Sids 12, Sids 12 × Misr 3 and Sids 12 × Line 2 were the best ones for yellow rust and had significant and negative SCA.

On the other hand, eight, ten, seven, seven and three crosses were undesirable with significant positive SCA for DH, DA, DM, PH and YR, respectively. Five, eight, seven, three and six crosses with significant negative SCA were undesirable for GFR, SP, KS, KW and GY. It is noticeable that the undesirable crosses were Giza 171 × Line 3, Sakha 95 × Misr 3, Sakha 95 × Line 1, Gemmeiza 12 × Shandweel, Shandweel 1 × Sids 14, Sids 12 × Line 3 for grain yield and Shandweel 1 × Sids 12, Sids 12 × Sids 14 and Giza 171 × Sids 14 for yellow rust. Significant desirable SCA values for most of the studied characters were also reported by Ahmad *et al.* (2016); Farhat and Darwish (2016); Saeed *et al.* (2016); Qabil (2017); Thomas *et al.* (2017) and Bhumika *et al.* (2018).

b- Quality characters

No cross had significant positive SCA (Table 10) for germination %. In addition, twelve crosses possess desirable significant negative SCA effects for electrical conductivity. Fifteen, fifteen and twelve crosses had desirable significant positive SCA effects for wet gluten, dry gluten and hydration capacity, respectively. Giza 171 × Line 3, Gemmeiza 12 × Line 2, Sakha 95 × Sids 14 and Sakha 95 × Line 2 had the highest SCA values and differed significantly from other crosses for wet gluten, in addition Sakha 95 × Line 2, Giza 171 × Sids 12 showed the highest SCA for dry gluten.

Table 10. Estimates of specific combining ability effects for the studied F_1 crosses for the studied quality characters.

Crosses	Germination %	Electrical conductivity	Wet gluten %	Dry gluten %	Hydration %
Giza 171 × Sakha 95	-0.62	-0.01	-0.86	0.22	-20.09*
Giza 171 × Gemmeiza 12	-2.51	0.24*	-5.55**	-3.95**	38.66**
Giza 171 × Shandweel 1	-5.39*	-0.21	-6.91**	-1.18**	-47.97**
Giza 171 × Sids 12	-5.73*	-0.16	3.2**	2.85**	-25.19*
Giza 171 × Sids 14	0.94	-0.32*	-1.58*	-2.1**	37.83**
Giza 171 × Misr 3	3.49	-0.21	1.31*	-0.38	19.28*
Giza 171 × Line 1	3.49	-0.19	2.78**	-2.3**	99.31**
Giza 171 × Line 2	-1.17	0.25*	-3.02**	0.35	-47.76**
Giza 171 × Line 3	2.72	0.11	5.62**	3.73**	-35.45**
Sakha 95 × Gemmeiza 12	1.16	0.03	0.43	1.86**	-35.53**
Sakha 95 × Shandweel 1	2.27	-0.24*	-4.67**	-4.35**	109.38**
Sakha 95 × Sids 12	1.94	-0.38**	-1.16*	-0.91*	-0.63
Sakha 95 × Sids 14	0.61	0.08	4.45**	1.98**	-13.59
Sakha 95 × Misr 3	3.16	0.19	0.53	1.11**	-28.52**
Sakha 95 × Line 1	0.49	-0.07	1.00	1.29**	-30.13**
Sakha 95 × Line 2	-0.17	0.87**	4.44**	3.69**	-49.57**
Sakha 95 × Line 3	-6.95**	-0.07	1.18*	0.04	0.27
Gemmeiza 12 × Shandweel 1	1.72	0.05	2.67**	1.08**	-3.66
Gemmeiza 12 × Sids 12	2.72	0.07	-0.46	-0.05	-3.58
Gemmeiza 12 × Sids 14	4.05	0.00	0.97	0.9*	-13.7
Gemmeiza 12 × Misr 3	1.27	0.15	1.00	-0.28	12.43
Gemmeiza 12 × Line 1	1.27	0.11	-3.42**	-0.67*	-21.77*
Gemmeiza 12 × Line 2	-0.73	-0.34*	5.41**	2.68**	-12.43
Gemmeiza 12 × Line 3	0.49	-0.41**	-3.08**	-2.79**	35.05**
Shandweel 1 × Sids 12	1.16	1.26**	1.10	-0.35	9.75
Shandweel 1 × Sids 14	3.83	-0.16	2.2**	2.07**	-33.19**
Shandweel 1 × Misr 3	2.38	-0.16	-3.47**	-2.24**	32.53**
Shandweel 1 × Line 1	2.38	-0.24*	0.07	0.40	-15.59
Shandweel 1 × Line 2	3.05	-0.43**	-0.51	-0.26	-2.34
Shandweel 1 × Line 3	1.61	0.16	1.72**	0.89*	-14.27
Sids 12 × Sids 14	2.16	-0.48**	2.44**	2.08**	-26.57**
Sids 12 × Misr 3	-0.62	-0.18	2.41**	2.45**	-33.49**
Sids 12 × Line 1	2.05	0.42**	0.66	0.52	-13.71
Sids 12 × Line 2	-1.28	0.26*	-7.22**	-4.1**	31.98**
Sids 12 × Line 3	1.27	0.42**	-8.66**	-5.2**	57.31**
Sids 14 × Misr 3	2.05	-0.33*	2.64**	1.38**	-12.14
Sd 14 × Line 1	-4.62*	-0.77**	-6.52**	-3.08**	21.97*
Sd 14 × Line 2	2.72	0.09	-6.2**	-2.73**	11.97
Sd 14 × Line 3	-0.06	-0.03	-6.25**	-2.87**	13.95
Misr 3 × Line 1	1.94	-0.12	-4.44**	-1.68**	-1.78
Misr 3 × Line 2	-0.06	-0.6**	1.34*	0.20	9.11
Misr 3 × Line 3	-1.51	-0.01	-1.00	-1.09**	21.16*
Line 1 × Line 2	-4.06	-0.23	-4.48**	-2.17**	16.98
Line 1 × Line 3	1.16	-0.01	-1.62**	-0.92**	3.30
Line 2 × Line 3	0.49	-0.39**	-3.31**	-1.82**	18.98*
L.S.D.05(sij-sik)	5.92	0.31	1.43	0.82	23.76
L.S.D.05(sij-skl)	5.65	0.29	1.37	0.79	22.66

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

On the other hand, Giza 171 × Shandweel 1, Giza 171 × Sids and Sakha 95 × Line 3 had undesirable significant and negative SCA for gemination %. In addition, seven crosses showed undesirable significant and positive SCA for electrical conductivity. While, eighteen, nineteen and thirteen crosses exhibited undesirable significant and negative SCA for wet gluten, dry gluten and hydration %, respectively. Sids 12 × Line 3, Sids 12 × Line 2, Giza 171 × Shandweel 1, Sids 14 × Line 1, Sids 14 × Line 2 and Sids 14 × Line 3 had the highest SCA values for wet gluten, while, Sids 12 × Line 2, Sids 12 × Line 3, Sakha 95 × Shandweel 1, Giza 171 × Gemmeiza 12 and Sids 14 × Line 1 had the highest SCA for dry gluten. These results were in accordance with those of Kumar and Kerkhi (2015) and Verma *et al*. (2016).

D- Heterosis percentages

The heterotic percentages were estimated only based on the best parent according to the desirable trend of each characters.

1- Agronomic characters

No desirable heterotic percentages (Table 11) were detected for DH, DA, DM, GFP, SP, YR and SR. Preferable heterosis with significant and positive values of GFR were observed only in Giza 171 × Misr 3 and Sids 12 × Misr 3. Significant and desirable negative heterotic effects in eleven crosses were recorded for PH and ranged from -9.46 % in Giza 171 × Sids 12 to -4.05 % in Gemmeiza 12 × Sids 14, Sakha 95 × Sids 14, Giza 171 × Line 3 and Giza 171 × Gemmeiza 12. The crosses Sids 14 × Line 1, Line 1 × Line 2 and Line 2 × Line 3 were reported with desirable significant and positive heterosis for KS. Desirable significant and positive heterosis for KW were observed in Gemmeiza 12 × Misr 3, Sids 12 × Misr 3, Sids 12 × Line 1 and Misr 3 × Line 1. In addition, the desirable significant and positive heterosis were showed only in Giza 171 × Misr 3 and Sids 12 × Misr 3 for GY.

Table 11. **Estimation of heterosis over better parent for F_1 crosses for the agronomic characters.**

Crosses	Days to heading	Days to anthesis	Days to maturity	Grain filling period	Grain filling rate	Plant height	No. of spikes plant^{-1}	No. of kernels spike^{-1}	100-kernel weight	Grain yield plant^{-1}	Yellow rust	Stem rust
Giza 171 × Sakha 95	-0.98	-0.30	0.00	3.42	-7.99	-5.41**	-26.94**	2.88	-0.27	-5.08	860.00	40.00
Giza 171 × Gemmeiza 12	0.98	2.09*	1.74*	1.63	13.68	-4.05*	-9.51	-6.05	-7.72	14.54	4700.00	257.14
Giza 171 × Shandweel 1	0.33	2.09*	1.53	0.00	-7.89	-5.41**	-10.03	-6.9*	1.48	-11.32	288.89*	74.42
Giza 171 × Sids 12	8.77**	7.84**	4.22**	0.81	7.81	-9.46**	-25.32**	-7.72*	-4.25	8.54	60.00	77.78
Giza 171 × Sids 14	2.61*	3.88**	2.83**	5.98	-9.84	-1.35	-11.33	7.27	-4.95	-4.24	566.67**	73.08
Giza 171 × Misr 3	0.00	0.30	1.96*	8.2**	19.39*	-5.41**	-10.75	3.41	-0.66	26.94**	0.00	97.67
Giza 171 × Line 1	0.98	1.80	3.35**	7.89*	-1.32	-2.70	-10.02	-10.82**	-4.19	-2.13	166.67	2300
Giza 171 × Line 2	2.68*	1.80	2.63**	4.88	7.42	-8.11**	-13.65*	5.96	-4.40	13.15	233.33	-9.09
Giza 171 × Line 3	1.63	2.69*	1.53	0.00	-28.14**	-4.05*	-8.48	-4.16	-5.72	-27.86**	166.67	50.00
Sakha 95 × Gemmeiza 12	-0.65	0.00	0.22	0.85	-6.36	-1.45	-27.15**	2.52	-2.26	-5.64	0.00	35.71
Sakha 95 × Shandweel 1	0.33	0.59	1.76*	5.13	-9.36	-2.90	-29.15**	6.30	7.77	-4.66	380.00	0.00
Sakha 95 × Sids 12	4.56**	1.88	0.00	6.84*	-8.02	-2.90	-39.15**	-15.7**	1.57	-1.60	5500**	22.22
Sakha 95 × Sids 14	0.97	2.07*	1.32	-0.85	-1.79	-4.05*	-9.75	0.58	-3.14	-2.62	860.00	573.08**
Sakha 95 × Misr 3	1.94	2.37*	3.08**	5.13	-25.62**	-7.25**	-30.79**	-2.36	3.27	-21.66**	0.00	190.70
Sakha 95 × Line 1	2.61*	2.69*	1.12	-3.51	-22.63**	0.00	-39.78**	-0.61	-1.42	-27.27**	-70.00	2700.00
Sakha 95 × Line 2	2.68*	2.10*	1.10	1.71	-17.8**	-2.90	-15.38**	6.18	1.73	-16.56*	0.00	-22.73
Sakha 95 × Line 3	-0.65	-0.59	0.00	1.71	-8.81	1.43	-29.61**	1.49	3.80	-7.23	80.00	80.00
Gemmeiza 12 × Shandweel 1	0.98	0.59	-0.65	-4.07	-27.47**	-2.94	-22.49**	-2.59	6.64	-33.82**	1000.00	96.43
Gemmeiza 12 × Sids 12	9.82**	7.52**	2.89**	-2.44	-2.54	-1.49	-15.07*	-4.65	1.53	-4.85	6300.00	-7.14
Gemmeiza 12 × Sids 14	3.22**	2.65*	0.43	-0.85	-17.82**	-4.05*	-21.11**	-11.65**	-4.35	-18.45**	1500.00	7.69
Gemmeiza 12 × Misr 3	2.25*	2.35*	0.86	-2.46	13.75	0.00	-20.77**	-4.07	14.38**	11.09	0.00	53.57
Gemmeiza 12 × Line 1	4.23**	4.79**	3.57**	0.00	-7.03	-2.99	-23.44**	-2.41	-1.90	-13.77	233.33	1340
Gemmeiza 12 × Line 2	3.34**	0.90	-0.22	-3.25	1.46	0.00	-28.72**	-6.14	2.37	-1.56	0.00	89.29
Gemmeiza 12 × Line 3	3.88**	3.24**	1.51	-2.46	3.77	-1.43	-0.78	-14.88**	-4.06	1.22	1000.00	150.00
Shandweel 1 × Sids 12	11.93**	10.03**	5.33**	-4.65	-18.5*	-1.47	-3.92	-17.25**	-6.70	-22.57**	1705.56**	-34.88
Shandweel 1 × Sids 14	5.21**	4.39**	2.36**	2.56	-23.87**	-2.70	-12.46	-7.26*	-6.54	-21.67**	358.33	57.69
Shandweel 1 × Misr 3	-0.65	-0.88	0.86	5.74	1.36	4.41*	-13.98*	1.39	8.04	1.49	0.00	-4.65
Shandweel 1 × Line 1	0.33	2.99**	3.57**	5.26	-6.66	-5.88**	-15.68*	-7.96*	4.54	-13.26	300.00	1540
Shandweel 1 × Line 2	2.01	0.60	1.75*	4.88	-12.82	7.94**	-19.5**	1.73	1.30	-12.34	0.00	0.00
Shandweel 1 × Line 3	4.23**	4.11**	1.73*	-4.92	-4.27	2.94	-6.31	-6.24	-15.9**	-11.11	533.33	-6.98
Sids 12 × Sids 14	9.47**	8.15**	3.33**	2.56	-14.8*	12.31**	-8.55	-12.5**	-4.57	-12.53	1045.83**	188.46
Sids 12 × Misr 3	6.32**	4.08**	0.89	0.00	19.5*	11.29**	-9.89	-3.00	10.02*	19.65*	500.00	190.70
Sids 12 × Line 1	6.67**	3.13**	1.12	8.77**	-0.94	1.54	-29.88**	-4.01	14.92**	7.73	3677.78**	1540.00
Sids 12 × Line 2	7.02**	6.27**	2.22**	-1.63	0.30	1.59	-40.55**	-3.34	5.02	-0.76	1533.33	-22.22
Sids 12 × Line 3	10.88**	9.09**	3.78**	-2.46	-36.83**	1.54	-20.7**	-30**	-16.08**	-38.47**	1400.00	61.11
Sids 14 × Misr 3	2.56*	3.80**	1.94*	0.85	-7.16	17.74**	-12.59	2.48	-0.56	-6.48	1000.00	188.46
Sd 14 × Line 1	0.98	2.40*	2.23**	1.75	-5.22	7.69**	-20.03**	11.45**	-1.98	-6.02	122.22	3300.00
Sd 14 × Line 2	3.34**	2.1*	0.22	0.00	-11.15	9.52**	-20.53**	3.72	3.32	-11.09	0.00	957.69**
Sd 14 × Line 3	4.21**	4.11**	2.59**	2.56	-6.55	0.00	-13.17*	1.68	-5.50	-4.06	900.00	169.23
Misr 3 × Line 1	0.65	0.60	2.01*	6.14	3.22	8.06**	-22.29**	-5.35	9.87*	2.54	0.00	1020
Misr 3 × Line 2	3.01*	1.50	1.53	2.46	-2.66	8.06**	-15.37*	-7.09*	2.86	-1.20	0.00	39.53
Misr 3 × Line 3	3.24**	2.05*	1.08	-1.64	-1.42	14.52**	-3.37	-7.53*	0.99	-2.89	0.00	74.42
Line 1 × Line 2	3.34**	2.40*	2.46**	2.63	13.11	7.94**	-20.46**	9.16*	4.43	7.81	0.00	3300.00
Line 1 × Line 3	0.65	2.69*	3.35**	5.26	10.87	4.62*	-0.87	1.95	-0.80	9.16	-5.56	3300.00
Line 2 × Line 3	3.68**	2.99**	2.41**	1.64	-3.48	6.35**	-7.39	14.73**	-3.26	-2.02	0.00	81.82

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

On the other hand, twenty-seven crosses showed undesirable heterosis for DH and their values ranged from 2.25 to 11.93 % in Gemmeiza 12 × Misr 3 and Shandweel 1 × Sids 12, respectively. For DA, thirty-one crosses were undesirable in relation to heterosis values and were in the range of 2.05 to 10.03 % in Misr 3 × Line 3 and Shandweel 1 × Sids 12. The crosses with inferior heterosis for DM were twenty-five with range of 1.73 to 5.33 % in Shandweel 1 × Line 3 and Shandweel 1 × Sids 12. The crosses Giza 171 × Misr 3, Giza 171 × Line 1, Sakha 95 × Sids 12 and Sids 12 × Line 1 were the worst ones for heterosis values for GFP. Ten crosses showed undesirable heterosis for GFR and were between -14.8 and -36.83 % in Sids 12 × Sids 14 and Sids 12 × Line 3, respectively. For PH, thirteen crosses were with undesirable heterosis values and ranged from 4.41 to 17.74 % in Shandweel 1 × Misr 3 and Sids 14 × Misr 3, respectively. Undesirable heterosis for SP were detected in twenty-one crosses and differed from -13.17 % in Sids 14 × Line 3 to -40.55 % in Sids 12 × Line 2. The undesirable crosses for KS differed in thirteen crosses in the range of -7.96 % in Shandweel 1 × Line 1 and -30.0 % in Sids 12 × Line 3. Only Shandweel 1 × Line 3 and Sids 12 × Line 3 were with inferior heterosis values for KW. The worst crosses for GY were nine ones and ranged from -16.56 % in Sakha 95 to -38.47 % in Sids 12 × Line 3. For YR, the worst crosses were Giza 171 × Shandweel 1, Giza 171 × Sids 14, Sids 12 × Sids 14, Shandweel 1 × Sids 12, Sids 12 × Line 1 and Sakha 95 × Sids 12. Only Sakha 95 × Sids 14 and Sids 14 × Line 2 were the undesirable ones for SR. As observed in the present study, several workers reported the presence of considerable heterosis in wheat crosses for most characters (Farhat and Darwish, 2016; Saeed *et al.*, 2016; Qabil, 2017; Thomas *et al.*, 2017 and Bhumika *et al.*, 2018).

2- Grain quality characters

The heterotic effects for better parent (Table 12) for the germination % showed significant positive values in Gemmeiza 12 × Sids 14, Shandweel 1 ×Sids 14 Shandweel 1 × Misr 3 and Sids 14 × Misr 3.

Table 12. Estimation of heterosis over better parent for the studied F_1 crosses for the the studied grain quality characters.

Crosses	Germination %	Electrical conductivity	Wet gluten	Dry gluten	Hydration %
Giza 171 × Sakha 95	-1.39	29.64**	-6.70*	-11.15**	-35.69**
Giza 171 × Gemmeiza 12	-2.78	13.99*	-26.11**	-39.24**	29.66**
Giza 171 × Shandweel 1	-6.94*	-4.78	-34.81**	-26.24**	-31.07**
Giza 171 × Sids 12	-6.94*	28.27**	-3.52	6.63*	-17.11
Giza 171 × Sids 14	-1.39	-28.3**	-23.69**	-39.22**	12.62
Giza 171 × Misr 3	2.78	-18.43**	-11.36**	-25.57**	8.45
Giza 171 × Line 1	2.78	-12.61*	-11.39**	-40.09**	81.15**
Giza 171 × Line 2	-4.05	9.21	-33.86**	-26.04**	-41.71**
Giza 171 × Line 3	0.00	18.03*	1.35	2.50	-6.16
Sakha 95 × Gemmeiza 12	2.78	22.55**	-2.08	-0.24	-47.59**
Sakha 95 × Shandweel 1	2.78	14.76	-22.61**	-48.6**	31.87**
Sakha 95 × Sids 12	2.78	4.25	-12.87**	-22.11**	-29.39**
Sakha 95 × Sids 14	0.00	15.17	10.61**	22.12**	-27.86**
Sakha 95 × Misr 3	4.17	33.29**	-1.24	24.27**	-32.53**
Sakha 95 × Line 1	1.39	28.89**	-12.55**	-15.14**	-32.97**
Sakha 95 × Line 2	-1.35	61.7**	4.82	40.74**	-42.74**
Sakha 95 × Line 3	-8.11*	5.93	-8.91**	-27.25**	-17.81**
Gemmeiza 12 × Shandweel 1	5.71	4.27	-0.65	-9.67**	-8.74
Gemmeiza 12 × Sids 12	5.63	30.27**	-10.44**	-7.79*	-7.98
Gemmeiza 12 × Sids 14	7.14*	-9.06	-14.19**	-16.3**	-25.12**
Gemmeiza 12 × Misr 3	5.71	5.65	-11.7**	-24.3**	-2.44
Gemmeiza 12 × Line 1	4.23	10.58	-26.37**	-25.24**	-13.48
Gemmeiza 12 × Line 2	-1.35	-17.28**	-4.77	-8.96**	-27.51**
Gemmeiza 12 × Line 3	0.00	-12.82	-26.11**	-42.53**	46.11**
Shandweel 1 × Sids 12	2.82	92.79**	-11.39**	-22.11**	3.00
Shandweel 1 × Sids 14	10.45**	-16.21**	-13.92**	-5.62	-20.55**
Shandweel 1 × Misr 3	8.82*	-7.66	-30.40**	-41.57**	27.44**
Shandweel 1 × Line 1	4.23	-4.49	-21.20**	-26.05**	0.66
Shandweel 1 × Line 2	1.35	-18.34**	-28.11**	-31.49**	-6.49
Shandweel 1 × Line 3	0.00	17.27*	-14.25**	-25**	3.08
Sids 12 × Sids 14	2.82	-5.02	-14.98**	-10.24**	-30.25**
Sids 12 × Misr 3	1.41	21.06**	-12.73**	-7.24*	-28.76**
Sids 12 × Line 1	4.23	57.58**	-16.61**	-19.16**	-4.46
Sids 12 × Line 2	-2.7	36.39**	-50.43**	-59.51**	0.22
Sids 12 × Line 3	0.00	36.02**	-48.87**	-62.24**	62.67**
Sids 14 × Misr 3	7.35*	-32.59**	-2.22	2.55	-8.56
Sd 14 × Line 1	-4.23	-41.21**	-49.86**	-57.93**	12.66
Sd 14 × Line 2	0.00	-10.44	-46.62**	-48.71**	-1.90
Sd 14 × Line 3	-2.7	-4.74	-48.48**	-58.93**	9.22
Misr 3 × Line 1	4.23	-17.39**	-40.96**	-47.05**	5.19
Misr 3 × Line 2	-1.35	-26.58**	-12.71**	-12.29*	-0.78
Misr 3 × Line 3	-2.7	7.26	-28.23**	-45.23**	21.27**
Line 1 × Line 2	-5.41	-7.07	-48.29**	-56.63**	4.06
Line 1 × Line 3	0.00	14.28*	-33.15**	-42.05**	25.19**
Line 2 × Line 3	0.00	-14.87*	-43.73**	-56.6**	6.54

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

Desirable negative and significant heterotic effects of electrical conductivity were recorded in twelve crosses and ranged from -41.21 to -12.61 %. Only Sakha 95 × Sids 14 showed desirable significant and positive heterosis for wet gluten with value 10.61 %. The data of dry gluten showed significant positive heterotic effects for Giza 171 × Sids 12, Sakha 95 × Sids 14, Sakha 95 × Misr 3 and Sakha 95 × Line 2 and were in the range of 6.63 to 40.74 %. Desirable positive and significant heterotic effects for gluten hydration capacity were observed in seven crosses with values of 27.44 to 81.15 %.

On the other hand, Germination % were observed to be undesirable for heterosis in Giza 171 × Shandweel 1, Giza 171 × Sids 12 and Sakha 95 × Line 3. Sixteen crosses ranged from 13.99 % in Giza 171 × Gemmeiza 12 to 92.79 % in Shandweel 1 × Sid 12 were the worst ones for electrical conductivity for heterosis. Wet gluten had inferior heterosis in thirty-six crosses and the values ranged from -50.43 % in Sids 12 × Line 2 to -6.7 % Giza 171 × Sakha 95. For dry gluten, there were thirty-seven crosses with heterosis values from -62.24 % in Sids 12 × Line 3 to -7.24 % in Sids 12 × Misr 3 were the most undesirable ones. Fifteen crosses had gluten hydration capacity with heterosis values of -47.59 % in Sakha 95 × Gemmeiza 12 to -17.81 % Sakha 95 × Line 3 and were detected the worst ones. Many previous studies reported desirable heterosis for the grain quality traits (Kumar and Kerkhi, 2015 and Verma *et al*., 2016).

E- Correlation, path analysis coefficients and stepwise regression

1- Grain yield

The results presented in Table 13 showed that grain yield plant-1 had significant and positive values of correlation coefficients with each of grain filling rate, plant height, number of spikes plant-1 and 100-kernel weight, while these coefficients were significant and negative with electrical conductivity. The correlation between grain yield plant-1 and each of wet and dry gluten was negative but not significant and these results were previously reported by Amiri *et al*. (2018) and Lindeque *et al*, (2018). It seems that starch accumulation increase due to photosynthesis and supply of assimilates caused reduction of the protein and fiber ratios in grain (Amiri *et al*., 2018). In line with these results, Abd El-Mohsen and Abd El-Shafi (2014) obtained significant positive correlation estimates between grain yield plant-1 and each of number of tillers plant-1, number of grains spike-1 and 1000-grain weight. Contrary, they found negative association of days to heading and plant height with grain yield plant-1.

In the path analysis, the correlations between grain yield plant-1 on one hand and the sixteen characters on the other, have been portioned into direct and indirect effects. The highest positive direct effect on grain yield plant-1 was obtained by grain filling period (0.94), followed by wet gluten (0.88), then days to maturity (0.33) and days to heading (0.13), indicating that slight increase in these characters may directly participate in grain yield. On the other hand, the highest negative direct effect was detected by dry gluten (-1.23), hydration capacity % (-0.54) and days to anthesis (-0.46).

Table 13. Simple correlation coefficients (r), direct (in diagonal within bracts), indirect effects and total indirect effects (T) for the estimated sixteen characters on grain yield plant^{-1} in fifty-five genotypes (ten parents and forty-five F_1 crosses).

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	T	r
Days to heading (X1)	(0.13)	-0.44	0.22	-0.03	0.06	-0.01	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	-0.15	0.20	-0.03	-0.07	-0.07
Days to anthesis (X2)	0.12	(-0.46)	0.27	-0.02	0.07	-0.01	0.01	-0.02	0.00	0.00	0.00	0.00	0.00	-0.21	0.27	-0.04	-0.03	-0.03
Days to maturity (X3)	-0.37	0.09	(0.33)	0.01	0.04	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.22	0.28	-0.05	0.10	0.10
Grain filling period (X4)	0.07	-0.07	0.19	(0.05)	-0.07	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.02	-0.02	-0.01	0.20	0.20
Grain filling rate (X5)	0.00	0.01	-0.04	0.01	(0.94)	-0.01	0.01	0.01	0.02	0.00	0.00	0.00	0.01	-0.15	0.30	-0.13	0.96	0.96**
Plant height (X6)	0.38	0.04	-0.14	0.10	0.00	(-0.03)	0.00	-0.01	0.02	0.00	0.00	0.00	0.01	0.02	0.02	-0.03	0.38	0.38**
No. of spikes plant^{-1} (X7)	-0.01	0.04	-0.14	0.08	-0.01	0.48	(0.02)	-0.02	0.00	0.00	0.00	0.00	0.00	0.04	0.09	-0.09	0.47	0.47**
No. of kernels spike^{-1} (X8)	0.00	-0.05	0.13	-0.02	0.02	0.10	0.00	(0.06)	0.00	0.00	0.00	0.00	0.00	-0.03	-0.10	0.08	0.21	0.21
100-kernel weight (X9)	0.00	-0.02	0.06	-0.03	0.00	0.44	-0.01	0.00	(0.03)	0.00	0.01	0.00	0.01	-0.19	0.26	-0.07	0.49	0.49**
Yellow rust (X10)	-0.01	0.01	-0.04	0.07	0.01	-0.25	0.00	0.00	0.00	(0.01)	0.00	0.00	-0.01	0.13	-0.22	0.08	-0.22	-0.22
Stem rust (X11)	0.00	-0.03	0.07	-0.05	0.00	0.16	0.00	0.00	-0.01	0.02	(0.02)	0.00	0.01	-0.08	0.06	0.01	0.17	0.17
Germination % (X12)	0.00	0.01	-0.03	0.01	0.00	-0.22	0.00	0.00	-0.01	0.00	0.00	(-0.01)	0.00	0.01	0.05	-0.06	-0.24	-0.24
Electrical conductivity (X13)	0.00	0.01	-0.01	0.01	0.00	-0.35	0.01	0.00	-0.01	-0.01	0.00	-0.01	(-0.02)	0.16	-0.25	0.11	-0.35	-0.35**
Wet gluten (X14)	0.00	-0.02	0.11	-0.08	0.00	-0.16	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	(0.88)	-1.12	0.23	-0.17	-0.17
Dry gluten (X15)	0.80	-0.02	0.10	-0.08	0.00	-0.22	0.00	0.00	0.01	-0.01	0.00	0.00	0.00	0.00	(-1.23)	0.41	-0.24	-0.24
Hydration % (X16)	0.94	0.01	-0.03	0.03	0.00	0.22	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	-0.38	(-0.54)	0.24	0.24

Coefficient of determination = 0.99 and effect of residual variation = 0.034

The direct effect of grain filling rate on grain yield plant-1 (0.94) accounted for the total correlation between them (r = 0.96), so the correlation clears the true relationship and a direct selection through grain filling rate will be effective. The correlation coefficient is positive, but the direct effect is negative or negligible for grain filling period, plant height, number of spikes plant-1, number of kernel spike-1, 100-kernel weight, stem rust and hydration capacity %, indicating that the indirect effects seem to be cause of correlation and are to be considered simultaneously for selection. In addition, correlation coefficients were negative but the direct effect is positive and high for days to heading and wet gluten, indicating that the undesirable indirect effects should be nullified in order to make use of the direct effect. The residual effect determines how best the studied characters account tor the variability of grain yield plant-1. Residual effects with 0.034 indicated that the studied sixteen characters account for about 96.6 % of the variability in the grain yield. Besides, some other factors which have not been considered here, need to be included in this analysis to account fully for the variation in yield.

In previous studies, major portion of total variability in grain yield plant^{-1} was attributable to characters such as tillers plant^{-1}, number of grains spike^{-1}, 1000-grain weight (Abd El-Mohsen and Abd El-Shafi, 2014 and Rharrabti and Elhani, 2014).

Stepwise regression was used to remove non-effective traits in regression model on grain yield. Grain yield plant-1 was used as dependent variable and other traits were used as independent. The results in Table 14 showed that days to heading, grain filling period and rate, 100-kernel weight, yellow rust and electrical conductivity with R^2 = 99.8%, had justified the maximum of grain yield plant-1 changes. Remaining characters were excluded from the model because their low relative contributions. Based on the final step of stepwise regression analyses, the equation for prediction of grain yield plant-1 will be:

GY = -59.62 + 0.059 DH + 1.302 GP + 40.040 GR + 0.202 KW - 0.019 YR + 0.188 EC,

Where, GY, DH, GP, GR, KW, YR and EC are grain yield plant-1, days to heading, grain filling period and rate, 100-kernel weight, yellow rust and electrical conductivity, respectively. In them study, Pirdashti *et al.* (2012) assumed that high yield of wheat genotypes could be obtained by selecting breeding materials with number of filled grains and 1000-grain weight.

Table 14. Regression coefficient (b), standard error (SE), t-value, and probability (P) in predicting wheat grain yield plant^{-1} by the stepwise procedure analysis

Step	Variable entered	b	SE	t-Value	P
1	Days to heading	0.059	0.019	3.21	0.002
2	Grain filling period	1.302	0.029	44.89	0.000
3	Grain filling rate	40.040	0.258	155.30	0.000
4	100-kernel weight	0.202	0.124	1.64	0.108
5	Yellow rust	-0.019	0.006	-3.40	0.001
6	Electrical conductivity	0.188	0.0883	2.13	0.038

Constant = -59.62, R^2 = 0.998, R^2 (adjusted) = 0.998

2- Dry gluten

The correlation coefficient (Table 15) was significant and positive between dry gluten and wet gluten and significant negative between dry gluten and hydration capacity. In this respect, Drikvand *et al.* (2013) found that 1000-kernel weight had positive correlation with grain protein percentage and gluten weight.

The highest positive direct effect on dry gluten was obtained by wet gluten (0.72), followed by grain filling rate (0.57), then days to maturity (0.21), suggesting that inconsiderable increase in these characters may directly contribute to dry gluten. While, the highest negative direct effect on dry gluten was obtained by grain yield plant-1 (-0.61) followed by hydration capacity (-0.44) then days to anthesis (-0.30), indicating that low increment in these characters may directly decrease dry gluten.

The direct effect on dry gluten by days to heading (-0.30), grain filling period (0.03), plant height (-0.02) number of kernels spike-1 (0.05), grain yield plant-1 (-0.61), wet gluten (0.72) and hydration capacity (-0.44) accounted for the total correlation between them (r = (-0.22, 0.02, -0.02, 0.08, -0.24, 0.91 and -0.76, respectively), so the correlation account for the true relationship and a direct selection through grain filling rate will be effective. The correlation coefficient is positive, but the direct effect is negative or negligible for yellow rust and electrical conductivity, indicating that the indirect effects seem to be cause of correlation and are to be considered simultaneously for selection. Correlation coefficients are negative but the direct effect is positive and high for days to maturity and grain filling rate, indicating that the undesirable indirect effects should be nullified in order to make use of the direct effect. Residual effects were 0.024, consequently about 97.6 % of the variability in the dry gluten were contributed by the sixteen studied traits. In addition, some other characters, need to be included in this analysis to account fully for the variation in dry gluten. The relationship pattern of grain quality with other characters varies in different sets of genotypes and growth environments (Drikvand *et al.*, 2013 and Amiri *et al*., 2018).

In stepwise regression (Table 16), dry gluten was used as dependent variable and other traits were used as independent. No. of kernels spike^{-1}, wet gluten and hydration capacity % with R^2 = 98.7%, had justified the maximum of dry gluten changes. Other characters were eliminated from the model because their low relative contributions. Consequently, based on the final step of stepwise regression analyses, the equation for prediction of dry gluten can be obtained: DG = 0.923 + 0.015 KS + 0.407 WG - 0.034 HC, Where, DG, KS, WG and HC are dry gluten, No. of kernels spike^{-1}, wet gluten and hydration capacity %, respectively. In the study of Drikvand *et al.* (2013) and based on the first and second steps of stepwise regression analysis, protein percentage and falling number were the most effective traits in explaining different trait variations.

F- Selection the best crosses in F_1 to F_2 generation

Under Egyptian conditions, the best crosses to be advanced to the next generations those have high yield and resistant to the rusts diseases with appropriate height. As mentioned above in Table 4 and 5, the highest parents for grain yield plant-1 had the values 56.22 to 60.86 g without significant differences. There are fourteen crosses (Table 17) in the same range of the highest parents and only the cross Giza 171× Misr 3 surpassed the highest parents and had 65 g, while the remaining thirteen crosses were in the range of the highest parents. In addition, the fourteen crosses had appropriate height. From the fourteen crosses, Giza 171 × Misr 3, Line 1 × Line 3, Sids 12 × Misr 3, Giza 171 × Line

2, Sakha 95 × Shandweel 1, Sakha 95 × Gemmeiza 12 and Shandweel 1 × Misr 3 were resistant to yellow rust and moderately susceptible to stem rust and will be favorable in wheat breeding programs. Moreover, Sakha 95 × Gemmeiza 12 and Sids 12 × Misr 3 were the best crosses with dry gluten values of 14.14 and 13.02 % and will be favorable to breeding for wheat grain quality. Exploiting the important characters like grain yield, plant height and rusts resistance to select the best plants or families was performed in some previous studies like Hussain *et al.* (2017); Laala *et al.* (2017) and Darwish *et al.* (2018).

Table 15. Simple correlation coefficients (r), direct (in diagonal within bracts), indirect effects and total indirect effects (T) for the estimated sixteen characters on dry gluten content % in fifty-five genotypes (ten parents and forty-five F_1 crosses).

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	T	r
Days to heading (X1)	(0.09)	-0.28	0.14	-0.01	0.03	-0.01	0.00	-0.02	0.00	0.04	0.00	0.00	0.00	0.00	-0.12	-0.02	-0.25	-0.16
Days to anthesis (X2)	0.08	(-0.30)	0.17	-0.01	0.05	-0.01	0.00	-0.01	0.00	0.02	0.00	0.00	0.00	0.00	-0.17	-0.03	0.08	-0.22
Days to maturity (X3)	0.06	-0.24	(0.21)	0.01	0.02	-0.01	0.00	0.00	0.00	-0.06	0.00	0.00	0.00	0.00	-0.18	-0.04	-0.44	-0.23
Grain filling period (X4)	-0.05	0.13	0.04	(0.03)	-0.04	0.00	0.00	0.02	0.00	-0.12	0.00	0.00	0.00	0.00	0.01	0.00	-0.01	0.02
Grain filling rate (X5)	0.01	-0.02	0.01	0.00	(0.57)	-0.01	0.01	0.01	0.01	-0.59	0.00	0.00	0.00	0.01	-0.12	-0.11	-0.81	-0.24
Plant height (X6)	0.03	-0.09	0.06	0.00	0.23	(-0.02)	0.00	-0.01	0.01	-0.23	0.00	0.00	0.00	0.00	0.01	-0.02	0.00	-0.02
No. of spikes plant^{-1} (X7)	0.02	-0.09	0.05	0.00	0.29	-0.01	(0.01)	-0.01	0.00	-0.29	0.00	0.00	0.00	0.00	0.03	-0.07	-0.08	-0.07
No. of kernels spike^{-1} (X8)	-0.03	0.09	-0.01	0.01	0.06	0.00	0.00	(0.05)	0.00	-0.13	0.00	0.00	0.00	0.00	-0.02	0.07	0.03	0.08
100-kernel weight (X9)	-0.01	0.04	-0.02	0.00	0.27	-0.01	0.00	0.00	(0.02)	-0.30	0.00	0.01	0.00	0.01	-0.16	-0.06	-0.23	-0.21
Grain yield plant^{-1} (X10)	-0.01	0.01	0.02	0.01	0.54	-0.01	0.00	0.01	0.01	(-0.61)	0.00	0.00	0.00	0.01	-0.12	-0.11	0.37	-0.24
Yellow rust (X11)	0.01	-0.03	0.04	0.00	-0.15	0.00	0.00	0.00	0.00	0.13	(0.01)	0.00	0.00	-0.01	0.11	0.07	0.17	0.18
Stem rust (X12)	-0.02	0.05	-0.03	0.00	0.10	0.00	0.00	-0.01	0.01	-0.10	0.00	(0.02)	0.00	0.01	-0.06	0.00	-0.07	-0.05
Germination % (X13)	0.01	-0.02	0.00	0.00	-0.13	0.00	0.00	-0.01	0.00	0.15	0.00	0.00	(0.00)	0.00	0.01	-0.05	-0.04	-0.04
Electrical conductivity (X14)	0.01	-0.01	0.01	0.00	-0.21	0.00	0.00	-0.01	-0.01	0.21	0.00	0.00	0.00	(-0.02)	0.13	0.09	0.22	0.20
Wet gluten (X15)	-0.02	0.07	-0.05	0.00	-0.10	0.00	0.00	0.00	-0.01	0.10	0.00	0.00	0.00	0.00	(0.72)	0.19	0.19	0.91**
Hydration % (X16)	0.00	-0.02	0.02	0.00	0.14	0.00	0.00	-0.01	0.00	-0.15	0.00	0.00	0.00	0.00	-0.31	(-0.44)	-0.32	-0.76**

Coefficient of determination = 0.99 and effect of residual variation = 0.024

Table 16. Regression coefficient (b), standard error (SE), t-value, and probability (P) in predicting wheat dry gluten by the stepwise procedure analysis

Step	Variable entered	b	SE	t-value	P
1	No. of kernels spike^{-1}	0.015	0.007	2.05	0.046
2	Wet gluten	0.407	0.010	40.60	0.000
3	Hydration %	-0.034	0.001	-24.99	0.000

Constant = 3.923, R^2 = 0.987, R^2 (adjusted) = 0,986

Table 17. Performance of the highest crosses for grain yield compared to the highest parents.

Crosses	Days to heading	Days to maturity	Plant height (cm)	No. of spikes plant^{-1}	No. of kernels spike^{-1}	100-kernel weight (g)	Grain yield plant^{-1} (g)	Yellow rust	Stem rust	Wet gluten %	Dry gluten %
Giza 171 × Misr 3	102.00	156.00	116.70	20.80	94.60	4.93	65.00	0.05	5.67	26.00	9.63
Line 1 × Line 3	103.00	154.30	113.30	22.10	82.30	4.71	60.00	0.28	5.67	21.10	7.73
Sakha 95 × Sids 12	99.30	150.00	111.70	17.80	85.20	4.54	59.90	9.33	7.33	27.50	10.93
Sakha 95 × Sids 14	104.00	153.70	118.30	26.40	84.90	4.50	59.30	1.60	11.67	29.80	11.67
Sids 12 × Misr 3	101.00	151.30	115.00	21.00	98.00	4.49	59.00	0.30	8.33	27.60	13.02
Giza 171 × Gemmeiza 12	103.00	155.70	118.30	20.70	85.50	4.58	58.70	2.40	6.67	22.70	8.61
Giza 171 × Line 2	102.30	156.30	113.30	20.90	89.40	4.75	58.60	0.17	6.67	19.40	9.57
Sakha 95 × Shandweel 1	102.70	154.30	111.70	20.70	96.60	4.82	58.00	0.80	2.87	23.20	6.10
Giza 171 × Sakha 95	101.00	151.70	116.70	21.30	86.80	4.95	57.80	1.60	11.67	27.40	11.50
Sakha 95 × Gemmeiza 12	102.30	152.00	113.30	21.30	93.30	4.37	57.40	0.05	2.53	30.10	14.14
Shandweel 1 × Misr 3	101.70	156.00	118.30	20.00	92.70	4.16	57.10	0.05	2.73	20.80	6.93
Sakha 95 × Line 3	102.30	151.70	118.30	20.60	84.60	4.92	56.50	0.30	15.00	26.90	9.70
Sd 14 × Line 3	107.30	158.30	116.70	20.50	85.90	4.48	56.50	4.00	4.67	15.20	5.48
Giza 171 × Sids 14	104.70	157.30	121.70	20.90	90.60	4.72	56.40	10.67	3.00	22.40	7.87

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التربية لبعض صفات المحصول وجودة الحبوب في قمح الخبز

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أجريت هذه الدراسة خلالي موسمي ٢٠١٦/٢٠١٥ و٢٠١٧/٢٠١٦ في محطة البحوث الزراعية بسخا. وقد استخدمت عشرة تراكيب وراثية من قمح الخبز (جيزة ١٧١، سخا ٩٥، جميزة ١٢، شندويل ١، سدس ١٢، سدس ١٤ ومصر ٣، سلالة ١، سلالة ٢ وسلالة ٣). وتم تقييم هذه الآباء العشرة مع هجنها الخمسة والأربعين باستخدام ستة عشرة من صفات المحصول وجودة الحبوب. وكانت مصادر التباين للتراكيب الوراثية، الآباء، الهجن، الآباء مقابل الهجن، والقدرة العامة والخاصة على التآلف معنوية لمعظم الصفات. وكانت النسبة بين القدرة العامة والخاصة على التآلف أكبر من الوحدة لكل الصفات مما يشير إلى أهمية كل من التأثرات الوراثية المضيفة وغير المضيفة في توارث الصفات المدروسة مع وجود أهمية أكبر للتأثيرات الوراثية المضيفة. وكان أفضل الآباء لمحصول حبوب النبات هي سخا ٩٥، سدس ١٤ وشندويل ١، ولمقاومة الصدأ الأصفر هي كل الآباء ما عدا سدس ١٢ وجيزة ١٧١، ولمقاومة الصدأ الأسود هي سلالة ١، ولمحتوى الجلوتين الجاف هي جميزة ١٢ وسدس ١٢. أما أحسن الآباء قدرة على التآلف فكانت سخا ٩٥، سدس ١٤، جيزة ١٧١، ومصر ٣ لمحصول حبوب النبات، جيزة ١٧١، سخا ٩٥، جميزة ١٢، وشندويل ١ لمحتوى الجلوتين الطري والجاف. وكان الارتباط موجبا ومعنويا بين محصول حبوب النبات وكل من معدل امتلاء الحبوب، طول النبات، عدد حبوب السنبلة، ووزن الحبة. كذلك كان الارتباط معنويا وموجبا بين محتوى الجلوتين الجاف ومحتوى الجلوتين الطري، وكان معنويا وسالبا بين محتوى الجلوتين الجاف والقدرة على الامتصاص. أظهر تحليل معامل المسار أن صفات فترة امتلاء الحبوب، محتوى الجلوتين الطري، عدد الأيام حتى النضج الفسيولوجي، وعدد الأيام حتى طرد السنابل كانت أعلى الصفات في التأثير المباشر الموجب على محصول حبوب النبات. وعلى الجانب الآخر كانت صفات القدرة على الامتصاص وعدد الأيام حتى التزهير هي الأعلى في التأثير المباشر السالب على محصول حبوب النبات. بينما كانت صفات محتوى الجلوتين الطري ومعدل امتلاء الحبوب وعدد الأيام حتى النضج الفسيولوجي هي الأعلى في التأثير المباشر والموجب على محتوى الجلوتين الجاف. في حين كانت صفة القدرة على الامتصاص وعدد الأيام حتى التزهير هي الأعلى في التأثير المباشر السالب على محتوى الجلوتين الجاف. وباستخدام تحليل الانحدار المتدرج، كانت صفات عدد الأيام حتى طرد السنابل، وفترة ومعدل امتلاء الحبوب، وزن الحبة، مقاومة الصدأ الأصفر، والتوصيل الكهربائي كانت الأكثر مساهمة في محصول حبوب النبات. بينما كانت صفات عدد حبوب السنبلة، محتوى الجلوتين الطري والقدرة على الامتصاص الأكثر مساهمة في محتوى الجلوتين الجاف. كانت هجن جيزة ١٧١ × مصر ٣، سلالة ١ × سلالة ٣، سدس ١٢ × مصر ٣، جيزة ١٧١ × سلالة ٢، سخا ٩٥ × شندويل ١، سخا ٩٥ × جميزة ١٢، وشندويل ١ × مصر ٣ ذات قدرة محصولية عالية ومقاومة للصدأ الأصفر ومتوسطة الحساسية للصدأ الأسود، وبالتالي من المتوقع أن تكون جيدة في برامج تربية القمح. بينما الهجينان سخا ٩٥ × جميزة ١٢، وسدس ١٢ × مصر ٣ هما الأفضل بالنسبة لمحتوى الجلوتين الجاف ويتوقع أن تكون مبشرة في التربية لجودة حبوب القمح.