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Improvement of Yield, Rust Resistance and Grain Quality Characters in Bread Wheat Cross Sids 12 X Misr 3

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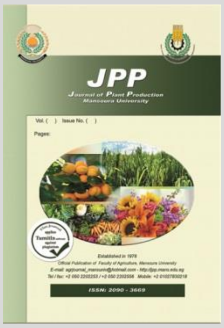

ABSTRACT

Bread wheat cross Sids 12 x Misr 3 was studied in F_1, F_2, F_3 and F_4 generations to develop promising genotypes for improvement of grain yield, rust resistance and grain quality. The two parents differed significantly for most characters under study showing sufficient variability in F_2 and F_3 generations to calculate the genetic parameters. The genetic variances indicated important role coupled with moderate to high broad sense heritability for most studied characters in F_2 and F_3 generations. Both grain filling rate and number of spikes m^{-2} were the most important characters in selection for high grain yield in F_3 generation. Rust resistance in the two parents was controlled by one dominant gene for yellow rust, two dominant genes for leaf rust and two complementary dominant genes for stem rust. Thirty-seven families out of 100 families were superior for grain yield, but the susceptibility of the three rusts eliminated 17 families and only 20 families were resistant or moderately resistant to the three rusts. Five out of the selected 20 families had good grain quality characteristics. In F_4 generation, five wheat plants characterized by an adequate resistance to the three rusts and good agronomic characters were selected for further evaluation as F_5 lines.

Keywords: wheat, *Triticum aestivum* L., breeding, rust resistance, grain quality, selection, genetic variance

INTRODUCTION

Wheat is the primary food crop in Egypt in respect to its area and consumption and the gap between wheat production and consumption is a chief economy challenge in Egypt. Developing high yielding wheat cultivars is the main objective of any wheat breeding program to achieve food security facing challenges like stress conditions (Zampieri *et al*., 2017 and Hatfield and Dold, 2018).

The three rusts, stripe, leaf and stem, caused by *Puccinia graminis* f. sp. *tritici*, *P. triticina* and *P. striiformis* f. sp. *tritici*, respectively, are the main cause of yield losses in wheat production worldwide, therefore these had high consideration in wheat breeding programs (Singh *et al*., 2011). Breeding for rust resistance in wheat is the most effective economical and environmentally safe strategy for controlling rust diseases of wheat (Aglan *et al*., 2020).

In most developing countries, the grain quality has not been a strong criterion for variety selection. However, the Egyptian farmers are critically looking for high-quality varieties suited for the preparation of a range of end products from wheat. However, Tadesse *et al*. (2017) revealed that because of the negative correlation between yield and quality traits, it may be difficult to combine high-yield potential with high grain quality. In light of this, it is important to develop new cultivars with good grain quality traits and high productivity.

Correlation and path coefficient analysis help to improve selection efficiency in breeding programs based on trait selection (Kandel *et al*., 2017). Previous researchers have already quantified associations between yield and yield component characters (Baye *et al*., 2020; Khanala *et al*., 2020).

The present study aimed to (1) investigate the inheritance of some agronomic, rust resistance and grain quality traits in F_2, F_3 and F_4 generations of wheat cross Sids 12 x Misr 3, (2) select new promising bread wheat genotypes with high yield potential, resistant to the three rust diseases and better grain quality, (3) investigate the inheritance of the three wheat rusts in F_2 and F_3 populations and (4) find out the most contributing characters in grain yield improvement.

MATERIALS AND METHODS

The two Egyptian wheat cultivars Sids 12 and Misr 3 (Table1) and their F_1, F_2, F_3 and F_4 generations were studied from 2015/16 to 2019/20 seasons on the Experimental Farm of Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt (31° 5' 12" North, 30° 56' 49" East). In addition, the grain quality studies were performed in the Lab of Seed Technology Res. Sec. of Sakha Agricultural Research Station.

Table 1. Name, pedigree and selection history of Sids 12 and Misr 3 cultivars.

Genotype	Pedigree	Selection history
Sids 12	BUC//7C/ALD/5/MAYA74/ON //1160.147/3/BB/GLL/4/CHAT" S"/6/MAYA/VUL//CMH74A.6 30/4*SX	SD7096-4SD-1SD-1SD-0SD
Misr 3	ATTILA*2/PBW65*2 /KACHU	CMSS06Y00582T-099TOPM-099Y-099ZTM-099Y-099M-10WGY-0B-0EGY

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The two parents were crossed in 2015/16. The F_1 cross was planted in 2016/17 to obtain F_2 seeds. The F_2 plants were planted in 2017/18 and 100 plants were randomly selected to advance to F_3 generation. The F_2 (200 plants) and its F_1 (50 plants) and the two parents (50 plants) were planted on 20 November, 2018/19 and the plants were spaced in rows 30 cm apart and 10 cm among plants within rows. Meantime, 100 F_3 families were evaluated with their parents as checks and repeated three times in RCBD design. The F_3 families and their parents were represented by one row of 1.75 m long and 30 apart and 5 cm among plants within rows. In the growing season i.e. 2019/20, the selected F_3 families were advanced to the F_4 and the bulk of each family was grown in one row 24 m long, 30 cm apart and 5 cm within row for visual selection.

The plants were surrounded by mixture of highly susceptible wheat genotypes to yellow, leaf and stem rusts.

The average of maximum and minimum temperatures and relative humidity % were 23.4 and 17.8 °C and 68.7 % in 2018/19 and 23.9 and 17.5 °C and 67 % in 2019/20 growing seasons, respectively.

Data were recorded on single plants for the parents and their F_1 and F_2 and on row means for F_3 families and their checks. The estimated traits in F_2 and F_3 were number of days to heading and maturity, grain filling period (day), grain filling rate (g day^{-1} plant^{-1} but g day^{-1} m^{-2} in F_3), plant height (cm), no. spikes plant^{-1} (but no. spikes m^{-2} in F_3), 100-kernel weight (g) (but 1000-kernel in F_3), grain yield plant^{-1} (but grain yield m^{-2} in F_3) (g) and yellow, leaf and stem rust resistance.

The reaction of the three rusts were recorded at heading and anthesis plant stage under field conditions, and clustered to resistant (R), moderately resistant (MR), moderately susceptible (MS) and susceptible (S) and disease severity % was assessed according to Stakman *et al.* (1962). Wheat plants with infection types of O, R, and MR were considered as resistant, while MS and S as susceptible (Stakman *et al.*, 1962). After that the significance of the deviation of observed from expected ratios was detected by Chi-square test (χ^2) (Steel *et al.*, 1997). In addition, the F_3 families were clustered to homozygous resistant and susceptible and segregant ones.

Quality characters were assessed only for the selected F_3 families using seed samples taken randomly in bulk and the crude protein (AOAC, 1990), wet and dry gluten percentage (Pleshkov, 1976) and hydration capacity percentage of gluten were estimated as [wet gluten – dry gluten] × 100 / dry gluten.

The t-test was used to test the significance of parents differences. The phenotypic, genotypic and environmental variances were calculated from parents and their F_1 and F_2 plants data (Acquaah, 2012). The significance of the differences between F_2 variance and the parallel environmental variance was tested by F ratio. Broad sense heritability (H^2 %) was calculated as reported by Acquaah (2012). The statistical analysis were performed using the statistical routines available in Microsoft EXCEL (2016).

The evaluated 100 F_3 families plus their checks were analyzed as in Steel *et al.* (1997) and differences between means of genotypes were tested with LSD at 5% level of probability. The variance components were estimated using the expected mean squares as stated by Acquaah (2012). Simple correlation was computed for the F_3 families according to Steel *et al.* (1997). Path coefficient analysis was carried out using phenotypic correlation coefficients and grain yield was kept as effects, while the other studied characters kept as cause. Direct and indirect effects of the studied characters on grain yield were achieved according to Dewey and Lu (1959) using the Genes software (Cruz, 2016). Stepwise regression was calculated according to Draper and Smith (1981) using Minitab (2020) 19 software to detect the most important traits (independent variables) significantly contributed to grain yield (dependent variable) characters. Recommended cultural practices for wheat cultivation in delta region (old land) in Egypt were applied at the proper time. The preceding crop was maize in all studied seasons.

RESULTS AND DISCUSSION

Farhat and Mohamed (2018) studied ten parents including Sids 12 and Misr 3 and their forty-five F_1 hybrids. They found that Sids 12 and Misr 3 were divergent for earliness, grain yield and its components, grain quality and yellow, leaf and stem rusts resistance characters. Moreover, they indicated that F_1 cross of Sids 12 × Misr 3 had high yield potentiality and was resistant to yellow rust and moderately susceptible to stem rust, also was one of the best crosses for dry gluten, then they expected this cross will be favorable for rusts resistance and grain quality in wheat breeding programs.

F_2 generation

Data in Table 2 illustrate the descriptive statistics of the studied characters for the two parents, F_1 and F_2 populations. The two cultivars differed significantly (P <0.01 or 0.05) for all characters, except for leaf rust and revealed different genetic background, supporting the results of Farhat and Mohamed (2018). The cultivar Sids 12 surpassed the cultivar Misr 3 for grain filling period, no. kernels spike^{-1}, 100-kernel weight and yellow and stem rusts, while Misr 3 had higher values for other traits.

The means of F_1 values exceeded or was near to the equivalent high parent's values for days to heading and maturity, plant height, number of spikes plant^{-1}, no. kernels spike^{-1}, 100-kernel weight and grain yield plant^{-1}. Furthermore, the means of the F_1 values were lower than or close to the equivalent to lowest parent mean estimates for grain filling period and rate and yellow and stem rusts. The F_1 and its two parents had very close values for leaf rust.

The means of F_2 exceeded the means of the two parents for days to maturity, grain filling period, plant height and leaf and stem rust. Further, the means of the F_2 values were lower than or close to the correspondent lowest parent mean values for grain filling rate, number of spikes plant^{-1}, no. kernels spike^{-1}, 100-kernel weight and yellow rust. Meanwhile, the F_2 means exhibited intermediate scores between the two parents for days to heading and grain yield plant^{-1}. Moreover, the ranges of the F_2 values went out the means of the two cultivars Sids 12 and Misr 3 for the studied characters. These results indicate that there was sufficient variability in F_2 generations permitting to calculate the genetic parameters. Similar findings were found by Darwish *et al.* (2018b) and Aglan *et al.* (2020).

Table 2. Descriptive statistics of the studied characters for the two cultivar Sids 12 and Misr 3 and their F_1 and F_2 populations in 2018/19 season.

Parent/generation		Days to heading	Days to maturity	Grain filling period (days)	Grain filling rate (g day^{-1})plant^{-1}	Plant height (cm)	No. spikes plant^{-1}
Sids 12	Mean	102.9	150.9	48.2	0.63	97.2	10.1
	SE	0.34	0.15	0.19	0.03	0.62	0.3
	Variance	5.77	1.15	1.82	0.03	19.4	4.53
Misr 3	Mean	104.6	152.4	47.4	0.94	101.94	19.7
	SE	0.41	0.24	0.34	0.04	0.55	0.78
	Variance	8.24	2.88	5.89	0.08	15.1	30.13
Parents mean		103.8	151.6	47.8	0.79	99.6	14.9
t test		**	**	*	**	**	**
F_1	Mean	105.2	151	46.1	0.77	105.8	10.2
	SE	0.24	0.13	0.23	0.03	0.7	0.53
	Variance	2.88	0.8	2.69	0.03	24.17	13.79
F_2	Mean	103.6	152.4	48.8	0.76	101.6	13.5
	SE	0.26	0.19	0.16	0.03	1.28	0.46
	Min	94	148	43	0.38	60	5
	Max	112	158	57	2.07	140	30

Table 2. cont.

Parent/ generation		No. kernels spike^{-1}	100-kernel weight (g)	Grain yield plant^{-1} (g)	Yellow rust	Leaf rust	Stem rust
Sids 12	Mean	89.3	4.6	29.5	22.58	1.01	4.52
	SE	1.3	0.08	1.26	0.36	0.03	0.07
	Variance	84.2	0.33	79.79	6.45	0.04	0.26
Misr 3	Mean	74.7	4.24	45.1	0.05	1	1
	SE	0.61	0.05	1.99	0	0.03	0.03
	Variance	18.88	0.15	198.77	0	0.04	0.04
Parents mean		82	4.42	37.3	11.32	1	2.76
t test		**	**	**	**	ns	**
F_1	Mean	91.9	4.69	38.1	0.43	1	0.6
	SE	2.22	0.03	1.62	0.06	0.03	0.03
	Variance	245.5	0.05	130.54	0.15	0.04	0.04
F_2	Mean	62.4	4.28	37.1	7.48	2.61	3.61
	SE	1.49	0.05	1.27	1.09	0.75	0.76
	Min	33	2.65	19	0.05	0.05	0.05
	Max	113.3	6.09	96	80	80	80

*** and ** and ns = significant at 0.05, 0.01 levels of probability (ns) = no significant, respectively.**

Some genetic parameters for the two parents, F_1 and F_2 in the two seasons are shown in Table 3. The phenotypic variances in the F_2 generation differed significantly ($P < 0.01$ or 0.05) from the corresponding environmental variances for all characters. In addition, the highest phenotypic, genotypic and environmental variances were detected for plant height, number of spikes plant^{-1}, no. kernels spike^{-1}, grain yield plant^{-1} and yellow, leaf and stem rusts. Furthermore, the genetic variance exceeded the corresponding environmental variances for all studied characters, except for grain filling period. Moreover, all characters showed moderate to high values of broad sense heritability and ranged from 32.92 for grain filling period to 99.96 for leaf rust. The important role of the genetic variances compared to the phenotypic ones and the moderate to high broad sense heritabilities for most studied characters indicate the effectiveness of selection in the early generations and that modified pedigree/bulk and selected bulk are recommended methods in this cross (Abdelkhalik, 2019). These results are generally in line with those of Ali, (2017); Darwish *et al.* (2018b) and Aglan *et al.* (2020).

F_3 generation

The variance analysis of the studied characters for F_3 families are presented in Table 4. Variations among F_3 families for all the studied characters were found to be significant ($P < 0.05$ or 0.01). These results indicate sufficient genetic variability to estimate various genetic parameters. Similar findings were recorded by Aglan and Farhat (2014); Darwish *et al.*, (2018a) and Aglan *et al.* (2020). The two parents differed significantly for all characters, except for grain filling period and 1000-kernel weight. The coefficients of variations were in the range of 1.5 % for days to maturity and 12.9 % for no. kernels spike^{-1}.

Table 3. Phenotypic (σ_P^2), genotypic (σ_g^2) and environmental (σ_E^2) variances and broad sense heritability (H^2) for the studied characters in Sids 12 x Misr 3 F_2 population.

Character	σ_P^2	σ_E^2	σ_g^2	H^2
Days to heading	13.94**	5.63	8.31	59.62
Days to maturity	7.29**	1.61	5.68	77.89
Grain filling period	5.17*	3.47	1.7	32.92
Grain filling rate	0.14**	0.05	0.09	64.15
Plant height	326.47**	19.58	306.9	94.0.
No. spikes plant^{-1}	42.28**	16.15	26.13	61.8
No. kernels spike^{-1}	446.54**	116.18	330.36	73.98
100 kernel weight	0.56**	0.18	0.38	68.39
Grain yield plant^{-1}	322.22**	136.37	185.85	57.68
Yellow rust	238.93**	2.2	236.73	99.08
Leaf rust	113.53**	0.04	113.49	99.96
Stem rust	116.49**	0.11	116.38	99.90

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

Table 4. Mean squares of the studied characters for the 100 F_3 families and their two parents Sids 12 and Misr 3 as checks.

SOV	df	Days to heading	Days to maturity	Grain filling period	Grain filling rate	Plant height	Number of spikes plant^{-1}	Number of kernels spike^{-1}	1000-kernel weight	Grain yield m^{-2}
Replication	2	53.95**	4.0	31.53**	5.93	102.04*	440.84	20.32	0.56**	0.002
Genotypes	101	39.35**	16.97**	13.52**	48.65**	423.54**	18597.43**	263.89**	1.05**	0.1**
Families	99	40.02**	17.21**	13.75**	47.73**	425.99**	17871.85**	222.69**	1.02**	0.097**
Check	1	10.67*	8.17*	0.17	85.14**	266.67*	32266.67**	204.17*	0.20	0.194**
Families vs Check	1	0.76	1.74	4.8*	103.89	338.28	76760.32	4402.49	4.98	0.283
Error	202	5.62	5.08	6.34	2.34	28.78	2721.01	32.18	0.12	0.004
Total	305									
CV		2.3	1.5	5.3	11.8	4.8	12.9	9.6	8.5	10.6

Table 5 presents some descriptive statistics and variance components for the studied characters in the F_3 families during 2018/19 season. Compared to Misr 3, and Sids 12, F_3 families had lower values for days to heading and maturity, plant height, grain filling rate, no. spikes m^{-2} and grain yield m^{-2}, while had higher values for grain filling period, no. kernels spike^{-1} and 1000-kernel weight.

The maximum values of the F_3 families transgress their two parents for all studied characters, except for no. spikes m^{-2} and grain yield m^{-2}, in which the maximum values of F_3 families were close to its high parent (Misr 3). These results indicate the presence of transgressive segregation and enable to select the best families with the improved characters. Genotypic variances were higher than environmental variances for all characters, except for days to maturity and grain filling period. Moderate to high broad sense heritabilities were detected for all characters, except for grain filling period, indicating the possibility to improve these characters. Estimation of variance components in the segregating generations has been considered in many investigations to select the promising genotypes. In several studies, the estimated broad sense heritability was medium to high (Darwish et al., 2018a; Fellahi et al., 2018; Gaur, 2019 and Aglan et al., 2020).

Table 5. Some descriptive statistics and variance components for the studied characters for the 100 F_3 families and their two parents.

Parameter	Days to heading	Days to maturity	Grain filling period (days)	Grain filling rate (g days^{-1} m^{-2})	Plant height (cm)	Number of spikes plant^{-1}	Number of kernels spke^{-1}	100- kernel weight (g)	Grain yield (kg m^{-2})
Minimum	95.7	146.3	43.3	4.71	71.7	200.0	37.0	2.38	0.224
Maximum	116.7	161.7	51.7	24.03	133.3	550.0	84.9	5.62	1.044
Families man	103.7	151.3	47.6	12.91	110.9	402.4	58.5	4.00	0.611
Sids 12	102.0	150.7	48.7	13.35	96.7	443.3	91.7	5.10	0.650
Misr 3	104.7	153.0	48.3	20.88	110.0	590.0	80.0	4.73	1.010
Parents mean	103.3	151.8	48.5	17.12	103.3	516.7	85.8	4.92	0.830
σ^2_p	17.11	9.14	8.90	17.47	161.41	7786.97	95.52	0.42	0.035
σ^2_g	11.46	4.03	2.43	15.13	132.29	5042.44	63.59	0.30	0.031
σ^2_e	5.65	5.11	6.47	2.34	29.12	2744.53	31.93	0.11	0.004
H^2	66.95	44.14	27.26	86.62	81.96	64.75	66.57	72.57	87.96

σ^2_p = Phenotypic variance, σ^2_g = Genetic variance, σ^2_e = Environmental variance and H^2 = broad sense heritability.

The priorities of Egyptian wheat breeding program are high grain yield, rusts resistance, and tolerance to abiotic stresses such as drought and heat. To encounter the needs of farmers, it is critical to breed for grain quality. In many breeding programs, quality characters are assessed in late stages due to expensive coast and the large amount of needed grains. It can be concluded from Farhat and Mohamed (2018) results that the parent Misr 3 is a new Egyptian cultivar characterized by high yield potentiality and rusts resistance, but it does not meet the preferences of Egyptian farmers in grain quality attributes. To breed for quality traits, one of the parents must be of high standard of quality, so Sids 12 was chosen to improve the grain quality in this cross.

Table 6 illustrate the means of the selected families for the agronomic and grain quality characters. The means of F_3 families were compared to the two parents as checks using LSD, and as a result, 37 F_3 families (20 %) were not significantly different from the cultivar Sids 12. Out of 37 families, only 20 families were resistant or moderately resistant to the three rusts. From the twenty selected families, five families were close to or higher than the best parent for quality characters. The best families for the grain quality were No. 2, 81, 51, 98 and 23 that gave the highest protein content of 12.8, 14.5 and 12.9, 13.2 and 13.8 %, the highest dry gluten of 10.8, 11.5, 10.7, 10.3 and 11.8 % at the same time had high relative hydration of 142.1, 136.5, 108.8, 94.9 and 105.1 %, respectively.

The minimum values of the selected families were lower than the lowest parent for all characters, except for plant height and grain yield. In addition, the maximum values of the selected families were higher than the highest parent for all characters, except for number of spikes m^{-2}, number of kernels spke^{-1} and dry gluten.

Table 6. Means of the selected families and the two parents as checks for the agronomic and grain quality characters.

Family No.	DH	DM	GFP	GFR	PH	SM
36	102.3	149.7	47.3	22.2	125.0	536.0
4	105.0	153.7	48.7	16.4	111.7	528.7
2	105.3	151.3	46.0	8.4	120.0	248.0
81	101.0	149.0	48.0	11.9	113.3	413.3
6	105.3	152.7	47.3	19.6	111.7	518.7
86	105.7	152.3	46.7	10.2	113.3	377.3
58	103.7	151.3	47.7	17.9	103.3	486.7
56	106.0	150.0	44.0	18.8	125.0	430.7
25	110.0	153.7	43.7	18.9	110.0	473.3
51	106.3	152.0	45.7	16.4	110.0	426.7
60	97.7	149.3	51.7	14.5	110.0	476.0
96	106.7	153.0	46.3	16.3	115.0	497.3
98	107.3	151.7	44.3	15.5	118.3	473.3
23	105.7	154.7	49.0	13.5	120.0	344.0
41	102.0	150.3	48.3	15.1	116.7	410.7
40	109.7	153.7	44.0	15.6	116.7	413.3
82	104.3	152.0	47.7	14.5	110.0	460.0
89	101.3	148.0	46.7	14.3	106.7	412.0
63	103.7	149.3	45.7	15.0	110.0	424.0
68	105.3	148.7	43.3	15.7	126.7	400.0
Mean	104.7	151.3	46.6	15.5	114.7	437.5
Min	97.7	148.0	43.3	8.4	103.3	248.0
Max	110.0	154.7	51.7	22.2	126.7	536.0
Sids 12	102.0	150.7	48.7	13.4	96.7	443.3
Misr 3	104.7	153.0	48.3	20.9	110.0	590.0
LSD0.05	3.8	3.6	4.1	4.1	8.6	84.0

Table 6. Cont.

Family No.	KS	KW	GY	WG	DG	RH	PR
36	66.1	4.6	1044.3	20.7	8.3	149.9	11.10
4	58.1	3.6	963.8	20.7	8.3	149.9	11.10
2	56.0	3.8	956.9	24.2	10.8	124.1	12.80
81	45.0	3.2	916.1	27.2	11.5	136.5	14.50
6	71.7	4.3	906.5	19.5	6.4	204.2	10.10
86	70.1	4.1	855.5	19.2	7.8	146.2	11.40
58	62.6	5.5	833.1	19.5	6.4	204.2	10.10
56	60.5	4.6	824.9	16.8	5.6	200.0	8.10
25	70.5	3.8	800.6	25.9	8.9	189.7	9.20
51	68.8	4.1	796.5	22.4	10.7	108.8	12.90
60	59.7	4.5	785.2	18.5	6.9	167.4	10.50
96	66.3	4.3	776.7	20.1	6.7	201.8	9.70
98	64.9	3.9	773.3	20.1	10.3	94.9	13.20
23	50.7	4.2	770.0	24.2	11.8	105.1	13.80
41	62.8	4.5	766.7	22.4	7.8	187.2	11.20
40	47.3	4.1	763.3	17.6	7.2	144.4	10.40
82	71.9	4.5	762.5	15.4	8.8	75.0	10.70
89	58.3	4.4	761.8	20.8	7.6	173.7	11.00
63	59.4	4.8	696.7	18.5	6.9	167.4	10.50
68	54.6	4.1	696.7	15.9	6.1	158.9	8.90
Mean	61.3	4.2	822.6	20.5	8.2	154.5	11.06
Min	45.0	3.2	696.7	15.4	5.6	75.0	8.10
Max	71.9	5.5	1044.3	27.2	11.8	204.2	14.50
Sids 12	91.7	5.1	650.0	25.2	11.4	121.1	12.80
Misr 3	80.0	4.7	1010.0	19.6	8.4	133.1	12.20
LSD0.05	9.1	0.6	101.2	-	-	-	-

DH = days to heading, DM = days to maturity, GFP = grain filling period (days), GFR = grain filling period (g days^{-1} m^{-2}), PH = plant height (cm), SM = number of spikes m^{-2}, KS = number of kernels spke^{-1}, KW = 1000-kernel weight (g), GY = grain yield (kg m^{-2}), WG = wet gluten %, DG = dry gluten %, RH = relative hydration % and PR = Protein %.

Table 7 presents the simple correlations and path analysis coefficients for the studied eight characters on grain yield m^{-2} in F_3 families. The grain yield m^{-2} had significant and positive values of correlation coefficients with each of grain filling rate, plant height, number of spikes m^{-2}, number of kernels spike^{-1} and 1000-kernel weight.

Knowledge on the genetic variability and correlation of agronomic traits with grain yield are useful for effective selection. In this respect, Aglan *et al*. (2020) obtained significant positive correlation estimates between grain yield and grain filling rate as well as yield components for F_3 families in the cross Giza171 x Sids 12. Aisawi *et al*. (2015) and Gerard *et al*. (2020) reported that the grain yield progress in CIMMYT material was mainly associated with increased grain weight, days to maturity and grain filling period.

Beside correlation, it is necessary to use a method considering the causal relationship between the variables and the degree of this relationship. In the path analysis, the correlations between grain yield m^{-2} on one hand and the eight characters on the other hand, have been divided into direct and indirect effects. The highest positive direct effect on grain yield m^{-2} was belonged to grain filling rate (1.04), followed by days to heading (0.87), then grain filling period (0.65), indicating that small increase in grain filling rate, days to heading and grain filling period may directly contribute in grain yield. On contrary, the highest negative direct effect was detected by days to maturity (-0.57). The direct effect of grain filling rate on grain yield m^{-2} (1.04) explained the total correlation between them (r = 0.99), indicating that small decrease in days to maturity may directly contribute to grain yield improvement. The correlation coefficient is positive, but the direct effect is negative or negligible for grain filling period, plant height, number of spikes m^{-2} and number of kernels spike^{-1}, displaying the true relationship and that the direct selection through grain filling rate will be effective for grain yield. In addition, correlation coefficients were negative or negligible but the direct effect is positive and high for days to heading and maturity. Residual effects with 0.042 indicated that the studied eight characters account for about 95.68 % of the variability in the grain yield. In previous studies, major portion of total variability in grain yield was owing to characters such as spikes number, grain number and weight (Farhat and Mohamed, 2018 and Rajput, 2019); grain-filling period and plant height (Mecha *et al*., 2017; Sabit *et al*., 2017 and Baye *et al*., 2020). Moreover, negative direct effect of days to maturity on grain yield was also reported (Dabi *et al*., 2016; Mecha *et al*., 2017; Sabit *et al*., 2017; Rajput, 2019; Baye *et al*., 2020 and Khanala *et al*., 2020).

Table 7. Simple correlation coefficients (r), direct (in diagonal within bracts), indirect effects and total indirect effects (T) for the estimated eight characters on grain yield plant^{-1} in 100 F_3 families for the cross Sids 12 x Misr 3.

Characters	X1	X2	X3	X4	X5	X6	X7	X8	T	r
Days to heading (X1)	(0.87)	-0.47	-0.51	0.23	0.00	0.00	0.00	0.00	0.13	0.13
Days to maturity (X2)	0.72	(-0.57)	-0.19	0.05	0.00	0.00	0.00	0.00	0.01	0.01
Grain filling period (X3)	-0.68	0.17	(0.65)	-0.35	0.00	0.00	0.00	0.00	-0.20	-0.20
Grain filling rate (X4)	0.20	-0.03	-0.22	(1.04)	0.00	0.00	0.00	0.00	0.99	0.99**
Plant height (X5)	-0.32	0.28	0.05	0.25	(-0.01)	0.00	0.00	0.00	0.25	0.25*
Number of spikes m^{-2} (X6)	0.11	-0.04	-0.09	0.77	0.00	(-0.01)	0.00	0.00	0.75	0.75**
Number of kernels spike^{-1} (X7)	-0.12	0.12	-0.01	0.30	0.00	0.00	(-0.01)	0.00	0.30	0.30**
100-kernel weight (X8)	-0.17	0.16	0.02	0.31	0.00	0.00	0.00	(0.01)	0.31	0.31**

Coefficient of determination = 0.99 and effect of residual variation = 0.042

Grain yield is a complex trait that is results from numerous related characteristics. Stepwise regression analysis aimed to eliminate non-effective traits in regression model on grain yield (Table 8). Grain yield m^{-2} was used as dependent variable and other traits were used as independent. Days to heading (DH) and maturity (DM), grain filling period (GFP) and rate (GFR), plant height (PH) and number of spikes m^{-2} (SM) with R^2 = 99.6%, had justified the maximum of grain yield m^{-2} changes. The other characters were excluded from the model for their low relative contributions. Based on the final step of stepwise regression analyses, the equation for prediction of grain yield m^{-2} will be:

$$\mathbf{GY = -6.45 - 7.16\ DH + 4.09\ DM + 3.56\ GFP + 46.505\ GFR - 0.396\ PH + 0.04\ SM.}$$

Farhat and Mohamed (2018) found similar results for grain filling period and rate and different results for days to heading in F_1 crosses. Al-Ashkar *et al*. (2020) used multivariate analysis (stepwise regression and path coefficient) and suggested that grain filling rate, 100-kernel weight, days to maturity, and number of kernels per spike had the highest influence on grain yield.

Table 8. 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	-7.16	1.26	-5.69	0.00
2	Days to maturity	4.09	1.21	3.39	0.00
3	Grain filling period	3.56	1.33	2.68	0.01
4	Grain filling rate	46.505	0.471	98.65	0.00
5	Plant height	-0.396	0.101	-3.91	0.00
6	Number of spikes m^{-2}	0.0338	0.0232	1.46	0.15

Constant = -6.45, R^2 = 0.996, R^2 (adjusted) = 0.996

Inheritance of rust resistance

Distribution and chi square (χ^2) estimates of F_2 and F_3 populations for the disease reaction of the three rusts under field conditions are displayed in Table 9. For yellow rust, the parent Misr 3 was resistant, while the parent Sids 12 was susceptible and the F_1 plants showed the dominance of resistance over susceptibility. F_2 generation segregated to a 3 resistant: 1 susceptible. The families in F_3 generations segregated to the ratio of 1 homozygous resistant: 2 segregating: 1 homozygous susceptible. These results indicate that the yellow rust resistance in the two parents was a simple inherited trait that controlled by one dominant gene.

Regarding leaf rust, the two parents and their F_1 were resistant against this rust pathogen. In addition, the segregation in F_2 and F_3 was fit to the ratio of 13 (resistant) : 3 (susceptible) and 8 homozygous resistant : 7 segregating : 1 homozygous susceptible ratio, respectively.

Therefore, resistance to leaf rust in the two parents under study i.e. Sids 12 and Misr 3 were controlled by two dominant genes.

In addition, the two parents i.e. Misr 3 and Sids 12 as well as F_1 plants showed stem rust resistance reaction under field conditions (Table 9). However, wheat plants in F_2 generation were fitted to the ratio of 15 (resistant) : 1 (susceptible). In addition, the families in F_3 generation segregated to the ratio of 8 homozygous resistant : 7 segregating : 1 homozygous susceptible . These results suggest that stem rust resistance in the two parents under study for stem rust is controlled by two complementary dominant genes.

Table 9. Segregation and chi square (χ2) analysis of F_2 wheat plants (200 plants), F_3 (100 families) from Sids 12 x Misr 3 cross in addition to the two parents and their F_1 reaction to yellow, leaf and stem rusts under field condition.

Rust disease	Parents/generations	R or HR	Seg	S or HS	% R or HR	% S	% S or HS	Expected ratio	χ2	P value
	Sids 12	0	-	50	0.0	-	100.0			
	Misr 3	50	-	0	100.0	-	0.0			
Yellow rust	F_1	50	-	0	100.0	-	0.0			
	F_2	146	-	54	72.81	-	27.19	3:1	0.29	0.59
	F_3	16	51	33	16.00	51.00	33.00	1 : 2 : 1	5.82	0.05
	Sids 12	50	-	0	100	-	0			
	Misr 3	50	-	0	100	-	0			
Leaf rust	F_1	50	-	0	100	-	0			
	F_2	175	-	25	87.72	-	12.28	13:3	3.13	0.08
	F_3	47	42	11	47.00	42.00	11.00	7 : 8 : 1	5.13	0.08
	Sids 12	0	-	50	0	-	100			
	Misr 3	50	-	0	100	-	0			
Stem rust	F_1	50	-	0	100	-	0			
	F_2	182	-	18	90.91	-	9.09	15:1	1.52	0.22
	F_3	52	42	6	52	42	6	7 : 8 : 1	2.85	0.24

R = number of resistant plants, HR = homogenous resistant families, Seg = number of segregant families, S = number of susceptible plants and HS = homogenous susceptible families

In this respect, Elkot *et al* (2020) used SSR markers linked to stem rust resistance genes and reported in their study the presence of stem rust resistance gene Sr2 in the new wheat cultivar Misr 3. However, this gene (Sr2 complex) was found to be effective and widespread against the local *Pgt* population in Egypt and are not prone to infection by the aggressive stem rust race Ug99 and its variants (Rahmatov *et al*., 2019). Therefore, it is of high importance to broaden the genetic basis in the future wheat varieties by pyramiding multiple stem rust resistance genes, especially those effective against local *Pgt* races. In addition, El-Orabey *et al*. (2019) previously reported that wheat cultivar Misr 3 is found to be highly resistant to the three rusts i. e. leaf, stem and yellow in 2016-2019 growing seasons.

F_4 generation

The twenty selected F_3 families in 2018/19 growing season were retained and advanced to the F_4 generation in season 2019/20. Visual selection was carried out on the individual plants and those showing acceptable and adequate levels of yellow, leaf and stem rust resistance and good agronomic features were retained for harvest. Only five plants fulfilled the above selection requirements of the wheat breeding program at the trial location, including two plants from families no. 36 and one plant from family no. 40, 96 and 98. The five selected plants will be evaluated as F_5 lines in the next season and then follow the previous selection process.

In this respect, Aglan *et al*. (2020) used Giza171 × Sids 12 hybrid and selected thirteen promising families with high yield potential and high levels of resistance to the three wheat rusts. Also, five of them were preferable for grain quality. Considering the effective characters like grain yield and rusts resistance to select the superior plants or families was achieved in some earlier research like Laala *et al*. (2017) and Darwish *et al*. (2018a and b).

CONCLUSION

Cross Sids 12 x Misr 3 is a promising one for wheat breeders to select for important purposes like high grain yield, an adequate level of rust resistance and preferable grain quality. The most important characters contributing in grain yield improvement in F_3 generation were grain filling rate and number of spikes m^{-2}, while the grain yield components had its effect on grain yield through the indirect effect of grain filling rate. The cultivar Misr 3 beside it's high yield potential is also considered to be an important source of resistance to the three wheat rusts.

After visual selection in the F_4 generation, there was expected five promising lines in the F_5 generation characterized with high yield potentiality, an acceptable levels of resistance to the three rust diseases and were preferable for grain quality.

REFFERENCES

Abdelkhalik, S. A. M. (2019). Assessment of some genetic parameters for yield and its components in four bread wheat crosses using six parameter model. Egypt. J. Plant Breed., 23 (5): 719-36.

Acquaah, G. (2012). Principles of plant genetics and breeding. 2nd ed. John Wiley & Sons.

Aglan, M. A. A. and W. Z. E. Farhat (2014). Genetic studies on some earliness and agronomic characters in advanced generations in bread wheat. International Journal of Plant & Soil Science, 3 (6): 790-98.

Aglan, M. A.; Eman N. M. Mohamed and A. A. Shahin (2020). Selection for yield, rust resistance and quality traits in early generations of Giza 171 x Sids 12 cross of bread wheat. Journal of Plant Production, 11 (3): 259-66.

Aisawi, K.; M. Reynolds; R. Singh and M. Foulkes (2015). The physiological basis of the genetic progress in yield potential of CIMMYT spring wheat cultivars from 1966 to 2009. Crop Sci., 55 (4): 1749-1764.

Al-Ashkar, I.; M. Alotaibi; Y. Refay; A. Ghazy; A. Zakri, and A. Al-Doss (2020). Selection Criteria for High-Yielding and Early-Flowering Bread Wheat Hybrids under Heat Stress. PloS one 15 (8): e0236351.

Ali, Ola I. M. (2017). Durable resistance to leaf rust in some Egyptian wheat cultivars. Ph.D., Faculty of Agric., Cairo Univ.

AOAC (1990). Official methods of analysis of the association of official analytical chemists. 15th ed. [published by association of official analytical chemists Arlington, Virginia, USA.]

Baye, A.; Baye B.; B. Muluken; D. Bitwoded and T. M. Manuel (2020). Genotypic and phenotypic correlation and path coefficient analysis for yield and yield-related traits in advanced bread wheat (*Triticum aestivum* L.) Lines. Cogent Food & Agriculture, 6, no. 1.

Cruz, C. D. (2016). Genes Software – extended and integrated with the R, Matlab and Selegen. Acta Scientiarum, 38 (4): 547-552.

Dabi, A.; F. Mekbib and T. Desalegn (2016). Estimation of genetic and phenotypic correlation coefficients and path analysis of yield and yield contributing traits of bread wheat (*Triticum aestivum* L.) genotypes. International Journal Natural Resource Ecology Management, 1(4): 145-154.

Darwish, M. A. H.; Thanaa H. A. Abd El-Kreem and W. Z. E. Farhat (2018a). Selection studies in three bread wheat F_3 crosses at Sakha and Nubaria locations. J. Plant Production, Mansoura Univ., 9 (1): 81- 89.

Darwish, M. A. H.; W. Z. E. Farhat, and A. Elsabagh (2018b). Inheritance of some agronomic characters and rusts resistance in fifteen F_2 wheat populations. Cercetări Agronomice în Moldova, 1 (173): 5-28.

Dewey, D. R. and K. H. Lu (1959). A correlation and path coefficient analysis of components of crested wheat grass seed production. Agron. J., 51: 515–518.

Draper, N. R. and H. Smith (1981). Applied regression analysis. 2nd edition. Wiley series in probability and mathematical statistics. John Wiley & Sons. N.Y., pp. 709.

Elkot, A. F.; W. M. El-Orabey; I. S. Draz and S. R. Sabry (2020). Marker-assisted identification of stem rust resistance genes Sr2, Sr13, Sr22 and Sr24 in Egyptian wheat cultivars. Egypt. J. Plant Breed., 24 (1): 225-245.

El-Orabey, W.; I. Elbasyoni; S. El-Moghazy and M. Ashmawy (2019). Effective and ineffective of some resistance genes to wheat leaf, stem and yellow rust diseases in Egypt. Journal of Plant Production, 10 (4): 361-71.

Farhat, W. Z. E and Eman N. M. Mohamed (2018). Breeding for some Agronomic and Quality Characters in Bread Wheat. J. Plant Production, Mansoura Univ., 9 (3): 215-231.

Fellahi, Z. E. A.; A. Hannachi and H. Bouzerzour (2018). Analysis of direct and indirect selection and indices in bread wheat (*Triticum aestivum* L.) segregating progeny. Int. j. of agronomy. Article ID 8312857, 11 pages.

Gaur, S.C. (2019). Genetic improvement through variability, heritability and genetic advance for grain yield and its contributing traits in wheat (*Triticum aestivum* L. em Thell). Int. J. Pure App. Biosci., 7(1): 368-373.

Gerard, G. S.; L. A. Crespo-Herrera; J. Crossa; S. Mondal; G. Velu; P. Juliana; J. Huerta-Espino; M. Vargas; M. S. Rhandawa; S. Bhavani; H. Braun and R. P. Singh (2020). Grain yield genetic gains and changes in physiological related traits for CIMMYT's high rainfall wheat screening nursery tested across international environments. Field Crops Res, 249:107742.

Hatfield, J. L. and C. Dold (2018). Agroclimatology and wheat production: Coping with climate change. Front. Plant Sci., 9, 224.

Kandel, B. P.; A. Poudel; S. Sharma and M. Subedi (2017). Correlation and path coefficient analysis of early maize genotypes in western hill of Nepal. Nepalese Journal of Agriculture, 1: 119-124.

Khanala, D.; D. B. Thapab; K. H. Dhakala and M. P. P. B. P. Kandelc (2020). Correlation and path coefficient analysis of elite spring wheat lines developed for high temperature resistant ance. Environment & Ecosystem Science, 4(2): 56-59.

Laala, Z.; A. Benmahammed; A. Oulmi; Z. E. A. Fellahi, and H. Bouzerzour, (2017). Response to F_3 selection for grain yield in durum wheat [*Triticum turgidum* (L.) Thell. ssp. *turgidum* conv. *durum* (Desf.) Mac Key] under South Mediterranean Conditions. Annual Research & Review in Biology, 21(2): 1-11.

Mecha, B., S. Alamerew; A. Assefa; D. Dutamo, and E. Assefa (2017). Correlation and path coefficient studies of yield and yield associated traits in bread wheat (*Triticum aestivum* L.) genotypes. Adv Plants Agric. Res., 6(5), 1-10.

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

MINITAB (2020). MINITAB Reference Manual, Release 19 for Windows. PA: Minitab Inc. State College, Harrisburg, Pennsylvania, USA.

Pleshkov, B.P. (1976). Plant Biochemistry. Kolos, Moscaw. Pp 230-236.

Rahmatov, M., M. Otambekova, H. Muminjanov, M. N. Rouse, M. S. Hovmøller, K. Nazari, B. J. Steffenson and E. Johansson (2019). Characterization of stem, stripe and leaf rust resistance in Tajik bread wheat accessions. Euphytica 215:55. https://doi.org/10.1007/s10681-019-2377-6.

Rajput, R. S. (2019). Path Analysis and genetic parameters for grain yield in bread wheat (*Triticum aestivum* L.). Annual Research & Review in Biology, 31(3): 1-8.

Sabit, Z.; B. Yadav and P. K. Rai (2017). Genetic variability, correlation and path analysis for yield and its components in F_5 generation of bread wheat (*Triticum aestivum* L.). Journal of Pharmacognosy and Phytochemistry, 6(4): 680–687.

Singh, R.P.; J. Huerta-Espino; S. Bhavani; S.A. Herrera-Foessel; D. Singh; P.K. Singh; G. Velu; R.E. Mason; Y. Jin; P. Njau, and J. Crossa (2011). Race non-specific resistance to rust diseases in CIMMYT spring wheats. Euphytica, 179(1): 175-186.

Stakman, E. C.; D. M. Stewart and W. Q. Loegering (1962). Identification of physiologic races of *Puccinia graminis* var. *Tritici*. ARsS, USDA., Agr. Res. Serv. Bull., E6/7, 53 pp.

Steel, R. G. D.; J. H. Torrie and D. A. Dickey (1997). Principle and procedures of statistics: A biochemical approach. 3rd Ed., McGraw-Hill Book Company Inc., New York, USA.

Tadesse, W.; A. Amri; M. Sanchez-Garcia; M. El-Bouhssini; M. Karrou; S. Patil; F. Bassi, and M. Baum (2017). Improving wheat production in the Central and West Asia and North Africa (CWANA) region. In: Langridge, P. (Ed.) (2017). Achieving sustainable cultivation of wheat Volume 2. London: Burleigh Dodds Science Publishing.

Zampieri, M.; A. Ceglar; F. Dentener; and A. Toreti (2017). Wheat yield loss attributable to heat waves, drought and water excess at the global, national and subnational scales. Environ. Res. Lett., 12, 064008.

تحسين صفات المحصول، مقاومة الأصداء وجودة الحبوب في هجين قمح الخبز سدس 12 × مصر 3

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تمت دراسة الهجين سدس12 x مصر 3 في أجياله الأول، الثاني، الثالث والرابع للحصول على تراكيب وراثية جديدة تتميز بالمحصول المرتفع ومقاومة الأصداء وصفات جودة عالية للحبوب. وقد اختلف الأبوان معنويا لمعظم الصفات وانعكس ذلك في وجود اختلافات في الجيل الثاني والثالث كانت كافية لحساب المعالم الوراثية. بالإضافة لذلك كان المكون الوراثي من التباين مهما وترافق ذلك مع قيم متوسطة لمرتفعة من المكافئ الوراثي لمعظم الصفات المدروسة في الجيل الثاني والثالث. وكانت صفة معدل امتلاء الحبوب وعدد السنابل م$^{-2}$ أكثر الصفات مساهمة في تحسين محصول الحبوب في عائلات الجيل الثالث. وكانت صفة مقاومة الصدأ الأصفر في الأبوين محكومة بجين واحد سائد. وكذلك كانت صفة مقاومة صدأ الأوراق محكومة في الأبوين بجينين سائدين. أما صفة مقاومة صدأ الساق في الأبوين فكانت تعود إلى جينين سائدين متكاملين. وقد نتج 37 عائلة من 100 عائلة في الجيل الثالث كانت متميزة في محصول الحبوب، ثم تم استبعاد 17 عائلة منهم بسبب الإصابة بالأصداء وكانت 20 عائلة فقط مقاومة أو متوسطة المقاومة للأصداء الثلاثة. وتميزت خمس عائلات من الـ 20 عائلة المنتخبة بصفات جودة عالية للحبوب. وفي الجيل الرابع تم انتخاب خمس نباتات فقط مقاومة للأصداء وذات صفات محصولية متميزة للتقييم كسلالات في الجيل الخامس.