Research Article

Genetic Variability and Correlation Analysis in F2 Wheat Populations

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Abstract | Development and evaluation of segregating derived from diallel cross provides an opportunity to identify potential transgressive segregant in early generation. To assess genetic variability, broad sense heritability and traits varied from, 36 lines of wheat were field tested in RCBD with three replications. The experimental materials include twenty eight F_2 population and eight parents. Data showed considerable genetic variation amongst the studied lines, parents, F_2 progeniessand parent versus F_2 progenies for all the studied traits. Among parents, best lines were Atta-Habib for plant height (95.10cm) and tillers plant^{-1} (12.30), Janbaz for economic yield per plant (20.93g) and spike length (10.87cm), Khatakwal for 100-grain weight (3.27g). Among F_2 progenies, best combinations were Khatakwal × Lalma-13 for plant height (93.96 cm), Janbaz × Pirsabak-05 for tillers plant^{-1} (12.90), Khatakwal × Tatara-96 for economic yield per plant (28.36 g), Pirsabak-05 × Lalma-13 for spikeletsspike^{-1} (20.10) and Pirsabak-13×janbaz for 100-grain weight (4.33 g). High broad sense heritability (0.69%) was recorded in cross combinations, Panjab11 × Lalma-13 for Tillers plant^{-1}, Khatakwal × Pirsabak-13 for 100-grain weight (0.89%) and Pirsabak-05 ×Punjab-11 for economic yield per plant (0.99%) whereas genetic advance was recorded maximum for cross combination Tatara-96 × Lalma-13 for 100-gain weight and grain yield^{-1}. Economic yield per plant displayed positive significant varied from with spikelet's spike^{-11}(r = 0.43**), 100 grain weight (r=0.58**) and spike length (r = 0.62**). The F_2 progenies, Pirsabak-05× Lalma-13, Khatakwal × Pirsabak-13, Atta Habib × Pirsabak-05 and Tatara-96 × Punjab-11 were found promising for most of the traits and thus could be recommended for exploitation in future wheat breeding program.

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Introduction

Wheat is a self-pollinating annual crop which belongs to grass family Gramineae and one of the most growing cereal crops globally. Wheat delivers food to 36% of the worldwide inhabitants and subsidizes 20% of food calories. Wheat is grinded to flour which is the key product of wheat used for making different food items like roti, pastry, cakes, chapattis, and wafers, whereas straw is used for feeding animals. The total protein found in wheat is about 75%, among which gluten is one of the key proteins found in grains of wheat. Due to it wider adaptability and products derived from wheat grains, wheat is cultivated across forty-four nations worldwide (Kumar *et al.*, 2017).

Wheat being a principal food of Pakistan, inhabits a noticeable position in the cropping-pattern of the country. As king off cereals, wheat is the most consumed grain crop leaving behind maize and rice in almost all parts of the globe due to its wider adaptability. During 2017-18 crop season, it was planted on wheat was cultivated on an area of 0.222 billion hectares with overall production of 0.75 billion tons with average yield of 3400 tons per hectares, worldwide (USDA, 2018). Likewise, total area under wheat cultivation was 0.0092 billion hectares which produced 0.0256 billion tons of wheat grains with average production of 2780kg per hectare, including the contribution of Khyber Pakhtunkhwa province of 0.0014 billion tons from 0.00077 billion hectares with average yield of 1814 kg ha^{-1} (PBS, 2017). Wheat production is affected significantly due to progressive global-climatic change and lack of water resources and deteriorating eco-environment (Singh and Chaudary, 2006). Pakistan has been facing wheat shortage with increasing population, and identification and development of better-quality varieties is key aim of every wheat breeder across the globe (Asif *et al*., 2005).

Heritability estimations deliver the data about index of transmission of the quantitative trait of commercial importance and are important for the current crop breeding approach. Genetic advance provides perfect representation and accurate picture of separating progenies for probable selection in the succeeding generation. Maximum values of broad sense heritability together-with high genetic-advance (GA) approve the possibility of selecting potentially new lines having desired features (Ajmal *et al*., 1995). Heritability and genetic advance are very valuable for calculating genetic progress in breeding program (Gite *et al*., 2018).

Correlation coefficient is a significant statistical technique which can help wheat breeders in selection of lines for maximizing yield. Literature exhibited the positive varied from between grain yield and yield associated traits in wheat such as spikes number $plant^{-1}$ (Mondall *et al*., 2001), plant height (Mohamad, 1999), 1000-grain weight (Akbar *et al*., 1995). Nabi *et al*. (1998) and Shah *et al*. (1999) described positive varied from of grain yield with plant height, number of tillers $plant^{-1}$, grains $spike^{-1e}$ and 1000-grain weight together at genotypic and phenotypic levels. In the current experiment, genotypic variability, heritability in broad sense, characters varied froms for identifying potential progenies which could be utilized in future wheat breeding programs.

Materials and Methods

This experiment was conducted in designated research farm of Agriculture University Peshawar during 2016-2017. Thirty-six lines including 8 parents and 28 F_2 progenies were planted in standard RCB (randomized complete block) design having three repetitions (Table 1a and 1b). Each wheat lines were grown in 4.5 m long four rows with row - row and plant - plant distances of (30 & 15 cm, correspondingly.

Table 1a: *List of parents used in the hybridization program.*

Parent	Parentage	Breeding Centre
Atta Habib	"INQILAB 91*2/TUKURU	Agri. Uni. Peshawar
Khatakwal	Landrace	--
Janbaz	GEN*2//BUC/FILK/3/BUCHIN	Agri. Uni. Peshawar
Lalma-13	"PASTOR/3/ALTAR84/AE.SQUARROSA(TAUS)//OPATA(SOKOLL)	NIFA, Peshawar
Tatara-96	JUP/ALO"S"//KLT"S"/3/VEE"S"	NIFA, Peshawar
Punjab-11	SA 42 *2/4CC/INIA//BB/3/ INIA/HD832	WRI, Faisalabad
Pirsabak-05	MUNIA/SHTO//AMSEL	CCRI, Pirsabak
Pirsabak-2013	CS/TH.SC//3*PVN/3/MIRLO/BUC/4/MILAN/5/TILHI	NARC, Islamabad

Traits measurment

The height of the randomly selected plants was measured from the base to the top of the plants without awns using meter-rod at the stage of physiological maturity. Ten randomly selected plants were used to count productive tillers. Length of the spikes were measured using ten randomly selected spikes from the base until the top spikelets using scale at the stage of physiological maturity. The spikelet's count per spike was recorded in the same spike used earlier for spike length. The selected spikes were later threshed to get 100 grains which were weighed to get the data of 1000-grain weight. Final data on grain or economic yield per plant was recorded by threshing each plant separately and weighed individually.

Table 1b: *List of F_2 progenies used in the experiment.*

F_2 progenies		
1. Lalma-13 × Atta Habib	11. Pirsabak-13 × Atta Habib	21.Khatakwal × Pirsabak13
2. Tatara-96 × Atta Habib	12. Pirsabak-13 × Lalma-13	22. Janbaz × Atta Habib
3. Tatara-96 × Lalma-13	13. Pirsabak-13 × Tatara-96	23. Janbaz × Lalma-13
4. Punjab-11 × Atta Habib	14. Pirsabak-13 × Punjab-11	24. Janbaz × Tatara-96
5. Punjab-11 × Lalma-13	15.Pirsabak-13 × Pirsabak-05	25. Janbaz × Punjab-11
6. Punjab-11 × Tatara-96	16. Khatakwal × Atta Habib	26. Janbaz × Pirsabak-05
7. Pirsabak-05 × Atta Habib	17. Khatakwal × Lalma-13	27. Janbaz × Pirsabak-13
8. Pirsabak-05 × Lalma-13	18. Khatakwal × Tatara-96	28. Janbaz × Khatakwal
9. Pirsabak-05 × Tatara-96	19. Khatakwal × Punjab-11	
10.Pirsabak-05 × Punjab-11	20. Khatakwal × Pirsabak-05	

Statistical analysis

Data collected on various parameters was analyzed using statistical package MSTATC. Upon significant variation among lines, averages were separated using Least significant variation) (LSD) test.

Broad Sense Heritability

The heritability in broad sense (h^2_{BS}) were computed following the equation:

$$h^2_{bs} = \frac{VF_2 - \sqrt{VP_1 \times VP_2}}{VF_2}$$

Where;

H^2_{bs}: Broad sense heritability; VF_2: F_2 Variance; VP_1: Parent 1 variance; VP_2: Parent 2 variance.

Genetic advance (GA)

The values of genetic advance were estimated using the equation suggested by Panse and Sukhatme (1965).

$$GA = k \times \sqrt{\sigma^2 p} \times h^2$$

Where;

GA: Genetic advance; K: 1.76 (10% selection intensity); $\sqrt{\sigma^2 p}$: Phenotypic standard deviation; h^2: Broad-sense heritability for a specific trait.

Genetic advance was expressed as percent of mean using the following formula;

$$GA\% = \frac{GA}{\bar{x}} \times 100$$

Where;

$\bar{x}$: mean of F_2 population for a specific trait.

Correlation

Correlation (between) yield and yield components characters were computed.

$$Correlation(r) = Cov_{(xv)} \times \sqrt{V(x).V(y)}$$

Cov: Covariance between x and y traits; V(x): Variance of x trait; V(y): Variance of y trait.

Table 2: *Average squares>for<different characters of 36-wheat lines (8 parents and 28 F_2 progenies) studied Agriculture University Peshawar.*

SOV	DF	Plant height	Tillers plant^{-1}	Spikels spike^{-1}	Spike length	100-gran weight	Economic yield per plant
Reps	2	1.78	1685.79	17.32	2.66	0.76	1.40
Lines	35	35.73**	1.89**	3.39	1.52**	0.62**	26.12**
Parents	7	56.53**	0.84	1.05	0.83	0.17	1.01
F_2	27	31.66**	2.23**	3.75	1.65**	0.59	29.54**
P vs. F_2	1	0.05	0.15	9.99*	2.70**	4.47**	109.45**
Error	70	5.29	0.94	2.41	0.43	0.34	2.61
CV (%)		2.57	15.71	11.31	6.16	17.58	7.37

*, ** = *substantial at>5%>and 1%>probability level.*

Results and Discussion

Plant height

The analysis exhibited) substantial variation (($P \leq 0.05$) in lines, parents and their F_2 progenies, whereas parents vs. F_2 progenies contrast was found non-substantial for plant height (Table 2). Khalid *et al.* (2011) and Sobia *et al.* (2014) found high substantial

Table 3: *Average data of all lines (parents & their F_2 population) for various characters.*

Parents/ F_2 Progenies	Plant height (cm)	Tillers plant^{-1}	Spikelets spike^{-1}	Spike length (cm)	100-grain weight (g)	Economic yield per plant (g)
Atta Habib	95.10	12.30	17.30	9.33	2.80	19.37
Lalma-13	91.50	11.60	17.73	10.67	2.67	20.30
Tatara-96	91.36	11.50	17.70	10.70	2.63	20.33
Punjab-11	91.83	10.36	17.03	10.20	3.13	20.03
Pirsabak-05	88.30	11.70	16.06	10.00	3.17	19.17
Pirabaq-13	90.96	11.60	16.36	10.57	2.93	19.70
Khatakwal	83.20	11.80	16.93	10.83	3.27	20.30
Janbaz	82.83	11.73	16.76	10.87	3.07	20.93
Range	82.83 – 95.10	10.36 – 12.30	16.06 – 17.73	9.33 – 10.87	2.63 – 3.27	19.17 – 20.93
Lalma-13 × Atta Habib	86.13	12.40	18.36	10.40	2.93	19.50
Tatara-96 × Atta Habib	87.50	12.03	16.90	10.00	2.67	22.30
Tatara-96 × Lalma-13	93.20	12.06	17.83	10.26	2.67	20.90
Punjab-11 × Atta Habib	90.10	12.00	18.00	10.77	2.67	21.20
Punjab-11 × Lalma-13	91.43	11.40	16.86	11.43	3.67	22.47
Punjab-11 × Tatara-96	87.43	12.60	18.10	10.17	3.80	18.50
Pirsabak-05 × Atta Habib	88.06	10.43	18.16	11.07	4.33	24.33
Pirsabak-05 × Lalma-13	85.40	12.30	20.10	11.27	3.67	23.80
Pirsabak-05 × Tatara-96	88.50	12.60	17.86	10.80	3.33	22.33
Pirsabak-05 × Punjab-11	89.93	11.60	18.13	10.77	3.66	20.17
Pirsabak-13 × Atta Habib	91.06	9.40	14.20	10.60	3.86	26.83
Pirsabak-13 × Lalma-13	90.93	11.60	16.56	10.80	3.67	27.50
Pirsabak-13 × Tatara-96	90.63	12.20	17.80	10.27	3.40	25.53
Pirsabak-13 × Punjab-11	90.80	10.40	17.86	11.29	3.67	21.07
Pirsabak-13 × Pirsabak5	91.23	10.57	17.83	11.43	3.37	27.93
Khatakwal × Atta Habib	84.90	12.50	17.63	10.43	3.33	18.00
Khatakwal × Lalma-13	93.96	11.90	17.70	10.37	3.67	27.33
Khatakwal × Tatara-96	87.93	12.60	17.93	11.93	3.33	28.37
Khatakwal × Punjab-11	89.33	10.40	16.96	10.57	3.03	20.70
Khatakwal × Pirsabak-05	92.53	10.10	16.50	9.00	3.73	20.00
Khatakwal × Pirsabak-13	91.53	12.70	18.26	10.00	3.83	19.33
Janbaz × Atta Habib	90.90	11.00	17.03	11.80	3.67	22.00
Janbaz × Lalma-13	93.26	11.00	17.86	10.17	3.47	23.33
Janbaz × Tatara-96	89.33	12.00	18.86	11.13	3.67	25.33
Janbaz × Punjab-11	89.83	12.10	19.33	10.43	3.63	19.03
Janbaz × Pirsabak-05	92.43	12.90	16.60	10.40	3.70	21.97
Janbaz × Pirsabak-13	78.93	11.00	16.56	12.83	4.10	20.16
Janbaz × Khatakwal	84.40	10.50	17.26	11.33	3.00	18.33
Range	78.93 – 93.96	9.40 - 12.90	14.20 – 19.33	9.00 – 12.83	2.67 – 4.33	18.00 – 28.37
LSD (5%)	3.72	1.57	2.51	1.06	0.95	2.6

genotypic variation among wheat lines for plant height. The average of lines for plant height ranged from (82.83 -95.10 cm). Minimum and maximum values of plant height was noted for parent Janbaz (82.83 cm) and Atta Habib (95.10 cm), correspondingly (Table 3). Average values of F_2 progenies for plant height ranged from 78.93 to 93.96 (Table 3). Maximum value for plant height (78.93) was recorded for population, Janbaz × Pirsabak-13, while maximum (93.96) was recorded for population, Khatakwal× Lalma-13 (Table 3).

Table 4: *Broad sense heritability>and<genetic-advance (GA) for various traits in wheat.*

Lines	Tillers plant^{-1}			Plant height		
	Var.	h^2	GA (%)	Var.	h^2	GA (%)
Parents						
Atta Habib	1.47			0.07		
Lalma-13	0.63			2.17		
Tatara-96	1.99			3.22		
Punjab-11	0.42			3.12		
Pirsabak-05	1.33			4.17		
Pirabaq-13	1.11			4.00		
Khatakwal	0.64			11.59		
Janbaz	0.65			5.76		
F2 Population						
Lalma-13 × Atta Habib	1.21	0.17	0.32	0.50	0.23	0.28
Tatara-96 × Atta Habib	2.26	0.24	0.65	2.01	0.76	1.91
Tatara-96 × Lalma-13	1.32	0.11	0.23	6.07	0.56	2.45
Punjab-11 × Atta Habib	1.00	0.21	0.37	1.33	0.65	1.32
Punjab-11 × Lalma-13	1.72	0.69	1.58	3.20	0.19	0.59
Punjab-11 × Tatara-96	1.51	0.39	0.85	4.26	0.26	0.93
Pirsabak-05 × Atta Habib	1.8	0.22	0.53	4.96	0.89	3.49
Pirsabak-05 × Lalma-13	2.17	0.56	1.44	6.79	0.56	2.55
Pirsabak-05 × Tatara-96	1.96	0.17	0.42	4.69	0.22	0.83
Pirsabak-05 × Punjab-11	0.84	0.11	0.17	4.64	0.22	0.84
Pirsabak-13 × Atta Habib	1.83	0.37	0.88	3.12	0.09	0.28
Pirsabak-13 × Lalma-13	1.00	0.12	0.22	3.57	0.18	0.58
Pirsabak-13 × Tatara-96	1.93	0.23	0.56	4.56	0.21	0.80
Pirsabak-13 × Punjab-11	1.09	0.37	0.68	4.57	0.23	0.85
Pirsabak-13 × Pirsabak5	1.54	0.21	0.46	5.20	0.21	0.86
Khatakwal × Atta Habib	1.96	0.51	1.24	1.00	0.10	0.17
Khatakwal × Lalma-13	0.73	0.09	0.13	7.90	0.37	1.81
Khatakwal × Tatara-96	1.81	0.38	0.89	7.41	0.18	0.84
Khatakwal × Punjab-11	0.91	0.25	0.41	4.44	0.20	0.76
Khatakwal × Pirsabak-05	1.33	0.31	0.62	9.82	0.29	1.61
Khatakwal × Pirsabak-13	1.69	0.50	1.15	9.17	0.26	1.37
Janbaz × Atta Habib	1.48	0.34	0.72	1.00	0.36	0.64
Janbaz × Lalma-13	1.17	0.54	1.16	4.65	0.24	0.91
Janbaz × Tatara-96	1.72	0.34	0.78	7.06	0.39	1.82
Janbaz × Punjab-11	1.33	0.30	0.16	9.32	0.47	2.55
Janbaz × Pirsabak-05	1.57	0.41	0.89	6.77	0.27	0.53
Janbaz × Pirsabak-13	1.71	0.50	1.16	10.58	0.55	3.13
Janbaz × Khatakwal	1.29	0.50	1.00	17.01	0.52	3.77

***Var. = Variation; h^2 = Broad sense heritability and GA (%) = Genetic advance as percent of average*

High heritability and expected (genetic advance ranged from 0.89%) to 0.09%, and 3.77% to 0.28% correspondingly, high heritability (0.89%) was recorded (for)Pirsabak-05 × Lalma-13 while low heritability (0.09%) was recorded for Pirsabak-13 × Atta-Habib. (Table 4). Maximum genetic advance (3.77%) was recorded for Janbaz× Khatkwal while minimum (0.28%) was recorded for Pirsabak-13× Atta-Habib. Kisana *et al.* (1982) reported (high heritability) for plant height in wheat population. Deshmukh *et al.* (2006) found high heritability and expected genetic advance for plant height. Sial ett al. (2013) also noted high heritability of various lines for (plant height.)

Plant height showed substantial positive correlation with tillers plant^{-1} (0.86**), spikelet's spike^{-1} (0.69**), spike length (0.62**), 100-grain weight (0.96**) and economic yield per plant (0.66**) (Table 7). Similarly, Ahmad *et al.* (2013) reported substantial positive varied from of plant height with grain (yield) in wheat lines. Kaleem *et al.* (2013) also found positive correlation between plant height and (harvest) index. Ali *et al.* (2008) noticed positive substantial varied from of plant height) with seed weight.

Number of tiller plant^{-1}

Analysis of variance showed (substantial variation ($P \leq 0.05$)) of lines, and F_2 progenies, while parents and parents versus F_2 progenies showed non-substantial variation for number of tiller plant^{-1}. Substantial variation of wheat lines for tiller plant^{-1} were also noted by Tahmasebi *et al.* (2013) and Ali *et al.* (2012). The coefficient of variation was recorded 15.71 %. The averages of lines for parents ranged from (10.36 to 12.30 cm). Minimum and maximum values of tillers plant^{-1} was noted for parent Punjab-11 (10.36 cm) and Atta Habib (12.30 cm), correspondingly (Table 3). F_2 progenies averages values for tiller plant^{-1} ranged from 9.40 to 12.90 (Table 3). Maximum value for tiller plant^{-1} (12.90) was recorded for population Janbaz × Pirsabak-05, while minimum (9.40) was recorded for population Pirsabak-13 × Atta Habib (Table 3).

Heritability and genetic advance estimation ranged from 0.12 to 0.69 and 0.13 to 1.44 correspondingly. High heritability (0.69) was recorded for population Punjab-11 × Lalma-13 while minimum (0.12) was recorded for Pirsabak-13× Lalma-13. Similarly genetic advance of 1.44% was recorded for Pirsabak05×Lalma-13 while 0.13% was recorded for population Khatakwal × Lalama-13 (Table 4). Bhushan *et al.* (2013) reported high heritability and moderate genetic advance for (number) of till-

er plant^{-1} in 30 lines of bread wheat. Waqas *et al.* (2014) recorded minimum to maximum heritability for fertile tillers. Hussain *et al.* (2012) also reported high heritability of wheat lines for tillers per plant^{-1}.

Number of tiller per plant^{-} showed positively substantial an with plant height (0.86**), spikelet's spike^{-1}(0.78**), spike length (0.58**), 100-grain weight (0.89**) and economic yield per plant (0.52**) (Table 7), Kashif and Khaliq (2004) observed substantial varied from of fertile tillers per plant^{-} with (grain) yield development. Singh *et al.* (2016) observed positively substantial varied from of (tillers) plant^{-1}grain yield andd100-grain weight. Din *et al.* (2018) recorded positive correlation of tiller m^{-1} with grain yield and biological yield. Khan (2013) found substantial correlation among most of the traits with numbers of tiller plant^{-1}.

Spikelet's spike^{-1}

Analysis of (variance)exhibited highly substantial variation (P ≤ 0.01)) for F_2 population while, non-substantial variation were noted for lines, parents, and parents versus F_2 progenies for spikelet's spike^{-1}. Gashaw *et al.* (2010) and Subhashchandra *et al.* (2009) also found substantial variances of wheat lines for spikelet's spike^{-1-}. However, Khan *et al.* (2008) found non-substantial variation for spikelet's spike^{-1} in some wheat lines. The coefficient of variation was 11.31% for spikelet's spike^{-1}. The averages of lines for spikelet's spike^{-1} ranged from (16.06 to 17.73). Minimum and maximum values of spikelet's spike^{-1} was noted for parent Pirsabak-05 (16.06) and Lalma-13 (17.73), correspondingly (Table 3). The average values for F_2 progenies ranged from 14.20 to 20.10 (Table 3). Maximum number of spikeletsspike^{-1} (20.10) were recorded for progenies Pirsabak-05 × Lalma-13, while minimum (14.20) for Pirsabak-13 ×Atta Habib (Table 3).

Heritability and genetic advance estimation ranged from 0.12 to 0.99 and 0.28 to 6.41 correspondingly. High heritability (0.99) was recorded for population Khatakwal × Atta Habib, while minimum (0.12) was recorded for Janbaz× Punjab-11. Similarly genetic advance of 6.41% was recorded for Pirsabak-13×Atta Habib while 0.28% was recorded for population Tatara-96 × Atta Habib (Table 4). (Table 5). Dutamo *et al.* (2016) exhibited high heritability estimates for spikelet spike^{-1} in wheat. Subhashchandra *et al.* (2009) and Waleed *et al.* (2008) also observed high (heritability) for spikelet's spike^{-1}.

Table 5: *Broad sense heritability>and<genetic-advance (GA) for various traits in wheat.*

Lines	Spike length			Spikelets spike^{-1}		
	Var.	h^2	GA (%)	Var.	h^2	GA (%)
Parents						
Atta Habib	0.33			0.01		
Lalma-13	0.08			0.16		
Tatara-96	0.01			0.52		
Punjab-11	0.39			0.70		
Pirsabak-05	0.19			1.21		
Pirabaq-13	0.93			0.42		
Khatakwal	0.08			0.82		
Janbaz	0.02			4.08		
F2 POPULATION						
Lalma-13 × Atta Habib	1.03	0.84	1.50	2.06	0.98	2.48
Tatara-96 × Atta Habib	0.09	0.36	0.19	0.13	0.45	0.28
Tatara-96 × Lalma-13	0.72	0.96	1.44	0.86	0.66	1.08
Punjab-11 × Atta Habib	0.44	0.19	0.22	1.92	0.96	2.33
Punjab-11 × Lalma-13	0.66	0.73	1.04	0.44	0.24	0.28
Punjab-11 × Tatara-96	0.86	0.93	1.52	5.89	0.90	3.83
Pirsabak-05 × Atta Habib	1.00	0.75	1.32	2.84	0.96	2.85
Pirsabak-05 × Lalma-13	0.41	0.70	0.79	7.09	0.94	4.39
Pirsabak-05 × Tatara-96	0.97	0.96	1.66	3.74	0.79	2.68
Pirsabak-05 × Punjab-11	0.47	0.41	0.49	3.24	0.72	2.27
Pirsabak-13 × Atta Habib	1.08	0.52	0.95	15.73	0.92	6.41
Pirsabak-13 × Lalma-13	0.49	0.82	1.01	0.52	0.50	0.63
Pirsabak-13 × Tatara-96	0.10	0.69	0.39	4.09	0.89	3.15
Pirsabak-13 × Punjab-11	0.26	0.26	0.23	4.17	0.87	3.13
Pirsabak-13 × Pirsabak5	1.42	0.91	1.90	5.58	0.87	3.62
Khatakwal × Atta Habib	0.44	0.62	0.73	6.62	0.99	4.47
Khatakwal × Lalma-13	0.16	0.49	0.35	0.73	0.50	0.75
Khatakwal × Tatara-96	0.93	0.69	0.37	1.96	0.67	1.64
Khatakwal × Punjab-11	0.54	0.65	0.84	0.76	0.29	0.44
Khatakwal × Pirsabak-05	1.24	0.90	1.76	1.48	0.32	0.70
Khatakwal × Pirsabak-13	1.33	0.93	1.90	3.66	0.84	2.83
Janbaz × Atta Habib	0.52	0.83	1.05	0.30	0.33	0.32
Janbaz × Lalma-13	0.16	0.73	0.52	3.90	0.79	2.75
Janbaz × Tatara-96	0.92	0.93	1.66	6.16	0.76	0.34
Janbaz × Punjab-11	0.25	0.74	0.65	2.52	0.12	0.33
Janbaz × Pirsabak-05	0.39	0.83	0.91	2.92	0.24	0.71
Janbaz × Pirsabak-13	0.25	0.82	0.72	1.77	0.26	0.61
Janbaz × Khatakwal	0.33	0.87	0.88	2.76	0.34	0.98

***Var. = Variation; h^2 = Broad sense heritability and GA(%) = Genetic advance as percent of average*

Spikelet's spike^{-1} showed positively substantial varied from with plant height (0.69**), tillers plant^{-1} (0.78**), spike length (0.56**), 100-gain weight (0.70**) and economic yield per plant (0.43**). (Table 7). Mohibullah *et al.* (2011) reported positive correlation of number of spikelet spike^{-1} with grain yield while working with 100-bread wheat lines. Kaleem *et al.* (2013) reported highly substantial varied from for grain per spike with number of tiller plant^{-1}, grain yield and (1000-grain weight.)

Spike length

Data analysis showed substantial (P ≤ 0.05) variation for (lines,) F_2 and parents vs. F_2 progenies for spikes (length), while parents exhibited non-substantial variation. Husain *et al.* (2012) found substantial variation of lines, for spike length, while Khalid *et al.* (2011) also found lines with no-substantial variation for spike length. These variation in result could be due to different lines they used for experiments. The coefficient of variation was recorded 6.16%. The averages of parental lines ranged from 9.33 to 10.87 cm. Minimum and maximum values of spike length was noted for parent Atta Habib (9.33 cm) and Janbaz (10.87 cm), correspondingly (Table 3). The average values of F_2 progenies for spike length are from 9.0-12.83 cm (Table 4). Maximums value for spike length (12.83cm) was recorded for population, Janbaz × Pirsabak-13, while minimum value (9.0 cm) was recorded for population, Khatakwal × Pirsabak-05 (Table 3).

Heritability and genetic advance estimation ranged from 0.19 to 0.96 and 0.19 to 1.90 correspondingly. High heritability (0.96)) was recorded for population Tatara-96 × Lalma-13 while minimum (0.19) was recorded for Pinjab-11× Atta Habib. Similarly, genetic advance of 1.90% was recorded for Khatakwal×Pirsabak-13 while 0.19% was recorded for population Tatara-96 × Atta Habib (Table 5). Yousaf *et al.* (2008) observed heritability, and genetic advance in high range for spike length. Shah *et al.* (2018), Kumar *et al.* (2017) and Subhashchandra *et al.* (2009) observed high heritability, and high genetic, advance for spike length. Gashaw *et al.* (2010) also found high>heritability of wheat lines for spike > length. Spike length > had positively substantial varied from with plant height (0.62**), tillers plant^{-1} (0.58**), spikelet's spike^{-1} (0.56**), 100-gain weight (0.67**) and economic yield per plant (0.62**) (Table 7). Mohibullah *et al.* (2011) reported positively substantial varied from of spike length with number<of spikelet per > spike, grain > yield per plant and 1000-grain<weight. Shah *et al.* (2018) found positive high substantial correlation of spike length with grain < weight < spike^{-1} and 100-grain > weight. Subhashchandra *et al.* (2009) observed highest positive varied from off spike length with grain yield >plant^{-1} and tillers plant^{-1}.

100-grain weight

Data exhibited substantial (P ≤ 0.01) variation among lines and parents vs. F2 population contrast, while non-substantial variation were noticed for parents and their F2 progenies for 100-grain weight. Bhutto *et al.* (2016) also found substantial variation of wheat lines for 100 grain weight. Singh *et al.* (2016) found non-substantial variances for 100-grain weight of wheat lines. The different results may be due to the use of different lines in their experiments. The coefficient of variation recorded was 17.57% for 100-grain weight. The averages of lines for 100-grain weight ranged from 2.63 to 3.27 g. Minimum and maximum values of 100-grain weight was noticed for parent Tatara-96 (2.63 g) and Khatakwal (3.27 g), correspondingly, (Table 3). The average values of F2 progenies for 100-grain weight ranged from 2.7 to 4.33 g. Maximum values for 100 grain weight (4.33 g) was recorded for population Pirsabak 13 × Janbaz, while minimum (2.7 g) was recorded for genotype Lalma-13 (Table 3).

Heritability and genetic advance estimation ranged from 0.11 to 0.89 and 0.18 to 2.27 correspondingly. High heritability (0.89) were recorded for population Khatakwal × Pirsabak-13 while minimum (0.11) was recorded for Pirsabak-13× Atta Habib. Similarly, genetic advance of 2.27% was recorded for Tatara-96×Lalma-13 while 0.18% was recorded for population Pirsabak-05 × Atta Habib. Gite *et al.* (2018) and Dutamo *et al.* (2015) also found > high < heritability. Hundred grain weight showed positive substantial varied from with plant height (0.96**), tillers plant^{-1} (0.89**), spikelet's spike^{-1} (0.70**), spike length (0.67**) and economic yield per plant (0.58**) (Table 7). Mohibullah *et al.* (2011) also exhibited highly > substantial > positive varied from of 1000grain weight with grain yield in 30 wheat lines. Gashaw *et al.* (2010) found positive varied from among 100grain weight and most of the yield characters.

Table 6: *Broad sense heritability>and<genetic-advance (GA) for various traits in wheat.*

Lines	Economic yield per plant (g)			100- grain weight (g)		
	Var.	h^2	GA (%)	Var.	h^2	GA (%)
Parents						
Atta Habib	0.40			0.52		
Lalma-13	0.27			0.33		
Tatara-96	2.33			0.30		
Punjab-11	0.03			0.50		
Pirsabak-05	0.08			0.14		
Pirabaq-13	0.37			0.01		
Khatakwal	0.27			0.30		
Janbaz	2.61			0.01		
F2 POPULATION						
Lalma-13 × Atta Habib	1.71	0.81	1.86	1.01	0.59	1.04
Tatara-96 × Atta Habib	4.27	0.77	2.81	1.37	0.71	1.47
Tatara-96 × Lalma-13	12.63	0.94	5.86	2.25	0.86	2.27
Punjab-11 × Atta Habib	5.32	0.99	4.03	0.92	0.45	0.75
Punjab-11 × Lalma-13	0.25	0.88	0.78	0.54	0.25	0.32
Punjab-11 × Tatara-96	0.25	0.65	0.57	0.67	0.42	0.60
Pirsabak-05 × Atta Habib	1.33	0.86	1.75	0.33	0.18	0.18
Pirsabak-05 × Lalma-13	0.49	0.69	0.85	0.33	0.34	0.35
Pirsabak-05 × Tatara-96	1.33	0.67	1.36	0.33	0.37	0.38
Pirsabak-05 × Punjab-11	2.82	0.99	2.94	0.33	0.19	0.20
Pirsabak-13 × Atta Habib	10.49	0.22	1.25	1.62	0.11	0.25
Pirsabak-13 × Lalma-13	2.11	0.85	2.17	0.33	0.80	0.81
Pirsabak-13 × Tatara-96	5.00	0.81	3.21	0.48	0.87	1.06
Pirsabak-13 × Punjab-11	1.21	0.97	1.88	0.33	0.75	0.77
Pirsabak-13 × Pirsabak5	0.81	0.78	1.24	0.30	0.86	0.83
Khatakwal × Atta Habib	1.00	0.67	1.18	0.52	0.24	0.30
Khatakwal × Lalma-13	0.33	0.19	0.19	1.33	0.76	1.55
Khatakwal × Tatara-96	1.40	0.43	0.91	0.44	0.32	0.37
Khatakwal × Punjab-11	0.27	0.87	0.80	0.72	0.89	1.33
Khatakwal × Pirsabak-05	7.00	0.98	4.56	0.41	0.50	0.56
Khatakwal × Pirsabak-13	10.33	0.97	5.48	0.58	0.89	1.20
Janbaz × Atta Habib	7.00	0.85	3.97	0.33	0.75	0.76
Janbaz × Lalma-13	1.33	0.37	0.75	0.20	0.67	0.53
Janbaz × Tatara-96	6.33	0.61	2.70	0.33	0.81	0.82
Janbaz × Punjab-11	1.32	0.65	1.31	0.30	0.86	0.83
Janbaz × Pirsabak-05	2.17	0.79	2.04	0.27	0.84	0.77
Janbaz × Pirsabak-13	1.14	0.14	0.26	0.07	0.81	0.38
Janbaz × Khatakwal	1.08	0.22	0.41	0.13	0.51	0.32

***Var. = Variation; h^2 = Broad sense heritability and GA(%) = Genetic advance as percent of average*

Table 7: *Pearson correlation-coefficient between different parameters of wheat.*

	Plant height	Tiller Plant^{-1}	Spike-lets-spike^{-1}	Spike length	100-grain weight	Economic yield
Plant height	-	0.86**	0.69**	0.62**	0.96**	0.66**
Tiller Plant^{-1}		-	0.78**	0.58**	0.89**	0.52**
Spike-lets-spike^{-1}			-	0.56**	0.70**	0.43**
Spike length				-	0.67**	0.62**
100-grain weight					-	0.58**

Economic yield per plant (g)

Average squares for economic yield per plant exhibited highly substantial (P ≤ 0.01) variation of lines, <F_2> population and parents vs. F_2 progenies, whereas, nonsubstantial variation were noted for parents. Rajper *et al.* (2018) observed substantial variation for economic yield per plant of 8 wheat lines. Salman *et al.* (2014) also noted substantial variances of 65 wheat > lines > for economic yield per plant, whereas, Khan *et al.* (2008) found non-substantial variation among wheat lines for grain yield. The coefficient of variation was 7.37% for economic yield per plant.

The averages of lines for parents ranged from 19.17 to 20.93 g (Table 3). Maximum average economic yield per plant (20.93g) was recorded for Janbaz, while minimum (19.19 g) was recorded for genotype Pirsabak-05 (Table 4). The averages of F_2 progenies ranged from 18.00 to 28.36g (Table 3). Maximum average economic yield per plant (28.36g) was recorded for Khatakwal × Tatara-96, while minimum (18.00 g) was recorded for genotype Khatakwal × Atta Habib (Table 4).

Heritability and genetic advance estimation ranged from 0.14 to 0.99 and 0.26 to 5.86 correspondingly. High heritability (0.99) was recorded for population Pirsabak-05 × Punjab-11, while minimum (0.14) was recorded for Janbaz× Pirsabak-13. Similarly, genetic advance of 5.86% was recorded for Tatara-96×Lalma-13 while 0.26% was recorded for population Janbaz × Pirsabak-13. (Table 6). Dutamo *et al.* (2016) also exhibited high heritability and genetic advance for grain yield in wheat lines. Deshmukh *et al.* (2006) found moderate to<high>heritability estimations with genetic advance for grain yield in wheat crosses. Sobia *et al.* (2014) also estimated > high > heritability for economic yield per plant.

Economic yield per plant exhibited positively substantial varied from<with plant height (0.66**), tillers plant^{-1} (0.52**), spikelet's spike^{-1} (0.43**), spike length (0.62**) and 100-grain weight (0.58**) < (Table 7). Waleed *et al*. (2008) reported positive and substantial correlation of all characters with<grain<yield. Hassan (2017) reported that grain yield has positive substantial varied from with grain spike^{-1}. Rajper *et al*. (2018) also noted positively substantial varied from of grain yield with biological yield, harvest index and grain weight.

Conclusions and Recommendations

Means sum of squares exhibited substantial variation for lines, parents, F_2 progenies, and parents vs. F_2 progenies for all the characters representing existence of appropriate variability for improvement. High heritability was noticed in cross combinations, Panjab11 × Lalma-13 for Tillers plant^{-1}, Khatakwal × Pirsabak-13 for 100-grain weight and Pirsabak-05 ×Punjab-11 for economic yield per plant . Whereas genetic advance was recorded maximum for cross combination, Tatara-96 × Lalma-13 for 100-gain weight and economic yield per plant. Grain<yield plant^{-1} was positively substantial associated with plant height, tillers plant^{-1}, spikelet's spike^{-1}, spike length and 100grain weight, therefore these characters can be<used as indirect selection criteria for<yield improvement in wheat. F_2 progenies, Pirsabak-05 × Lalma-13, Khatakwal × Pirsabak-13, Janbaz × Pirsabak-05, and Pirsabak-13 × Janbaz and Khatakwal× Tatara-96 showed best performance for most of the characters and therefore their potential could be exploited in future>breeding>programs.

Novelty Statement

The F2 progenies (Pirsabak-05×Lalma-13, Khatakwal × Pirsabak-13, Atta Habib × Pirsabak-05 and Tatara-96 × Punjab-11) were found promising for most of the traits and thus could be beneficial for exploitation in future wheat breeding program.

Author's Contribution

Abdul Haleem: Conceived the idea of the experi-ment and conduct the research.
Ghulam Hassan: Major supervisor, technical input and support at every step.
Arshad Iqbal: Helped in manuscript modification and technical improvement.
Fahim Ullah Khan: Helped in statistical analysis
Muhammad Sajid: Technical writing
Farhad Ahmad: Data recording
Rafi Ullah Khan: Helped in review of literature
Mohammad Ilyas: Data recording and references writing

Conflict of interest
The authors have declared no conflict of interest.

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