



International Journal of Agricultural and
Environmental Research
FREE AND OPEN ACCESS
Available online at www.ijaaer.com
ISSN 2414-8245 (Online)
ISSN 2518-6116 (Print)



ASSESSMENT OF YIELD COMPONENTS AND THEIR ASSOCIATION IN F₂ POPULATIONS OF WHEAT

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Abstract

Keeping in view the role of wheat in Pakistan, among F₂ populations, maximum grain yield plant the current research was conducted to compute the¹ was given by cross combinations Barsat / Siren extent of transmissibility and to derive information (27.93 g), AUP-5008 / Siren (26.09 g) and Tatara / on the correlation of grain yield with its PS-05 (25.65 g). The assessments of heritability component traits. Sixteen F₂ populations of wheat and genetic advance manifested that F₂ and their eight parental lines were evaluated at the populations, Saleem-2K / Janbaz, Tatara / F.S, University of Agriculture, Peshawar-Pakistan AUP-5008 / PS-05 and Tatara / PS-05 had highly during wheat season of 2013-14. Experiment was heritable characters along with high genetic conducted in randomized block design advance, which offer an opportunity for earlier with three replicates. Analysis of variance selection. Hence, more emphasis should be given manifested significant differences among to these crosses in future wheat breeding genotypes for all the studied traits. Similarly, programs. Moreover, the perusal of correlation mean squares due to parents, F₂ populations and analysis revealed that traits like days to maturity, parents vs. F₂'s were also significant for all the flag leaf area, plant height, fertile tillers plant⁻¹, traits under study except harvest index. On the biological yield and harvest index appeared to be basis of mean performance, maximum grain yield most essential sources of affecting the final yield, plant⁻¹ among parents was given by Fakhr-e-suggesting that upsurge in wheat yield could be Sarhad (27.16 g) and PS-05 (26.06 g), while admissible by selecting these traits.

Key words: Correlation, genetic advance, heritability, F₂ populations and wheat.

INTRODUCTION

Wheat is life and prince among cereals and plays promising role in the food and nutritional security of Pakistan. It is the most essential and major consumable food cereal in our country, therefore, it holds unique significance in the agricultural policies of the government. Wheat contributes 2.2% to GDP and about 10.3% to the total value added in agriculture. According to FBS (2015), the total wheat production in Pakistan was 25.24 million tons from 9039.0 thousand hectares with an average yield of 2987 Kg ha⁻¹ in which Khyber Pakhtunkhwa contributes about 1140.6 thousand tons from 729.8 thousand hectares with an average yield of 1560 Kg ha⁻¹. Genetic variability in plants is the initial step in understanding how to improve or produce new plants with better yield potential, and its reduction makes the crops progressively vulnerable to

diseases and adverse climatic changes/stresses (Aremu, 2012). Therefore, it is important to get satisfactory information on the extent and type of genetic variability and their corresponding heritability. In Pakistan, significant upsurge in wheat yield had mere achieved through conventional breeding methods like hybridization followed by isolation of desirable pure lines at the end. Among segregating generations, the second filial generation holds significant importance, where selection of desirable phenotypes has to be done more critically. Hence, to exercise more effective selection, a thorough knowledge on the extent of transmissibility of yield components is needed. According to Ijaz *et al.* (2013), the exploration of genetic variation in breeding material is of major interest to plant breeders and helpful in achieving higher return per unit area in any crop plant. Since there is direct relation between heritability and response to selection

(genetic advance), therefore, higher estimates of heritability and genetic advance simplifies selection procedures for plant breeders (Shoukat *et al.*, 2007). Rashid *et al.* (2013) estimated high heritability accompanied by high genetic advance for some polygenic traits in seven F₂ populations of wheat. Similarly, Hussain *et al.* (2013) estimated higher percentage of heritability and genetic advance in different F₂ populations of wheat. Attempts have been made since 1966 to develop high yielding varieties with consistent performance. As yield is a complex character and is the product of multi-growth factors, therefore, initiating any wheat breeding program based on yield components requires the knowledge of association between the yield and its component traits. Gelalcha and Hanchinal (2013) found that tillers plant⁻¹, spikes m⁻², spike length and biomass yield showed significant contribution towards grain yield. Abderramane *et al.* (2013) pointed out that spikes plant⁻¹, grains spike⁻¹ and total biomass was positively correlated with grain yield. Similarly, Abd El-Mohsen *et al.* (2012) found notable contribution of spike length, spikelets and grains spike⁻¹ and test weight at both phenotypic and genotypic levels towards grain yield in wheat. Association among yield components are therefore important because if the association between two traits is positive then one trait could be improved indirectly by improving the other trait. The present research study was therefore conducted to assess the extent on transmissibility and correlation coefficient among selected characters to screen out suitable F₂ populations of wheat for onward breeding program.

MATERIALS AND METHODS

Sixteen F₂ populations were evaluated along with their parents in randomized complete block design in three replications at the experimental field of Department of Plant Breeding and Genetics, The University of Agriculture, Peshawar-Pakistan during Rabi 2013-14. Each entry was planted in 4 rows with a row length of 3 m length with plant to plant and row to row distances of 15 cm and 30 cm, respectively. All the biometrical observations were recorded on randomly selected 20 guarded plants from parents and F₂ populations respectively in each replication. The mean values recorded for yield and yield attributing traits *viz.*, days to 50% heading and maturity, flag leaf area, plant height, fertile tillers plant⁻¹, biological yield plant⁻¹, spike length, spikelets and grains spike⁻¹, 100-grain weight, grain yield plant⁻¹ and harvest index plant⁻¹ were used for statistical analysis following the analysis of variance technique as outlined for RCB design by Singh & Chaudhary (1985). Broad-sense heritability [$h^2_{(B.S)}$] for each character was assessed using the formula described

by Mahmud & Kramer (1951) as: $h^2_{(B.S)} = [VF_2 - \sqrt{(VP_1) \times (VP_2)}] / VF_2$, where VF₂ = variance of Particular F₂ population, VP₁ = Variance of particular Parent 1 and VP₂ = Variance of particular Parent 2. The magnitude of heritability was characterized as low (0-30%), moderate (>30-60%) and high (<60%) according to Robinson *et al.*, 1949. Expected genetic advance (GA) was computed according to Allard (1960) as: GA = $\sigma^2_p \times k \times h^2_{(B.S)}$, where σ^2_p = phenotypic standard deviation, k is standardized selection differential constant (1.40) at 20% selection intensity and $h^2_{(B.S)}$ = broad-sense heritability of particular trait in fraction. Phenotypic correlation was computed following the method of Al-Jibouri *et al.* (1951) as:

$$(rp) = \frac{COV_{P(x_1, x_2)}}{\sqrt{\sigma^2_{P(x_1)} \cdot \sigma^2_{P(x_2)}}}$$

Where;

COV_{P(x₁x₂)} = Phenotypic covariance among traits x₁ and x₂

$\sigma^2_{P(x_1)}$ = Phenotypic variance of trait x₁

$\sigma^2_{P(x_2)}$ = Phenotypic variance of trait x₂

RESULTS AND DISCUSSION

Genetic variability and Mean performance:

Plants breeder's real aim and objective is to develop cultivars with high yield potential, better quality and consistent performance. Achievement of this goal depends on inbuilt genetic variability, in which desirable lines are to be selected for further exploitation, to achieve the target. Plant breeders are interested in short duration early maturing wheat genotypes. Minimal days to heading are preferred while breeding for early maturity. Similarly, Flag leaf area is also important character assessed by plant breeders, because it is directly associated with final yield (Rashid *et al.*, 2013). It plays prominent role in determining yield potential of wheat because it accounts for about 70% of photoassimilates that go directly into seeds. Plant height in wheat is very important in terms of lodging resistance. In literature, it is reported that deal plant height in respect of fertilizer responsiveness and lodging resistance may range from 90-100 cm (Dogan, 2009). Fertile tillers plant⁻¹, spike length and spikelets and grains spike⁻¹ are important production traits in wheat, and play significant role in grain yield plant⁻¹. Maximum fertile tillering capacity and longer and healthier spikes with more spikelets and grains will obviously lead to higher return. The analyzed data manifested significant ($P \leq 0.01$) differences among genotypes for all the studied traits, representing sufficient genetic variability for

effective selection (Table 1). Mean squares due to parents, F₂ populations and parents vs. F₂'s were also significant ($P \leq 0.05$ & 0.01) for all the studied traits except harvest index for parents vs. F₂'s. Studies on assessment of genetic variability in segregating populations of wheat has been conducted earlier (Saleem *et al.*, 2016; Azam *et al.*, 2013; Sial *et al.*, 2013; Eid, 2009; Firouzain *et al.*, 2003). The variability observed among genotypes for all the assessed traits was high, as reflected by its wide range from 122.00 to 133.33 days for heading, 22.79 to 36.43 cm² for flag leaf area, 168.67 to 173.67 days for maturity, 90.71 to 108.97 cm for plant height, 7.40 to 10.23 for fertile tillers plant⁻¹, 37.87 to 60.93 g biological yield plant⁻¹, 10.96 to 13.52 cm for spike length, 18.22 to 22.47 for spikelets spike⁻¹, 60.77 to 78.88 for grains spike⁻¹, 3.64 to 4.85 g for 100-grain weight, 13.80 to 27.93 g for grain yield plant⁻¹ and 36.23 to 47.87% for harvest index plant⁻¹ (Table 2). The earliest maturing parent was Siren which took 168.67 days to maturity, followed by Barsat (169.33 days). Maximum flag leaf area (34.43 cm²), plant height (108.97 cm) and 100-grain weight (4.71 g) was calculated for PS-05, respectively, while maximum values for flag leaf area (23.74 cm²), plant height (90.71 cm) and fertile tillers plant⁻¹ (8.13) were observed for Saleem-2K, respectively. Maximum mean value for fertile tillers plant⁻¹ (10.23) was observed for AUP-5008, while Barsat produced the longest spikes (13.30 cm) among parents. Janbaz shows

superiority for biological yield plant⁻¹ (59.03 g) and spikelets spike⁻¹ (21.97), while Fakhr-e-Sarhad was best in respect of grains spike⁻¹ (74.10), grain yield plant⁻¹ (27.16 g) and harvest index (47.87%). Similarly, among F₂ populations, Tatar / Janbaz was the earliest in heading (122.00 days) and manifested maximum flag leaf area (30.34 cm²), while Saleem-2K / PS-05 was the earliest maturing (168.67 days) cross combination. Late heading (133.33) and maturity (173.67 days) was observed in Saleem-2K / Siren and Saleem-2K / FS and AUP-5008 / Janbaz, respectively. In respect of height, most of the F₂ populations achieved considerable plant height. AUP-5008 / FS (9.92), AUP-5008 / Siren (9.77) and AUP-5008 / PS-05 (9.72) were high tillering cross combinations. The longest spikes (13.52 cm), maximum grain yield (27.93 g) and biological yield plant⁻¹ (60.93 g) among all F₂ populations was produced by Barsat / Siren. Tatar / Janbaz was the next best cross combination in respect of spike length (13.18 cm), while AUP-5008 / Siren (26.09 g) and Tatar / PS-05 (25.65 g) were the next high yielding cross combinations. Saleem-2K / Janbaz (22.47) and Basrat / PS-05 (78.88) produced utmost number of spikelets and grains spike⁻¹, respectively. Maximum hundred grain weight of 4.85 g was recorded for Tatar / PS-05, followed by Barsat / Siren (4.72 g), while maximum harvest index was recorded for AUP-5008 / Siren (45.47%), followed by Barsat / Siren (45.30%).

Table 1: Mean squares for various traits of 24 of wheat genotypes.

Source of variation	Rep (df=2)	Genotypes (df=23)	Parents (P) (df=7)	F ₂ populations (df=15)	P vs. F ₂ s (df=1)	Error (df=46)	CV (%)
Days to 50% heading	9.50	36.91**	50.14**	31.69**	22.57*	4.08	1.57
Flag leaf area	2.96	25.40**	48.96**	14.70**	20.99*	4.29	7.49
Days to maturity	1.93	9.71**	9.05**	9.27**	21.01**	2.84	0.98
Plant height	23.79	69.46**	91.22**	58.99**	74.21**	10.67	3.27
Fertile tillers plant ⁻¹	0.26	1.99**	1.61*	1.83**	7.07**	0.66	9.07
Biological yield	7.87	119.28**	193.41**	90.89**	26.15*	5.31	4.58
Spike length	0.50	1.39**	1.65**	1.18**	2.65*	0.46	5.44
Spikelets spike ⁻¹	1.02	2.83**	5.18**	1.69**	3.61**	0.50	3.49
Grains spike ⁻¹	2.60	64.21**	74.39**	61.93**	27.08**	2.58	2.36
100-grain weight	0.03	0.28**	0.44**	0.20**	0.24**	0.02	3.50
Grain yield plant ⁻¹	1.55	37.68**	66.56**	25.86**	12.86**	1.40	5.48
Harvest index	10.13	17.38**	34.87**	10.08**	4.40	3.90	3.64

*, ** = Significant at 5% and 1% level of probability, respectively.

Heritability and genetic advance: Heritability together with genetic advance (gain) provides approximate estimates of achievable gain at specific selection intensity. In this regard, Memon *et al.* (2005) reported that high heritability and genetic advance in wheat offer better opportunity for selecting better genotypes in early generations, because higher magnitude of heritability makes selection procedure more effective and simpler (Firouzain *et al.*, 2003). Similarly, Khan *et al.* (2003) also suggested that higher magnitude of heritability and genetic advance simplifies the selection procedure. Hence, it is concluded that assessment of heritability along with genetic advance had significant role in deciding the strategy and suitability for selection of a character. The present study revealed that all the characters were highly heritable in most of the F₂ crosses. Higher estimates of heritability (>60%) and genetic advance for flag leaf area (0.56-0.92 and 5.07-12.16 cm²), plant height (0.25-0.87 and 2.06-15.59 cm), fertile tillers (0.27-0.84 and 0.87-4.22 tillers), biological yield (0.72-0.95 and 18.18-28.64 g), spikelets spike⁻¹ (0.45-0.83 and 1.07-2.55 spikelets), grains spike⁻¹ (0.56-88 and 4.76-14.83 grains), grain yield (0.69-0.92 and 8.96-13.48 g) and harvest index (0.48-0.82 and 4.89-10.86%) in most of the F₂ crosses (Table 3) signifies the chance of success through efficient selection. These results also indicated high genetic potential for these traits, minimal environmental effects and presence of predominant role of additive genes; hence early generation selection based on these traits could be fruitful. Saleem *et al.* (2016) observed genetic variability and assessed high heritability and genetic advance for days to heading, plant height, flag leaf area and grain yield in most of the F₂ populations of wheat and suggested that these traits are under genetic control. Similarly, studies conducted on genetic variability and heritability by Ijaz *et al.* (2015), Waqas *et al.* (2014), Hussain *et al.* (2013), and Ajmal *et al.* (2009) also observed significant differences among F₂ populations and assessed high heritability accompanied by high genetic advance for the studied traits in most of the F₂ crosses. However, Ijaz and Samiullah (2013) observed moderate heritability estimates for spike length and flag leaf area and low for tillers plant⁻¹ and grain yield in segregating populations of wheat. Characters like spike length (0.32-0.61: 0.43-1.04 cm) and 100-grain weight (0.11-80: 0.07-0.85 g) were low (<30%) to moderately

heritable (>30%) and manifested low to moderate genetic advance in most of the segregating populations as reflected by its range. Such magnitude of heritability and genetic advance manifested that selection based on these characters should be practiced with care or should be delayed to later generations for improvement. These results are partially in line with the results reported earlier by Rashid *et al.* (2013), Karim and Jahan (2013) and Saleem *et al.* (2003).

Correlation analysis: Johnson *et al.* (1955) stated that two main reasons are believed for traits association; 1) pleiotropic gene effect which means that one gene influences two or more traits and 2) linkage effect which affect both traits simultaneously. Assessment of association between traits has significant importance in selecting best genetic stock for achieving maximum return per unit area in wheat. In this regard, correlations were assessed among various characters in order to identify desirable characters for indirect improvement of grain yield in bread wheat. Correlation analysis among grain yield and other traits manifested that traits like flag leaf area (rp=0.31), days to maturity (rp=0.29), plant height (rp=0.51), fertile tillers plant⁻¹ (rp=0.31), biological yield (rp=0.94) and harvest index (rp=0.73) showed significant contribution towards grains yield (Table 4). These results envisage the use of these traits for yield improvement in wheat. Reddy *et al.* (2017) pointed out that tillers plant⁻¹, grains spike⁻¹, test weight, biological yield plant⁻¹ and harvest index are important traits, significantly affecting grain yield. Similarly, Zeeshan *et al.* (2014), Iftikhar *et al.* (2013) and Ghafoor *et al.* (2013) also pointed out significant contribution of days to maturity, flag leaf area, plant height, tillers plant⁻¹ and biological yield towards grain yield. However, Baranwal *et al.* (2012) assessed significantly negative association between plant height and grain yield. No correlation between grains spike⁻¹ and grain yield and spikelets spike⁻¹ and grain yield is in line with the results of Khan *et al.* (2013) and Ajmal *et al.* (2009), respectively. Contrary to our results, Moustafa and Omer (2014) assessed correlation in some derived segregating wheat populations and pointed out significant phenotypic correlation of grain yield with spikelets and grains spike⁻¹. Similarly, Kashif and Khaliq (2004) also pointed out notable contribution of spike length and spikelets and grains spike⁻¹ towards grain yield.

Table 2: Mean values for various traits of 24 of wheat genotypes.

Genotypes	DH	FLA	DM	PH	FT	BY	SL	SSP	GSP	HGW	GY	HI
Parents												
Janbaz	125.33	25.81	169.67	100.57	9.30	59.03	12.90	21.97	72.47	4.22	24.81	42.07
Siren	125.67	25.93	168.67	94.66	9.07	50.76	13.03	20.73	60.77	4.38	21.66	42.73
Fakhr-e-Sarhad	134.33	31.78	173.33	100.27	10.03	56.92	13.24	21.50	74.10	3.64	27.16	47.87
Pirsabak-2005	130.33	36.43	173.00	108.97	10.17	58.25	12.67	18.90	64.10	4.71	26.06	44.98
AUP-5008	132.33	26.60	169.67	94.54	10.23	37.87	12.90	20.03	68.13	3.98	13.80	36.23
Tatara	123.67	28.99	169.67	100.68	9.60	46.34	10.96	18.00	63.43	4.51	18.78	40.69
Saleem-2K	125.00	23.74	170.67	90.71	8.13	45.01	12.64	19.77	71.70	3.94	18.03	40.42
Barsat	124.33	27.92	169.33	98.40	8.83	41.62	13.30	19.57	63.73	4.69	17.64	42.59
Mean (Parents)	127.63	28.40	170.50	98.60	9.42	49.47	12.70	20.06	67.30	4.26	20.99	42.20
LSD_(0.05)	3.54	3.63	2.95	5.72	1.43	4.04	1.19	1.24	2.81	0.27	2.07	3.46
F₂ populations												
AUP-5008 / Janbaz	129.67	29.44	173.67	103.84	7.97	53.24	12.85	21.07	70.93	4.20	22.41	42.03
Tatara / Janbaz	122.00	30.34	169.33	98.74	7.40	46.64	13.18	20.62	70.00	4.61	20.44	43.25
Saleem-2K / Janbaz	131.00	26.28	170.67	94.78	8.13	45.98	12.61	22.47	71.33	4.59	20.24	44.07
Barsat / Janbaz	132.00	28.91	173.67	100.58	7.63	40.96	12.70	20.37	70.25	4.45	16.86	39.65
AUP-5008 / Siren	125.67	23.52	173.67	103.86	9.77	56.95	12.26	20.52	65.72	4.19	26.09	45.47
Tatara / Siren	131.00	29.65	172.00	102.28	7.95	53.87	12.19	19.97	66.37	4.44	22.02	40.53
Saleem-2K / Siren	133.00	26.56	173.33	92.60	9.32	50.66	11.96	19.95	73.32	4.01	21.74	42.55
Barsat / Siren	128.00	27.54	170.67	101.34	9.55	60.93	13.52	20.55	65.63	4.72	27.93	45.39
AUP-5008 / FS	125.33	28.46	170.33	106.99	9.92	51.51	12.04	19.85	64.15	4.38	21.73	42.40
Tatara / FS	124.33	26.02	170.00	101.43	8.83	46.01	11.42	19.68	65.27	4.39	19.85	43.72
Saleem-2K / FS	133.33	22.79	173.00	95.94	8.60	45.21	12.05	21.67	63.82	4.16	18.18	39.63
Barsat / FS	128.00	26.15	173.00	99.65	8.55	50.02	12.83	20.43	61.68	4.48	21.66	43.00
AUP-5008 / PS-05	130.33	28.96	171.33	107.12	9.72	57.07	11.27	19.45	72.15	4.57	24.41	42.59
Tatara / PS-05	131.33	28.63	173.33	107.35	8.92	57.56	11.69	20.53	65.40	4.85	25.65	44.62
Saleem-2K / PS-05	128.33	24.85	168.67	96.97	8.98	46.76	11.78	20.70	72.78	3.94	19.41	40.89
Barsat / PS-05	127.67	27.98	169.67	98.57	8.87	48.65	12.43	20.72	78.88	4.10	21.61	43.78
Mean (F₂ populations)	128.81	27.25	171.65	100.75	8.76	50.75	12.30	20.53	68.61	4.38	21.89	42.72
LSD_(0.05)	3.37	3.45	2.81	5.45	1.36	3.84	1.13	1.18	2.68	0.25	1.97	3.29
Mean (Genotypes)	128.42	27.64	171.26	100.03	8.98	50.33	12.43	20.38	68.17	4.34	21.59	42.55
LSD_(0.05)	3.32	3.40	2.77	5.37	1.34	3.79	1.11	1.17	2.64	0.25	1.94	3.25

Note: DH- days to 50% heading, FLA- flag leaf area, DM- days to maturity, PH- plant height, FT- fertile tillers plant⁻¹, BY- biological yield plant⁻¹, SL- spike length, SSP- spikelets spike⁻¹, GSP- grains spike⁻¹, HGW- 100-grain weight, GY- grain yield plant⁻¹ and HI- harvest index.

Table 3: Heritability and genetic advance for various quantitative traits of 16 F₂ populations of wheat.

F ₂ Populations	FLA		PH		FT		BY		SL		SSP		GSP		HGW		GY		HI	
	<i>h</i> ²	GA	<i>h</i> ²	GA	<i>h</i> ²	GA	<i>h</i> ²	GA	<i>h</i> ²	GA	<i>h</i> ²	GA	<i>h</i> ²	GA	<i>h</i> ²	GA	<i>h</i> ²	GA	<i>h</i> ²	GA
AUP-5008 / Janbaz	0.56	5.49	0.25	2.06	0.27	0.87	0.72	18.48	0.36	0.55	0.50	1.13	0.68	11.85	0.30	0.20	0.69	9.21	0.48	5.92
Tatara / Janbaz	0.89	9.74	0.43	4.16	0.65	2.15	0.89	18.18	0.56	0.89	0.65	1.49	0.66	5.98	0.48	0.33	0.88	10.43	0.70	7.14
Saleem-2K / Janbaz	0.92	11.48	0.62	7.30	0.82	3.69	0.93	25.26	0.49	0.77	0.54	1.38	0.85	11.75	0.66	0.74	0.91	11.91	0.73	8.23
Barsat / Janbaz	0.78	7.97	0.66	6.46	0.60	2.20	0.88	21.46	0.57	0.87	0.66	1.46	0.65	6.30	0.52	0.35	0.90	11.34	0.71	8.13
AUP-5008 / Siren	0.78	6.9	0.58	5.03	0.71	3.02	0.91	22.63	0.47	0.62	0.76	1.87	0.83	11.20	0.63	0.50	0.92	12.98	0.68	7.39
Tatara / Siren	0.86	9.71	0.87	14.99	0.67	2.50	0.91	24.64	0.61	0.91	0.83	2.55	0.88	14.83	0.67	0.55	0.91	12.60	0.78	9.47
Saleem-2K / Siren	0.85	8.71	0.60	5.70	0.78	3.55	0.89	24.22	0.56	0.81	0.55	1.34	0.83	11.78	0.22	0.15	0.92	12.70	0.71	7.93
Barsat / Siren	0.81	8.74	0.66	6.44	0.64	2.45	0.89	21.64	0.55	0.82	0.77	2.07	0.84	12.00	0.52	0.35	0.91	11.93	0.60	5.85
AUP-5008 / F.S	0.84	9.25	0.71	7.09	0.78	3.55	0.94	26.38	0.50	0.73	0.59	1.21	0.85	11.77	0.38	0.25	0.90	11.55	0.65	6.71
Tatara / F.S	0.89	12.16	0.61	5.83	0.78	3.26	0.87	18.59	0.54	0.81	0.61	1.31	0.79	9.32	0.39	0.24	0.85	8.96	0.82	10.86
Saleem-2K / F.S	0.74	6.17	0.63	6.00	0.74	2.90	0.85	18.67	0.42	0.59	0.45	1.07	0.66	6.18	0.22	0.16	0.86	9.02	0.70	7.45
Barsat / F.S	0.78	8.4	0.47	3.58	0.73	2.98	0.91	22.94	0.55	0.88	0.67	1.58	0.87	12.76	0.51	0.36	0.90	11.02	0.69	7.55
AUP-5008 / PS-05	0.83	8.8	0.87	15.59	0.77	3.53	0.95	28.64	0.61	1.04	0.74	1.90	0.87	13.25	0.44	0.28	0.92	13.48	0.57	5.48
Tatara / PS-05	0.83	9.07	0.82	13.85	0.84	4.22	0.92	25.84	0.55	0.85	0.66	1.57	0.79	9.94	0.80	0.85	0.90	12.21	0.56	4.89
Saleem-2K / PS-05	0.68	5.07	0.76	10.79	0.77	3.27	0.86	19.41	0.43	0.62	0.61	1.75	0.56	4.76	0.11	0.07	0.88	10.49	0.62	6.18
Barsat / PS-05	0.81	9.25	0.57	5.71	0.77	3.54	0.91	22.82	0.32	0.43	0.66	1.58	0.83	11.17	0.40	0.24	0.90	11.82	0.72	8.49

Note: FLA- flag leaf area, PH- plant height, FT- fertile tillers plant⁻¹, SL- spike length, BY- biological yield, SSP- spikelets spike⁻¹, GSP- grains spike⁻¹, HGW- 100-grain weight, GY- grain yield plant⁻¹ and HI- harvest index.

Table 4: Correlation coefficients for various quantitative traits with grain yield.

Traits	Phenotypic correlation (<i>rp</i>)	<i>P</i> -value
Days to heading	0.08	0.506
Flag leaf area	0.31	0.008
Days to maturity	0.29	0.014
Plant height	0.51	0.000
Fertile tillers plant ⁻¹	0.31	0.007
Biological yield	0.94	0.000
Spike length	0.07	0.559
Spikelets spike ⁻¹	0.13	0.273
Grains spike ⁻¹	0.05	0.665
100-grain weight	0.16	0.183
Harvest index	0.73	0.000

CONCLUSIONS AND RECOMMENDATIONS

1. Significant differences were observed among all the genotypes for all the traits studied, representing sufficient genetic variability for effective selection.

2. Most of the assessed traits witnessed high heritability and genetic advance in most of the F₂ populations, which suggested that improvement for these traits would be fruitful through selection of these traits.

3. Traits like days to maturity, flag leaf area, plant height, fertile tillers plant⁻¹, biological yield and harvest index manifested notable contribution towards grain yield, therefore, may be considered as effective criteria for selection towards improvement of grain yield in wheat.

AUTHORS CONTRIBUTIONS

This research article is an integral part of Masters Study of the first author *T. Iqbal*. *G. Hassan* conceived the idea and formulated the research. *T. Iqbal* performed the experiment and wrote the first draft of the manuscript. *G. Hassan* made critical corrections in the first draft. *I. Hussain* helps in data collection and provided technical support. All authors read and approved the final manuscript.

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