Research Article

# Heritability and Selection Response for Grain Yield and Associated Traits in $F_3$ Wheat Populations

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**Abstract** | Broad sense heritability and selection responses were assessed for grain yield and related traits in 12 $F_3$ populations of wheat got from mating of six advanced lines and two widely cultivated cultivars (Pirsabak-08 and Janbaz) at University of Agriculture, Peshawar during 2013-14. All wheat genotypes (8 parents and 12 $F_3$ populations) showed significant differences for all traits. Cultivar Janbaz had maximum spike length (13.9 cm) and maximum number of grains spike$^{-1}$ (89.2). Parental line B-IV(N)5 had maximum single spike weight (4.6 g), 100-grain weight (4.6 g) and grain yield (32.0 g plant$^{-1}$). $F_3$ population B-RF7 × Janbaz had 100-grain weight (4.5 g) and grain yield (31.9 g plant$^{-1}$). Similarly, $F_3$ population B-RF1 × Janbaz had more single spike weight (4.1 g). Population B-RF3 × Janbaz had maximum spike length (14.5 cm) and number of grains spike$^{-1}$ (85.1). $F_3$ populations B-RF7 × Pirsabak-08, B-IV(N)5 × Pirsabak-08, B-RF7 × Janbaz, B-IV(N)5 × Pirsabak-08, B-RF7 × Janbaz, B-RF1 × Janbaz, B-IV(N)12 × Janbaz had maximum heritability and selection responses for plant height (0.76 and 10.96 cm), spike length (0.93 and 4.51 cm), grains spike$^{-1}$ (0.93 and 25.54), single spike weight (0.89 and 3.08 g), 100 grain weight (0.90 and 1.26 g) and grain yield plant$^{-1}$ (0.75 and 12.15 g), respectively. On basis of high heritability coupled with high selection response for yield related traits, $F_3$ populations B-IV(N)5 × Pirsabak-08, B-IV(N)5 × Janbaz, B-RF1 × Janbaz and B-RF7 × Janbaz should be advanced further for possible development of high yielding wheat cultivars.

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## Introduction

Wheat has always been under major research to improve its grain production as well as quality. However, there is still broad space for genetic improvement of wheat to meet the developing necessities of the expanding population. Genetic exploitation is the most ideal approach to increase wheat production. In this way, it is essential to study the hereditary changes and mode of inheritance of distinctive parameters for effective wheat breeding projects (Ijaz and Khan, 2009). Wheat breeders are attempting to grow new cultivars which are high yielding, drought tolerant and have resistance against diseases and insects/pests. Wheat breeders are generally selecting required genotypes in initial filial generations when a trait has high heritability or late selection until advanced filial generations, when the offspring are nearly homozygous. Direct assessment of yield is mostly difficult in initial generation selection. So, plant breeders are selecting those traits which ultimately increase yield. Breeding yield traits to increase grain

yield is more efficient way if these traits are highly heritable and positively correlated with grain yield. The selection measures for increasing production may be yield or one or more parameters of yield like number of spikes per unit area, grains spike$^{-1}$ and grain weight (Donmez et al., 2001). Heritability provides selection response, which help in predicting performance in the next generation for effective breeding programs. Various approaches have been adopted to improve yield potential of wheat (Ahmedi and Bajelan, 2008; Siddiqui et al., 1991). High heritability associated with high selection response play a major role in selecting high yielding genotypes, because high heritability with high selection response has additive genetic variation for character of interest (Iqbal and Khan, 2003). Current research was planned to compare performance and to determine heritability and selection response for yield and its contributing traits from variances of parents and 12 $F_3$ populations as well as from expected mean squares of ANOVA.

## Materials and Methods

In this study, eight parental wheat cultivars/lines and their 12 $F_3$ populations were evaluated in a randomized complete block design with three replications. A plot for each genotype had two rows, each 3-meter long. Row to row and plant to plant distance for each parental and $F_3$ population in a replication was 30 and 10 cm, respectively. Urea and DAP fertilizers were applied to provide 120 kg N and 60 kg P ha$^{-1}$. Half of N and full dose of P was applied at sowing time, while the remaining N was applied at tillering stage.

### *Statistical analysis*

The average data of 8 parental lines/cultivars and 12 $F_3$ population was subjected to analysis of variance for RCB design by Singh and Chaudhary (1985).

Heritability and selection response for traits were estimated by two methods as explained below.

### *Using variances of parents and $F_3$ populations*

Using variances of parental lines/cultivars and $F_3$ populations, broad sense heritability for yield and its contributing traits was computed for each cross combination using the following formula an analogy of Mahmud and Kramer (1951).

$$h^2_{B.s} = [VF3 - \sqrt{(Vp1 \times Vp2)}] / VF3$$

Where;
VF3 = Variance derived from 30 plants of a specific F3 population for a trait; Vp1 and Vp2 = Variance resulting from 15 plants each of parent 1 and parent 2 of a specific F3 population; Expected selection response (Re) was calculated for all traits pertaining to each of the 12 $F_3$ populations using the following method (Fehr, 1993).

$$Re = i \times \sqrt{(Vp)} \times h^2$$

Where;
Re = Expected selection response; i = 1.40 at 20% selection intensity; Vp = phenotypic variance of a trait; h2B.S = broad sense heritability for a trait.

Thus, for each trait there were 12 values of heritability and selection responses, each pertaining to a different F3 population. This helped in identification of F3 populations with a potential to produce desirable segregants in succeeding generations.

### *Using expected mean squares*

For each trait, genetic and environmental variances was also computed from the expected mean squares as follows:

Genetic variance = $V_g$ = (M2 - M6)/r
Environmental variance = $V_e$ = M6
Phenotypic variance = $V_p = V_g + V_e$
Heritability = $V_g / V_p$

$$Re = i \times \sqrt{(Vp)} \times h^2$$

Where;
i = 1.4 at 20% selection intensity; Vp = phenotypic variance for a specific trait; h2 = heritability for a specific trait

## Results and Discussion

### *Plant height (cm)*

Mean squares were highly significant in wheat genotypes, parents and $F_3$ population (P = 0.01) for plant height, while parents vs $F_3$ populations contrast was non-significant (Table 1). Plant height ranged from 76.2 to 109.9 cm among parents. Parental line B-RF3 had maximum plant height (109.9 cm), while Pirsabak-08 had minimum plant height (76.2 cm) among parents. Among $F_3$ populations, plant height ranged

**Table 1:** *Mean squares for different traits of 20 wheat genotypes (8 parents and 12 $F_3$ populations).*

| Source | Df | Plant height | Spike length | Single spike weight | Number of grains spike$^{-1}$ | 100-grain weight | Grain yield plant$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Replication | 2 | 112.46$^{ns}$ | 1.46$^{ns}$ | 15.26$^{ns}$ | 9.42$^{ns}$ | 0.37* | 15.26$^{ns}$ |
| Genotypes | 19 | 276.72** | 1.38** | 39.17** | 79.26** | 0.36** | 39.17** |
| Parents | 7 | 388.52** | 1.96** | 40.74* | 44.51$^{ns}$ | 0.60** | 40.74* |
| $F_3$ Pops | 11 | 230.28** | 0.80$^{ns}$ | 12.97$^{ns}$ | 58.93* | 0.16$^{ns}$ | 12.97$^{ns}$ |
| Parents vs $F_3$ Pops | 1 | 4.87$^{ns}$ | 3.62* | 316.37** | 546.12** | 0.71* | 316.37** |
| Error | 38 | 35.94 | 0.51 | 12.59 | 24.08 | 0.11 | 12.59 |
| CV (%) | - | 6.17 | 5.40 | 14.49 | 6.36 | 8.87 | 14.49 |

*, **: *Significant at 5 and 1% probability level, respectively;* **ns:** *Non-significant.*

from 80.3 to 112.8 cm (Table 3). Maximum plant height (112.8 cm) was recorded for $F_3$ population B-RF1 × Janbaz while minimum plant height (80.3 cm) was recorded for B-IV(N)5 × Pirsabak-08. Yield components and some morphological characters were studied in an experiment comprising 42 winter wheat genotypes by Khalil et al. (2011). They reported highly significant differences among the wheat genotypes for plant height which is in accordance to our findings.

**Table 2:** *Heritability ($h^2$) and expected selection response ($R_s$) derived from expected mean squares of 20 wheat genotypes (8 parents and 12 $F_3$ populations).*

| Trait | Vg | Ve | $h^2$ | $R_e$ |
|---|---|---|---|---|
| Plant height (cm) | 80.26 | 35.94 | 0.69 | 10.42 |
| Spike length (cm) | 0.29 | 0.51 | 0.36 | 0.45 |
| Single spike weight (g) | 0.14 | 0.21 | 0.41 | 0.34 |
| Grains spike$^{-1}$ (no) | 18.39 | 24.08 | 0.43 | 3.95 |
| 100- grain weight (g) | 0.08 | 0.11 | 0.43 | 0.26 |
| Grain yield plant$^{-1}$ (g) | 8.86 | 12.59 | 0.41 | 2.68 |

Variances for plant height ranged from 24.4 to 74.3 among Parents (Table 4). Minimum variance (24.4) was obtained for parental line B-RF7 and maximum (74.3) for parental line B-IV(N)12. Variances among $F_3$ populations for plant height ranged from 43.5 to 135.6. Hence, variances among $F_3$ populations were greater in magnitude than parental lines. Maximum variance (135.6) for plant height among $F_3$ population was observed for B-IV(N)5 × Pirsabak-08, while minimum variance (43.5) for B-RF7 × Janbaz (Table 4). Heritability of plant height ranged from 0.20 to 0.76 with selection responses of 2.11 to 10.96 cm (Table 3). Maximum heritability (0.76) with maximum selection response (10.96 cm) was observed for $F_3$ population B-RF7 × Pirsabak-08. In contrast, lowest heritability (0.20) coupled with minimum selection response (2.11 cm) for plant height was observed for $F_3$ population B-IV(N)12 × Pirsabak-08. Using expected mean squares from ANOVA of plant height broad sense heritability was 0.69 along with selection response of 10.42 (Table 2). High heritability values were also reported by Ikramullah et al. (2011) for plant height in wheat genotypes in irrigated (0.85) as well as non-irrigated (0.87) environment. Baloch et al. (2013) and Bilgin et al. (2011) have also recorded high heritability (0.99 and 0.92, respectively) for plant height in wheat genotypes.

*Spike length (cm)*

Significant differences were observed among the wheat genotypes (P = 0.01), parents (P=0.01) and parents vs $F_3$ population contrast (P=0.05) for spike length. However, differences among $F_3$ populations were non-significant for spike length (Table 1). Spike length ranged from 11.8 to 13.9 cm among parents (Table 3). Parental line B-IV(N)5 and cultivar Janbaz had maximum spike length (13.9 cm), while B-IV(N)11 had minimum spike length (11.8 cm) among parents. Among $F_3$ populations, spike length ranged from 12.8 to 14.5 cm (Table 3). Thus, spike length was more in $F_3$ population than the parental line. Maximum spike length (14.5 cm) was recorded for population B-RF3 × Janbaz, while B-RF1 × Pirsabak-08 had minimum spike length (12.8 cm). El-Shafi (2013) has also reported significant differences among wheat genotypes and their three generations ($F_2$, $F_3$ and $F_4$) for spike length.

Variances among parents for spike length ranged from 0.4 to 2.4 (Table 3). Maximum variance (2.4) was recorded for wheat parental lines B-RF1 and B-RF3 and minimum (0.4) for parental line B-RF7. Variances among $F_3$ populations for spike length ranged from 1.6 to 12.1 (Table 3). $F_3$ population

**Table 3:** *Mean values for different traits of 20 wheat genotypes (8 parents and 12 $F_3$ populations).*

| Genotypes | Plant height (cm) | Spike length (cm) | Single spike weight (g) | Number of grains spike$^{-1}$ | 100-grain weight (g) | Grain yield plant$^{-1}$ (g) |
|---|---|---|---|---|---|---|
| **I. Parents** | | | | | | |
| B-IV(N)11 | 86.9 | 11.8 | 3.9 | 81.1 | 3.8 | 31.2 |
| B-VI(N)5 | 99.3 | 13.9 | 4.6 | 81.3 | 4.6 | 32.0 |
| B-VI(N)12 | 106.9 | 13.3 | 4.4 | 78.5 | 4.3 | 31.5 |
| B-RF1 | 108.2 | 12.9 | 3.9 | 79.4 | 3.6 | 28.6 |
| B-RF3 | 109.9 | 13.3 | 3.6 | 83.1 | 3.6 | 30.6 |
| B-RF7 | 97.3 | 12.7 | 3.3 | 77.5 | 3.4 | 32.0 |
| Pirsabak-08 | 76.2 | 11.9 | 3.4 | 77.8 | 3.4 | 31.3 |
| Janbaz | 96.9 | 13.9 | 4.3 | 89.2 | 4.1 | 31.2 |
| Parents Mean | 97.7 | 13.0 | 3.9 | 81.0 | 3.9 | 31.1 |
| **II. $F_3$ Populations** | | | | | | |
| B-IV(N)11 × Pirsabak-08 | 92.3 | 12.9 | 3.3 | 72.6 | 3.3 | 29.9 |
| B-IV(N)11 × Janbaz | 96.9 | 13.7 | 3.1 | 70.9 | 3.4 | 30.1 |
| B-IV(N)5 × Pirsabak-08 | 80.3 | 13.4 | 3.6 | 75.6 | 3.6 | 30.8 |
| B-IV(N)5 × Janbaz | 94.4 | 14.0 | 3.5 | 72.0 | 3.7 | 29.4 |
| B-IV(N)12 × Pirsabak-08 | 97.5 | 13.0 | 3.6 | 80.3 | 3.7 | 31.2 |
| B-IV(N)12 × Janbaz | 91.6 | 13.1 | 3.4 | 73.1 | 3.5 | 30.1 |
| B-RF1 × Pirsabak-08 | 98.4 | 12.8 | 3.3 | 73.2 | 3.7 | 30.9 |
| B-RF1 × Janbaz | 112.8 | 13.7 | 4.1 | 77.8 | 3.9 | 31.7 |
| B-RF3 × Pirsabak-08 | 88.9 | 13.1 | 3.5 | 75.0 | 3.7 | 31.2 |
| B-RF3 × Janbaz | 100.0 | 14.5 | 3.8 | 85.1 | 3.7 | 31.8 |
| B-RF7 × Pirsabak-08 | 100.6 | 13.7 | 3.2 | 71.2 | 3.7 | 30.4 |
| B-RF7 × Janbaz | 111.5 | 13.5 | 3.9 | 69.8 | 4.5 | 31.9 |
| $F_3$ Mean | 97.1 | 13.5 | 3.5 | 74.7 | 3.7 | **30.8** |
| LSD (5%) | 9.9 | 1.2 | 0.8 | 8.1 | 0.5 | 5.9 |

B-IV(N)5 × Pirsabak-08 had maximum variance (12.1), while minimum variance (1.6) was recorded in populations B-IV(N)12 × Pirsabak-08 and B-RF1 × Janbaz for spike length. Estimates of heritability and selection response for spike length ranged from 0.20 to 0.93 and 0.37 to 4.51 cm, respectively. $F_3$ population B-IV(N)5 × Pirsabak-08 exhibited highest heritability (0.90) with selection response of 4.51 cm. In contrast, $F_3$ population B-IV(N)5 × Janbaz had minimum heritability of 0.20 with selection response of 0.39 cm for spike length. While minimum selection response was observed for $F_3$ population B-IV(N)12 × Pirsabak-08. Using expected mean squares, spike length had 0.36 heritability with selection response of 0.45 cm (Table 2). Ijaz and Khan (2009) assessed six $F_2$ populations involving five wheat varieties/lines and recorded moderate heritability (0.52) for spike length.

*Single spike weight (g)*

Statistical analysis revealed significant differences among the wheat genotypes (P = 0.01), parents (P = 0.05), and parents vs $F_3$ populations contrast (P = 0.01), however non-significant differences were observed among $F_3$ populations for single spike weight (Table 1). Among parents, single spike weight ranged from 3.3 to 4.6 g (Table 3). Maximum spike weight (4.6 g) was recorded for parental line B-IV(N)5, while minimum (3.3 g) for parental line B-RF7. Among $F_3$ populations, spike weight ranged from 3.1 to 4.1 g (Table 3). Population B-RF1 × Janbaz had maximum spike weight (4.1 g), while population B-IV(N)11 × Janbaz had minimum (3.1 g). Thus, spike weight of $F_3$ population was lower than parental lines. A set of 28 elite wheat lines was assessed in a randomized complete block design with factorial treatment (unclipped and clipped) by Khalil et al. (2008) and Shuja et al. (2010) evaluated six spring wheat genotypes (Pirsbak-85, Dera-98, Ghaznavi-98, Fakhr-e-Sarhad, Takbeer and SARC-3) and reported significant differences among wheat genotypes for single spike weight.

**Table 4:** *Variances, heritability ($h^2$) and expected selection response ($R_e$) for different traits of 12 $F_3$ populations derived from 8 wheat parents.*

| Genotypes | Plant height (cm) | | | Spike length (cm) | | | Single spike weight (g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Variance | $h^2$ | $R_e$ | Variance | $h^2$ | $R_e$ | Variance | $h^2$ | $R_e$ |
| **I. Parents** | | | | | | | | | |
| B-IV(N)11 | 32.2 | - | - | 2.3 | - | - | 0.5 | - | - |
| B-VI(N)5 | 72.2 | - | - | 0.8 | - | - | 0.9 | - | - |
| B-VI(N)12 | 74.3 | - | - | 1.6 | - | - | 0.8 | - | - |
| B-RF1 | 58.0 | - | - | 2.4 | - | - | 1.3 | - | - |
| B-RF3 | 29.2 | - | - | 2.4 | - | - | 0.4 | - | - |
| B-RF7 | 24.4 | - | - | 0.4 | - | - | 0.5 | - | - |
| Pirsabak-08 | 27.6 | - | - | 1.0 | - | - | 0.3 | - | - |
| Janbaz | 37.8 | - | - | 0.5 | - | - | 0.8 | - | - |
| **II. $F_3$ Populations** | | | | | | | | | |
| B-IV(N)11 × Pirsabak-08 | 62.9 | 0.53 | 5.84 | 2.1 | 0.28 | 0.56 | 2.4 | 0.84 | 1.82 |
| B-IV(N)11 × Janbaz | 69.5 | 0.50 | 5.81 | 2.5 | 0.57 | 1.26 | 4.9 | 0.87 | 2.70 |
| B-IV(N)5 × Pirsabak-08 | 135.6 | 0.67 | 10.94 | 12.1 | 0.93 | 4.51 | 4.0 | 0.87 | 2.44 |
| B-IV(N)5 × Janbaz | 111.8 | 0.73 | 10.86 | 1.9 | 0.20 | 0.39 | 2.5 | 0.85 | 1.87 |
| B-IV(N)12 × Pirsabak-08 | 56.6 | 0.20 | 2.11 | 1.6 | 0.21 | 0.37 | 3.0 | 0.84 | 2.03 |
| B-IV(N)12 × Janbaz | 83.6 | 0.37 | 4.69 | 3.4 | 0.74 | 1.90 | 4.7 | 0.83 | 2.52 |
| B-RF1 × Pirsabak-08 | 96.4 | 0.58 | 8.04 | 2.2 | 0.30 | 0.61 | 3.1 | 0.80 | 1.97 |
| B-RF1 × Janbaz | 90.6 | 0.48 | 6.44 | 1.6 | 0.32 | 0.56 | 1.8 | 0.43 | 0.81 |
| B-RF3 × Pirsabak-08 | 94.4 | 0.70 | 9.51 | 4.3 | 0.64 | 1.86 | 3.2 | 0.89 | 2.23 |
| B-RF3 × Janbaz | 47.4 | 0.30 | 2.88 | 1.7 | 0.36 | 0.65 | 3.1 | 0.82 | 2.02 |
| B-RF7 × Pirsabak-08 | 106.9 | 0.76 | 10.96 | 4.8 | 0.87 | 2.66 | 3.5 | 0.89 | 2.33 |
| B-RF7 × Janbaz | 43.5 | 0.30 | 2.79 | 2.9 | 0.85 | 2.02 | 5.9 | 0.89 | 3.04 |

Variances among parents for single spike weight ranged from 0.3 to 1.3 (Table 4). Parental line B-RF1 had maximum variance (1.3) for single spike weight, while Pirsabak-08 had minimum variance (0.3) among parental lines. Variances for single spike weight ranged from 1.8 to 5.9 among $F_3$ populations (Table 4). Maximum variance (5.9) was recorded for $F_3$ population B-RF7 × Janbaz, while population B-RF1 × Janbaz had minimum variance (1.8) for single spike weight (Table 4). Heritability and selection responses for spike weight ranged from 0.43 to 0.89 and 0.81 to 3.04, respectively. $F_3$ populations B-RF3 × Pirsabak-08, B-RF7 × Pirsabak-08 and B-RF7 × Janbaz had highest heritability (0.89) along with selection responses of 2.23, 2.33 and 3.04 g, respectively. While $F_3$ population B-RF1 × Janbaz had lowest heritability (0.43) with the minimum selection response of 0.81 g for single spike weight. Based on mean squares broad sense heritability for single spike weight was 0.73 with selection response of 0.90 g (Table 2).

### *Number of grains spike$^{-1}$*

Mean squares for grains spike$^{-1}$ were highly significant differences among genotypes (P = 0.01), $F_3$ populations (P = 0.05), parents vs $F_3$ populations contrast (P = 0.01). However, differences among parents were non-significant for grains spike$^{-1}$ (Table 1). Grainshspike$^{-1}$ ranged from 77.5 to 89.2 among parents (Table 3). Maximum number of grains (89.2 spike$^{-1}$) were recorded in cultivar Janbaz, while minimum (77.5 spike$^{-1}$) for parental line B-RF7. Among $F_3$ populations, grains spike$^{-1}$ ranged from 69.8 to 85.1 (Table 3). $F_3$ population B-RF3 × Janbaz exhibited maximum grains (85.1 spike$^{-1}$), while minimum grains (69.8 spike) were recorded in B-RF7 × Janbaz. Aycicek et al. (2006) evaluated 20 wheat genotypes and reported significant differences for grains spike$^{-1}$. Similarly, Azam et al. (2013) also reported significant differences for grain spike$^{-1}$ in wheat genotypes.

Variances for number of grains spike$^{-1}$ ranged from 12.9 to 102.6 among parents (Table 5). Parental line B-IV(N)12 had maximum variance (102.6) for grains spike$^{-1}$, while Pirsabak-08 had minimum variance (12.9) for number of grains spike$^{-1}$. Variances among $F_3$ populations for number of grains spike$^{-1}$ ranged

**Table 5:** *Variances, heritability ($h^2$) and expected selection response ($R_e$) for different traits of 12 $F_3$ populations derived from 8 wheat parents.*

| Genotypes | Number of grains spike$^{-1}$ | | | 100-grain weight (g) | | | Grain yield plant$^{-1}$ (g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Variance | $h^2$ | $R_e$ | Variance | $h^2$ | $R_e$ | Variance | $h^2$ | $R_e$ |
| **I. Parents** | | | | | | | | | |
| B-IV(N)11 | 49.5 | - | - | 0.3 | - | - | 31.8 | - | - |
| B-VI(N)5 | 35.8 | - | - | 0.2 | - | - | 42.3 | - | - |
| B-VI(N)12 | 102.6 | - | - | 0.1 | - | - | 32.0 | - | - |
| B-RF1 | 93.8 | - | - | 0.1 | - | - | 34.5 | - | - |
| B-RF3 | 36.1 | - | - | 0.3 | - | - | 43.4 | - | - |
| B-RF7 | 33.6 | - | - | 0.1 | - | - | 36.9 | - | - |
| Pirsabak-08 | 12.9 | - | - | 0.2 | - | - | 32.3 | - | - |
| Janbaz | 22.5 | - | - | 0.1 | - | - | 34.2 | - | - |
| **II. $F_3$ Populations** | | | | | | | | | |
| B-IV(N)11 × Pirsabak-08 | 157.5 | 0.84 | 14.75 | 0.8 | 0.69 | 0.87 | 55.1 | 0.42 | 4.35 |
| B-IV(N)11 × Janbaz | 171.6 | 0.81 | 14.77 | 1.3 | 0.87 | 1.38 | 60.3 | 0.45 | 4.93 |
| B-IV(N)5 × Pirsabak-08 | 290.7 | 0.93 | 22.11 | 1.2 | 0.83 | 1.28 | 74.7 | 0.51 | 6.11 |
| B-IV(N)5 × Janbaz | 381.7 | 0.93 | 25.54 | 1.4 | 0.83 | 1.37 | 114.5 | 0.67 | 10.00 |
| B-IV(N)12 × Pirsabak-08 | 152.2 | 0.76 | 13.14 | 0.7 | 0.80 | 0.93 | 55.9 | 0.42 | 4.45 |
| B-IV(N)12 × Janbaz | 174.0 | 0.72 | 13.37 | 0.7 | 0.86 | 1.00 | 133.3 | 0.75 | 12.15 |
| B-RF1 × Pirsabak-08 | 208.0 | 0.83 | 16.81 | 0.6 | 0.76 | 0.83 | 55.7 | 0.40 | 4.19 |
| B-RF1 × Janbaz | 149.6 | 0.69 | 11.87 | 1.0 | 0.90 | 1.26 | 92.9 | 0.63 | 8.50 |
| B-RF3 × Pirsabak-08 | 165.2 | 0.87 | 15.64 | 0.5 | 0.51 | 0.50 | 68.3 | 0.45 | 5.23 |
| B-RF3 × Janbaz | 296.7 | 0.90 | 21.80 | 0.5 | 0.65 | 0.65 | 55.6 | 0.31 | 3.21 |
| B-RF7 × Pirsabak-08 | 220.4 | 0.91 | 18.82 | 0.7 | 0.80 | 0.93 | 81.8 | 0.58 | 7.32 |
| B-RF7 × Janbaz | 232.0 | 0.88 | 18.80 | 0.5 | 0.80 | 0.79 | 48.3 | 0.26 | 2.57 |

from 149.6 to 381.7. $F_3$ Population B-IV(N)5 × Janbaz had maximum variance (381.7), while population B-RF1 × Janbaz had minimum variance (149.6) (Table 5). Heritability and selection response estimates for grains spike$^{-1}$ ranged from 0.69 to 0.93 and 11.87 to 25.54, respectively. $F_3$ Populations B-IV(N)5 × Pirsabak-08 and B-IV(N)5 × Janbaz had highest heritability (0.93 each) along with the selection responses of 22.11 and 25.54, respectively. In contrast, $F_3$ population B-RF1 × Janbaz had lowest heritability (0.69) along with the selection response (11.87) for number of grains spike$^{-1}$. Using expected mean squares broad sense heritability for grain spike$^{-1}$ was 0.43 along with selection response of 3.95 (Table 2). Memon et al. (2007) reported moderate heritability (0.56) which confirms our research findings.

*100-grain weight (g)*

Analysis of variance for 100-grain weight showed significant differences among genotypes (P = 0.01), parents (P = 0.01) and parents vs $F_3$ contrast (P = 0.05), while non-significant differences were observed for $F_3$ populations (Table 10). 100-grain weight of wheat parents ranged from 3.4 to 4.6 g (Table 1). Maximum 100-grain weight (4.6 g) was observed for parental line B-IV(N)5, while B-RF7 and Pirsabak-08 both had minimum (3.4 g). 100-grain weight among $F_3$ populations, ranged from 3.3 to 4.5 g (Table 3). $F_3$ Population B-RF7 × Janbaz had maximum 100-grain weight (4.5 g), while minimum 100-grain weight (3.3 g) was observed for B-IV(N)11 × Pirsabak-08. Mushtaq et al. (2011) assessed two wheat genotypes (Mairaj-2008 and Fareed-2006) to evaluate the effect of drought introduced at different crop growth stages and reported significant differences among wheat genotypes. Majumder et al. (2008) evaluated twenty spring wheat varieties to find out genetic variability and genetic association among grain yield and associated traits. They reported significant variation for 100-grain weight in wheat genotypes.

Variances for 100 grain-weight ranged from 0.1 to 0.3 among wheat parents (Table 5). Maximum variance (0.3) for 100-grain weight was observed for two wheat

parental lines (B-IV(N)11 and B-RF3), while minimum (0.1) variance was recorded for 4 parental lines/cultivars viz. B-IV(N)12, B-RF1, B-RF7 and Janbaz. Among $F_3$ populations, variances for 100-grain weight ranged from 0.5 to 1.4 (Table 5). Maximum variance (1.4) for 100-grain weight was observed for $F_3$ population B-IV(N)5 × Janbaz, while minimum variance (0.5) was recorded for B-RF3 × Pirsabak-08, B-RF3 × Janbaz and B-RF7 × Janbaz. Heritability and selection responses for 100-grain weight ranged from 0.51 to 0.90 and 0.50 to 1.38 g, respectively (Table 5). Maximum heritability (0.90) was observed for $F_3$ population B-RF1 × Janbaz. Maximum selection response of 1.38 g was recorded for B-IV(N)11 × Janbaz. Likewise, $F_3$ population B-RF3 × Pirsabak-08 had lowest heritability (0.51) with minimum selection response of 0.50 g for 100-grain weight. Broad sense heritability for 100-grain weight from expected mean squares was 0.43 with selection response of 0.26 g (Table 2).

*Grain yield plant$^{-1}$ (g)*

Analysis of variance for grain yield plant$^{-1}$ indicated significant differences among wheat genotypes (P = 0.01), parents (P = 0.05), and parents vs $F_3$ populations contrast (P = 0.01). However, differences among $F_3$ populations were non-significant for grain yield plant$^{-1}$ (Table 1). Grain yield ranged from 28.6 to 32.0 g plant$^{-1}$ among parents and 29.4 to 31.9 g plant$^{-1}$ among $F_3$ populations (Table 3). Parental lines B-IV(N)5 and B-RF7 had maximum grain yield (32.0 g plant$^{-1}$ each), while B-RF1 had minimum grain yield (28.6 g plant$^{-1}$) among parents. $F_3$ population B-RF7 × Janbaz had maximum grain yield (31.9 g plant$^{-1}$), while B-IV(N)5 × Janbaz had minimum grain yield (29.4 g plant$^{-1}$). Ikramullah et al. (2011) assessed 22 $F_{5:7}$ wheat genotypes along with four check cultivars as independent experiments under irrigated and rainfed environments and reported significant differences among wheat genotypes for grain yield plant$^{-1}$. Similarly, Haq et al. (2008) and Cheema et al. (2006) have also reported significant differences among wheat genotypes for grain yield plant$^{-1}$.

Variances of wheat parental lines/cultivars for grain yield plant$^{-1}$ ranged from 31.8 to 43.4 (Table 5). Maximum variance (43.4) for grain yield was recorded for parental line B-RF3, while minimum (31.8) for wheat parent B-IV(N)11. In contrast variances among $F_3$ populations for grain yield plant$^{-1}$ ranged from 48.3 to 133.3 (Table 5). $F_3$ population B-IV(N)12 × Janbaz had maximum variance (133.3), while B-RF7 × Janbaz had minimum variance (48.3) for grain yield plant$^{-1}$. Heritability and selection responses for grain yield ranged from 0.26 to 0.75 and 2.57 to 12.15 g plant$^{-1}$, respectively (Table 5). Highest heritability (0.75) for grain yield was observed for $F_3$ population B-IV(N)12 × Janbaz along with maximum selection response of 12.15 g plant$^{-1}$. In contrast, minimum heritability (0.26) for grain yield plant$^{-1}$ was observed in population B-RF7 × Janbaz coupled with the selection response of 2.57 g plant$^{-1}$. Using expected mean squares of ANOVA, broad sense heritability was 0.74 with selection response of 7.10 g plant$^{-1}$ (Table 2).

## Conclusions and Recommendations

Parental genotypes and $F_3$ populations evaluated in present study expressed significant genetic variability for yield and yield related traits. Parents vs $F_3$ populations contrast was significant for spike length, grains spike$^{-1}$, single spike weight, 100-grain weight, and grain yield plant$^{-1}$. Among $F_3$ populations, maximum grains spike$^{-1}$ were recorded for population B-RF3×Janbaz. $F_3$ population B-RF7 × Janbaz had highest 100-grain weight and grain yield plant$^{-1}$. On basis of high heritability, selection response and mean performance for yield related traits, $F_3$ populations B-IV(N)11 × Janbaz, B-IV(N)5 × Pirsabak-08, B-IV(N)5 × Janbaz, B-RF1 × Janbaz and B-RF7 × Janbaz are recommended for evaluation in $F_4$ and later generations to derive desirable genotypes.

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## Author's Contribution

**Tariq Aziz:** Conducted the experiments.
**Iftikhar Hussain Khalil:** Supervised the research.
**Quaid Hussain:** Wrote the paper.
**Tariq Shah:** Revised the paper.
**Nazir Ahmad:** Data analysis.
**Amir Sohail:** Data collection.

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