Estimation of Heritability in F2 Generation of Bread Wheat (*Triticum aestivum* L.)

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Abstract

**Objectives:** To estimate the heritability in a broad sense and the genetic advance F2 generation of bread wheat.

**Methods/Statistical Analysis:** The collected data were statistically analyzed for analysis of variance by Gomez and Gomez, heritability in a broad sense and the genetic advance was worked out after Falconer. **Findings:** The results showed that genotypes parents, percent x crosses were highly significant at 0.01 level for days to 75% heading, days to 90% maturity, plant height (cm), tiller plant-1, spike length (cm), spikelet spike-1, grain spike-1, grain yield plant-1 (g), Biological yield and harvest index (%) while seed index (1000 grain weight, g) showed non-significant for parents vs crosses. Mean performance of six commercial and F2 hybrids revealed that early heading (62.2) presented by Kiran-95 and his F2 hybrids (59.95%), days to 75% heading taken by Benazir x TD-1, minimum days (114.8) to 90% maturity shown by variety TJ-83, dwarf plant (59.82cm) shown by variety Hamal. The maximum tiller plant-1 (13.76) produced by cross Benazir x TD-1, longer spike length (9.95cm) shown by the variety Kiran-95, while the genotype TD-1 produced maximum number of spikelet spike-1 (20.76), maximum grain spike-1 (56.03) highest grain yield plant-1 (30.53 g) and highest biological yield was obtained from the cross TD-1 x Sindhu. Highest weight for 1000-grain was recorded for TD-1, (50.20). The highest biological yield was shown by Benazir (61.03g). Among the hybrids, higher grain yield plant-1 displayed by Sindhu x Kiran-95, within the F2 population maximum harvest index of 56.45% was observed in Sindhu x TJ-83. The cross Benazir x TD-1 showed higher heritability for tiller plant-1, spike length, spikelets spike-1 and harvest index. While Benazir x Sindhu exhibited higher heritability for grain spike-1, plant height. Variety TD-1, Kiran-95, and Sindhu may be selected in further breeding programs and crossed Benazir x TD-1 could be evaluated in the subsequent generation and selection could be made on spikelets spike-1 and harvest index. **Application/Improvements:** The variety TD-1 performs better in spikelets spike-1, grains spike-1, grain yield plant-1, seed index, while variety Kiran-95 had higher in spike length, and harvest index.

**Keywords:** Bread Wheat, F2 Generation, Genetic Advance, Heritability

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1. Introduction

Southwestern Asia is the region where the wheat crop has been cultivated in, which is its geographic center of origin, since more than 10,000 years. Its related wild species still grow in Lebanon, Eastern Turkey, Syria, Iraq, and Northern Israel. Human began breeding wheat in the early 1800s from then, the improvement in the yield and grain quality has been noticed, modifications in the plant architecture and increased resistance to drought, lodging, insect-pest and disease pathogens.

Wheat is an important part of human nutrition in all parts of the world. For the world’s population, it is an important cereal crop and staple food. Wheat is a globally significant crop that grows in diverse environments. Wheat is consumed in various forms and is consumed by populations such as bread, crepes, porridge, flour, and suji. Among cereal crops, the wheat yield is a complex quantitative feature and an incentive for many yield contributors. These characteristics directly or indirectly affect grain production, and breeders are naturally interested in investigating the degree and type of association of these traits. Wheat is an important food crop in the world and a source of food and livelihood for more than 1 billion people in developing countries. It is considered to be one of the “three major cereal crops”. Rice, wheat, and corn. Today, more than 200 million hectares of wheat cultivated in the world is the most important agricultural product in international trade. Approximately 35% of the world’s population feeds on this. Wheat (Triticum aestivum L.) is the main grain grown not only in Pakistan but throughout the world. Pakistan is one of the top ten wheat producers, with 80% of the agricultural community growing wheat. Wheat production in 2015-16 increased from 8.69 million hectares to 25.4 million tons, showing an increase of 3.2% in the region with an average yield of 2,787 kg per hectare. In 2015-16, wheat accounted for 9.9% of agricultural value added and 2.0% of Pakistan’s GDP. The area planted with wheat increased from 9.204 million hectares last year to 9.26 million hectares, an increase of 0.6%. Wheat production in 2015-16 was 25,482 million tons, an increase of 1.6% from last year’s output of 250.86 million tons. As crops are sown at the right time and available moisture, especially at the Barani Track, the use of germination/growth and availability and inputs is still sufficient, and production is increasing. Depending on the climate, seed type, and soil conditions, it usually takes between 150 and 180 days between planting and harvesting. It is the world’s most widely grown crop, accounting for about one-sixth of the total area of cultivated land. Wheat has been extensively and continuously researched to maximize food production while also increasing food production per unit area. However, there is still considerable room for improvement, especially in order to expand the ongoing genetic improvement efforts of wheat to meet the growing needs of a growing population. Genetic manipulation is the best way to increase wheat yield. It is necessary to estimate and study the genetic variation and genetic patterns of different plant parameters in order to initiate an effective wheat breeding program. The stagnant wheat production in Pakistan is due to the limited diversity of germplasm in breeding programs.

In order to develop effective breeding strategies for crops, important knowledge of the genetic traits of quantitative traits is also essential. In this case, the heritability of the trait/genotype contributes to plant breeding to predict the behavior of subsequent generations to make the desired selection. Heritability studies provide breeders with valuable genetic information to predict the interaction of genes in isolated generations. Observations of hereditary and genetic progression have led us to understand the inheritance of parents and their responses to their offspring. Heritability is an estimate of the genetic part of the physical appearance. Heritability and genetic progression values help us make choices more effective and estimate responses to choices. Heritability is a component of the phenotype determined by genetic factors. If the environmental variability associated with genetic differences is small, the choice will be more effective. Studies of statistical parameters such as mean, variance, heritability, and genetic progression help us measure the genetic diversity, genetic potential, and stability of any genotype.

2. Material And Methods

The experiment was carried out at Southern wheat research station Tando Jam, during rabi season 2016–2017. The experiment was conducted in a randomized complete block design (RCBD) with three replications using 6 varieties and their 15 F2 hybrids. The sowing was done by dibbling with the space of 22.5 cm between row to row and 7.5 cm between in plants.
At maturity, 10 plants per genotype per replication was tagged for recording data.

**Varieties = 6**

- Benazir
- Hamal
- TD-1
- Sindhu
- TJ-83
- Kiran-95

**CROSSES = 15**

- Benazir X Hamal
- Benazir X TD-1
- Benazir X Sindhu
- Benazir X TJ-83
- Benazir X Kiran-95
- Hamal X TD-1
- Hamal X Sindhu
- Hamal X TJ-83
- Hamal X Kiran-95
- TD-1 X Sindhu
- TD-1 X TJ-83
- TD-1 X Kiran-95
- Sindhu X TJ-83
- Sindhu X Kiran-95

**Statistical Analysis:** The collected data were statistically analyzed for analysis of variance by Gomez and Gomez\(^{15}\) (1984), heritability in a broad sense and the genetic advance was worked out after Falconer\(^{16}\) (1987).

### 3. Results

#### 3.1 Analysis of Variance

The mean square regarding genotype, parent, and crosses were highly significant (P > 0.01) for all the traits studied, while parents vs crosses (p × c) were highly significant at P > 0.01 level of probability for all the traits studied except seed index which is non-significant (Table 1).

#### 3.2 Mean Performance

**Days to 75% Heading:** Mean performance of six commercial varieties among parental lines and their F\(_2\) hybrids presented in Table 2 revealed that early heading (62.2) was observed by Kiran-95 and maximum days to heading (74.96) shown by variety Sindhu. In case of F\(_2\) hybrids (58.93) days to heading by cross Benazir x TD-1 and the higher days to 75% heading (74.0) was expressed by cross Benazir x Kiran-95 (Table 2).

| Source of variance | d.f | Days to 75% heading | Days to 90% maturity | Plant height | Tiller plant | Spike length | Spikelets Spike\(^1\) | Grains Spike\(^1\) | Grain yield plant\(^1\) | Biological yield plant\(^1\) | Seed index (1000 grain weight) | Harvest index |
|--------------------|-----|---------------------|----------------------|--------------|--------------|--------------|------------------------|-----------------|------------------------|-----------------------------|-------------------------------|-----------------|
| Replication        | 2   | 10.287              | 11.427               | 9.020        | 2.7351       | 1.88         | 8.2102                 | 23.774         | 13.3286                | 16.144                      | 14.6312                      | 11.53          |
| Genotypes          | 20  | 64.064**            | 58.323**             | 381.95       | 0**          | 16.532**     | 9.72**                 | 14.671**       | 304.0 35**             | 42.328 1**                  | 205.6 51**                  | 31.612**       |
| Parents (p)        | 5   | 69.96**             | 64.22**              | 652.33**     | 9**          | 9.433**      | 9.36**                 | 22.1646**      | 202.08 4**             | 41.055 9**                  | 252.26 3**                  | 35.036**       |
| Crosses (C)        | 14  | 64.03**             | 58.289**             | 273.4**      | 6**          | 2.6406**     | 2.88**                 | 7.64946**      | 140.17 6**             | 33.906 6**                  | 199.34 1**                  | 29.956**       |
| P × C              | 1   | 5.9311**            | 5.935**              | 378.87**     | 9**          | 6.79**       | 6.472**                | 14.5151**      | 61.90 8**              | 7.149 3**                   | 52.92 2**                   | 5.080 2NS       |
| Error              | 40  | 0.306               | 0.458                | 1.827        | 0.149        | 0.147        | 0.3715                 | 1.102          | 0.2689                 | 0.172                      | 4.5184                      | 1.18             |
| Total              | 82  | -                   | -                    | -            | -            | -            | -                      | -              | -                      | -                           | -                            | -               |
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Table 2. Mean performance of parents and F₂ population for yield and its related traits of bread wheat (Triticumaestivum L.)

| Genotype            | Days to 75% heading | Days to 90% maturity | Plant height (cm) | Tillers plant¹ | Spike length (cm) | Spikelet sspike¹ | Grain yield plant¹ (g) | Seed index (1000 grain weight in g) | Biological weight (g) | Harvest index% |
|---------------------|---------------------|----------------------|-------------------|----------------|-------------------|------------------|-----------------------|---------------------------------------|-----------------------|---------------|
| **PARENTS**         |                     |                      |                   |                |                   |                  |                       |                                       |                       |               |
| Benazir             | 68.76               | 128.03               | 90.23             | 6.76           | 9.90              | 17.00            | 54.66                 | 29.21                                 | 48.45                 | 61.03         | 47.94         |
| Hamal               | 64.83               | 123.20               | 59.82             | 7.50           | 7.35              | 13.26            | 37.33                 | 21.91                                 | 41.53                 | 41.74         | 52.49         |
| TD-1                | 63.33               | 123.17               | 96.34             | 6.23           | 9.34              | 20.76            | 56.03                 | 30.53                                 | 50.20                 | 58.49         | 51.93         |
| Sindhu              | 74.96               | 126.30               | 99.52             | 6.93           | 8.86              | 18.36            | 48.80                 | 29.30                                 | 45.13                 | 54.49         | 58.03         |
| TJ-83               | 63.53               | 114.80               | 77.61             | 7.76           | 9.65              | 19.86            | 47.73                 | 24.73                                 | 43.63                 | 41.78         | 59.19         |
| Kiran-95            | 62.20               | 125.17               | 90.92             | 5.16           | 9.95              | 16.16            | 44.76                 | 25.26                                 | 42.57                 | 41.93         | 59.95         |
| **Average**         | 66.27               | 123.44               | 85.74             | 6.72           | 9.18              | 17.57            | 48.22                 | 26.82                                 | 45.25                 | 49.91         | 54.92         |
| **F2 POPULATIONS**  |                     |                      |                   |                |                   |                  |                       |                                       |                       |               |               |
| Benazir x hamal     | 64.53               | 123.93               | 97.73             | 10.70          | 11.34             | 19.36            | 62.73                 | 23.70                                 | 51.17                 | 46.32         | 51.15         |
| Benazir x TD-1      | 58.93               | 121.10               | 74.50             | 13.60          | 14.74             | 22.46            | 72.76                 | 25.42                                 | 51.09                 | 50.30         | 50.51         |
| Benazir x Sindhu    | 73.70               | 128.17               | 99.03             | 13.43          | 13.78             | 22.80            | 76.60                 | 26.86                                 | 49.60                 | 54.28         | 49.49         |
| Benazir x TJ-83     | 66.20               | 120.70               | 91.50             | 10.20          | 11.45             | 19.40            | 56.66                 | 21.62                                 | 46.49                 | 42.21         | 51.22         |
| Benazir x kiran-95  | 74.00               | 132.20               | 108.60            | 11.40          | 13.19             | 20.20            | 58.13                 | 23.57                                 | 45.02                 | 41.75         | 56.45         |
| Hamal x TD-1        | 65.20               | 117.73               | 78.30             | 9.90           | 9.84              | 17.66            | 57.00                 | 18.94                                 | 45.55                 | 37.52         | 50.44         |
| Hamal x Sindhu      | 66.70               | 124.70               | 98.14             | 9.80           | 10.62             | 18.23            | 65.36                 | 19.85                                 | 46.49                 | 38.80         | 51.14         |
| **Average**         | 64.62               | 124.96               | 92.27             | 10.52          | 11.13             | 19.99            | 62.30                 | 24.00                                 | 46.95                 | 47.75         | 50.42         |
| **LSD (5%)**        | 0.4517              | 0.5526               | 1.1037            | 0.3152         | 0.3129            | 0.4977           | 0.8597                | 0.4234                                | 1.7356                | 0.3389        | 0.8887        |

Days to 90% Maturity: For the trait days to 90% maturity, minimum days (114.8) to 90% maturity were depicted by variety TJ-83 and maximum (128.03 days) was displaced by variety Benazir. In case of hybrids, minimum days to 90% maturity (117.73) was manifested by cross Hamal x TD-1 while maximum days to 90% maturity (132.37) was taken by cross Sindhu x Kiran-95 (Table 2).

Plant Height (cm): Plant height is a quantitative trait affecting other yield parameters. The results revealed that the minimum value for height was shown by variety Hamal (59.82cm) and maximum value shown by variety Sindhu (99.52). In the case of F₂ hybrids, the minimum value for height (74.5) disclosed by cross Benazir x TD-1 while the maximum value for height (108.6) observed by Benazir x Kiran-95 (Table 2).
**Tillers Plant**: Productive tiller plant have a straight impact on grain yield plant. The variety Kiran-95 produced a minimum number of tillers plant (5.16) and a maximum number of tillers plant (7.76) produced by variety TJ-83 (Table 2). In the case of hybrids, a minimum number of tillers plant (7.70) produced by cross HAMAL x TJ-83 and a maximum number of tillers plant (13.6) was produced by cross Benazir x TD-1.

**Spike Length (cm)**: Table 2 revealed that longer spike length (9.95 cm) obtained by the variety Kiran-95 whereas the lower spike length (7.35 cm) measured by variety Hamal. In the case of hybrids, maximum spike length (14.74 cm) was measured by cross Benazir x TD-1 and minimum spike length (7.71 cm) was measured by cross TD-1 x TJ-83.

**Spikelets Spike**:\ According to results presented in Table 2 depicted that the genotype TD-1 had a maximum number of spikelets spike (20.76), while minimum spikelets spike was counted by variety Hamal (13.26). In the case of hybrids, a maximum number of spikelets spike (22.80) counted by cross Benazir x Sindhu and minimum number for spikelets spike (17.66) was obtained by cross Hamal x TD-1 (Table 2).

**Grain Spike**: According to the results genotype TD-1 had produced maximum grains spike (56.03), while minimum grains spike was obtained from variety Hamal (37.33). In the case of hybrids, maximum grain spike (79.73) was counted by cross TD-1 x TJ-83 and minimum grain spike (53.30) from in hybrid Sindhux TJ-83.

**Grain Yield Plant**: The data revealed that the highest grain yield plant was (30.53) for the parental genotype TD-1 and lowest grain yield plant was recorded in Hamal (21.19 g). In the case of hybrids, maximum grain yield plant (31.43) was obtained by cross TD-1 x Sindhu and minimum grain yield plant (18.94) was shown by cross Hamal x TD-1.

**Biological Yield Plant**: The data disclosed that the highest biological yield plant (61.03 g) was measured by parental genotype Benazir whereas the lowest biological yield plant was observed in Hamal (41.53 g). Among the cross combinations TD-1 X TJ-83 had greater (51.41g) weight for 1000-grains and the lowest seed index was noticed for Hamal x TJ-83 (41.0 g).

**Harvest Index (%)**: Most of the wheat cultivar revealed good harvest index extending between 47.94% to 59.95%. Although, the highest harvest index of 59.95% was manifested in wheat variety Kiran-95. The lowest harvest index of 47.94% was displayed by the variety Benazir. Within the F2 populations, maximum harvest index of 56.45% was revealed by Benazir x Kiran-95, while the lowest harvest index of 43.53% was displayed by in TD-1 x Kiran-95.

### 3.3 Heritability

#### Days to 75 % Heading: Genetic analysis of days to 75% heading displayed (Table 3) that all the crosses showed high heritability the range of genotypic and phenotypic

| F2 populations | **δ²g** | **δ²e** | **δ²p** | **h² %** | **G.A.** |
|----------------|--------|--------|--------|---------|---------|
| Benazir x Hamal | 1065.54 | 32.50 | 1098.04 | 97.04 | 66.24 |
| Benazir x TD-1 | 883.86 | 31.50 | 915.36 | 96.56 | 60.18 |
| Benazir x Sindhu | 1401.34 | 29.00 | 1430.34 | 97.97 | 76.33 |
| Benazir x TJ-83 | 1122.46 | 32.50 | 1154.97 | 97.19 | 68.04 |
| Benazir x Kiran-95 | 1410.45 | 31.50 | 1441.95 | 97.82 | 76.52 |
| Hamal x TD-1 | 1088.02 | 31.50 | 1119.52 | 97.19 | 66.99 |
| Hamal x Sindhu | 1232.80 | 29.00 | 1261.80 | 97.70 | 71.49 |
| Hamal x TJ-83 | 928.07 | 32.50 | 960.57 | 96.62 | 61.69 |
| Hamal x Kiran-95 | 1111.33 | 31.50 | 1142.83 | 97.24 | 67.72 |
| TD-1 x Sindhu | 903.79 | 29.00 | 932.79 | 96.89 | 60.96 |
| TD-1 x TJ-83 | 927.43 | 32.50 | 959.93 | 96.61 | 61.66 |
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Variances ranged from 883.86 and 915.36 (Benazir x TD-1) to 1410.45 and 1441.95 (Benazir x Kiran-95) respectively. The highest heritability (97.97%) showed by Benazir x Sindh followed by Benazir x Kiran -95 and the highest genetic advance (76.52) observed in Benazir x Kiran-95. The minimum heritability and genetics advance displayed by the cross (Benazir x TD-1).

**Days to 90% Maturity:** Genetic analysis of days to 90% maturity presented in (Table 4) which disclosed that genotypic and phenotypic variances ranged from 3596.47 and 3658.47 (Hamal x TD-1) to 4541.05 and 4604.38 (Sindhu x Kiran-95) respectively. The highest heritability (98.62%) and GA (137.86) produced by Sindhu x Kiran-95 and followed by Benazir x Sindhu. The lowest heritability and genetics advance displayed by the cross (Hamal x TD-1).

**Plant Height:** Plant height revealed that all the crosses showed high heritability (Table 5) the range of genotypic and phenotypic variances ranged from 1416.33 and 1032.20 to 1063.70 and 97.04 respectively. The highest heritability (97.04%) showed by TD-1 x Kiran-95 followed by TD-1 x Sindhu and the highest genetic advance (65.20) observed in TD-1 x TD-1. The minimum heritability and genetics advance displayed by the cross (TD-1 x TD-1).

### Table 4. Phenotypic variance ($\delta^2_p$), environment variance ($\delta^2_e$), genetic variance ($\delta^2_g$), heritability ($h^2$%) and genetic advance (GA) of $F_2$ populations for days to (90%) maturity

| Crosses name       | $\delta^2_g$ | $\delta^2_e$ | $\delta^2_p$ | $h^2$ % | G.A  |
|--------------------|--------------|--------------|--------------|--------|------|
| Benazir x Hamal    | 3982.33      | 61.00        | 4043.33      | 98.49  | 129.01 |
| Benazir x TD-1     | 3781.74      | 64.50        | 3846.24      | 98.32  | 125.61 |
| Benazir x Sindhu   | 4264.11      | 61.00        | 4325.11      | 98.59  | 133.57 |
| Benazir x TJ-83    | 3773.77      | 61.00        | 3834.77      | 98.41  | 125.54 |
| Benazir x Kiran-95 | 4537.61      | 63.33        | 4600.94      | 98.62  | 137.81 |
| Hamal x TD-1       | 3596.47      | 62.00        | 3658.47      | 98.31  | 122.49 |
| Hamal x Sindhu     | 4031.75      | 61.00        | 4092.75      | 98.51  | 129.82 |
| Hamal x TJ-83      | 3655.61      | 61.00        | 3716.61      | 98.36  | 123.52 |
| Hamal x Kiran-95   | 4068.87      | 63.33        | 4132.20      | 98.47  | 130.39 |
| TD-1 x Sindhu      | 4219.20      | 61.00        | 4280.20      | 98.57  | 132.85 |
| TD-1 x TJ-83       | 3905.36      | 61.00        | 3966.36      | 98.46  | 127.74 |

### Table 5. Phenotypic variance ($\delta^2_p$), environment variance ($\delta^2_e$), genetic variance ($\delta^2_g$) heritability ($h^2$%) and genetic advance (GA) of $F_2$ populations for plant height (cm)

| Crosses name       | $\delta^2_g$ | $\delta^2_e$ | $\delta^2_p$ | $h^2$ % | G.A  |
|--------------------|--------------|--------------|--------------|--------|------|
| Benazir x Hamal    | 2466.56      | 47.50        | 2514.06      | 98.11  | 101.34 |
| Benazir x TD-1     | 1416.33      | 46.50        | 1462.83      | 96.82  | 76.28  |
| Benazir x Sindhu   | 2542.71      | 37.00        | 2579.71      | 98.57  | 103.13 |
| Benazir x TJ-83    | 2164.46      | 39.00        | 2203.46      | 98.23  | 94.99  |
| Benazir x Kiran-95 | 3056.70      | 48.50        | 3105.20      | 98.44  | 113.00 |
| Hamal x TD-1       | 1579.92      | 34.00        | 1613.92      | 97.89  | 81.01  |
| Hamal x Sindhu     | 2486.01      | 37.00        | 2523.01      | 98.53  | 101.96 |
| Hamal x TJ-83      | 2002.09      | 39.00        | 2041.09      | 98.09  | 91.29  |
| Hamal x Kiran-95   | 2494.73      | 48.50        | 2543.23      | 98.09  | 101.91 |
| TD-1 x Sindhu      | 2091.93      | 37.00        | 2128.93      | 98.26  | 93.40  |
| TD-1 x TJ-83       | 1558.13      | 39.00        | 1597.13      | 97.56  | 80.32  |
1462.83 (Benazir x TD-1) to 3056.70 and 3105.20 (Benazir x Kiran-95) respectively. The highest heritability (98.57%) was noticed by Benazir x Sindhu followed by Hamal x Sindhu where the highest genetic advance is observed in Benazir x Kiran-95 followed by Benazir x Sindhu. The lowest heritability and genetics advance obtained by cross Benazir x TD-1.

**Productive Tillers Plant**: Productive tillers showed (Table 6) that all the crosses showed high heritability the range of genotypic and phenotypic variance ranged from 11.72 and 15.72 (Hamal x TJ-83) to 46.03 and 49.43 (Benazir x TD-1) respectively. The highest heritability (92.93%) produced by Benazir x TD-1 followed by Benazir x Kiran-95 where the highest genetic advance (13.47) was displayed by Benazir x TD-1 followed by Benazir x Sindhu. The lowest heritability and genetic advance showed by the cross (Hamal x TJ-83).

**Spike Length**: Table 7 showed the heritability for the character spike length which displayed that all the crosses displayed high heritability, the range of genotypic and phenotypic variance ranged from 11.27 and 15.77 to 46.03 and 49.43 (Benazir x TD-1) respectively. The highest heritability (92.93%) produced by Benazir x TD-1 followed by Benazir x Kiran-95 where the highest genetic advance (13.47) was displayed by Benazir x TD-1 followed by Benazir x Sindhu. The lowest heritability and genetic advance showed by the cross (Hamal x TJ-83).

**Table 6.** Phenotypic variance ($\delta^2p$), environment variance ($\delta^2e$), genetic variance ($\delta^2g$), heritability ($h^2%$) and genetic advance (GA) of F$_2$ populations for number of tillers plant$^{-1}$

| Crosses name | $\delta^2g$ | $\delta^2e$ | $\delta^2p$ | $h^2$% | G.A |
|--------------|-------------|-------------|-------------|--------|-----|
| Benazir x Hamal | 27.42 | 3.00 | 30.42 | 90.14 | 10.24 |
| Benazir x TD-1 | 46.03 | 3.50 | 49.43 | 92.93 | 13.47 |
| Benazir x Sindhu | 39.95 | 7.67 | 47.62 | 83.90 | 11.93 |
| Benazir x TJ-83 | 23.88 | 4.00 | 27.88 | 85.65 | 9.32 |
| Benazir x Kiran-95 | 31.43 | 3.00 | 34.43 | 91.29 | 11.03 |
| Hamal x TD-1 | 22.34 | 3.50 | 25.84 | 86.45 | 9.05 |
| Hamal x Sindhu | 17.02 | 7.67 | 25.57 | 70.02 | 7.29 |
| Hamal x TJ-83 | 11.72 | 4.00 | 15.72 | 74.56 | 6.09 |
| Hamal x Kiran-95 | 13.91 | 3.00 | 16.91 | 82.26 | 6.97 |
| TD-1 x Sindhu | 22.45 | 7.67 | 30.12 | 74.55 | 8.43 |

**Table 7.** Phenotypic variance ($\delta^2p$), environment variance ($\delta^2e$), genetic variance ($\delta^2g$), heritability ($h^2%$) and genetic advance (GA) of F$_2$ populations for spike length (cm)

| Crosses name | $\delta^2g$ | $\delta^2e$ | $\delta^2p$ | $h^2$% | G.A |
|--------------|-------------|-------------|-------------|--------|-----|
| Benazir x Hamal | 28.92 | 5.00 | 33.92 | 85.26 | 10.23 |
| Benazir x TD-1 | 52.32 | 5.00 | 57.32 | 91.28 | 14.24 |
| Benazir x Sindhu | 40.16 | 5.00 | 45.16 | 88.93 | 12.31 |
| Benazir x Kiran-95 | 20.02 | 3.00 | 23.92 | 87.46 | 8.81 |
| Hamal x TD-1 | 2033.20 | 48.50 | 2081.70 | 97.67 | 91.80 |
| Hamal x TJ-83 | 2349.13 | 39.00 | 2388.13 | 98.09 | 99.03 |
| Hamal x Kiran-95 | 2484.39 | 7.72 | 2532.89 | 90.15 | 11.83 |
| TD-1 x TJ-83 | 33.40 | 4.00 | 37.40 | 89.31 | 11.25 |
| TD-1 x Kiran-95 | 2430.00 | 3.50 | 27.50 | 89.09 | 9.63 |
| Sindhu x TJ-83 | 36.00 | 4.00 | 40.60 | 90.15 | 11.83 |
| Sindhu x Kiran-95 | 20.02 | 3.00 | 23.92 | 87.46 | 8.81 |
| TJ-83 x Kiran-95 | 16.90 | 3.00 | 19.90 | 84.93 | 7.81 |
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(TD-1 x TJ-83) to 52.32 and 57.32 (Benazir x TD-1) respectively. The highest heritability (91.28%) observed by Benazir x TD-1 followed by Benazir x Kiran-95 where the highest genetic advance disclosed in cross Benazir x TD-1 followed by Benazir x Sindhu. The lowest (71.47%) heritability and genetic advance (5.85) was obtained by the cross (TD-1 x TJ-83).

Spikelets Spike\(^{-1}\): All the crosses showed the highest heritability for the character spikelets spike\(^{-1}\) (Table 8). The range of genotypic and phenotypic variance ranges from 73.84 and 83.34 (Hamal x TJ-83) to 125.49 and 133.99 (Benazir x TD-1) respectively. The highest heritability (93.66%) was depicted by Benazir x TD-1 followed by TD-1 x Kiran-95 where the highest genetic advance (22.33) was gained by cross Benazir x TD-1 followed by Benazir x Sindhu. The lowest heritability for this character and genetic advance manifested by cross Hamal x Sindhu.

Grains Spike\(^{-1}\): Higher heritability displayed by all the cross for the character grain spike\(^{-1}\). The range of genotypic and phenotypic variances ranged from 768.06 and 790.50 (TJ-83 x Kiran-95) to 1524.83 and 1544.33 (Sindhu x TJ-83). The range of genetic advance ranged from 59.89 (Hamal x TD-1) to 57.98 (Hamal x TJ-83) with a mean of 60.46.

Table 8. Phenotypic variance (\(\delta^2p\)), environment variance (\(\delta^2e\)), genetic variance (\(\delta^2g\)) heritability (\(h^2\%\)) and genetic advance (GA) of \(F_2\) populations for a number of spikelets spike\(^{-1}\)

| Crosses name | \(\delta^2g\) | \(\delta^2e\) | \(\delta^2p\) | \(h^2\%\) | GA |
|--------------|--------------|--------------|--------------|-----------|----|
| Benazir x Hamal | 87.35 | 10.50 | 97.85 | 89.27 | 18.19 |
| Benazir x TD-1 | 125.49 | 8.50 | 133.99 | 93.66 | 22.33 |
| Benazir x Sindhu | 125.31 | 12.00 | 137.31 | 91.26 | 22.03 |
| Benazir x TJ-83 | 89.98 | 9.50 | 99.48 | 90.45 | 18.58 |
| Benazir x Kiran-95 | 97.61 | 8.50 | 106.11 | 91.99 | 19.52 |
| Hamal x TD-1 | 75.51 | 7.00 | 82.51 | 91.52 | 17.12 |
| Hamal x Sindhu | 74.77 | 12.00 | 86.77 | 86.17 | 16.54 |
| Hamal x TJ-83 | 73.84 | 9.50 | 83.34 | 88.60 | 16.66 |
| Hamal x Kiran-95 | 82.48 | 8.50 | 90.98 | 90.66 | 17.81 |

Table 9. Phenotypic variance (\(\delta^2p\)), environment variance (\(\delta^2e\)), genetic variance (\(\delta^2g\)) heritability (\(h^2\%\)) and genetic advance (GA) of \(F_2\) populations for grain spike\(^{-1}\)

| Crosses name | \(\delta^2g\) | \(\delta^2e\) | \(\delta^2p\) | \(h^2\%\) | GA |
|--------------|--------------|--------------|--------------|-----------|----|
| Benazir x Hamal | 1016.48 | 28.00 | 1044.48 | 97.32 | 64.79 |
| Benazir x TD-1 | 1366.37 | 28.00 | 1394.37 | 97.99 | 75.38 |
| Benazir x Sindhu | 1524.83 | 19.50 | 1544.33 | 98.74 | 79.93 |
| Benazir x TJ-83 | 822.10 | 23.50 | 845.60 | 97.22 | 58.24 |
| Benazir x Kiran-95 | 867.30 | 22.50 | 889.80 | 97.47 | 59.89 |
| Hamal x TD-1 | 829.46 | 28.00 | 857.46 | 96.73 | 58.35 |
| Hamal x Sindhu | 1105.58 | 19.50 | 1125.08 | 98.27 | 67.90 |
| Hamal x TJ-83 | 824.47 | 22.50 | 846.97 | 97.34 | 58.36 |
(Benazir x Sindhu) respectively. The highest heritability (98.74%) produced by (Benazir x Sindhu) followed by (TD-1 x Sindhu). The highest genetic advance (79.93) displayed by the cross (Benazir x Sindhu) followed by Benazir x TD-1. The lowest heritability and genetic advance for the character grains spike⁻¹ was observed by cross Sindhu x TJ-83 (Table 9).

Grain Yield Plant⁻¹: Grain yield plant⁻¹ displayed that all the crosses showed high heritability, the range of genotypic and phenotypic variance ranged from 78.88 and 94.46 by Hamal x TD-1 to 230.24 and 244.97 by TD-1 x Sindhu respectively. The highest heritability (94.09%) obtained by Sindhu x Kiran -95 followed by TD-1 X Sindhu. The lowest heritability and genetic advance noticed by cross Hamal x TD-1 (Table 10).

**Table 10.** Phenotypic variance (δ²p), environment variance (δ²e), genetic variance (δ²g), heritability (h²%) and genetic advance (GA) of F₂ populations for grain yield plant⁻¹

| Crosses name | δ²g | δ²e | δ²p | h² % | G.A |
|--------------|-----|-----|-----|------|-----|
| Benazir x Hamal | 137.68 | 11.09 | 148.76 | 92.55 | 23.25 |
| Benazir x TD- 1 | 155.93 | 14.78 | 170.70 | 91.34 | 24.59 |
| Benazir x Sindhu | 175.15 | 14.73 | 189.88 | 92.24 | 26.18 |
| Benazir x TJ-83 | 110.38 | 12.63 | 123.00 | 89.74 | 20.50 |
| Benazir x Kiran-95 | 135.14 | 12.42 | 147.56 | 91.58 | 22.92 |
| Hamal x TD-1 | 78.88 | 15.59 | 94.46 | 83.50 | 16.72 |
| Hamal x Sindhu | 122.99 | 14.73 | 127.72 | 88.47 | 20.60 |
| Hamal x TJ-83 | 83.40 | 12.63 | 96.02 | 86.85 | 17.53 |
| Hamal x Kiran -95 | 85.69 | 12.42 | 98.11 | 87.34 | 17.82 |

**Table 11.** Phenotypic variance (δ²p), environmental variance (δ²e), genetic variance (δ²g), heritability (h²%), and genetic advance (GA) of F₂ populations for biological yield plant⁻¹

| Crosses name | δ²g | δ²e | δ²p | h² % | G.A |
|--------------|-----|-----|-----|------|-----|
| Benazir x Hamal | 547.11 | 20.72 | 567.83 | 96.35 | 47.30 |
| Benazir x TD- 1 | 642.45 | 29.16 | 671.61 | 95.66 | 51.07 |
| Benazir x Sindhu | 743.33 | 27.12 | 770.44 | 96.48 | 55.17 |
| Benazir x TJ-83 | 450.01 | 20.84 | 470.84 | 95.57 | 42.72 |
| Benazir x Kiran-95 | 550.55 | 21.14 | 571.69 | 96.30 | 47.43 |
| Hamal x TD-1 | 343.05 | 20.16 | 372.21 | 92.17 | 36.63 |
| Hamal x Sindhu | 460.12 | 27.12 | 487.24 | 94.43 | 42.94 |
| Hamal x TJ-83 | 375.55 | 20.84 | 396.38 | 94.74 | 38.86 |
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ranged from 343.05 and 372.21 Hamal x TD-1 to 1019.05 and 1046.17 TD-1 x Sindhu respectively (Table 11). The highest heritability (97.69%) was produced by TD-1 x Kiran-95 followed by Sindhu x Kiran-95 (97.51%) and the lowest heritability and genetic advance 92.17% and 36.63 was respectively performed by cross Hamal x TD-1. The highest genetic advance displayed by cross TD-1 x Sindhu (64.90) followed by TD-1 x Kiran-95 (60.87).

**Seed Index (1000 grain weight):** Higher heritability expressed by all the crosses studied for the character seed index (1000 grain weight). The range of genotype

**Table 12.** Phenotypic variance ($\delta^2 p$), environment variance ($\delta^2 e$), genetic variance ($\delta^2 g$) heritability ($h^2$%) and genetic advance (GA) of F2 populations for seed index (1000-grain weight)

| Crosse name         | $\delta^2 g$ | $\delta^2 e$ | $\delta^2 p$ | $h^2$% | G.A  |
|---------------------|-------------|-------------|-------------|-------|------|
| Benazir x Hamal     | 966.59      | 20.62       | 987.20      | 97.91 | 63.37|
| Benazir x TD-1      | 662.93      | 24.25       | 687.17      | 96.47 | 52.10|
| Benazir x Sindhu    | 624.10      | 23.99       | 648.09      | 96.30 | 50.50|
| Benazir x TJ-83     | 550.63      | 19.64       | 570.27      | 96.56 | 47.50|
| Benazir x Kiran-95  | 512.64      | 20.98       | 533.61      | 96.07 | 45.72|
| Hamal x TD-1        | 520.57      | 25.54       | 546.11      | 95.32 | 45.89|
| Hamal x Sindhu      | 553.15      | 23.99       | 577.14      | 95.84 | 47.43|
| Hamal x TJ-83       | 423.51      | 19.64       | 443.15      | 95.57 | 41.44|
| Hamal x Kiran-95    | 539.38      | 20.98       | 560.36      | 96.26 | 46.94|
| TD-1 x Sindhu       | 651.03      | 23.99       | 675.01      | 96.45 | 51.62|
| TD-1 x TJ-83        | 676.48      | 19.64       | 696.12      | 97.18 | 52.82|

(423.51 to 966.59) and phenotypic variance (443.15 to 987.2) displayed by Hamal x TJ-83 and Benazir x Hamal respectively. The highest heritability and genetic advance (97.91%) and (63.37) exhibited by Benazir x Hamal followed by TD-1 X TJ-83 (97.18% and 52.82). The lowest heritability shown by cross Hamal x TJ-83 whereas the lowest genetic advance exhibited by Hamal x TJ-83 (Table 12).

**Harvest Index:** Heritability for the character harvest index presented in Table 13 revealed that all the crosses showed higher heritability. The range of genotypic and

**Table 13.** Phenotypic variance ($\delta^2 p$), environment variance ($\delta^2 e$), genetic variance ($\delta^2 g$) heritability ($h^2$%) and genetic advance (GA) of F2 populations for harvest index

| Crosse name         | $\delta^2 g$ | $\delta^2 e$ | $\delta^2 p$ | $h^2$% | G.A  |
|---------------------|-------------|-------------|-------------|-------|------|
| Benazir x Hamal     | 660.26      | 26.75       | 687.01      | 96.11 | 51.89|
| Benazir x TD-1      | 652.08      | 23.77       | 675.84      | 96.48 | 51.67|
| Benazir x Sindhu    | 617.66      | 27.15       | 644.81      | 95.79 | 50.11|
| Benazir x TJ-83     | 660.36      | 30.31       | 690.67      | 95.61 | 51.76|
| Benazir x Kiran-95  | 649.30      | 29.38       | 678.68      | 95.67 | 51.34|
| Hamal x TD-1        | 646.18      | 26.72       | 672.89      | 96.03 | 51.32|
| Hamal x Sindhu      | 672.08      | 27.15       | 699.22      | 96.12 | 52.36|
| Hamal x TJ-83       | 608.07      | 30.31       | 638.37      | 95.25 | 49.58|
| Hamal x Kiran-95    | 632.24      | 29.38       | 661.62      | 95.56 | 50.63|
| TD-1 x Sindhu       | 587.09      | 27.15       | 614.23      | 95.58 | 48.80|
| TD-1 x TJ-83        | 591.71      | 30.31       | 622.02      | 95.13 | 48.87|
| TD-1 x Kiran-95     | 477.59      | 29.38       | 506.97      | 94.20 | 43.70|
phenotypic variance ranged from 477.59 and 506.97 (TD-1 X Kiran-95) to 717.08 and 747.38 (Sindhu x TJ-83) respectively. The highest heritability (96.48%) was shown by Benazir x TD-1 followed by Hamal x Sindhu. The lowest heritability and genetic advance obtained by cross TD-1 x Kiran-95. The highest GA (54.03) is depicted by cross Sindhu x TJ-83 followed by TJ-83 x Kiran-95 (53.69).

4. Discussion

Mean performance of six commercial and their F2 hybrids revealed that among parents Kiran-95 early heading (62.2) was found, while in F2 hybrids 58.93 days to 75% heading taken by cross Benazir x TD-1 For the trait days to 90% maturity, minimum days (114.8) to 90% maturity look by variety TJ-83 and in case of hybrids minimum days to 90% maturity (117.23) was taken by cross Hamal x TD-1. The previous worker like17 reported significant differences formed in days to heading between crosses and parents, while22 reported moderate heritability for physiological maturity. The heading and maturity period are closely related with available moisture % in the cells of the plant as the % of moisture decreases the plant will be headed and mature earlier. The result revealed that the dwarf plant (59.82cm) shown by variety Hamal and in F2 hybrids dwarf plants height (74.5cm) shown by cross Benazir x TD-1, productive tiller plant1 had a straight impact on grain yield plant1, the maximum number of tiller plant1 (7.76) look by variety TJ-83, while in hybrids maximum number of tiller plant1 (13.6) produced by cross Benazir x TD-117. Reported that grain yield/plant had a positive and significant association with tiller/plant and described that dwarf plant is higher yield. The longer spike length (9.95cm) shown by the variety Kiran-95, whereas in hybrids maximum the spike length (14.74cm) produced by cross Benazir x TD-1 from the result displayed that the genotype TD-1 had maximum number of spikelets spike1 (20.76), while maximum number of spikelets spike1 (22.8) shown by cross Benazir x Sindhu. The result of this research with the accordance with21,22 and A. Unay (2012), they described that spike length in the main criteria for higher yield. According to the data genotype TD-1 had produced maximum grains spike1 (56.03), while among hybrids maximum grain spike1 (79.73) shown by cross TD-1 x TJ-83, while the highest grain yield plant1 was recorded (30.53g) from the parental genotype TD-1and among the hybrids TD-1 x Sindhu displayed higher grain yield/plant. The previous researchers like21 worked on the F3 population and reported that parents had higher grain/spike than their F2 population, whereas the hybrids displayed higher seed index. It is one important character that determines the actual grain yield. Highest weight for 1000 - grain were recorded for TD-1. (50.2g) among the cross combination TD-1, x TJ-83 had greater (51.41g) weight for 1000-grains. Most of the wheat cultivar revealed good harvest index extending between 47.94% to 59.95% although the highest harvest index of 59.95% was noticed in Kiran-95, and within the F2 population maximum harvest index of 56.45% was observed in Benazir x Kiran-95. Our results similar with the research of21,22 they formed significant difference among the genotype for yield-associated trait.

Heritability days to heading suggested that all the crosses showed high heritability. The range of genotypic and phenotypic variance ranges from 883.86 and 915.36 (Benazir x TD-1) to 1410.45 and 1441.95 (Benazir x Kiran-95) respectively. The highest heritability % (97.97) displayed by Benazir x Sindhu followed by Benazir x Kiran-95 and the genetic advance in reciprocal of the above crosses, while the highest heritability (98.62%) produce by Benazir x Kiran-95 and Sindhu x Kiran -95 for the trait days to 90% maturity24. Reported the magnitude of the phenotypic coefficient of variance recorded for grain yield plant-1, whereas high heritability for days heading to 50% was being reported. While22 reported higher heritability for days to 50% flowering. The higher heritability of 50% flowering in connected with higher genotypic variance, modern wheat is dwarf in height therefore the vegetative period of dwarf variety is shorter as compared to the old wheat. Plant height displayed that all the crossed should high heritability the range of genotypic and phenotypic variance ranges from 1416.33 and 1462.83 Benazir x TD-1 to 3056.70 and 3105.20 (Benazir x Kiran-95) respectively. The highest heritability (98.57%) displayed by Benazir x Sindhu, whereas highest genetics advance observed in Benazir x Kiran-95. Productive tiller for that all the crossed showed higher heritability, the range of genotypic
and phenotypic variance ranges from 11.72 and 15.72 (Himal x TJ-83) to 46.03 and 49.43 (Benazir x TD-1) respectively. The highest heritability (92.93%) and genetic advance (13.47) produce by Benazir x TD-1. The previous worker like\(^{25}\) reported moderate to higher heritability for the trait tiller/plant with the moderate ranges of genetic advance, whereas\(^{24, 27}\) reported high heritability estimates for plant height and explained that high heritability coupled with high genetic advance which indicates predominance of additive gene action in inheritance of this character, while\(^{26}\) found low to moderate genetics advance for tillers/m\(^2\). The heritability for the character spike length which displayed that all the crossed showed higher heritability, the ranged of genotypic and phenotypic variance range from 11.27 and 15.77 (TD-1 x TJ-83) to 52.32 and 57.32 (Benazir x TD-1) respectively. The highest heritability (91.28%) and higher genetic advance (14.24) displayed by Benazir x TD-1. Crosses showed higher heritability for the character spikelets spike\(^{-1}\). The range of genotype and phenotypic variance ranges from 73.84 and 83.34 (Himal x TJ-83) to 125.49 and 133.99 (Benazir x TD-1) respectively. The highest heritability (93.66%) and genetic advance (22.33) showed by Benazir x TD-1. The results of this research are inverse with the research of\(^{25}\), they reported lower to moderate heritability for spike length and the same situation of genetic advance for the trait spikelets/spike, further they explained that their selected cross and the parental line should be observed critically in breeding performance. Whereas\(^{25}\) observed the highest genetics/environmental variance ratio for spike length and spikelets/spike and intimated that this character should be given top priority during the selection of genotype. Higher heritability displayed by all the cross for the character grain spike\(^{-1}\). The range of genotypic and phenotypic variance ranges from 768.06 and 790.50 (TJ-83 x Kiran-95) to 1524.83 and 1544.33 Benazir x Kiran-95 respectively. The highest heritability (98.74%) and GA (79.93) produced by Benazir x Sindhu. Grain yield plant\(^{-1}\) displayed that all the crossed should higher heritability, the range of genotypic and phenotypic variance ranges from 78.88 and 94.46 Hamal x TD-1 to 230.24 and 244.97 (TD-1 x Sindhu). Heritability estimates revealed that all the crosses showed moderate to low range of genetic and phenotypic variance for character biological yield plant\(^{-1}\). All the crosses were highly heritable. The crossTD-1 x Kiran-95 shows the highest heritability (97.69%) for further, our results are in similar with the results of previous researchers like\(^{25}\). The highest heritability 94.09% displayed by Sindhu x Kiran-95 whereas highest genetic advance showed by TD-1 x Sindhu (30.30). The previous researchers like Collaku and Harrison\(^{31}\) reported the lowest heritability for grain yield and high heritability for seed index and reported that 17% more grain yield obtained when the selection base made on seed index. The other worker of similar research described high heritability for seed index and explained that selected varieties transfer their genetics character to any high yielding genotype for maximizing the grain yield. Vichitra\(^{32}\) described that on the basis of divergence good recombinant could be obtained and genetically diverse genotype is expected to exhibit high heterosis and may result in new recombinants with the desired traits. Higher heritability shown by all the crosses studied for the character seed index (1000-grain weight). The range of genotypic (423.51 to 966.59) and phenotypic variance (443.15 to 987.2) displayed by Hamal x TJ-83 and Benazir x Hamal respectively. The highest heritability and genetic advance (97.91%) and (63.37) exhibited by Benazir x Hamal. Heritability for the character harvest index revealed that all the crossed showed higher heritability whereas to genotypic and phenotypic variance ranges from 477.59 and 506.97 (TD-1 x Kiran-95) to 717.08 and 747.38 (Sindhu x TJ-83) respectively. The highest heritability (96.48%) showed by Benazir x TD-1, the highest GA (54.03) shown by cross Sindhu x TJ-83\(^{33}\). Worked out low heritability for kernel weight per spike and explained that traits can be enhanced easily due to the high value of heritability and phenotypic variance. While\(^{34, 35}\) worked out high heritability along with high genetic advance for 1000 grain weight that was due to the additive genetic effects\(^{36}\). Worked out heritability of seed index in two F\(_2\) populations and conducted that cross combination and their parental lines must be given due consideration in a subsequent generation or further breeding programs.

5. Conclusions

- The mean square regarding genotype, parent, and crosses were highly significant (P > 0.01) for all the traits studied, while parents vs crosses (p x c) were highly significant at P > 0.01 level of probability for all the traits studied except seed index which is non-significant.
• The variety TD-1 performs better in spikelets spike\(^{-1}\), grains spike\(^{-1}\), grain yield plant\(^{-1}\), seed index, while variety Kiran-95 had higher in spike length, and harvest index.

• The cross Benazir x TD-1 showed higher heritability for tillers plant\(^{-1}\), spike length, spikelets spike\(^{-1}\), and harvest index. While Benazir x Sindhu exhibited higher heritability for grains spike\(^{-1}\) and plant height.

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