Morphological evaluation of wheat genotypes for grain yield under arid environment of Balochistan

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Abstract
Wheat is the most famous cereal crop in the world mainly used as a staple food for mankind. Drought is a leading environmental stress that restricts the productivity of wheat in water-scare regions. In this study, we evaluated the performance of 10 advanced lines and two commercial varieties for grain yield during 2018-19, at Balochistan Agriculture College, Quetta. Results revealed the highly significant differences between genotypes for number of days to heading, days to maturity, plant height at maturity (cm), number of fertile tillers plant⁻¹, number of grains spike⁻¹, 1000-grain weight (g), grain yield plant⁻¹ and grain yield (kg/ha), while significant (P > 0.05) for days to grain filling period. In addition, the principal component analysis indicated that first two principal components (PC1 and PC2) accounted for 83.77% of the total variation. The genotype BAC-51 performed superior for grain yield and other morphological traits, suggesting that BAC-51 should be tested at different locations in the upland of Balochistan and may be released as a drought-tolerant variety after the certification process.

Keywords: Drought; Genetic diversity; Grain yield; Wheat

Introduction
Bread wheat (Triticum aestivum L. 2n = 6x = 42) is the most popular cereal crop of the world that consumed by 2.5 billion people around the globe. It meets the food requirements of one-third of the world’s population and is used as a staple food in South Asian countries such as Bangladesh, India and Pakistan [1]. Wheat is the major crop of Pakistan grown on an area of more than 8.6 million hectares annually with a total production of 24.94 million tons per annum. The agricultural value-added share of wheat is about 8.7 per cent and 1.7 per cent in the country's GDP [2]. Due to high nutritional value, wheat contains around 72% calories with a significant amount of dietary protein and other vitamins and minerals [3]. The overall world wheat production in 2017–18 reported to 758.4 million tons and then
Wheat is considered a profitable crop for the local farming community of Balochistan by successful cultivation under rainfed arable lands. Therefore, it is the most essential crop of upland Balochistan under spate irrigation systems, where majority of the cropping lands rely on annual rainfall [13]. In the early winter season, it is sown on stored soil moisture from summer rains. At the same time, the severity of water stress can vary from season to season [14]. The grain formation period, however, is the most critical time, so local wheat genotypes in these areas are highly adaptable to the multifarious environmental conditions [15].

The present study was aimed to evaluate the wheat advance lines for high grain productivity under arid condition and to estimate the phenotypic diversity of studied genetic material. The knowledge obtained from this study will greatly help in improving local breeding materials that might have yield potential for rainfed cultivation.

Materials and Methods
The current research was carried out in the experimental field area of Balochistan Agriculture College, Quetta, during the growing season Rabi 2018-19. The experimental material consists of ten advance wheat lines, encoded as BAC-51, BAC-52, BAC-53, BAC-54, BAC-55, BAC-56, BAC-57, BAC-58, BAC-59 and BAC-60 were collected from wheat wide crosses breeding program, National Agriculture Research Centre (NARC), Islamabad and two local checks includes, Sariab-92 and Tijaban-10 obtained from ARI, Sariab Quetta. The genotypes were evaluated under limited water conditions for yield and yield components. Only two irrigations were given during the cropping cycle, first at pre-soaking doze and second at tillering stage to avoid the critical growth stages for average grain yield. The meteorological data was recorded during the wheat cropping cycle are presented in (Table 1).
Table 1. Meteorological data of experimental site during 2018-2019

| Months      | Minimum Temperature (°C) | Maximum Temperature (°C) | Humidity (%) | Total Rainfall (mm) |
|-------------|--------------------------|--------------------------|--------------|---------------------|
| October, 2018 | 7.35                      | 20.37                     | 23.34        | 1.56                |
| November, 2018 | 5.59                      | 18.43                     | 21.58        | 17.77               |
| December, 2018 | 2.46                      | 15.18                     | 19.15        | 0.50                |
| January, 2019  | 0.47                      | 12.75                     | 24.79        | 37.34               |
| February, 2019 | 1.56                      | 12.23                     | 23.72        | 35.04               |
| March, 2019    | 4.99                      | 17.91                     | 23.56        | 25.7                |
| April, 2019    | 11.09                     | 24.73                     | 12.21        | 11.45               |
| May, 2019      | 15.46                     | 29.07                     | 16.67        | 4.13                |

Source: Department of Plant Breeding and Genetics, Balochistan Agriculture College

The experiment was sown on 28 October 2018 in randomized complete block design with three replications. Four rows of 5-meter length were allocated for each genotype, whereas one-row space was left between the unit plots for the recognition of each genotype. The space between plant to plant was kept 5 cm and the distance between row to row was adjusted 25 cm. After well land preparation, the seeds of each genotype was sown at the rate of 120 kg/ha. All agronomic practices such as hoeing, weeding and fertilizer (NPK) were applied as recommended previously for wheat [9]. Ten randomly selected plants of each genotype from each replication were harvested and data was recorded for number of days to heading (DTH), maturity days (DM), plant height (PH), days to grains filling period (DGFP), number of fertile tillers per plant (NFTP), number of grains per spike (NGPS), grain yield plant\(^{-1}\) (GYP), 1000-grain weight (g) (TSW), and total grain yield (kg/ha) (GYH). The collected data was utilized for the statistical variance analysis and means were compared by employing least significant differences (LSD) test using computer software Statistix 8.1, whereas principal component analysis (PCA) was performed using computer software Minitab version 16.

**Results and Discussion**

The analysis of variance (ANOVA) in term of mean square revealed the highly significant variations (\(P > 0.01\)) among the advance line and standard check varieties for days to heading, days to maturity, plant height, number of tillers plant\(^{-1}\), number of grains spike\(^{-1}\), 1000-grain weight, grain yield per plant and grain yield (kg/ha) as presented in (Table 2). The differences were observed significant only for grain filling period at \(P > 0.05\) level of probability. This variation among genotypes indicate that the genetic background of studied germplasm very divergent and selection of promising lines may be helpful in future breeding programs. In similar studies, significant differences between wheat genotypes for yield and other related traits have been reported previously by various wheat breeders [12, 16].

**Days to heading**

The data regarding days to heading was ranged from 131 days to 139 days with mean value of 135.08 days, as mentioned in (Table 3). The genotype BAC-60 had taken maximum days for heading followed by BAC-56, whereas the lowest days were recorded in genotype BAC-52. The concerned parameter is highly linked with maturity, therefore, the genotypes took fewer days to heading also saved time and escaped the period of terminal drought. These
findings are supported by Sohail et al. [9] who stated that early heading wheat genotypes could escape the stressed condition, while the outcomes of our study contradicting with the earlier findings [17].

Table 2. Mean square variances for various morphological traits of Triticum aestivum under rainfed condition

| S.O.V      | df | No. of days to heading | No. of days to maturity | Plant height (cm) | Grain filling period | No. of fertile tillers per plant | No. of grains per spike | 1000-grains weight | Grain yield plant⁻¹ (g) | Grain yield (Kg/ha) |
|------------|----|------------------------|-------------------------|-------------------|----------------------|-------------------------------|------------------------|-------------------|------------------------|---------------------|
| Replication| 2  | 13.0                   | 7.69                    | 12.02             | 2.52                 | 13.02                        | 40.4                   | 12.06             | 11.85                  | 8.616               |
| Genotypes  | 11 | 18.0**                 | 19.74**                 | 41.45**           | 5.23**               | 2.39**                       | 136**                  | 33.65**           | 0.28**                 | 41933.7**           |
| Error      | 22 | 1.0                    | 0.69                    | 0.03              | 1.61                 | 0.27                         | 16.74                  | 0.001             | 0.017                  | 104.49              |

* Significant; **Highly Significant

Days to maturity
The data for days to maturity ranged from 161 to 170 days with an average of 166.92 days were recorded among the twelve wheat genotypes. The highest days to maturity was observed for genotype BAC-60 followed by BAC-56, while minimum number of days to maturity was recorded for BAC-52. Minimum days required for wheat maturation also help to save input costs, while late ripening varieties are more predisposed to drought pressure. These findings are in agreement with previous results [18].

Plant height (cm)
The analysis of variance showed that plant height differed significantly in studied wheat genotypes. The range of plant height varied from 47.3 cm to 59.90 cm with mean value of 55.60 cm. The tallest plant height was attained by genotype BAC-56, closely followed by genotype BAC-51 and BAC-53 while short stature was observed in BAC-52. The dwarf varieties may accumulate the plant biomass in the form of grain under drought stress. Thus, developing short stature desired varieties for rainfed areas is the priority of wheat breeders. These results concur with the previous finding [19-21]. They reported a substantial difference in plant height of different wheat lines planted under rain-fed conditions.

Days to grain filling period
Days to grain filling period ranged from 30 days to 33.33 days with an average value of 31.78 days (Table 3). The results also revealed that genotype BAC-53 took longer days for grain formation, whereas three genotypes (BAC-52, BAC-54, and BAC-59) had shortest period for this trait. The extended grain filling period is desired for higher grain yield; thus, the genotype BAC-53 may contribute to high grain yield, if utilized in the wheat improvement program. Kilic and Agrasen (2010) recorded similar significant differences in wheat lines evaluated under rain-fed conditions [22].

Number of fertile tillers per plant
The recorded data of number of fertile tillers plant⁻¹ ranged from 5 to 8 with an average 5.92 tillers (Table 3). The maximum number of fertile tillers was observed for BAC-51 followed by BAC-52, while the lowest value was recorded for BAC-60 under rainfed field condition. The grain yield is highly dependent on number of fertile tillers plant⁻¹. Thus, it contributes significantly to other traits towards increased productivity. The present results are well conformity with earlier findings [23].

1000-grain weight (g)
Thousand-grain weight is an essential character that directly improve the economic
yield [24]. The data regarding 1000-grain weight varied from 38.67 g to 48.94 g with an average value of 43.87 g (Table 3). The maximum thousand grain weight was recorded for BAC-51, closely followed by BAC-53 and BAC-52, while the lightest grain weight was recorded for genotype BAC-60. These outcomes are in harmony with previous findings, in which some genotypes produced higher seed weight [25].

Table 3. Mean performance of 12 wheat genotypes for various morphological traits assessed during 2018-2019

| Genotypes  | Days to heading | Days to maturity | Plant height (cm) | Days to grain filling period | No. of fertile tillers per plant | 1000-grain weight (g) | No. of grains spike⁻¹ | Grain yield plant⁻¹ (g) | Grain yield per hectare (kg) |
|------------|-----------------|------------------|-------------------|-----------------------------|---------------------------------|-----------------------|------------------------|--------------------------|-----------------------------|
| BAC-51     | 135             | 167              | 58.6              | 32                          | 8.00                            | 48.94                 | 65.33                  | 6.76                     | 1953.79                    |
| BAC-52     | 131             | 161              | 47.3              | 30                          | 7.00                            | 46.68                 | 65                     | 6.45                     | 1835.17                    |
| BAC-53     | 133             | 166              | 58.4              | 33.33                       | 6.00                            | 47.48                 | 64                     | 6.36                     | 1855.76                    |
| BAC-54     | 133             | 163              | 47.3              | 30                          | 6.00                            | 44.50                 | 62.33                  | 6.56                     | 1871.40                    |
| BAC-55     | 135             | 168              | 55.1              | 33                          | 6.00                            | 43.41                 | 62                     | 6.08                     | 1843.40                    |
| BAC-56     | 136             | 169              | 59.9              | 33                          | 6.00                            | 42.33                 | 54.33                  | 5.98                     | 1811.28                    |
| BAC-57     | 136             | 168              | 59.6              | 32                          | 5.00                            | 41.73                 | 55                     | 6.03                     | 1684.44                    |
| BAC-58     | 135             | 168              | 56                | 33                          | 5.00                            | 41.60                 | 50.67                  | 5.98                     | 1639.12                    |
| BAC-59     | 137             | 167              | 58.6              | 30                          | 5.00                            | 38.77                 | 46.67                  | 5.93                     | 1603.71                    |
| BAC-60     | 139             | 170              | 58.27             | 31                          | 5.00                            | 38.67                 | 47                     | 5.74                     | 1606.18                    |
| SARIAB-92  | 136             | 169              | 53.5              | 33                          | 6.00                            | 45.55                 | 58.33                  | 6.00                     | 1655.60                    |
| TIJABAN-10 | 135             | 167              | 54.60             | 31                          | 6.00                            | 46.73                 | 56.67                  | 5.89                     | 1769.27                    |
| Grand Mean | 135.08          | 166.92           | 55.60             | 31.78                       | 5.92                            | 43.87                 | 57.28                  | 6.15                     | 1760.76                    |
| Standard Error | 0.57        | 0.48             | 47.3              | 0.73                        | 0.30                            | 5.774                 | 0.02                   | 2.36                     | 14.58                      |
| L.S.D (0.05) | 1.69      | 1.41             | 58.4              | 2.15                        | 0.88                            | 6.92                  | 42.75                  |

Number of grains per spike
The final grain yield of the wheat is directly associated with the highest grains per spike. The range of twelve wheat genotypes for number of grains spike⁻¹ varied from 46.67 to 65.33 with the mean value of 57.28 grains (Table 3). The genotype BAC-51 showed maximum number of grains per spike pursued by BAC-52 and BAC-53, while genotype BAC-59 showed the least number of grains per spike. These findings are also validating the results obtained by other researchers [26].

Grain yield per plant (g)
The data relevant to grain yield plant⁻¹ showed highly significant variances among the studied wheat genotypes under rainfed conditions. The grain yield per plant was varied from 5.74 g to 6.76 g with the average value of 6.15 g (Table 3). The highest grain yield plant⁻¹ was recorded for genotype BAC-51 followed by BAC-54 while the minimum value observed for genotype BAC-60. These results are in agreement with the earlier studies which were conducted on wheat under rainfed conditions [27, 28].

Grain yield per hectare (kg)
Grain yield is the most prominent trait with economic benefit of any commercial field crop. The range of grain yield varied from 649 kg to 790.67 kg with an average of 712.56 kg (Table 3). Maximum grain yield was recorded for BAC-51 followed by BAC-54, while the lowest yield was noticed for
genotype BAC-59 under rainfed situation. Grain yield is directly associated with number of fertile tillers, number of spikes and 1000-grain weight. These results are comparable with earlier findings in which yield has been found highly significant under rainfed conditions [20].

**Principal component analysis**

The principal component analysis (PCA) is a useful technique in selecting diverse parents for the hybrid breeding orientation programs. Loading plot depicted the genetic variability among evaluated wheat genotypes in term of measured trait (Fig. 1). Out of the nine principal components, the first two principal components having eigenvalues (>1) was considered to be significant and contributed 83.77% of the estimated variability. The projection of loading traits of first two main components viz; PC1 and PC2 accounted for 62.86% and 20.91% respectively, towards the estimated variability (Table 4). The morphological traits that drawn the PC1 were NFTP, NGPS, GYP, TGW, and GYH, whereas PC2 mainly characterized by DTH, DM, PH and DGFP. These finding well supported by Pasandi et al. [29], who estimated the diversity among 56 wheat genotypes based on morphological characteristics. Many researchers also used principal component analysis to determining phenotypic diversity in wheat [10, 30]. Score plot showed that the genotypes farthest from the point of origin had the highest dissimilarities. First two PCs showed maximum diversity between the genotypes BAC-60, BAC-52, and BAC-51 (Fig. 2). The consideration of these advance breeding lines which substantially performed better under low rainfed condition, may be given chance in future breeding programs. Several earlier studies depicted the efficiency of principal component analysis in the determination of diversity and classification of wheat genotypes and other crops based on morphological attributes [31, 32].

**Table 4. Eigenvalues, variability (%) and cumulative variance (%) for nine morphological traits assessed under rainfed condition**

| Traits                        | PC 1   | PC 2   | PC 3   |
|-------------------------------|--------|--------|--------|
| Days to heading               | -0.881 | 0.190  | 0.358  |
| Days to maturity              | -0.787 | 0.573  | 0.058  |
| Plant height (cm)             | -0.608 | 0.635  | 0.285  |
| Days to grain filling period  | -0.145 | 0.857  | -0.470 |
| Number of fertile tillers per plant | 0.835 | 0.303  | 0.338  |
| 1000- grain weight (g)        | 0.858  | 0.347  | -0.066 |
| Number of grains per spik     | 0.938  | 0.246  | -0.117 |
| Grain yield plant per plant (g)| 0.895 | 0.079  | 0.234  |
| Grain yield per hectare (kg)  | 0.869  | 0.318  | 0.162  |
| **Eigenvalues**               | 5.65   | 1.88   | 0.646  |
| **Variability (%)**           | 62.864 | 20.913 | 7.187  |
| **Cumulative variance (%)**   | 62.8644| 83.7769| 90.9637|
Figure 1. Loading plot of PC1 and PC2 demonstrated the phenotypic variability for nine morphological traits.

Figure 2. Score plot of PC1 and PC2 illustrated the agronomic diversity of 12 wheat genotypes.
Conclusion
Among the assessed genotypes, the advance wheat line BAC-51 performed superior for increased grain yield (1953.79 kg/ha) and other morphological attributes. The principal component analysis displayed a considerable variability among the studied genetic material and identified three diverse genotypes namely, BAC-51, BAC-60 and BAC-52 at extreme positions of score plot. The genotypes with higher genetic diversity may be utilized in future breeding programs for the development of drought-resilient cultivars. Moreover, the most promising advance line BAC-51 is highly recommended for the improvement of local wheat genetic resources with aim to develop the drought resistant cultivars for the rainfed areas of Balochistan.

Authors’ contributions
Conceived and designed the experiments: G Rasool,
Performed the experiments: A Ullah,
Analyzed the data: MA Tariq & G Rasool,
Contributed materials/ analysis/ tools: A Jan & Q Ahmad,
Wrote the paper: G Rasool & M Waris.

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