Research Article

Comparative Analysis of Genetic Variability and Heritability in Wheat Germplasms

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Abstract | This research project was performed to assess the genetic variability and heritability among exotic and local wheat genotypes at Cereal Crop Research Institute (CCRI) Pirsabak, Nowshera, Pakistan. A total of sixteen genotypes i.e., eight exotic and eight local germplasms were sown in a three-replication randomized complete block design. The different parameters were recorded including days to heading, flag leaf area, plant height, tillers per plant, spike length, spikelets per spike, grain yield per plant, biological yield per plant, and 1000-grain weight. The analysis of variance showed significant differences for all the mentioned parameters ($P \leq 0.05$). In local germplasms, all parameters revealed significant results excluding the 1000-grain weight, while the exotic germplasms also showed significant genetic variation except spikelets per spike and 1000-grain weight. The local varieties took more time for days to heading (Paseena-17, 147.7 days), more spikelets per spike (Khaista-17, 24.2), grain yield per plant (Gulzar-19, 27.6 g), biological yield per plant (Khaista-17, 73.3 g), 1000 grain weight (Pirsabak-19, 59.4 g). In contrast, exotic wheat had more flag leaf area (Akuri#1, 55.6 cm^2), plant height (Quaiu#2, 97.3 cm), tiller per plant (Navojoa-M-2007, 13.8), spike length (Kenya Tea, 16.9 cm). All parameters showed higher values for the phenotypic coefficient of variation (PCV) compare to the genotypic coefficient of variation (GCV). We also observed high heritability (h_2) value for days to heading (93.0) and flag leaf area (66.0), which shows that high heritability estimates genetic advance for such characters. In summary, we recommend Pirsabak-21 and Abaseen-21 as well as Kenya Tea and Akuri#1 for the maximum grain production respectively.

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Introduction

The bread wheat (*Triticum aestivum* L), is allohexaploid (2n=6x=42), which develop by two distinct natural hybridization events. The two grass species i.e., *Triticum speltoides* (B genome donor) and *Triticum urartu*, have been accidentally crossed into tetraploid wheat species termed *Triticum turgidum* (A genome donor). The hybridization of tetraploid (A genome donor) and *Triticum tauschi* (D genome donor) produced a novel hexaploid wheat. This hexaploid wheat possesses 7 chromosomes each, six complete genomes, and is reproductive. Wheat is one of the ancient and most important staple cereal crops. It is a grass belonging to the family Poaceae and is cultivated for grain production globally. It is being reported by United Nations Organization that 90% of the world's food is coming from land compared to other resources. The cereal grains (wheat, corn, rice, barley, sorghum, etc.) provide about 68% of the world's food supplies (Oleson, 1994). Wheat can be refined into starch, grain oil, and beer (40% of carbohydrate). Wheat is also used as a source of grass at earlier and post-harvest for animals. It is a wildly cultivated cereal crop and adapted from irrigated to dry, warm, and humid to cold environments. Based on taxonomy breeders further categorized wheat cultivators according to the seasons in which they grow, such as winter wheat and spring wheat, on kernel texture such as soft wheat and hard wheat as well as grain color (red, white, and amber).

Wheat is the main food source for a major portion of the world's population, including Pakistan. But there is an inappropriate availability of food due to some challenges. To overcome the food crisis, researchers all over the world trying to generate improved and advanced wheat lines to overcome different environmental challenges including drought, temperature salinity, etc. (Marwat *et al*., 2005). But still, some environmental factors like temperature, reduce wheat production by increasing from 30 °C (Vermeulen *et al*., 2012). The United States, China, and Russia are the world's major wheat producers however, India, Europe, Canada, Argentina, and Australia also extensively grow wheat. The average production of wheat throughout the world increased over the last 60 years (Fischer *et al*., 2022). China produced 134,250 thousand tonnes of wheat as of 2020, making up 20.66% of global production (Pal *et al*., 2022). The world wheat production was recorded at 780.28 million tonnes in 2021-22, with an increase of 4.45 million tonnes compared to 775.83 million tonnes during 2020-21 (USDA, 2021-22). It is estimated that the consumption of wheat is increasing throughout the globe and the expected quantity for 2021-2022 needs to be 789.63 million tonnes (USDA, 2021-22). Russia and Ukraine represent around 30% of the world's wheat trade. As a consequence of Ukraine's production capacity being harmed by Russia's military invasion in 2022, several nations restricted or ended trade links with Russia, driving up world wheat prices. Wheat in Pakistan is used as a major source of food and is most commonly used as bread. As an agricultural developing nation, Pakistan depends on agriculture to generate foreign cash, provide jobs, and foster the growth of other industrial businesses and sectors (Abbas and Waheed, 2017). Pakistan produces 131 Kg of wheat per person despite consuming 118 Kg per person annually, while its consumption is the highest in the world. Pakistan may likely see a modest shortfall of wheat production in the future, according to projected predictions for the period of 2007-15, which show a consistent increase of 1.6% (Sher and Ahmad, 2008). Since it accounts for 42.3% of all employment and 19.8% of Pakistan's GDP, agriculture is a significant component of the country's economy (Lateef *et al*., 2017). Conducive weather and climatic conditions are necessary for developing the agriculture industry (Hussain *et al*., 2007; Gull *et al*., 2019; Khan *et al*., 2021). The wheat production in Pakistan is 27,000 thousand tonnes cultivated over a total of 9,160 thousand hectares, of which KP produces 1700 thousand tonnes on 900 thousand hectares (https://suparco.gov.pk/wp-content/uploads/2021/05/V-XI-Issue-05-1-May-2021).

Pakistan's wheat production declined due to drought, flooding, and rapid population growth. To improve such losses in wheat production, the researchers going to estimate the grain yield through genetic variation. The dynamics of development and agricultural output include a lot of decision-making, and variability is a key indicator of that. Without respect to growth, it is critical to comprehend the nature of food security and income stability in order to examine changes in crop production. Crop production variations affect pricing and result in abrupt changes, but they also have a substantial impact on the amount of money that farmers may earn. Genetic variety is a propensity to compare different genotypes within a population.

The degree to which a trait varies in response to genetic and environmental influences is referred to as its variability. The main objective of this research is to estimate the genetic variability and heritability among the local and exotic wheat germplasms.

Materials and Methods

This research work was carried out to estimate genetic variability and correlation among exotic and local wheat germplasms at the Cereal Crop Research Institute (CCRI) Pirsabak, Nowshera, Pakistan during 2021-22. A set of sixteen germplasms, eight exotics, and eight local wheat lines were estimated in a randomized complete block design with three replications (Table 1). Sowing was done on 24th October 2021 and the crop was harvested on 7th May 2022. The plot for each genotype had two rows with a row length of 2 m and row to row distance of 25 cm. Standard agronomic practices were followed from sowing till harvest.

Table 1: *List of local and exotic wheat genotypes sown during 2021-2022. (CIMMYT=Centro Internacional de Mejoramiento de Maíz y Trigo, International Maize and Wheat Improvement Center).*

S. No.	Local wheat germplasms	S. No.	Exotic wheat germplasms	Origin
1	Paseena-17	1	Akuri#1	CIMMYT
2	Wadaan-17	2	King Bird#2	CIMMYT
3	Khaista-17	3	Kachu#2	CIMMYT
4	Pirsabak-19	4	Navojoa-M-2007	CIMMYT
5	Gulzar-19	5	Quaiu#2	CIMMYT
6	Abaseen-21	6	Villa Juarez- F-2009	CIMMYT
7	Zarghoon-21	7	Becord#1	CIMMYT
8	Pirsabak-21	8	Kenya Tae	CIMMYT

Data collection

Data were recorded from three plants randomly selected from each replication on days to heading, plant height, flag leaf area, spike length, tiller per plant, spikelets per plant, biological yield, grain yield and 1000 grain weight.

Statistical analysis

Data obtained from 16 wheat genotypes (8-exotic+8-local), was examined using the method for randomized complete block design. Further analysis of variance (ANOVA) is applied to each parameter to determine the sum of the square of each genotype. A single degree of freedom contrast of local vs exotic wheat was also computed. The least significant difference test was also used to compare the mean. Genetic and phenotypic correlations among trials were also computed.

Results and Discussion

Genetic variability and heritability

Mean square performance exhibited a high significance of difference (p=0.05) among wheat germplasms for all the morphological and grain-related traits. Among the local wheat genotypes, all the parameters were significantly variant in their genetic variation except 1000 grain weight. The same results were also reported by those researchers (Arya *et al*., 2017; Ali *et al*., 2008), except they don't support 1000 grain weight. In contrast, exotic wheat genotypes, also showed significant genetic variation except for spikelets per spike and 1000 grain weight, using different experimental data indicating the opposite result for tiller per plant. In contrast local vs exotic wheat germplasms presented high-significant result apart from flag leaf area, spikelets per spike, grain yield per plant, biological yield per plant, grain yield, and spikelets per spike is directly related to grain weight. The local and exotic wheat for a single degree of freedom also showed non-significance of genetic variation for spikelets per spike and grain yield per plant (Arya *et al*., 2017; Ali *et al*., 2008), showing inverse results for spikelets per spike and grain yield per plant in their experiment. Ali *et al*. (2008) used a different experimental design in fields with different wheat varieties from the international market. All parameters revealed a higher value for the phenotypic coefficient of variation (PCV) compare to the genotypic coefficient of variation (GCV) (Table 2). This low value of GCV shows that the environmental factor is mostly involved rather than the internal factor in variation. Among all the traits we observed a high heritability (h_2) value for days to heading (93.0) and flag leaf area (66.0) (Table 2), which indicates that high heritability estimate genetic advance for such characteristics (Kumar *et al*., 2003), represented same result for all the traits except days to the interval which is completely opposite to present an experiment that is highly heritability advance for days to heading. The last report mentioned above used different experimental materials and methods. Kumar *et al*. (2003) showed high PCV values for all the traits except for days to heading. The same result was obtained in the present experiment.

Table 2: *The sum of mean square performance of different parameters including days to heading, flag leaf area, spike length and spikelets per spike of local and exotic lines.*

Source	DF	Days to heading	Flag leaf area	Plant height	Spike length	Spikelets per spike
Replication	2	4.08*	11.14**	63.48**	2.96*	5.25**
Genotypes	15	25.11*	169.49*	76.55*	3.49*	2.81*
Local germplasm	7	40.17*	85.91*	61.69*	1.70*	4.58*
Exotic germplasm	7	12.67*	262.64*	50.02*	5.02*	1.43**
Local and exotic	1	6.75*	102.46**	366.31*	5.26*	0.06**
Error	30	0.57	25.13	11.77	0.59	1.63
CV%	--	0.53	12.84	3.89	5.57	5.87
R^2	--	95.73	77.28	78.31	76.80	51.90
h^2	--	0.93	0.66	0.65	0.62	0.20
PCV	--	2.07	21.91	6.54	1.36	6.54
GCV	--	2.00	17.76	5.26	9.07	2.89

**, significance; **, non-significance at 5% probability. DF: Degree of freedom; PCV: phenotypic coefficient of variation; GCV: genotypic coefficient of variation; h^2: heritability; CV: coefficient of variation; R^2: coefficient determination.*

Table 3: *Show the sum of the mean square performance of degree of freedom, tiller per plant, biological yield per plant and 1000 grain weight from left to right columns.*

Source	DF	Tiller per plant	Biological yield per plant	Grain yield per plant	1000 grain weight
Replication	2	10.68**	16.54ns	9.98ns	18.87ns
Genotypes	15	16.96**	189.23*	45.87**	71.70**
Local germplasm	7	11.98**	223.53*	61.70**	41.33ns
Exotic germplasm	7	22.41**	170.28*	33.38**	38.54ns
Local and exotic	1	13.60ns	81.86ns	22.50ns	516.47**
Error	30	2.91	37.13	11.80	28.59
Cv%	----	18.99	10.86	17.96	10.47
R^2	----	75.95	72.05	66.67	65.48
h_2	----	0.62	0.58	0.49	0.33
PCV	----	30.68	16.70	25.16	12.83
GCV	----	24.09	12.69	17.62	7.12

*The data were collected from local and exotic lines. *= significance, **= non-significance at 5% probability.*

Mean performance

Days to heading among the local wheat genotypes ranged from 137 to 147.7 days with LSD (least significance differences) of 0.73 at 5% probability (Table 4). Among the local wheat genotypes, the minimum days to heading were recorded for Pirsabak-21 (137 days), while the maximum for Paseena-17 (147.7 days) (Table 2). In contrast days to heading for exotic wheat genotypes ranged from 139.7 to 144.0 days. Minimum days to heading were noted for Akuri #1 (139.7 days) and maximum for Kenya Tea (144 days) in the current project (Table 4), which is in accordance with the previous findings (Ali *et al*., 2008).

Flag leaf area among the local wheat genotypes ranged from 32.5 to 50.5 cm^2 with LSD of 4.83 at 5% probability (Tables 2 and 4). Among the local wheat Genotypes, the minimum flag leaf area was noted for Pirsabak-21 (32.5 cm^2), while the maximum for Pirsabak-19 (50.5 cm^2) (Table 4). In contrast, the flag leaf area for exotic wheat genotypes ranged from 31 to 55.6 cm^2 (Table 4). The minimum flag leaf area was recorded for Quaiu# 2 (31 cm^2), and the maximum for Akuri#1 (55.6 cm^2). The average mean of flag leaf area for locals and exotics was 40.5 cm^2 and 37.6 cm^2, respectively. Hence local wheat had about 3 cm^2 more flag leaf area than exotic wheat.

Plant height among the local genotypes ranged from 81.3 to 93.2 cm with an LSD of 0.74 at 5% probability (Tables 2 and 4). Among local wheat genotypes, minimum plant height was recorded for Pirsabak-19 (81.3 cm) and maximum for Wadaan-17 (93.2 cm) (Table 4). In contrast, plant height in exotic wheat genotypes was in the range of 84.6 to 97.3 cm. Minimum plant height in exotic genotypes for Akuri#1 (84.6 cm), and maximum for Quaiu # 2 (97.3 cm) (Table 4).

Tiller per plant (tpp) in local genotypes of wheat ranged from 6.3 to 12.8 tiller per plant, with an LSD of 1.64 at 5% probability among the local wheat genotypes (Tables 3 and 5), minimum tiller per plant was noted for Paseena-17 (6.3 tpp), and maximum for Pirsabak-21 (12.8 tpp) (Table 5). In contrast, exotic wheat genotypes tiller per plant ranged from 6.8 to 13.8 tiller per plant respectively. Among the exotic genotypes, the minimum tiller per plant was recorded for Becord#1 (6.8 tpp) and the maximum for Navojoa-M-2007 (13.8 tpp) (Table 5).

Table 4: *Mean performance of local and exotic wheat lines with an LSD at 5% probability . The analysis was performed on different parameters including days to heading, flag leaf area, plant height, spike length, and spikelets per spike from left to right columns.*

Germplasm	Days to heading	Flag leaf area	Plant height	Spike length	Spikelets per spike
Local wheat lines					
Paseena-17	147.7	43.2	82.8	14.5	21.1
Wadaan-17	146.0	42.9	93.2	14.2	22.6
Khaista-17	143.0	38.6	82.3	13.8	24.2
Pirsabak-19	142.0	50.5	81.3	13.4	22.0
Gulzaar-19	139.0	36.3	82.0	13.2	20.0
Abaseen-21	146.0	40.9	87.7	13.0	21.3
Zarghoon-21	144.0	39.2	84.1	12.8	21.6
Pirsabak-21	137.0	32.5	91.0	12.3	21.3
Local mean	143.1	40.5	85.5	13.4	21.8
Exotic wheat lines					
Akuri#1	139.7	55.6	84.6	13.5	20.7
King Bird#2	144.0	46.8	90.4	13.7	21.8
Kachu#2	144.0	27.7	92.2	12.8	22.2
Navo-joa-M-2007	144.0	32.2	91.1	12.8	21.1
Quaiu#2	143.0	31.0	97.3	14.3	21.3
Villa Juarez-F-2009	140.0	33.8	93.4	14.6	21.6
Becord#1	140.0	33.9	86.2	13.9	22.0
Kenya Tae	144.0	39.9	93.3	16.9	22.9
Exotic mean	142.3	37.6	91.1	14.1	21.7
LSD%	0.73	4.83	3.30	0.74	1.23

Spike length among the local genotypes ranged from 12.3 to 14.5 cm (Tables 2 and 4). Among the local genotypes of wheat, the minimum spike length for Pirsabak-21 (12.3 cm) and maximum for Paseena-17 (14.5 cm) were recorded (Table 4). The spike length ranged from 12.8 to 16.9 cm for exotic wheat genotypes. The minimum length was recorded for Navojoa-M-2007 (12.8 cm) and the maximum for Kenya Tea (16.9 cm) (Table 4).

Table 5: *Show mean performance of tiller per plant, biological yield per plant, grain yield per plant and 1000 grain weight with an LSD at 5% probability. The mentioned parameters are for both local and exotic wheat lines.*

Germplasm	Tiller per plant	Biological yield per plant	Grain yield per plant	1000 grain weight
Local wheat				
Paseena-17	6.3	60.0	20.4	54.3
Wadaan-17	8.6	56.1	21.5	50.5
Khaista-17	6.9	73.3	16.0	51.8
Pirsabak-19	8.1	55.6	20.0	58.8
Gulzaar-19	9.4	42.2	16.6	51.9
Abaseen-21	8.0	60.0	27.6	57.5
Zarghoon-21	7.6	53.3	13.3	50.8
Pirsabak-21	12.8	58.9	23.1	59.4
Local mean	8.5	57.4	19.8	54.4
Exotic wheat				
Akuri#1	9.4	52.2	23.3	50.0
King Bird#2	12.6	62.2	17.1	41.2
Kachu#2	7.2	57.2	19.9	52.2
Navojoa-M-2007	13.4	53.0	17.4	46.6
Quaiu#2	10.1	45.0	16.7	48.2
Villa Juarez- F-2009	5.9	55.6	18.7	51.6
Becord#1	6.8	46.1	12.6	47.7
Kenya Tae	10.7	67.2	21.9	45.2
Exotic mean	9.5	54.8	18.4	47.8
LSD%	1.64	5.87	3.31	5.15

Spikelet per spike in local genotypes of wheat ranged from 21.1 to 24.2 (Tables 2 and 4). Among the local wheat genotypes the minimum spikelets per spike were noted for Gulzar-19 (21.1) and the maximum for Khaista-17 (24.2) (Table 4). In exotic genotypes of wheat, the spikelets per spike ranged from 21.1 to 22.8, with an LSD of 1.23 at a 5% probability (Table 4). The minimum spikelets were recorded for Pirsabak-21 (20.7) and the genotype possessing a maximum number of spikelets per spike was Kenya Tea (22.8) (Table 4).

Grain yield per plant among the local genotypes ranged from 9.7 to 27.6 g with LSD for 5% probability was 3.31 (Tables 3 and 5). Among the local wheat genotypes, the minimum grain per plant was recorded for Abaseen-21 (9.7 g) and the maximum for Gulzar-19 (27.6 g) (Table 5). In exotic wheat genotypes, grain yield per plant ranged from

12.6 to 23.3 g. Among the exotic wheat minimum grain yield per plant was observed for Becord#1(12.6 g) and the maximum for Akuri#1 (27.6 g), while the same results were recorded by Ibrahim (2019).

Biological yield per plant among the local genotypes ranged from 42.2 to 73.3 g with LSD for 5% probability was 5.87 (Table 5). Among the local wheat genotypes minimum biological yield per plant was recorded for Gulzar-19 (42.2 g) and the maximum was noted for Khaista-17 (73.3 g) (Table 5). In exotic wheat genotypes, biological yield per plant ranged from 46.1 to 67.2 g. Among the exotic wheat genotypes, the minimum biological yield per plant was recorded for Becord#1 (46.1 g) and the maximum for Kenya Tea (67.2 g). Our data is supported by past findings (Arya *et al*., 2017; Ali *et al*., 2008; Khan *et al*., 2022) as the same has been reported in the present experiment for all parameters.

The 1000-grain weight among the local wheat genotypes ranged from 50.5 to 59.4 g with LSD of 5.15 at 5% probability (Tables 3 and 5). Among the local wheat, a minimum of 1000-grain weight was recorded for Wadaan-17 (50.5 g) and a maximum for Pirsabak-19 (59.4 g) (Table 5). In exotic wheat genotypes, 1000-grain weight ranged from 41.2 to 52.2 g (Table 5). Among the exotic wheat genotypes, a minimum 1000-grain weight was noted for King Bird#1 (41.2 g) and a maximum for Kachu#1 (52.2 g) (Table 5).

Conclusions and Recommendations

A set of sixteen wheat germplasms (eight local + eight exotic) were analyzed to estimate the genetic variability and heritability. All the genotypes showed the best mean performance but Khaista-17, Paseena-17, and Gulzar-19 from local genotypes revealed significant estimation. The exotic Quaiu#2 and Kenya Tae, are the best genotypes in their performance. All parameters revealed a higher value for the phenotypic coefficient of variation compare to the genotypic coefficient of variation (GCV). This low value of GCV shows that the environmental factor is mostly involved rather than an internal factor in variation. Among all the traits examined, we observed high heritability (h_2) value for days to heading (93.0) and flag leaf area (66.0), which indicates that high heritability estimate genetic advance for such characters (Table 2).

We recommend Pirsabak-21 and Abaseen-21 for grain production from local varieties, while Kenya Tea and Akuri#1 from exotic ones.

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Novelty Statement

The analysis of sixteen wheat germplasms for the genetic variability and heritability revealed the best mean performance for local (Khaista-17, Paseena-17, Gulzar-19) and exotic genotypes (Quaiu#2, Kenya Tae). All parameters revealed a higher value for the phenotypic coefficient of variation compared to the genotypic coefficient of variation (GCV).

Author's Contribution

The authors are grateful to the following for their contributions to this BS (Hons) research project: Dr. Abdur Rauf and Dr. Khilwat Afridi (research design); Mr. Muhammad Sadiq (execution); Dr. Abdur Rauf, Dr. Ikramullah Khan, Dr. Farooq Jan. and Dr. Samrin Gul (manuscript writing and formatting), Dr. Muhammad Qayash, Dr. Muhammad Khalid, Mr. Muhammad Shoaib and Mr. Wisal Khan (statistical analysis).

Ethical approval
This project was approved by the departmental ethical committee of the Botany Department, Abdul Wali Khan University Mardan.

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

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