Research Article

Screening of Indigenous Bread Wheat (*Triticum aestivum* L.) Germplasm for Yield and Yield Contributing Traits

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Abstract | Improving the production potential of wheat (*Triticum aestivum* L.) crop is crucial to ensure food security worldwide, including Pakistan. This study aimed to screen out available wheat germplasm for parent selection through Line × Tester mating design. This field trial comprised 16 wheat cultivars grown in triplicate under a randomized complete block design. Data regarding average peduncle length, plant height, seed weight per main spike, spike length, seed per main spike, seed yield per plant, number of tillers per plant, biomass, and harvest index were collected at plant maturity. Statistical analysis of data showed highly significant differences among the wheat cultivars for all studied traits. The maximum number of tillers was exhibited by Sindhu 16 (10), the maximum seed yield per plant by NARC super (16.52 g), and the longest spike length by Darabi (12.5 cm). Average plant height was positively correlated with the peduncle length (0.64425). Whereas harvest index and biomass were negatively correlated (-0.17332). Principal component analysis 1 and 2 (PCA1 and PCA2) captured about 33.21 and 24.74% variation, respectively. All the studied traits showed positive coefficients for PCA, with plant height and harvest index showing the highest and lowest coefficients for PC 1 (*i.e.,* 0.47064 and 0.09179, respectively). The total variation captured by both PCAs was 57.95%. Fateh Jhang (L4), NARC Super (L8), Sindhu 16 (L2), and Zincol 16 (L3) were selected as female lines, and Millet (L15) and Gulzar 2017 (L10) were selected as male testers for the mating design. It is expected that these wheat lines would provide positive heterosis and would be proven to be good general and specific combiners for yield and yield contributing traits of the wheat crop.

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Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops, ensuring food security worldwide. The origin of wheat is from Southwestern Asia, and it is known as the king of cereals. It is the second most commonly cultivated crop around the world (Ahmad *et al.*, 2022). Among the cereal crops, wheat ranks among the top grain crops that are grown on a large scale worldwide due to its widespread acceptability, nutritional and economic importance (Ali *et al*., 2020; Ikram *et al*., 2022). It is the major staple food, and about 36% of the world population consumes wheat in different forms (Erenstein *et al*., 2022). Wheat grains contain carbohydrates, proteins, and other essential minerals (Rauf *et al*., 2023).

The production of wheat in the world is about 788.4 million tons per annum (FAO, 2024). In Pakistan, wheat is grown at about 22 million acres, contributing 7.8 percent of the value-added in agriculture and 1.8 percent of the country's GDP. During 2024-2025, the total area under wheat cultivation is estimated to be about 9.1 million hectares, and the total wheat production is estimated to be about 28.42 million tons, with an approximately 10% increase from the previous Rabi season crop (Pakistan Economic Survey, 2021-2022).

Limitations of cultivable land and climatic changes appear as major challenges for farmers and scientists to ensure food security. The production of wheat, however, can be increased by improving its yield potential, sustainable agronomic practices, and efficient use of resources (Khokhar *et al*., 2019; Guarin *et al*., 2022). Significant variations exist among the available wheat genotypes according to varied adaptation potential to the prevailing environmental stresses (Hossain *et al*., 2021; Li *et al*., 2024).

Breeding for better wheat genotypes with improved resistance to diseases and pests could increase their productivity (Bakala *et al*., 2021). For plant breeders, it is essential to develop wheat cultivars that are widely acceptable by the local growers and can exhibit significant yield attributes (Paux *et al*., 2022). The selection of parent lines for any crop breeding program is difficult for a breeder during the hybridization process. For the exploitation of heterosis, combining ability analysis proved to be very helpful in selecting desirable parents and crosses (Rashid *et al*., 2007; Khokhar *et al*., 2019; Kaur and Kumar, 2023). Grain yield in wheat, for instance, is influenced by several yield-contributing traits. Genetic variability present in a population is very helpful in improving crop cultivars as it gives better chances for improving yield under various agro-climatic conditions (Baye *et al*., 2020; Khan *et al*., 2023).

Correlation analyses revealed that the economic productivity is associated with different morphophysiological characters (Da Silva *et al*., 2009). The genetic variation is key in selecting hybrid lines with high productivity and yield (Schneider *et al*., 2021). Line × tester is one of the crucial techniques in plant breeding, in which the lines are the female parent and the testers are the male parent (Abdel Nour *et al*., 2011). This method elucidates the influence of general and specific combining abilities (GCA and SCA) in the F_1 generation. Based on line × tester outcome for the hybridization process, a breeder can choose a proficient genotype, cultivar, or variety of the crop with a high GCA or SCA of the required trait contributing to the yield (Din *et al*., 2021; Rauf *et al*., 2023).

Keeping in view the afore-mentioned information, the main objective of this study was to screen out the available wheat germplasm for parent selection through Line × Tester mating design, which provides information about additive gene action and general and specific combining abilities.

Table 1: *Wheat cultivars screened in this study for selection for the line × tester mating design.*

Cultivar code	Cultivar name
L1	Borloug 16
L2	Sindhu 16
L3	Zincol 16
L4	Fateh Jhang
L5	Pak 13
L6	Bari 2017
L7	FSD 2008
L8	NARC Super
L9	Dharabi
L10	Gulzar 2017
L11	Ujala 16
L12	Chenab
L13	Benazir
L14	Dilkash
L15	Millet
L16	Pirsabak

Materials and Methods

Experimental site and layout

The trial was conducted according to a Randomized Complete Block Design (RCBD) with 16 available or prevailing wheat cultivars (Table 1) arranged randomly to different plots with three replications for each cultivar or treatment. The experimental site (72°41'35" E; 32°07'54" N) was the farm area of the College of Agriculture, University of Sargodha, Sargodha. The selection of this site was based on its suitability for wheat cultivation and its accessibility to researchers and experimental resources. Wheat seeds were sown at the recommended seeding rate and planting density for the region. Standard planting techniques were followed to ensure uniform establishment of wheat plants across all experimental plots. Sowing was done on ridges with a sowing drill at row-to-row and plant-to-plant distances of 25 and 10 cm, respectively.

Experimental treatments and measurement of parameters
Treatments included 16 wheat genotypes. During the entire crop duration, each replication was equally treated, provided with proper irrigation, fertilization, weeding and other agronomic practices. Data regarding the following plant traits were collected at the maturity stage of the crop from randomly selected 5 plants from each treatment replication, and their average values were calculated.

The height of the plant (cm) was measured in centimeters using a measuring rod. Plant height was taken from the base of the main stem to the top of the spike of the main tiller, excluding awns. The peduncle length (cm) was measured from the top node where the flag leaf emerges to the base of the spike using a ruler or a meter rod. Spike length (cm) was measured from the base of the spike to the tip of the spike without awns. The number of tillers per plant was calculated by counting the total number of main stems or branches arising from the base of each plant. The main spike was harvested and threshed by hand, and the total number of seeds in the main spike was counted. All spikes from the selected plants were threshed manually without any losses, and the seeds were weighed using a digital weighing balance for each spike one by one, and the seed yield or weight (g) per plant was determined. When the crop reached its full maturity, the wheat plants were harvested from each plot, and the biomass yield (g) was determined by weighing the total plant.

Harvest index
The harvest index was calculated by the following formula.

$$Harvest\ index = \frac{Grain(seed)\ yield}{Biomass} \times 100$$

Statistical analysis
Data recorded for various parameters were analyzed statistically by using Statistix 8.1 software. Analysis of variance (ANOVA) was used for the determination of significant differences among treatments. Treatment means were further compared using the least significant difference (LSD) post-hoc test at a standard significance level, *i.e.,* at $\alpha = 0.05$. Correlation was done among the plant traits and yield characteristics. Principal component analysis (PCA) was done using Origin Pro 2024 software for the interpretation of the data. The principal components with eigenvalues >1 were selected and used for the interpretation of the results.

Results

Data were subjected to analysis of variance, and the sources of variation were calculated for replication, cultivars, and error. Mean square and sum of squares for different traits and yield components are presented. The correlation was also calculated and discussed below. The phenotypic data of 16 indigenously available wheat cultivars, and the cluster analysis was carried out by using Origin Pro software.

Data analysis, comprising analysis of variance followed by comparison of treatment means using the least significant difference post-hoc test, showed variations among all wheat cultivars regarding most of the yield and yield contributing traits determined in the study (Table 2). The variation among cultivars for average plant height revealed that L11 (Ujala 16) was the tallest plant with an average height of about 109 cm and fell in the 1st category (a), and L12(Chenab), L2 (Sindhu 16), and L3 (Zincol 16) averaged about 105 cm and fell in the 2nd category (ab). The lowest plant height was observed in L6 (Baye *et al*., 2020) with about 82 cm average plant height.

Regarding peduncle length, cultivar L12 (Chenab) showed the maximum average peduncle length of 45.83 cm. While cultivars L2 (Sindhu 16), L8 (NARC Super), and L15 (Millet) ranged from 41 to 40 cm. The lowest peduncle length was observed in L5 (Pak 13) with an average peduncle length of 28.67 cm. Similarly, the cultivar L2 (Sindhu 16) had the maximum number of tillers per plant, averaging

Table 2: *Analysis of variance (ANOVA) tables for yield and yield contributing traits of different wheat (Triticum aestivum L.) cultivars.*

	DF	SS	MS	F value	Pr (>F)
Plant height					
varieties	15	3789	252.63	24.243	1.02E-12
replications	2	15	7.27	0.698	0.506
Residuals	30	313	10.42		
Peduncle length					
varieties	15	929.4	61.96	7.438	1.81E-06
replications	2	5.7	2.83	0.34	0.715
Residuals	30	249.9	8.33		
Seeds per main spike					
varieties	15	5318	354.6	14.111	1.12E-09
replications	2	16	7.8	0.309	0.736
Residuals	30	754	25.1		
Tillers per plant					
varieties	15	151.65	10.11	3.484	0.00176
replications	2	14.29	7.146	2.463	0.10224
Residuals	30	87.04	2.901		
Spike length					
varieties	15	85.58	5.705	2.754	0.00885
replications	2	2.95	1.475	0.712	0.49876
Residuals	30	62.16	2.072		
Seed weight per spike					
varieties	15	8.706	0.5804	7.702	1.25E-06
replications	2	0.022	0.0108	0.143	0.867
Residuals	30	2.261	0.0754		
Seed yield per plant					
varieties	15	617.7	41.18	23.621	1.45E-12
replications	2	5.3	2.63	1.507	0.238
Residuals	30	52.3	1.74		
Biomass					
varieties	15	3574	238.26	21.878	4.01E-12
Replications	2	23	11.65	1.069	0.356
Residuals	30	327	10.89		
Harvest index					
Varieties	15	3733	248.88	8.035	7.93E-07
Replications	2	2	1.05	0.034	0.967
Residuals	30	929	30.98		

about 10. Cultivars L3 (Zincol 16), L13 (Benazir), and L4 (Dilkash) ranged about 8 to 7 tillers per plant. The lowest number of tillers per plant was shown by L9 (Dharabi) with an average of 3.67. Cultivar L9 (Dharabi) had the longest spikes averaged about 12.5 cm. Cultivars L12 (Chenab), L11 (Ujala 16), and L6 were close to each other with an average spike length of 11.5 cm. Regarding seeds per main spike, the highest number of seeds per main spike was exhibited by cultivar L12 (Chenab) with 67.7 seeds. The lowest number of seeds per main spike (averaged 27.3) was recorded for cultivar L2 (Sindhu 16). Regarding seed weight per main spike, again, cultivar L12 (Chenab) had the highest weight of seeds

Table 3: *Least significant difference (LSD) post-hoc test for yield and yield contributing traits of different wheat (Triticum aestivum L.) cultivars.*

Cultivars Codes	Plant height	Peduncle length	Seeds per main spike	Tillers per plant	Spike length	Seed weight per spike	Seed yield per plant	Biomass	Harvest index
L1	87.33 ef	35.33 d-g	55.3 c	4 e	9.67 c-f	1.76 fg	7.17 ef	19 def	37.94 def
L2	105.67 ab	41.73 ab	27.3 g	10.01 a	10.75 a-e	1.77 fg	14.3 bc	36.67 b	39.07 def
L3	105.00 ab	37.50 b-e	58.0 bc	8.67 ab	9.67 c-f	1.72 fg	13.03 c	21.67 cde	60.44 a
L4	95.33 c	33.17 e-h	54.0 c	7.67 abc	10.67 a-e	2.15 c-f	16.52 a	48.33 a	34.11 e-h
L5	88.33 de	28.67 h	35.0 fg	7.33 a-d	10.83 a-e	1.4 g	8.53 de	22 cde	39.32 c-f
L6	82.33 f	32.43 fgh	58.0 bc	5 cde	11.42 a-d	2.18 c-f	8.55 de	25 c	34.19 e-h
L7	86.17 ef	31.17 gh	40.7 ef	6 b-e	8 f	2.33 b-e	8.167 de	22.67 cd	36.61 efg
L8	102.67 b	40.83 bc	66.3 ab	6 b-e	9.17 def	2.59 bc	16.22 ab	33.33 b	48.54 bc
L9	93.00 cd	33.77 d-g	59.3 abc	3.67 e	12.5 a	2.55 bcd	5.51 fg	19.67 c-f	28.21 gh
L10	85.00 ef	31.17 gh	45.0 de	4.33 e	8.17 f	2.52 bcd	4.69 g	14.67 f	32.18 fgh
L11	109.33 a	38.43 bcd	55.7 c	6.33 b-e	11.67 abc	2.67 b	7.89 de	23 cd	34.87 e-h
L12	105.67 ab	45.83 a	67.7 a	6 b-e	12.33 ab	3.15 a	8.13 de	32 b	25.92 h
L13	85.17 ef	34.83 d-g	53.0 cd	7.67 abc	10 b-f	2.12 def	9.98 d	22 cde	46.71 bcd
L14	90.17 cde	36.17 c-f	44.0 e	4.67 de	8.83 ef	1.92 ef	7.23 ef	17 ef	42.94 b-e
L15	87.67 def	40.50 bc	56.3 c	4 e	11 a-e	2.29 b-e	5.34 fg	17.67 def	30.42 fgh
L16	85.33 ef	35.33 d-g	55.0 c	5 cde	9.2 def	2.42 bcd	8.46 de	16.67 ef	50.85 b

per main spike, reaching about 3.14 g. The lowest seed weight per main spike was recorded for cultivar L5 (Pak 13).

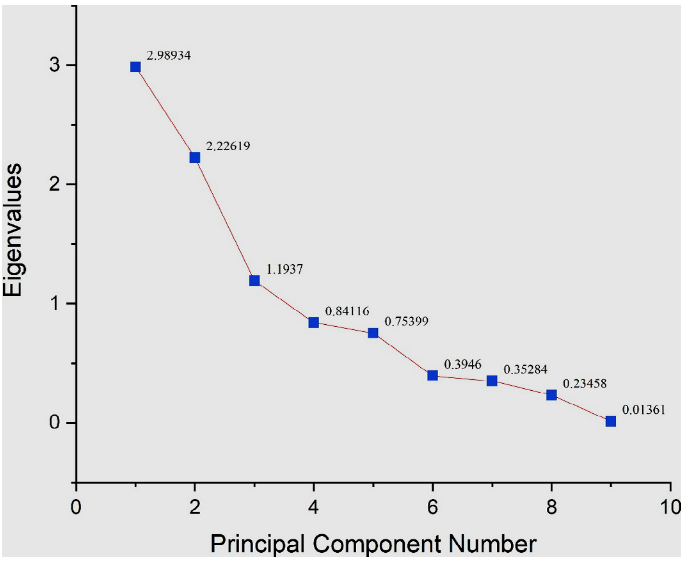

Figure 1: *Screen plot for Principal Component Analysis (PCA) of the yield and yield contributing traits of different cultivars of bread wheat (Triticum aestivum L.).*

The highest seed yield was shown by cultivar L4 (Fateh Jhang) with an average seed yield of about 16.52 g. While the lowest seed yield was recorded for cultivar L10, with an average seed yield of about 4.68 g. Regarding average plant biomass, values ranged from 48 to 14 g. The cultivar L4 (Fateh Jhang) showed the maximum biomass, with an average of about 48.33 g. The lowest biomass was observed for cultivar L10 (Guarin *et al*., 2022) with an average of 14.67 g. Moreover, cultivar L3 (Zincol 16) showed the highest harvest index with an average of about 60.44%, whereas the least average harvest index (25.91%) was exhibited by cultivar L12 (Chenab) (Table 3).

Correlation analysis

Almost all characters studied in this trial were positively correlated with each other, except few (Table 4). Harvest index showed a negative correlation with peduncle length (-0.02646). Number of seeds per main spike (-0.22234), spike length (-0.03325), and seed weight per main spike (-0.23711) were negatively correlated with the number of tillers per plant. Seed yield per plant showed a negative correlation with spike length (-0.02452) and harvest index. Seed weight per main spike was negatively correlated with seed yield per plant (-0.1146) and harvest index (-0.34753), and biomass was negatively correlated with the harvest index (-0.17332). There was a strong positive correlation between plant height and peduncle length (0.64425) (Table 4).

Principal component analysis (PCA)

Principal component analysis is a strong statistical tool that retains most of the variance in the data set

Table 4: *Correlation table for yield and yield contributing traits of different cultivars of bread wheat (Triticum aestivum L.)*

	PH	PL	NT/P	SL	S/MS	SW/MS	SY/P	BIO	HI
PH	1								
PL	0.6443	1							
NT/P	0.4661	0.2134	1						
SL	0.2441	0.2124	-0.0332	1					
S/MS	0.1508	0.3061	-0.2223	0.2861	1				
SW/MS	0.2027	0.2914	-0.2371	0.2133	0.5458	1			
SY/P	0.4744	0.2164	0.5891	-0.0245	0.0399	-0.1146	1		
BIO	0.4709	0.2798	0.5455	0.2051	0.0407	0.1013	0.7827	1	
HI	0.0889	-0.0265	0.2181	-0.3142	0.0167	-0.3475	0.4502	-0.1733	1

**PH=Plant Height, *PL=Peduncle Length, *NT/P=number of tillers per plant, *SL=Spike Length, *S/MS=Seed per main spike, *SW/MS=Seed, Weight per main spike, *SY/P=Seed Yield per plant, *BIO=Biomass, *HI=Harvest Index*

but simplifies the complexity of high-dimensional data. The scree plots displayed the Eigenvalues of the principal components (Figure 1). The amount of variance (Eigenvalues) captured by the principal component is represented by the Eigenvalues. The Eigenvalues decreased as the component number increased, indicating that each subsequent component captures less variance. PCA1 captured the highest variance with the greatest Eigenvalue of approximately 2.99 (Table 5). The variables that contributed most to PCA1 had strong positive coefficients, showing positive correlation, and they accounted for a substantial amount of the variance in the data in this dimension (Table 5). Second highest value of Eigenvalue (variance) was captured by PCA2 (approximately 2.23) (Figure 2). High positive PCA2 coefficient for variables like seed weight per main spike and seed per main spike showed that they significantly affect this component. Number of tillers per plant, seed yield per plant, biomass, and harvest index exhibited negative coefficients, indicating an inverse correlation with PCA2 (Table 5).

Biplot of principal components

In the biplot of principal component analysis (Figure 2), the red points indicate how each observation is represented in principal component space. In this dataset, wheat cultivars L12 (Chenab) and L15 (Millet) were separated from other observations along the PCA2 axis, indicating they have distinct characteristics compared to the others. Blue Points indicate how much and in which direction each original variable contributes to the principal components. Seed weight per main spike, seed per main spike, and spike length are in the same direction; they are closely positively correlated. Similarly, peduncle length, plant height, and biomass were also pointing in the same direction, which represent close positive correlation. For PCA1, all characters were positively correlated with variation. For PCA2, the average number of tillers per plant, seed yield per plant, biomass, and harvest index were negatively correlated. The PCA1 and PCA2 explained about 57.95% of the data volatility (Figure 2).

Table 5: *Extracted Eigenvalues regarding the principal component analyses of yield and yield contributing traits of different cultivars of bread wheat Triticum aestivum L.*

Plant traits	Coefficients of PCA 1	Coefficients of PCA 2
PH	0.47064	0.1082
PL	0.35465	0.26504
NT/P	0.40383	-0.30307
SL	0.14055	0.37125
S/MS	0.10626	0.44363
SW/MS	0.07672	0.53156
SY/P	0.47223	-0.25159
BIO	0.4704	-0.01877
HI	0.09179	-0.38126

**PH=Plant Height, *PL=Peduncle Length, *NT/P=number of tillers per plant, *SL=Spike Length, *S/MS=Seed per main spike, *SW/MS=-Seed, Weight per main spike, *SY/P=Seed Yield per plant, *BIO=Biomass, *HI=Harvest Index*

Discussion

Breeding and selection procedures are crucial strategies for wheat crop improvement to ensure the feeding of an exponentially growing global population (Ikram *et al*., 2022). In this study, the available wheat germplasm comprising 16 cultivars was screened for their vegetative growth, and yield-related characteristics such as average peduncle length, plant height, seed weight per main spike, spike length, seed per main spike, seed yield per plant, number of tillers per plant, biomass, and harvest index were collected at plant maturity. The ultimate aim of this field trial was to select parent genotypes or cultivars for further line × tester mating design, which is one of the important plant breeding techniques, because it provides information about general and specific combining abilities (Max *et al*., 2021).

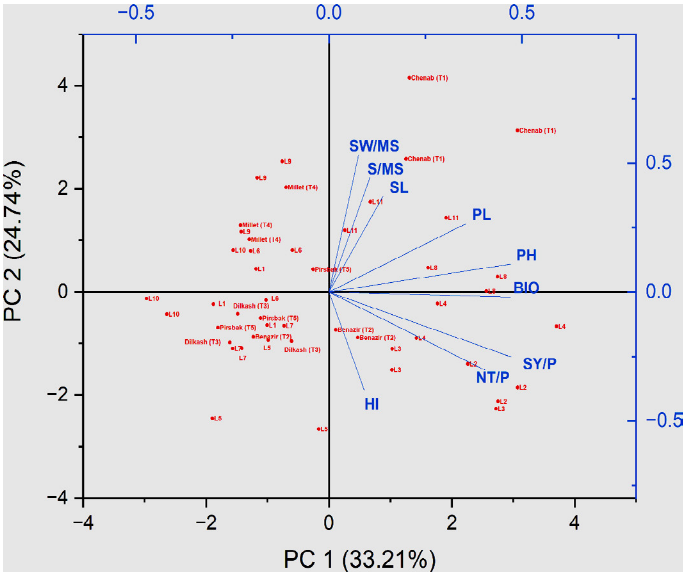

Figure 2: *Biplot plot for Principal Component Analysis (PCA) of the yield and yield contributing traits of different cultivars of bread wheat (Triticum aestivum L.).*

The average wheat plant height in this study ranged from 82 to 101 cm, and this is consistent with the findings of Baghestani *et al*. (2006), reporting the average wheat plant height of about 62 to 110 cm. As the highest impact in the expression of genetic yield potential is usually reflected by the grain weight or productivity of the crop (Tillett *et al*., 2022), wheat cultivar L12 (Chenab) and cultivar L4 (Fateh Jhang) had the highest weight of seeds per main spike and the maximum grain yield, respectively.

Regarding the correlation, most of the traits were found to be negatively correlated with each other. Harvest index was negatively associated with the peduncle length, seed yield per plant, and 100-seed weight. The strong correlation was shown by plant height and peduncle length. These findings are in line with the previous research works by Akhtar *et al*. (2011); Farooq *et al*. (2018); Zarghoona *et al*. (2025). Moreover, the plant biomass was negatively correlated with the harvest index, which is not in agreement with the results of Shahi *et al*. (2024), who found no significant correlation between wheat biomass and harvest index. Seed yield and weight showed a negative correlation with spike length, which corroborates the study of Ahmad *et al*. (2023); Khan *et al*. (2024).

Conclusions and Recommendations

Based on overall study results, among the 16 available wheat cultivars, the cultivars Fateh Jhang (L4), NARC Super (L8), Sindhu 16 (L2) and Zincol 16 (L3) were selected as female lines and Millet (L15) and Gulzar 2017 (L10) are recommended to be selected as male tester for mating design with supposition that these wheat cultivars would provide positive heterosis and will be good general and specific combiners for improved yield and yield contributing traits of wheat crop.

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Novelty Statement

From 16 locally available wheat cultivars, the cultivars Fateh Jhang (L4), NARC Super (L8), Sindhu 16 (L2) and Zincol 16 (L3) are selected as female lines and Millet (L15) and Gulzar 2017 (L10) as male tester for mating design with expectation that these wheat cultivars would provide positive heterosis and will be good general and specific combiners for improved yield and yield contributing traits of wheat crop.

Author's Contribution

Ikram Ul Haq: Conceived the research idea and technically proofread the draft.
Muhammad Huzaifa: Performed experiments and prepared first draft.
Naeem Akhtar: Supervised the research work and technically revise the manuscript.
Muhammad Tayyab Raza: Helped in conduction and data collection of laboratory bioassay.
Muhammad Zeeshan Majeed: Performed statistical

analyses and prepared results.
Ali Huzafa: Helped in data collection in laboratory and field.

Generative AI or AI assisted technology statement
The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest
The authors have no conflict of interest.

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