Pak. J. Bot., 57(1): 201-209, 2025. DOI: http://dx.doi.org/10.30848/PJB2025-1(13)

SELECTION IMPACT ON VARIABILITY IN YIELD RELATED TRAITS AMONG THE CHINESE WHEAT HYBRIDS UNDER THE CLIMATIC CONDITION OF PAKISTAN

ZAINAB IFTIKHAR[1], MUHAMMAD ARIF[2]*, AAMIR IQBAL[1], TAMANA BAKHT[4], GOHAR ZAMAN[1], XIANG ZHENG LIAO[3], CHANG PING ZHAO[3]*, SHENG QUAN ZHANG[3]* AND SAJID ALI[1,5]*

[1]*Institute of Biotechnology and Genetic Engineering, the University of Agriculture, Peshawar, Pakistan*
[2]*Department of Agronomy, the University of Agriculture, Peshawar, Pakistan*
[3]*Institute of Hybrid Wheat, Beijing Academy of Agricultural and Forestry Sciences, Beijing 100097, China*
[4]*Department of Environmental Science Shaheed Benazir Bhutto University Sheringal Dir upper, Peshawar, Pakistan*
[5]*Department of Agriculture, Hazara University, Mansehra, Pakistan*
**Corresponding author's email: bioscientist122@yahoo.com, marifkhan75@aup.edu.pk, zsq8200@126.com, cp_zhao@vip.sohu.com*

Abstract

Stagnancy in wheat yield over the past decades due to the dependence on limited source of germplasm necessitates exploration of novel sources of genetic variations including the potential of hybrid technology. The present work was designed to assess the potential of Chinese wheat hybrid germplasm for cultivation at Pakistan. For this purpose, 416 hybrids were studied in the year 2017-18 and a subset of high performing and better yielding 108 hybrids were selected and tested in 2018-19. Significant variability ($p<0.01$) was observed among the hybrids with better performing hybrids for all the studied parameters, particularly thousand grain weight, grain yield, biological yield and harvest index. Considering the yield related traits in the preliminary field evaluation of 416 hybrids (during 2017-18), 1000-grain weight ranged from 34 g (for 17BH088) to 50 g (for 17BH203) among the Chinese hybrids while it ranged from 36 g to 43 g among the local check varieties. For the grain yield, the values ranged from 2000 kg ha^{-1} (for 17BH016) to 6053 kg ha^{-1} (for 17BH218) among the hybrids while it was in the range of 3382 kg ha^{-1} to 4233 kg ha^{-1} among the local check varieties. The biological yield values among the Chinese hybrids ranged from 7733 kg ha^{-1} (for 17BH088) to 15893 kg ha^{-1} (for 17BH015) while among the local check varieties it ranged from 10687 kg ha^{-1} to 11971 kg ha^{-1}. The overall impact of selection was positive on the spike and yield related parameters. For example, the grain yield increased from 2982 kg ha^{-1} (in the preliminary collection) to 4138 kg ha^{-1} for the selected lines (during 2018-19). Although selection increased the mean value, the variability was decreased for most of the parameters. The selection differential and modified genetic advance, for 1000 grain weight, was 13.74% and 21.90%, respectively. For grain yield, selection differential was 41.21% and G.A was 38.74%; for biological yield, S.D was 34.46% and G.A was 32.79% while for harvest index, S.D was 5.58% and G.A was 2.883%. The performance of the hybrids was assessed for two years which was higher for all the parameters especially yield related parameters which increased for the second-year selected hybrids. Among the 108 hybrids, the maximum grain yield observed was 6053 kg ha^{-1} for 17BH218 (2017-18) and 6999 kg ha^{-1} for 17BH101 (2018-19), much higher than the local checks. In case of biological yield, the maximum value recorded was 15893 kg ha^{-1} for 17BH015 (2017-18) whereas 16019 kg ha^{-1} for 17BH035 (2018-19), higher than the check varieties. This will enable to come up with diverse set of varieties from distinct sources of germplasm to increase yield and reduce genetic homogeneity in the crop.

Key words: Chinese lines; Hybrid wheat; Production traits; Yield parameters.

Introduction

Considering the worldwide importance of wheat, increase in wheat production and reduction in crop losses are the prior objective of plant breeders and crop production experts. In Pakistan wheat is cultivated on around 9 million ha, while its production is around 30 million tones, which is almost sufficient for the local requirement of the wheat in Pakistan. Although increase in production and yield of wheat is always on top priority of many national and international research projects (Ali *et al.*, 2014), the wheat yield obtained on farmer fields is still low (Ali *et al.*, 2022). This low production could be explained by many factors, though the single component of all these factors is the increasingly narrow genetic background of wheat varieties, deployed in many parts of the world, particularly in the developing world (Li & Ali, 2022). The narrow genetic background results in rapid loss of effectiveness of the resistance (Singh *et al.*, 2010), particularly in the areas where the pathogen is passing through sexual recombination (Ali *et al.*, 2016). This necessitates to explore for more diverse genetic stock for different yield contributing traits (Iftikhar *et al.*, 2021), including better yield potential.

The wheat production is measured in terms of its grains (grain yield) and straw (biological yield), the parameters which are affected by many biotic and abiotic factors. Abiotic factors like drastic change in the temperature of a locality or an extreme exposure to heat may lowering the reproductive growth and thus yield of wheat crop. The biotic factors are characterized by the interaction of the plant with different pathogen causing diseases like the fungal rust diseases (Ali and Hodson., 2017; Ali *et al.*, 2022; Ismail *et al.*, 2021), viral diseases and powdery mildews (Iqbal *et al.*, 2023; Khan *et al.*, 2019), seed borne diseases (Saqib *et al.*, 2008) and crown and root disease (Afzal *et al.*, 2015), which results in reduced photosynthetic area, increase stress on the plant and impaired growth thus leading to reduced yield. Disease stress at an earlier growth stage, at which infection strike, may lead to a change in yield component and hence, declined yield (Madden and Nutter., 1995) depending on the time and extent of the infection (Madeira & Clark., 1991; Bastiaans., 1991; Bainsla & Meena, 2016).

The loss in yield due to these biotic and abiotic factors could be overcome by the exploitation of improved genetic stocks, as reported in the case of Green Revolution in 1960s and 1970s (Ziska *et al.*, 2012). There was an increase of production from 235 million tons in 1961 to an estimated 733 million tons in 2015 (Anon., 2014), which was achieved through the exploitation of genetically improved varieties with better yield potential and response to inputs. These genetically improved varieties were developed using diverse sources of genetic material, including the Pakistani landraces with the dwarf and semi dwarf sources like the descendants of Norin-10. However, since the inception of green revolution, the increase is not substantial, mainly due to the reliance on the CIMMYT germplasm. Thus, diverse sources of indigenous and exotic germplasm must be explored for wheat breeding in Pakistan, including the Chinese germplasm. Limited studies have been conducted to explore the potential of Chinese germplasm in Pakistan, in general, and Chinese hybrids, in specific. In fact, the utility of Hybrid technology in wheat needs thorough assessment, through intensive field testing to evaluate their yield potential and other characteristics.

The diverse exotic germplasm needs to be evaluated for their yield potential using both field experimentation and molecular characterization (Iqbal *et al.*, 2020; Iqbal *et al.*, 2021; Ali *et al.*, 2009). Breeders aims at the improvement of grain yield which is one of the ultimate objectives of farmers (Ali *et al.*, 2009). As this is one of the most complex traits, with contribution from various other components (Xie, 2015), improvement in grain yield requires thorough studies across environments and over years (Khaled *et al.*, 2015). The increase in grain yield, however, is dependent on several major traits contributing to the overall yield, ranging from crop duration parameters and plant characteristics to the grain yield components themselves like harvest index (Akram, 2011; Mushtaq *et al.*, 2011) biological yield (Youldash *et al.*, 2020) and 1000 grain weight (Khaled *et al.*, 2015).

As most of these traits are quantitative, large set of germplasm needs to be assessed, with subsequent selection to identify the more desirable and adapted lines. This is achieved through conducting a preliminary testing of a larger set of germplasm for different parameters (Iftikhar & Ali, 2021). A subset of lines is then selected along with estimation of selection differential and modified genetic advance (Iftikhar *et al.*, 2021). The most appropriate lines are then selected for further crossing and/or release of best suited lines as improved varieties. Thus, it is of utmost importance to conduct field-based screening for various phenotypic traits to decipher the overall performance of the introduced germplasm, particularly the non-traditional sources never exploited before.

The present study was, thus, designed to explore diversity for yield related traits in Chinese hybrids for various field-based parameters along with deciphering the impact of selection on these traits.

Material and Methods

A total of 416 Chinese Hybrids, received from Beijing Engineering Research Centre for Hybrid Wheat (BERCHW), China, was assessed for yield related parameters along with five check varieties i.e., Atta Habib, PirSabak-13, Ghanimat-e-IBGE, Shahkar-13, and Pirsabak-15 in the first year whereas a subset of selected 108 Chinese Hybrids was assessed during the second year for evaluation. Fresh seed were imported for these hybrids each year for the concerned trials.

The experiments for both the years were conducted at the experimental field of Sheerin Khan Research Farm, the University of Agriculture, Peshawar, Pakistan (34°1′21″N, 71°28′5″E). The experimental site had subtropical climate, with semi-arid conditions, receiving annual rainfall of 360 mm. The experimental site is located in the spring wheat zone of Pakistan where spring wheat is grown in winter season i.e., October/November to April/May (Ali *et al.*, 2022). The experiments were conducted over two years in order to evaluate the yield performance of wheat hybrids in comparison with local high yielding varieties of Pakistan.

Testing of the Chinese wheat hybrids: First trial comprised of 416 Chinese wheat hybrids and 5 check varieties *viz.,* Atta Habib, Shahkar-13, PirSabak-15, Ghanimat-e-IBGE and PirSabak-13. The aim of this experiment was to assess the preliminary field-based diversity for yield parameters among these Chinese hybrids in comparison with the local checks. Data was collected on spike related parameters i.e., spike weight (g), spike length (cm), spikelets spike^{-1}, grains spike^{-1}; and yield related parameters i.e., 1000-grain weight (g), biological yield (kg ha^{-1}), grain yield (kg ha^{-1}), harvest index (%). The data was collected following the method described earlier (Khan and Hassan, 2019). The field experimentation and crop husbandry were followed as per routine wheat production technology at the research farm.

The subset of 108 lines was selected considering their overall performance under the prevailing conditions with particular emphasis on yield, maturity and plant types. The subset of 108 lines was also tested in the second-year experiment as described above for the first-year experiment.

Field experimentation and crop husbandry: The field experiment was consisted of 8 blocks, 25 plots and 22 subplots, keeping the trial in an augmented design. The trial was categorized in sub-plots which consisted of two rows of 1.5 meter length. The row to row spacing was kept 25 cm. Each block was divided into a plot and then sub plotting was done which consisted of seventeen hybrids and five check varieties in repetition. The repetition of the check varieties were made in order to calculate the error mean square and block effect, as per standard procedure of augmented design. Planting was done at the seeding rate of 50 seeds plot^{-1}. Field experimentation and crop husbandry was done as per recommended practices.

Data collection for spike parameters and yield related traits: Considering the spike characteristics parameters, data was taken on spikelets spike^{-1} and grains spike^{-1}. Regarding the yield related parameters; data was taken on 1000-grain weight (g), biological yield (kg ha^{-1}), grain yield (kg ha^{-1}) and harvest index (%).

Data on spikelets spike^{-1} was recorded by counting number of spikelets in randomly selected ten spikes and then averaged. For recording grains spike^{-1}, ten randomly selected spikes from each plot were manually threshed and grains were counted using electronic grains counting machine and then the average was calculated. A sample of thousand grains were counted using electronic grains counting machine and separated for each plot. The grains were, then, weighed with the help of a sensitive electronic balance and thousand grains weight was noted. Biological yield was recorded by harvesting the whole plot. The harvested material was, then, sun dried, weighed and converted into kg ha^{-1}. The harvested material for obtaining biological yield was threshed using a mini wheat thresher and the grains obtained were weighed with the help of a sensitive digital balance and then data was converted into Kg ha^{-1}. Harvest index was calculated as the ratio of grain yield and biological yield using the formula:

$$\text{Harvest index} = (\text{Grain yield} / \text{Biological yield}) \times 100$$

Data analyses of preliminary field based morphological parameters: The collected data was subjected to analysis of variance (ANOVA) in the R-statistical software, by using the following model to determine whether the differences were significant for the parameters under consideration or not. Assumption for statistical significance was tested at 5% probability level. Diversity in Chinese wheat hybrids based on spike related parameters and yield related parameters traits was assessed through generation of Boxplots with R-statistical software. The field data was compiled in MS Excel in which mean values and standard deviations were estimated. Multivariate analyses-based approach "cluster analyses" was used to decipher diversity based on the field based morphological parameters in the R-statistical software. Selection differential was estimated as the percent difference between the selected lines and overall population, while modified form of the genetic advance (termed here as "modified genetic advance") was estimated in terms of subsequent year performance of the selected lines in comparison with the overall population (Iftikhar *et al.*, 2021).

Results

Our results revealed a highly significant variability among the tested wheat hybrids for spike related parameter and yield related parameters (Tables 1 and 2). In the first experiment, the results revealed a very high and significant variability among the Chinese hybrids, as revealed by the mean square values and their significance. The selected hybrids performance showed significant variability, with better performance for certain hybrids than the local checks (Fig. 1), suggesting their potential for subsequent selection. This variability in performance was further confirmed by the subsequent year performance of the selected hybrids. The work enabled to identify the hybrids with better performance than local checks.

Diversity for yield related traits in the overall 416 Chinese hybrid lines: The analysis of variance for the spikelets spike^{-1} revealed non-significant variability within hybrids and check varieties but significant for hybrid vs check (Fig. 2). The grains spike^{-1} revealed significant variability for all, hybrids (LSD: 21.17), varieties (LSD: 4.23) and hybrids vs checks. For thousand grain weight, significant differences were observed for all the sources of variations studied, i-e, hybrids (LSD: 21.17), varieties (LSD: 4.23) and the hybrid vs check varieties. The analysis of variance for grain yield revealed highly significant variation. The hybrids had highly significant (LSD: 1807) level of variability compared to the local checks (LSD: 361). The hybrid vs check differences were also significant. Biological yield revealed highly significant differences between the hybrids (LSD: 4183) and checks (LSD: 837). The hybrid vs check differences were also found to be significant. This showed higher variability among the hybrids compared to the local check varieties. When subjected to analysis of variance, harvest index revealed higher level of significance for hybrids (LSD: 7.79) and check varieties (LSD: 1.55). The differences amongst hybrids vs check varieties were found to be non-significant.

Table 1. Mean square values and their significance for various crop duration parameters, plant traits, spike characteristics, yield parameters and disease resistance traits, as recorded in the preliminary testing (overall population) tested during 2017-18. Degree of freedom is given at the bottom of the table.

Studied parameter	Mean square values			LSD (0.05) values	
	Check varieties	Hybrids	Hybrid vs. check	Among checks	Among hybrids
Spikelets spike^{-1}	14 NS	3 NS	28 *	NS	NS
Grains spike^{-1}	629 **	87 **	451 **	4.23	21.17
1000 grain weight (g)	629 **	87 **	451 **	4.23	21.17
Grain yield (Kg ha^{-1})	2410225 **	1125955 **	30031148 **	361	1807
Biological yield (Kg ha^{-1})	7323405 *	6777810 **	395172925 **	837	4183
Harvest index (%)	112 **	1`7.46 **	4 NS	1.55	7.79
Degree of freedom	4	415	1	4	415

* refers to significance at less than 5%, ** refers to significance at less than 1%; NS refers to "non-significant"

Table 2. Mean square values and their significance for various crop duration parameters, plant traits, spike characteristics, yield parameters and disease resistance traits, as recorded for the selected hybrids tested during 2018-19.

Studied parameter	Mean square values			LSD (0.05) values	
	Hybrids	Check varieties	Hybrid vs. check	Among hybrids	Among checks
Spikelets spike^{-1}	2 NS	4 *	37 **	NS	4.23
Grains spike^{-1}	311 **	122 **	2347 **	6.12	17.32
1000 grain weight (g)	41 NS	64 **	3 NS	NS	12.4
Grain yield (kg ha^{-1})	1721322 **	2219994 **	4 **	595	1682
Biological yield (kg ha^{-1})	3551399 **	7227397 **	5263547 *	863	2440
Harvest index (%)	13 NS	55 NS	2622 **	NS	NS

* refers to significance at less than 5%, ** refers to significance at less than 1%; NS refers to "non-significant"

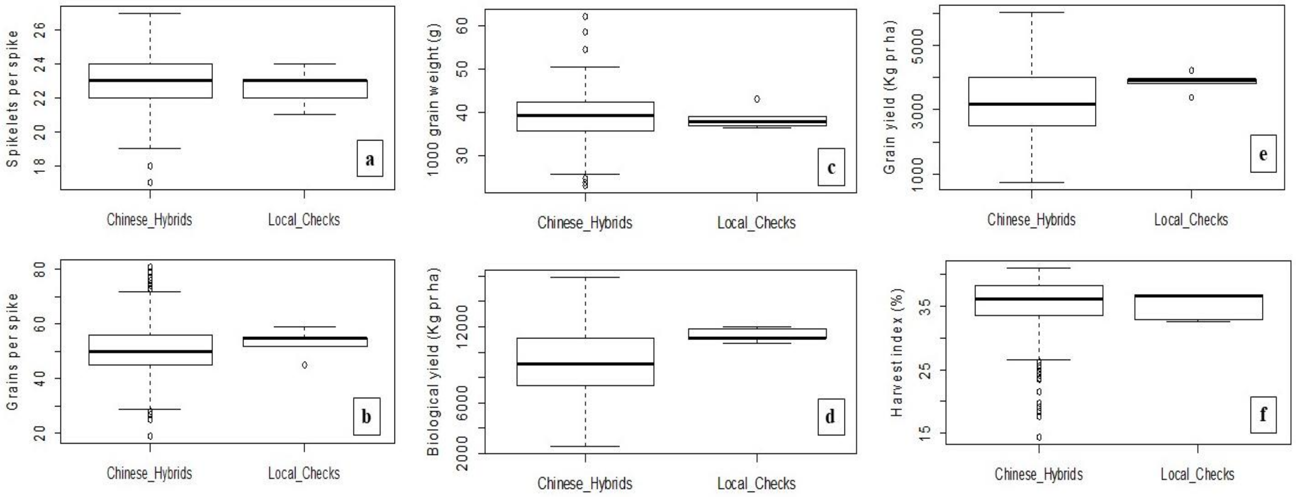

Fig. 1. Diversity for yield related traits in a set of 416 exotic Chinese hybrids, tested during 2017-18. The upper line represents the maximum, the lower line represents the minimum, while the middle bold line represents the average values. The dots represent the outlier values, if any.

Fig. 2. Clustering of 416 Chinese wheat hybrids and local check varieties based on various yield related traits.

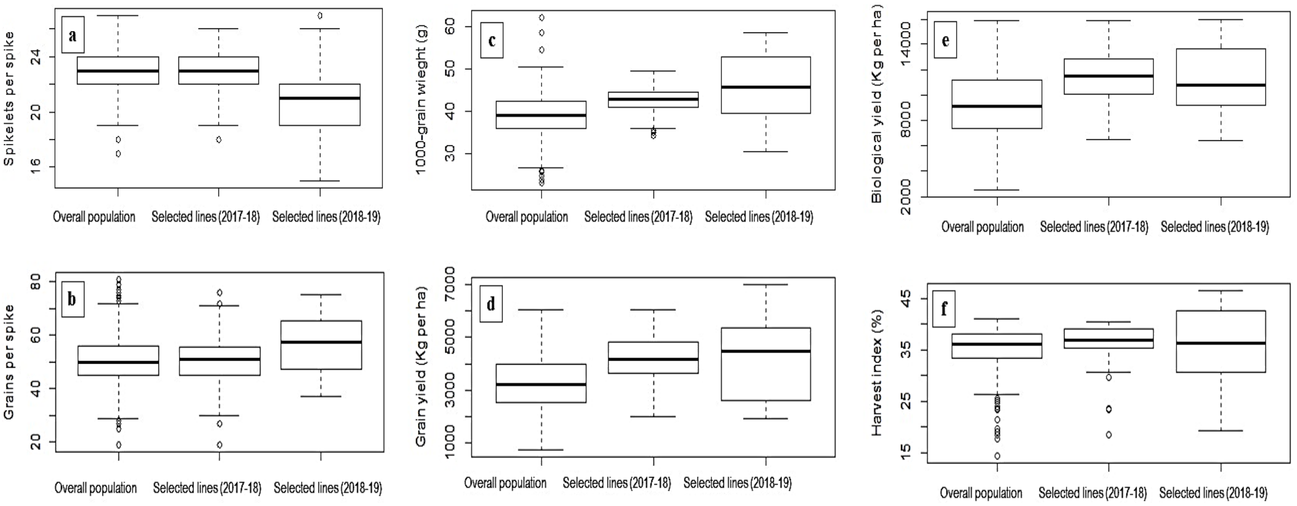

Fig. 3. Distribution of yield related traits for various set of Chinese wheat hybrids as subjected to selection. The upper line represents the maximum, the lower line represents the minimum, which the middle bold line represents the average values. The dots represent the outlier values, if any.

Table. 3. Descriptive parameters for the overall 416 Chinese wheat hybrids population, the selected hybrids and the progeny of selected hybrids.

Studied parameter	Overall population		Selected hybrids (2017-18)		Selected hybrids (2018-19)	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Spikelets spike^{-1}	23	1.60	23	1.63	21	1.99
Grains spike^{-1}	51	9.45	51	8.88	57	11.01
1000 grain weight (g)	38	5.03	43	3.30	46	7.81
Grain yield (kg ha^{-1})	2982	934	4211	829	4138	1478
Biological yield (kg ha^{-1})	8535	2339	11476	1986	11333	2632
Harvest index (%)	35	4.28	37	3.44	36	7.49

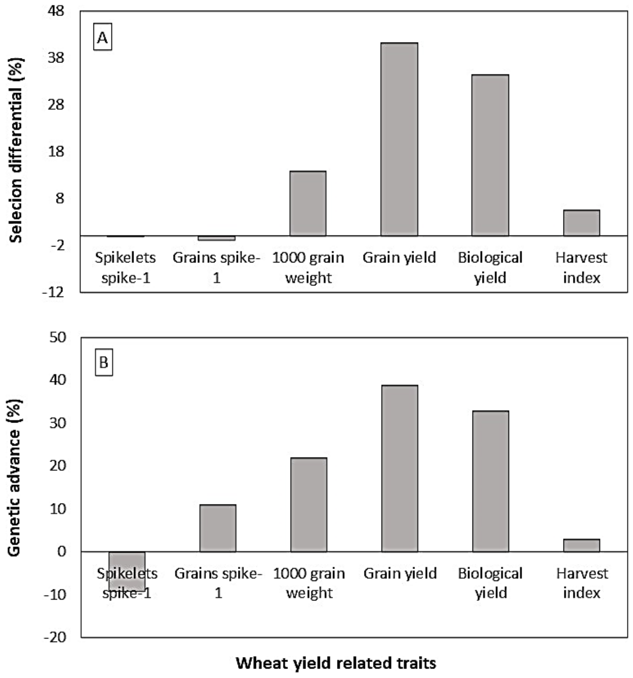

Fig. 4. Increase in yield related traits achieved due to selection in a set of 416 Chinese wheat hybrids, as assessed by selection differential (A) and modified genetic advance (B).

Variability for yield potential was assessed through characterization of these hybrids for spikelets spike^{-1}, the grains spike^{-1}, 1000-grain weight, biological yield, grain yield and harvest index. Analyses of the data revealed a higher diversity among the exotic Chinese hybrids as compared to the selected local check (Fig. 1).

Considering the spikelets spike^{-1}, a higher variability and diversity was observed among the hybrids, where the maximum was 27 whereas the minimum spikelets spike^{-1} observed were 17, with mean value of 23 and standard deviation of 1.61 (Fig. 1a). Among the local checks, minimum value recorded was 21 (for PirSabak-15) and maximum value recorded was 24 (for Ghanimat-e-IBGE), which were in between the maximum and minimum value range of hybrid values, with mean value of 23 and standard deviation of 1.13.

Variability of the grains spike^{-1} recorded among the hybrids was in the range of 19 to 81, with mean value of 51 and standard deviation of 9.33 (Fig. 1b). Among the local checks, the minimum grains spike^{-1} recorded was 45 (observed for Atta Habib) and the maximum value recorded for grains spike^{-1} was 59 (observed for Ghanimat-e-IBGE) with mean value of 53 and standard deviation of 5.41. This revealed the higher genetic variability among the hybrids.

For 1000-grain weight, the values of checks lines were in the range of maximum and minimum hybrid values. Among the Chinese hybrids, the maximum 1000 grain weight was 62 g while the minimum value was 23 g with the mean of 39 g and standard deviation of 5.19 (Fig. 1c). Among the local check varieties, the minimum 1000 grain weight ranged from 36 g (observed for Shahkar-13) to 43 g (observed for Ghanimat-e-IBGE) with mean value of 39 g and S. D. of 2.74.

The biological yield ranged from 10687 kg ha^{-1} (observed for Atta Habib) to 11971 kg ha^{-1} (observed for Ghanimat-e-IBGE), with mean value of 3862 kg ha^{-1} and S. D. of 310.44, among the local check varieties, which were well in the range of maximum and minimum values recorded for hybrids (Fig. 1d).

A high diversity was observed among the tested Chinese hybrids for grain yield, with the maximum of 6053 kg ha^{-1} and a minimum of 747 kg ha^{-1} with mean value of 3303 kg ha^{-1} and standard deviation of 1061.11 (Fig. 1e). Among the local check varieties, the maximum value recorded was 3382 kg ha^{-1} (observed for Atta Habib) and the maximum value recorded was 4233 kg ha^{-1} (recorded for Ghanimat-e-IBGE) with mean value of 3862 kg ha^{-1} and S.D. of 310.44. This revealed the higher genetic variability and variation among the hybrids which also included the range of values of the local check varieties.

Like all yield parameters, the diversity for harvest index was also huge among the Chinese hybrids. Among the Chinese hybrids, it ranged from 14% to 41%, with mean value of 35% and standard deviation of 4.18 (Fig. 1f); while among the local checks, it ranged from 33% (observed for Atta Habib and PirSabak-15) to 37% (observed for PirSabak-13, Ghanimat-e-IBGE and Shahkar-13), with mean value of 35% and standard deviation of 2.15.

Cluster analyses grouped the 416 hybrid lines and local checks into four clusters, out of which the first group G1 contained 26 lines; the second group G2 contained set of 136 lines, including the local checks; the third group G3 contained 187 lines; while the fourth group G4 contained 71 lines.

Diversity for yield related traits in the selected Chinese hybrid lines: As for the 416 lines trail, the analysis of variance for the selected set of lines revealed that for thousand grain weight the variations were significant for hybrids (LSD: 12.4). Non-significant differences were observed between local checks and hybrids vs check varieties. The differences for grain yield were highly significant between hybrids (LSD: 1682) and local checks (LSD: 595), along with the hybrids vs check varieties. Biological yield of the hybrids and local checks revealed highly significant differences between the hybrids (LSD:

2440) and local checks (LSD: 863). The hybrids vs checks were also found to have significant differences. Analysis of variance revealed non-significant results for harvest index among the hybrids and local checks. However, the hybrids vs. check varieties had significant differences. Overall, these yield related traits were positively influenced by selection with decreasing trend for variation and increasing for the mean performance.

The overall population and subsequent year (2018-19) selected hybrids shared the same mean of 23 and standard deviation of 1.6 in spikelets spike^{-1} which increased for selected progeny, which had mean of 21 and standard deviation of 1.99 (Table 3). The means and variations increased for grains spike^{-1} of the selected lines during the subsequent year (2018-19). The overall population and selected hybrids shared same mean of 51 with standard deviation of 9.48 and 8.88, respectively. The mean and standard deviation increased for subsequent year (2018-19) performance of selected hybrids which were 87 and 11.01, respectively. The mean of 1000-grain weight for overall population was 38 g while 43 g was for selected hybrids and 46 g for selected progeny, with standard deviation of 5.03, 3.3 and 7.81, respectively. Considering the grain yield values, it was 2982 kg ha^{-1} for overall population (S.D: 934), 4211 kg ha^{-1} for selected hybrids (S.D: 829) and 4138 kg ha^{-1} for the selected lines during subsequent year (2018-19) with S.D of 1478. The means biological yield was 8535 kg ha^{-1} for overall population, 11476 kg ha^{-1} for selected hybrids and 11333 kg ha^{-1} for subsequent year (2018-19). The mean for harvest index increased from 35 of overall population to 37 of selected hybrids, however, this decreased for the selected hybrids during the subsequent year (2018-19) which was 36.

Distribution of yield component parameters subjected to selection: The role of selection in improving yield parameters was assessed through collected data on these parameters in the overall population, selected hybrids during 2017-18 and the second year (2018-19) performance of the selected hybrids. The data was taken on yield related parameters included the 1000 grain weight, grain yield, biological yield and harvest index. Among the yield related components, better performance was shown by the selected hybrids for 1000 grain weight, grain yield and biological yield. Harvest index showed the highest values for the selected progeny. The selection had an overall better impact on the selected hybrids which could be seen through the ranges and mean values of their performance (Table 3, Fig. 3). The subsequent year (2018-19) performance of selected hybrids showed the second highest range, mean and standard deviation values.

The grains spike^{-1} was the second highest for the overall population with a range value of 25-80, with a mean value of 51. The selected hybrids had the minimum grains spike^{-1} of 19-76 and a mean value of 51 (Fig. 4c). The highest range value was observed for the selected lines during the subsequent year (2018-19) with a range value of 37-75 and a mean value of 87, which proved the impact of the selection to be limited in this case.

In case of spikelets spike^{-1}, the minimum for the subsequent year (2018-19) performance of selected hybrids had a range value of 15-27 and a mean value of 21 (Fig. 4d). In the overall population, it had a range of 17-27 and a mean of 23. The selected hybrids showed the range value of 18-26, and the mean of 23.

The 1000 grain weight values were the lowest for the overall population. The range values for the 1000 grain weight were 23 g-62 g, with mean value of 38 g (Fig. 3c). The highest mean value (43 g) was observed for the selected hybrids with a range of 34-50 g. The performance of the selected hybrids in the subsequent year (2018-19) had the highest mean (46g) with a range of 30g-59g.

Grain yield also had the same trend as that in the 1000 grain weight as the selected hybrids showed promising performance and had the highest range value of 2000-6053 kg ha^{-1} and a mean value of 4211 kg ha^{-1} (Fig. 3d). The subsequent year (2018-19) performance of selected hybrids had better performance than the overall population, with range values of 1934 - 6999 kg ha^{-1} with mean of 4138 kg ha^{-1}. The overall population had the minimum range value which was 747 kg ha^{-1} -5973 kg ha^{-1} with mean of 2982 kg ha^{-1}.

The biological yield was the highest for the selected hybrids with a range value of 6507 kg ha^{-1} -15893 kg ha^{-1} and a mean value of 11476 kg ha^{-1}. The subsequent year (2018-19) performance of selected hybrids showed the 2nd best performance having a range of 6400 kg ha^{-1}-16019 kg ha^{-1} and a mean value of 11333 kg ha^{-1} (Fig. 3e). The overall population had the lowest performance with range of 2533 kg ha^{-1}-15933 kg ha^{-1} and a mean observed as 8535 kg ha^{-1}.

The harvest index, on the contrary, showed a clear promising impact of selection, where the subsequent year (2018-19) performance of selected hybrids showed the best performance with a range of 19%-47% and mean of 36% (Fig. 3f). The selected hybrids displayed the second highest value for harvest index of 19%-40% and a mean=37%. The overall population had the minimum value of range of 14%-41% with a mean of 35%.

Selection differential and modified genetic advance: Selection differential and modified genetic advance (in terms of the 2nd year performance of the selected hybrids) were estimated to assess the impact of selection on the exotic Chinese wheat hybrids which revealed an overall improvement in various parameters in desired direction, except for number of spikelets per spike (Fig. 4). The selection differential and modified genetic advance was small for spikelets per spike, grains per spike and harvest index, while it was the maximum for grain yield.

For spike spike^{-1} and grains spike^{-1}, the selection differential values were negative i.e., -0.19% and -0.89%, respectively. It was the maximum (41.21%) for grain yield, while 34.46% for biological yield. The selection differential was relatively low (5.59%) for harvest index. It was 13.75% for 1000-grain weight.

In case of modified genetic advance, it was negative only for spikelets spike (-9.20%). For the rest of the studied parameters, it was positive with the minimum observed for harvest index (2.88%) and the maximum observed for grain yield (38.75%) followed by biological yield (32.79%). For 1000-grain weight it was 21.90% and for grains per spike it was 10.86%.

Discussion

The current work revealed the existence of variability among Chinese hybrid germplasm developed by the Beijing Engineering Research Centre for Hybrid Wheat (BERCHW), China. The Chinese germplasm have never been tested at Pakistan (Iftikhar *et al*., 2021) and should be included into the potential genetic stock for increasing variability in the available germplasm (Ali *et al*., 2022; Fufa *et al*., 2005). The study has enabled to gain better performance for most of the studied parameters after doing selection of a set of 108 lines from the total 416 lines, an important advancement for identifying the most suitable lines for subsequent release as variety.

Spike traits are a subset of plant characteristics, directly contributing to grain yield, variability, which has been shown to be linked to final yield (Baye *et al*., 2020; Yagdi & Sozen, 2009). The work revealed higher variability in the preliminary 416 Chinese hybrids than the promising local checks; this variability can be further selected to improve the distribution. The extent of genotypic variability for characters present within a population is necessary for developing improved cultivated varieties with better yield traits under different agro-ecological circumstances. There is a positive and significant association between grain yield plant^{-1}, biological yield plant^{-1}, number of spikelets spike^{-1} and spike length, both, at genotypic and phenotypic levels (Ahmad *et al*., 2018). Selection could be more effective for grain yield if spike characteristics are considered. Rana *et al*., (1999) have stated that the phenotypical selection is a significant property with regard to the grain weight per spike under both wet and arid conditions. The spikelets number has also been revealed to be linked with yield (El-Mohsen *et al*., 2011; Iftikhar *et al*., 2021). Variation among genetic potential of varieties may result in variation in grains per spike (Akhtar *et al*., 2001) and being the immense contributor to the yield, it should be given utmost importance. The three most significant contributors towards the grain yield are number of tillers plant^{-1}, number of grains plant^{-1} and 1000 grain weight (El-Mohsen *et al*., 2011). The final grain yield is resultant from important spike related parameters viz. spike length, number of spikelets per spike, 1000-grain weight, number of grains per spike and harvest index (Kazi *et al*., 2012; Abbas *et al*., 2013). Grain yield can be enhanced by traits selected for cultivation of best yielding varieties (Saleem *et al*., 2006; Kazi *et al*., 2012).

The grain yield parameters were significantly variable among the 416 Chinese hybrids during the preliminary testing. The distribution could show the presence of numerous hybrids in the range higher than local checks and thus, were useful for subsequent selection. Being a complex trait, grain yield is affected by certain yield contributing characters (Xie, 2015). An increase of 2% in wheat production is annually required for meeting the basic requirements of the ever increasing human population. Utilizing high yielding and early maturing cultivated varieties in cropping systems, along with the avoidance of the hot winds at the end of grain filling season, can help in overcoming the elevated demand of wheat production and consumption (Mondal *et al*., 2013). The average of seed yield along with the rest of plant dry matter constitutes biological yield (Dewan *et al*., 1998). High grain yield is thought to be fruitful for selection for biomass yield and harvest index in the initial generations (Donald & Hamblin, 1976). Biological yield and harvest index are positively correlated with grain yield. But in order to improve grain yield, the crop cycle could take time in order to get higher biological yield (Loffler & Busch, 1982).

It is very hard for the breeders of today to elevate wheat grain yield and improve the crop grain quality for end products (Goutam *et al*., 2013). Improved grain yield can be achieved from selection of higher biomass with higher vegetative and grain yield (Snape & Parker, 1984). Diverse germplasm can be harnessed for diversification and pre-breeding activities for development of such parental lines (Singh *et al*., 2010). Concerning our food security in developing countries, wheat yield extent could be increased (Duveiller *et al*., 2007). Development of improved cultivar with capability of producing better yield under various agro-climatic conditions depends upon the amount of genotypic variability present in a population for the traits (Ahmad *et al*., 2018). Indeed, some exotic hybrids may appear superior to the check cultivars in yield and component characters (Khaled *et al*., 2015). Wheat production can be increased by considering the valuable selection character of biomass yield which is constituted from above the ground plant parts (Sharma, 1993). More growing days and grain filling duration would ensure better collection of leaf photosynthates and hence, high grain yield and grain weight from better agglomeration of resources from leaf and stem. The grain production and regular monitoring of crop can result from the significantly important aboveground biomass of wheat (Ljubicic *et al*., 2018). The better yielding grains along with non-grain yielding straw (used for livestock) are obtained from high biomass yielding wheat genotypes which are also preferred by the farmers from the developing countries (Ali *et al*., 2022; Sharma, 1992).

Harvest index reflects on the transfer of nutrients from vegetative part to reproductive part which also give us necessary information and details about genotype selection in late sowing conditions. According to the literature, higher HI of a genotype can lead to greater biomass and hence, better performance in delayed sowing conditions (Akram, 2011; Mushtaq *et al*., 2011). Such variability among grain yield traits have been reported previously (Youldash *et al*., 2020; Raza *et al*., 2018; Khaled *et al*., 2015). The hybrids revealed highest mean values under normal planting dates which were detected in investigation of individual performance of parents and generations (Raza *et al*., 2018). Differential partitioning of the photosynthates has been linked to the harvest index as an important feature. In a crop of high physiological capacity, harvest index can be improved by mobilizing and translocating the photosynthates into plant parts with economic value (Iqbal *et al*., 2021; Wallace *et al*., 1972; Donald & Hamblin, 1976; Singh & Stoskopf, 1971).

The availability in the germplasm was also reported in the crop duration parameters, already published earlier (Iftikhar *et al*., 2021). These tested hybrids possessed high variability and even better performance than local checks for the crop duration parameters including days to heading and maturity (Iftikhar *et al*., 2021), which are important parameters contributing to the overall productivity of the crop, considering the cropping system of the area (Ali *et al*., 2022).

The availability of variation and proper selection is the key to any breeding programme (Iftikhar *et al*., 2021). The better selection strategy would ensure a good response to gain improvement in the final yield. Numerous traits could be considered while making the decision regarding which lines to be selected, though more the trait is linked with final yield, the better influence will be on the selected progeny. In our case, emphasis was given to grain yield and yield contributing traits to select the subset of Chinese hybrids, which enabled to improve substantially the final yield of the selected hybrids during subsequent years. Hybrids with better performance than the local checks were identified and would be recommended to be included in the commercial breeding programme to improve wheat yields in Pakistan.

The wheat germplasm in Pakistan is of very narrow genetic background with most of the varieties based on CIMMYT origin lines (Ali *et al*., 2022). The inclusion of diverse lineages would further diversify this genetic background of wheat and thus eradicate the stagnancy in wheat yield, considered to be owing narrow genetic background. This is further important as Pakistan lies in the center of origin of wheat yellow rust pathogen, where diverse pathogenic lineages are prevalent (Ali *et al*., 2014; Ali *et al*., 2017). In addition, wheat hybrids have never been exploited in Pakistan, while limited studies are available in other parts of the world, China being the pioneer on wheat hybrids. So the current work should provide valuable information regarding the potential of Chinese germplasm and hybrids for wheat improvement in Pakistan.

Conclusions

The current study revealed a high diversity among Chinese hybrids, an overall positive impact of tested hybrids was observed for spike characteristics and yield related parameters when compared with check varieties. The hybrids possessed high variability and even better performance than local checks. There is a huge potential for exploitation of wheat hybrid in Pakistan, to be explored in future. Future work should be done on these lines to test their performance under multilocation trials at different agro-ecological zones.

Acknowledgement

This work was partly supported by BAAFS International Science and Technology Cooperation Platform (2024-02); Science and Technology Innovation Project of BAAFS (KJCX20230124); the Creation of Water-efficient Hybrid Wheat for Pakistan and China` Project No.PSF/NSFC/Agr-KP AUP(14) funded by Pakistan Science Foundation, Islamabad, Pakistan; National Natural Science Foundation of China (31661143018. The work also received partial support from the research projects awarded to the senior author (Dr. Sajid Ali), namely the CIMMYT, Pakistan and RustWatch, EU.

References

Abbas, G., J.Z.K. Khattak, G. Abbas, M. Ishaque, M. Aslam, Z. Abbas, M. Amer and M.B. Khokhar. 2013. Profit maximizing level of potassium fertilizer in wheat production under arid environment. *Pak. J. Bot*., 45: 961-965.

Abd El-Mohsen, A.A. S.R.A. Hegazy and M.H. Taha. 2011. Genotypic and phenotypic interrelationships among yield and yield components in Egyptian bread wheat genotypes. *J. Plant Breed. Crop Sci.*, 4: 9-16.

Afzal, F., S.K. Chaudhari, A. Gul, A. Farooq, H. Ali, S. Nisar, B. Sarfaraz, K.J. Shehzadi and A. Mujeeb-Kazi. 2015. Bread wheat (*Triticum aestivum* L.) under biotic and abiotic stresses: An overview. In: (Ed.): Hakeem, K.R. Crop production and global environmental issues, 293-317. Springer International Publishing, Switzerland.

Ahmad, T., A. Kumar, D. Pandey and B. Prasad. 2018. Correlation and path coefficient analysis for yield and its attributing traits in bread wheat (*Triticum aestivum* L. em Thell). *J. Appl. Natur. Sci*., 10: 1078-1084.

Akhtar, M.Z.; M.A. Khan, K. Ahmad and M. Alam. 2001. Evaluation of wheat (*Triticum aestivum* L.) varieties for their potential grain yield under the agro-ecological conditions of D.I. Khan. *J. Biol. Sci.*, 1: 568-570.

Akram, M. 2011. Growth and yield components of wheat under water stress of different growth stages, Bangladesh. *J. Agric. Res.*, 36: 455-468.

Ali, S., S.J.A. Shah, I.H. Khalil, H. Rahman, K. Maqbool and W. Ullah. 2009. Partial resistance to yellow rust in introduced winter wheat germplasm at the north of Pakistan. *Aust. J. Crop Sci*., 3: 37-43.

Ali, S., P. Gladieux, M. Leconte, A. Gautier, A.F. Justesen, M.S. Hovmøller, J. Enjalbert and C. de Vallavieille-Pope. 2014. Origin, Migration Routes and Worldwide Population Genetic Structure of the Wheat Yellow Rust Pathogen *Puccinia striiformis* f.sp. *tritici*. *PLoS Pathog.* 10: e1003903.

Ali, S., S. Soubeyrand, P. Gladieux, T. Giraud, M. Leconte, A. Gautier, M. Mboup, M., C. de Vallavieille-Pope and J. Enjalbert. 2016. CloNcaSe: Estimation of sex frequency and effective population size by clonemate re-sampling in partially clonal organisms. *Mol. Ecol. Res*., 16: 845-861.

Ali, S. and D. Hodson. 2017. Wheat rust surveillance; field disease scoring and sample collection for phenotyping and molecular genotyping. In: (Ed.): Periyannan, S. *Methods in Mol. Biol.* Humana Press.

Ali, S., J. Rodriguez-Algaba, T. Thach, C. Sørensen, J.G. Hansen, P. Lassen, D. Hodson, K. Nazari, A.F. Justesen and M.S. Hovmøller. 2017. Yellow rust epidemics worldwide were caused by pathogen races from divergent genetic lineages. *Front. Plant Sci*., 8: 1058.

Ali, S., Z.A. Swati, M.R. Khan, A. Iqbal, Z.U. Rehman, M. Awais, G. Ullah, I. Khokhar, M. Imtiaz and M. Fayyaz. 2022. Wheat yellow rust status across Pakistan – a part of the pathogen center of diversity. In: (Ed.): Li and Ali. (2022), Wheat yellow rust in the extended Himalayan region and the Middle East. China Agriculture Press.

Anonymous. 2014. FAOSTAT, Food and Agriculture Organization of the United Nations Statistics Division. 2014. Rome: FAO.

Bainsla, N.K. and H.P. Meena. 2016. Breeding for resistance to biotic stresses in plants. *Rec. Adv. Plant Stress Physiol.*, 379-411.

Bastiaans, L. 1991. Leaf Photosynthesis of Rice Due to Leaf Blast. *Phytopathol.*, 81: 611-615.

Baye, A., B. Berihun, M. Bantayehu and B. Derebe. 2020. Genotypic and phenotypic correlation and path coefficient analysis for yield and yield-related traits in advanced bread wheat (*Triticum aestivum* L.) lines. *Cogent Food Agric.*, 6: 1752603.

Dewan, D.B., G. Rakow and R.K. 1998. Downey. Growth and yield of doubled haploid lines of oilseed *Brassica rapa*. *Can. J. Plant Sci.*, 78: 537-544.

Donald, C.M. and J. Hamblin. 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Adv. Agron.*, 28: 361-405.

Duveiller, E., R.P. Singh and J.M. Nicol. 2007. The challenges of maintaining wheat productivity: Pests, diseases, and potential epidemics, *Euphytica*, 157: 417-443.

Fufa, H., P.S. Baenziger, B.S. Beecher, I. Dweikat, R.A. Graybosch and K.M. Eskridge. 2005. Comparison of phenotypic and molecular marker-based classifications of hard red winter wheat cultivars. *Euphytica,* 145: 133-146.

Goutam, U., S. Kukreja, R. Tiwari, A. Chaudhary, R.K. Gupta and B.B. Dholakia. 2013. Biotechnological approaches for grain quality improvement in wheat: present status and future possibilities. *Aust. J. Cereal Sci.*, 7: 469-483.

Iftikhar, Z. and S. Ali. 2021. Diversity in Chinese wheat hybrids for Yield and Disease resistance through molecular markers and field testing. Institute of Biotechnology and Genetic Engineering. The University of Agriculture Peshawar. Pakistan.

Iftikhar, Z., M. Arif, I. Munir and S. Ali. 2021. Impact of selection on distribution of crop duration parameters in Chinese wheat hybrids. *Sarhad J. Agr.*, 37: 1178-1193.

Iqbal, A., Z.U. Rehman, M.R. Khan, A.M. Khan, S.U. Khan, M. Arif, J. Iqbal, M.U. Rehman, M. Ali, M. Qasim and S. Ali. 2023. Field response and molecular screening of European wheat germplasm against powdery mildew at the Himalayan region of Pakistan. *J. Appl. Genet.*, 64: 667-678.

Iqbal, A., M.R. Khan, M. Ismail, S. Khan, A. Jalal, M. Imtiaz and S. Ali. 2020. Molecular and field-based characterization of yellow rust resistance in exotic wheat germplasm. *Pak. J. Agric. Sci.*, 57: 1457-1467.

Ismail, M., M.R. Khan, A. Iqbal, Z.H. Facho, A. Jalal, I. Munir, Farhatullah and S. Ali. 2021. Molecular markers and field-based screening of wheat germplasm for leaf rust resistance. *Pak. J. Bot.*, 53: 1909-1920.

Kazi, A.G., A. Rasheed, T. Mahmood and A. Mujeeb-Kazi. 2012. Molecular and morphological diversity with biotic stress resistances of high 1000-grain weight synthetic hexaploid wheat. *Pak. J. Bot.*, 44: 1021-1028.

Khaled, A.G.A., M.H. Motawea and A.A. Said. 2015. Identification of ISSR and RAPD markers linked to yield traits in bread wheat under normal and drought conditions. *J. Genet. Eng. Biotechnol.*, 13: 243-252.

Khan, M.R., M. Imtiaz, S. Ahmad and S. Ali. 2019. Northern Himalayan region of Pakistan with cold and wet climate favors a high prevalence of wheat powdery mildew. *Sarhad J. Agric.*, 35: 187-193.

Khan, M.R., Z.U. Rahman, S.N. Nazir, S. Tshewang, S. Baidya, D. Hodson, M. Imtiaz and S. Ali. 2019. Genetic divergence and diversity in Himalayan *Puccinia striiformis* populations from Bhutan, Nepal and Pakistan. *Phytopathol.*, 109: 1793-1800.

Ljubicic, N., M. Kostić, O. Marko, M. Panić, S. Brdar, P. Lugonja, M. Knezevic, V. Minic, B. Ivosevic, R. Jevtic and V. Crnojevic. 2018. Estimation of aboveground biomass and grain yield of winter wheat using NDVI measurements. Proceedings of the IX International Agricultural Symposium "Agrosym 2018", held on 4th to 7th October, 2018, at Jahorina, Bosnia and Herzegovina.

Löffler, C.M. and R.H. Busch. 1982. Selection for grain protein, grain yield and nitrogen partitioning effeciency in hard red spring wheat. *Crop Sci.*, 22: 591-595.

Madden, L.V. and F.W. Nutter Jr. 1995. Modeling crop losses at the field scale. *Can. J. Plant Pathol.,* 17: 124-137.

Madeira, A.C. and J.A. Clark. 1991. Reduction in the efficiency of light use due to disease. *Anais do Instituto Superios de Agronomia.*, 43: 153-161.

Mondal, S., R. Singh, J. Crossa, J. Huerta-Espino, I. Sharma and R. Chatrath. 2013. Earliness in wheat: a key to adaptation under terminal and continual high temperature stress in South Asia. *Field Crops Res.*, 151: 19-26.

Mushtaq, T., S. Hussain, M. Bukhsh, J. Iqbal and T. Khaliq. 2011. Evolution of two wheat genotypes performance under stress condition at different growth stages. *Crop Environ.,* 2: 20-27.

Rana, V., S.C. Sharma and G.S. Sethi.1991. Comparative estimates of genetic variation in wheat under normal and drought stress conditions, *J. Hill Res.*, 12: 92-94.

Raza, H., A. Khan and N. Ahmed. 2018. Genetic analysis for some phenological and morphological traits in wheat (*Triticum aestivum* L.) under two different sowing windows. *Appl. Ecol. Environ. Res.*, 17: 2059-2071.

Saleem, U., I. Khaliq, T. Mahmood and M. Rafique. 2006. Phenotypic and genotypic correlation coefficients between yield and yield components in wheat. *J. Agric. Res.*, 44: 1-8.

Saqib, M.S., S.J.A. Shah, F. Muhammad, W. Khan, M. Ibrahim and S. Ali. 2008. Genotypic variability for *Alternaria alternata* (fr.) keissler infection in bread wheat. *Plant Pathol.*, 7: 34-39.

Sharma, R.C. 1992. Analysis of phytomass yield in wheat. *Agron. J.,* 84: 926-929.

Sharma, R.C. 1993. Selection for biomass yield in wheat. *Euphytica,* 70: 35-42.

Singh, I.D. and N.C. Stoskopf. 1971. Harvest index in cereals. *Agron. J.,* 63: 224-226.

Singh, S.K., R. Chatrath and B. Mishra. 2010. Perspective of hybrid wheat research: A review. *Ind. J. Agric. Sci.*, 80: 1013-1027.

Snape, J.W. and B.B. Parker. 1984. The effect of the Norin 10 dwarfing gene, Rht2 on yield-biomass relationships in wheat (*T. aestivum*). In semi-dwarf cereal mutants and their use in cross-breeding. II. IAEA-TECDOC 307. Proceedings of a Research Co-ordination Meeting, Joint FAO/IAEA Division, Davis, California (USA), 30th Aug to 3rd Sep, 1982. p. 71-77, IAEA, Vienna, Austria.

Wallace, D.H., J.L. Ozbun and H.M. Munger. 1972. Physiological genetics of crop yield. *Adv. Agron.,* 24: 97-146.

Xie, Q. 2015. Physiological and genetic determination of yield and yield components in a bread wheat× spelt mapping population [Doctoral dissertation]. University of Nottingham.

Yagdi, K. and E. Sozen. 2009. Heritability, variance components and correlations of yield and quality traits in durum wheat (*Triticum durum* Desf.). *Pak. J. Bot.*, 41: 753-759.

Youldash, K.M., C. Barutcular, A. El Sabagh, I. Toptas, G.T. Kayaalp, A. Hossain and M. Farooq. 2020. Evaluation of Grain yield in fifty-eight spring bread wheat genotypes grown under heat stress. *Pak. J. Bot.*, 52: 33-42.

Ziska, L.H., J.A. Bunce, H. Shimono, D.R. Gealy, J.T. Baker and P.C.D. Newton. 2012. Food security and climate change: on the potential to adapt global crop production by active selection to rising atmospheric carbon dioxide. *Proc. Biol. Sci.,* 279: 4097-4105.

(Received for publication 27 July 2023)