COMPARATIVE ANALYSIS OF YIELD COMPONENT TRAITS AND GENETIC PARAMETERS OF BREAD WHEAT ACROSS DIFFERENT ENVIRONMENTS IN PESHAWAR VALLEY

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Abstract

This investigation was performed to study genetic improvement in yield and its components at The University of Agriculture, Peshawar during 2021-22. Data was recorded on twelve morphological traits. Statistical analysis revealed highly significant differences for all the studied parameters across both environmental conditions. However, genotype by environment interactions were significant for majority of the traits. Performance of wheat genotypes ranged from 114 to 121 days for days to headings, 155 to 158 days for days to maturity, 86 to 94 cm for plant height, 292 to 364 for spikes meter^{-2}, 11 to 12 cm for spike length, 19 to 21 for spikelet's spike^{-1}, 41 to 54 for grains spike^{-1}, 1.74 to 2.35 g for grain weight spike^{-1}, 50 to 55 g for 1000-grain weight, 10698 to 12628 kg ha^{-1} for biological yield, 3708 to 5183 kg ha^{-1} for grain yield and 35 to 44% for harvest index across both environments. Best performing genotypes were CIM-10 for days to headings, CIM-06 and CIM-10 for days to maturity, CIM-11 for plant height, CIM-11 for spikes m^{-2}, CIM-11, CIM-11, CIM-16 and CIM-23 for spike length, CIM-04, CIM-08, CIM-09, CIM-12, CIM-16, CIM-19, CIM-20, CIM-21, CIM-23, Wadan-17, CIM-16 and CIM-21 for spikelet's spike^{-1}, CIM-12 for grains spike^{-1}, CIM-23 and CIM-20 for grain weight spike^{-1}, CIM-23 and CIM-20 for 1000-grain weight, CIM-12 and CIM-23 for biological yield, CIM-23 and CIM-06 for grain yield, CIM-23, CIM-16 and CIM-20 harvest index under irrigated and rainfed environments, respectively. These results suggested that selection could be delayed to later generations. Wheat genotype CIM-23 and CIM-06 was found superior for grain yield and is recommended for irrigated as well as rainfed environmental conditions.

Keywords: Agriculture, genotypes, genetic improvement, *Triticum aestivum*, irrigated, rainfed

Introduction

Wheat (*Triticum aestivum* L.) belongs to family Gramineae. Among different species of wheat most common and vital one is hexaploid/bread wheat as it is cultivated world-wide for purpose of human consumption. In recent years, it has been found that almost 95% of wheat species grown all over the world belongs to bread wheat (2n = 42). Wheat has become an important cereal crop in all aspects, providing more calories to the diet than other crops. It ranks first among all cereal crops and is considered "King of cereals" because of its evolutionary history and cultivation pattern. Wheat is cultivated across the world on about 30% area under cereal cultivation, and provides 20% of total calories for human beings (Khan *et al.*, 2015). Wheat is grown on about one sixth of the cultivated land around the world. The global wheat production was more than 778.6 million metric tons during 2020-21 (Shahbandeh, 2022). However, in Pakistan, wheat was cultivated on an area of 9.17 million hectares with total production of 27.29 million tons with an average yield of 2.97 tons ha^{-1} during 2021. Similarly, in Khyber Pakhtunkhwa its production was 1.49 million tons during same period (PBS, 2020-21). Wheat is grown as a rainfed crop on more than 67% of the land in Khyber Pakhtunkhwa, and its average yield is low due to lack of suitable wheat varieties for area's climate and planting times (Mukhtarullah and Akmal, 2016). There are many factors which are responsible for lower yield however, drought is among known main yield limiting factors in wheat (Nazir *et al.*, 2019). In recent years drought severity is being adversed by current climatic change. Globally, drought usually prevails in semi-arid and arid regions. In response to water stress, morphological and biochemical changes are witnessed in plants which results in functional damage and loss of yield (Arif *et al.,* 2020). The availability of genetic variation and interaction among genetic materials of different genotypes is critical for a successful wheat breeding program. Genetic diversity contributes to formation of a foundation for the advancement of crop genetic materials. The transmission of genetic diversity in a population and the availability of genetic information are interconnected (Kumbhar *et al.*, 2015). Grain yield is polygenic in nature and is affected by several genetic factors as well as environmental stresses. Consequently, genotype × environment interaction results in genotypic variations from one environment to another (Bacha *et al.*, 2017). However, selection effectiveness in wheat population is totally dependent on presence of high variability and the inherited portion of variability is termed as heritability (Khan *et al*., 2015). Keeping in view the above importance, the current study was designed to evaluate the performance of wheat genotypes for under irrigated and rainfed conditi0ns also estimate heritability and genetic gain for grain yield and its components traits acr0ss two envir0nments and identify stable wheat genotypes for the two tested envir0nments.

Materials and Methods

This experiment was conducted at research fields of department of Plant Breeding and Genetics, The University of Agriculture, Peshawar during 2021-22. Research material consisted of fourteen advanced wheat lines along with one local cultivar. All the fifteen genotypes were evaluated under irrigated and rainfed conditions. The research was laid out with two replications. Each genotype was allotted to a four rows plot of three meters length and row-to-row distance of 25 cm. All 30 entries received recommended cultural practices such as uniform application of fertilizers, irrigation and soil preparation in order to minimize ecological variations from the time of planting till harvesting. Data were recorded on following morphological parameters at various crop stages using ten plants from each entry.

1. **Days to 50% heading**
   Heading stage is regarded as the stage when spike emerge after unfolding of flag leaf. Data on days to heading were recorded by counting days from date of sowing to date of emergence of 50% headings in each plot.

2. **Days to physiological maturity**
   Data was recorded for days to maturity when over 50% of spikes turned yellow in each plot (Sheikh *et al*., 1998).

3. **Plant height (cm)**
   Plant height of ten randomly selected plants was measured from surface of the ground to tip of main spike excluding awns using a meter rod (Muhammad *et al*., 2011).

4. **Spikes meter^{-2}**
   Total spikes meter^{-2} were obtained by manual counting of total productive tillers in one square meter area of each genotype in each replication.

5. **Spike length (cm)**

Spike length was measured in centimeters with the help of a measuring tape. Length was measured from base of first spikelet to last spikelet at the tip of the spike excluding awns.

6. **Spikelets spike^{-1}**

Spikelets in each spike of randomly selected ten plants were counted and their mean was obtained to get data for spikelets spike^{-1}.

7. **Grains spike^{-1}**

Randomly selected ten plants in each replication were manually threshed and grains were counted to get data for grains spike^{-1}.

8. **Grain weight spike^{-1} (g)**

Grain weight spike^{-1} was obtained by weighing total grains collected from threshing each selected spike using an electronic balance.

9. **1000-grain weight (g)**

Thousand grains from total produce of each entry in each replication were weighed by using an electric balance to record data on 1000-grain weight (Khan *et al.,* 2010).

10. **Biological yield (kg ha^{-1})**

Plants of each and every plot were harvested separately at maturity and sun dried for 3 to 4 days. Dried plants of each plot were weighed with the help of a balance to record data on biological yield as follow.

$$\text{Biological yield (kg ha}^{-1}\text{)} = \text{(Biological yield plot}^{-1}\text{/ Plot area m}^{2}\text{)} \times 10{,}000 \text{ m}^{2}$$

11. **Grain yield (kg ha^{-1})**

Grains weight was obtained after threshing total produce in each plot to determine grain yield using following formula.

$$\text{Grain yield (kg ha}^{-1}\text{)} = \text{(Grain yield plot}^{-1}\text{/ Pl0t area m}^{2}\text{)} \times 10{,}000 \text{ m}^{2}$$

12. **Harvest index (%)**

Harvest index was calculated using the following formula.

$$\text{Harvest index (\%)} = \text{(Grain yield pl0t}^{-1}\text{/ Biol0gical yield plot}^{-1}\text{)} \times 100$$

Statistical analysis

Collected data was subjected to analysis of variance (ANOVA) technique as proposed by Steel and Torrie (1980). Moreover, LSD test was conducted for such traits which had significant differences among genotypes.

Results and Discussions

Days to headings

Statistical analysis uncovered highly significant variations among genotypes, environments as well as G × E interaction for days to headings (Table 1). This clearly indicated inconsistency of wheat genotypes under irrigated and rainfed environments. Mean performance of genotypes across two environments ranged from 114 to 121 days with an average of 118 days where genotype CIM-10 took minimum days to reach 50% headings while maximum days were recorded for genotype CIM-04 (Table 2). Similarly, heading days ranged from 118 to 125 days with an average of 122 days under irrigated and 111 to 125 days with an average of 114 days under rainfed environment. CIM-10 appeared as early heading genotype under irrigated as well as rainfed environments while maximum days to headings were taken by genotype CIM-04 under irrigated and CIM-13 under rainfed environmental conditions (Table 2). Genotypes that are unable to tolerate high temperatures can escape high temperature stresses at the end of season (Tewolde *et al.*, 2006). Heading time is evaluated in the field and thus varies depending on the growing environment. Similar results of significant variations among genotypes for days to headings have also been indicated by Shal *et al.*, (2022). Moreover, significant differences for G × E interaction specified variable enactment of wheat genotypes across two environments.

Days to maturity

Day to maturity revealed highly significant variations for genotypes, whereas non-significant variations revealed for genotype by environment interaction (Table 1). The overall mean for days to maturity ranged from 155 to 158 days with an average of 157 days across both studied environments. Wheat genotypes CIM-06 and CIM-10 took minimum days to reach physiological maturity while maximum days were recorded for genotype CIM-12 (Table 2). Similarly, mean performance of wheat genotypes ranged from 153 to 164 days with an average of 161 days under irrigated condition while 151 to 156 days with an average of 152 days under rainfed condition. Maximum days to maturity were recorded for genotype CIM-09 while minimum days were taken by genotype CIM-09 under irrigated condition. Likewise, genotype CIM-11 took maximum days to maturity while minimum days were exhibited by genotypes CIM-11 under rainfed condition (Table 2). Earliness in maturity ensures timely crop harvest and may also protect wheat from biotic and abiotic stresses such as disease, heat and drought (Poehlman and Sleper, 1995). Early maturity is vital for adaptation to temperature stresses and increasing productivity in South Asia (Mondal *et al.*, 2015). The results of present investigation are identical with that of Hassan *et al.*, (2022) who also stated significant variation among genotypes for days to maturity. Likewise, non-significant variations were detected for G × E interaction across two studied environments for days to maturity.

Plant height

Pooled analysis revealed non-significant variations among genotype by environment interaction (Table 1). Mean for plant height ranged from 86 to 94 cm with an average of 90.17 cm across two environments. Maximum height was depicted by genotype CIM-11 while minimum plant height was recorded for CIM-01 (Table 3). Likewise, mean of wheat genotypes ranged from 91 to 103 cm with an average of 94 cm under irrigated environment. Minimum plant height was attributed to genotype CIM-01 while maximum to wheat genotype CIM-11. Similarly, mean performance of genotypes ranged from 80 to 90 cm with an average height of 85 cm under rainfed environment. Maximum plant height was measured for genotype CIM-04 while minimum plant height was taken by genotype CIM-01 (Table 3). Plant height plays an important role in wheat breeding programs as breeders always prefer short-stature wheat varieties in water lodged areas while tall varieties for drought stressed areas (Khan *et al.*, 2010). These results are similar to those of Thapa *et al.*, (2019) who also observed significant variations among genotypes as well as genotype by environment interaction.

Spikes meter^{-2}

Combined analysis of variance disclosed highly significant differences among genotypes, and genotype by environment interaction (Table 1). This indicated difference in performance of wheat genotypes for studied trait across environments. Means for spikes meter^{-2} ranged from 292 to 364 with an average of 323 across two tested conditions. Similarly, mean values for spikes meter^{-2} ranged from 313 to 469 with an average of 379 and 239 to 259 with an average of 248 under irrigated and rainfed conditions, respectively (Table 3). Minimum spikes meter^{-2} were exhibited by genotype CIM-20 under irrigated as well as across environments whereas Wadan-17 recorded minimum spikes meter^{-2} under rainfed condition. Moreover, maximum spikes meter^{-2} were noted for genotype CIM-11 under irrigated and across environments while for CIM-11 under rainfed environmental condition (Table 3). Spikes meter^{-2} is an important trait that has direct relation with grain yield. Spikes contribution is about 20-30% to dry matter collection in grains (Sharma *et al.*, 2003). Similar outcomes of high variability among genotypes and significant G × E interaction were earlier described by Boussakouran *et al.*, (2021) and Adnan *et al.*, (2017). The genetic predictions together with heritability allow plant breeders to make an effective selection (Ijaz *et al.*, 2015).

Spike length

Analysis of variance showed non-significant variations among environment, genotypes and for genotype by environment interaction for spike length (Table 1). Non-significant G × E interaction indicated static performance of wheat genotypes across environments. Mean performance of wheat genotypes for spike length ranged from 11 to 12 cm with an average of 12 cm across two environments. Likewise, mean values for spike length ranged from 11 to 14 cm with an average length of 12 cm under irrigated whereas 11 to 12 cm with an average of 11 cm under rainfed environment (Table 4). Maximum spike length was recorded for wheat genotype CIM-11 under irrigated and across environments whereas CIM-11, CIM-16 and CIM-23 under rainfed environment. Minimum spike length was measured for genotype CIM-9, CIM-19, CIM-20 and Wadan-17 under irrigated, CIM-01, CIM-04, CIM-06, CIM-08, CIM-10, CIM-12, CIM-13, CIM-19, CIM-20, CIM-21, Wadan-17 under rainfed across both environmental conditions (Table 4). Spike length is the most crucial trait which is directly associated to grain yield along with grains spike^{-1} (Khan *et al.,* 2013). An increase in length of the spike brings an increase in grain yield due to more spikelet's and more grains formation (Shabbir *et al.,* 2011). These non-significant variations could be due to the fact that spike length is a varietal parameter. Non-significant G × E interactions for spike length were also stated by Ikramullah *et al.,* (2011).

Spikelet's spike^{-1}

Statistical analysis of data disclosed significant variations for genotypes, and environment while non-significant at genotype by environment interaction (Table 1). Means of wheat genotypes for spikelet's spike^{-1} ranged from 19 to 21 with an average of 20 across irrigated and rainfed environments. Likewise, mean for spikelet's spike^{-1} ranged from 21 to 23 with an average of 21 under irrigated environment and 17 to 20 with an overall mean value of 18 under rainfed environment, respectively. Minimum spikelet's spike^{-1} were produced by genotype CIM-04, CIM-08, CIM-09, CIM-12, CIM-16, CIM-19, CIM-20, CIM-21, CIM-23 and Wadan-17 under irrigated, whereas CIM-16 and CIM-21 under rainfed environment while maximum spikelets spike^{-1} were recorder for genotype CIM-10 and CIM-11 under irrigated, CIM-04, CIM-10 and CIM-20 under rainfed environmental conditions (Table 4). Significant differences among genotypes for spikelets spike^{-1} confirmed earlier findings of Mohapatra *et al.,* (2019). Our results of non-significant variations for genotype by environment interaction are in accordance with outcomes of Haq *et al.,* (2017) who also listed non-significant differences for genotype by environment interaction for this trait.

Grains spike^{-1}

Results for grains spike^{-1} depicted highly significant differences among genotypes, environment as well as G × E interaction across two tested environments (Table 1). Mean value for grains spike^{-1} ranged from 41 to 54 with an average of 47 across both environmental conditions, 42 to 57 with an average of 52 under irrigated condition and 40 to 51 with an overall mean of 43 under rainfed condition (Table 5). Minimum grains spike^{-1} was recorded in CIM-09 under irrigated environment whereas CIM-09, CIM-19 and CIM-23 exhibited maximum grains spike^{-1} under rainfed environment. Moreover, maximum grains spike^{-1} were obtained for genotypes CIM-16, CIM-21 and Wadan-17 under irrigated and Wadan-17 rainfed environmental conditions (Table 5). Grains spike^{-1} is also a vital trait in predicating total yield. Number of grains in a single spike primarily relies on other spike related traits like spikelets spike^{-1}, spike length and spike density (Firouzian *et al.*, 2003). Grains spike-1 has direct impact on yield potential which provides basis for plant breeders to develop new varieties or to improve existing wheat varieties in such manner that it results in a greater number of healthy grains spike^{-1} (Ullah *et al.,* 2008). Significant differences among wheat genotypes as well as genotype by environment interaction for grains spike^{-1} get support from earlier findings of Ahmad *et al.*, (2022) and Saeidi *et al.*, (2015).

Grain weight spike^{-1}

ANOVA uncovered non-significant differences among wheat genotypes, environments as well G × E interaction for grain weight spike^{-1} across both environmental conditions (Table 1). Means for grain weight ranged from 1.74 to 2.35 g with an overall mean value of 1.96 g across studied environments. Likewise, mean performance of wheat genotypes ranged from 1.70 to 2.64 g with an average of 2.25 g under irrigated and 1.03 to 2.17 g with an average of 1.68 g under rainfed environment (Table 5). Maximum grain weight spike^{-1} was attained by genotype CIM-23 while minimum grain weight spike^{-1} was noted for CIM-20 under irrigated condition. However, maximum grain weight spike^{-1} was expressed by genotype CIM-13 while minimum by genotype CIM-21 under rainfed as well as across two studied environments. Grain weight spike^{-1} plays an important role as its expression relies solely on environmental effect and has direct impacts in harvest index and grain yield. It also provides knowledge about fertilizers usage and its effects on plants genetics. Grain weight combines with other primary traits helps in formation of actual grain yield (Protich *et al.*, 2012). Due to composite relationship grain weight is associated to some other traits due to quantitative nature (Mohsin *et al.*, 2009).

1000-grain weight

Pooled analysis disclosed highly significant variations for 1000- grain weight among wheat genotypes as well as genotype by environment interaction depicting diversified performance of wheat genotypes across both environmental conditions (Table 1). Mean performance of wheat genotypes ranged from 50 to 55 g with an overall mean weight of 53 g across both environments. Similarly, means of wheat genotypes ranged from 49 to 54 g with an average of 51 g under irrigated condition and 49 to 55 g with an average value of 52 g under rainfed condition (Table 6). Maximum 1000-grain weight was exhibited by wheat genotype CIM-01 and CIM-23 under irrigated environment whereas CIM-01 obtained maximum 1000-grain weight under rainfed condition. However, minimum value was recorded for genotype CIM-04, CIM-06, CIM-10, CIM-11, CIM-12, and CIM-13 under irrigated and while minimum 1000-grain weight under rainfed condition was measured for genotype CIM-23 (Table 6). 1000-grain weight is one of the necessary parameters that can determine grain yield and can be used as a criterion for potential selection in wheat breeding program. More 1000-grain weight can cause an increase in average germination, seedlings appearance, tillers meter^{-2} and ultimately the yield (Cordazzo, 2002). The weight of the thousand grain greatly affects seed vigor, seed formation, germination percentage and total yield (Moshatati and Gharineh, 2012). ANOVA uncovered highly significant differences among genotypes as well as G × E interaction for 1000-grain weight. Thungo *et al.*, (2022) and Saleem *et al.*, (2016) also reported similar findings of significant variations among genotypes as well as genotype by environment interaction.

Biological yield

Highly significant differences were observed among wheat genotypes as well as genotype by environment interaction which indicated that genotypic performance of wheat genotypes was different across both studied environments (Table 1). Mean of studied genotypes ranged from 10698 to 12628 kg ha^{-1} with an overall mean of 11773 kg ha^{-1} across two environments, 11917 to 15383 kg ha^{-1} with an average of 13883 kg ha^{-1} under irrigated condition and 9267 to 10633 kg ha^{-1} with an average biological yield of 9663 kg ha^{-1} under rainfed condition (Table 6 and Figure 1). Maximum biological yield was produced by wheat genotypes CIM-12 under irrigated environmental conditions whereas genotype CIM-23 attained maximum biological yield under rainfed conditions. Similarly, minimum biological yield was recoded for genotype CIM-01 under irrigated and CIM-19 under rainfed environments (Table 6). Biological yield is one of the utmost essential attributes of cereals during selection under stressed environments. Farmers have great concern about grain yield, but they also focus on biomass, that's why biological yield is an important factor in selection (Shah *et al.,* 2011). Grain yield in wheat is directly dependent on total biomass. Increase or decrease in photosynthesis and green area of leaves will result in increase or decrease in biomass which will ultimately affect grain yield (Liu *et al.*, 2019). The results of significant variations among genotypes for biological yield are in line with earlier findings of Varsha *et al.,* (2019) and Khan *et al.,* (2015) whereas Ghallab *et al.,* (2016) reported similar results of significant differences among wheat genotypes as well G × E interaction for biological yield.

Grain Yield

Wheat genotypes revealed highly significant differences for grain yield while genotype as well genotype by environment interactions under irrigated and rainfed conditions (Table 1). These outcomes depicted stability in wheat genotypes across irrigated and rainfed conditions. Mean performance of studied wheat lines across two environments ranged from 3708 to 5183 kg ha^{-1} with an overall mean of 4645 kg ha^{-1}. Likewise, means of wheat genotypes ranged from 4083 to 6317 kg ha^{-1} with an average of 5434 kg ha^{-1} and 3333 to 4433 kg ha^{-1} with an average of 3856 kg ha^{-1} under irrigated and rainfed conditions, respectively. Maximum grain yield was recorded for wheat genotype CIM-23 while minimum for genotype CIM-01 under irrigated environment. Genotypes CIM-06 recorded maximum grain yield under rainfed conditions, whereas wheat genotype CIM-01 exhibited minimum grain yield under rainfed conditions (Table 8). Grain yield is a complex quantitative character of utmost significance in wheat which has direct or indirect impacts on other parameters. Increase in quality and quantity of yield related traits are necessary for increase in grain yield (Knezevic *et al.,* 2012). Breeders are focusing more on enhancing the adaptation of new varieties to environmental stresses in several wheat breeding programs. Water stress is a serious issue which has negative impacts on wheat quality and overall production, resulting in huge economic losses (Mardeh *et al.,* 2006). Analysis of interaction among genotypes and environment is being necessary for selection of superior genotypes (Dhungana *et al.*, 2007). Our results of significant differences among studied genotypes while non-significant differences for genotype by environment interaction are in conformity with previous findings of Ilyas *et al.,* (2013) and Khan *et al.,* (2007). Moderate heritability value for grain yield is in line with the results of Sharma *et al.,* (2022) and Mishra *et al.,* (2019).

Harvest index (%)

Statistical analysis of variance revealed significant results among genotypes as well genotype by environment interaction for harvest index across studied environments (Table 1). This may be because the harvest index is less affected by growing conditions. Means for harvest index across environments ranged from 35 to 44% with an overall average value of 40%. Means of wheat genotypes ranged from 32 to 46% with an average of 39% under irrigated condition. Similarly, the means of studied genotypes ranged from 34 to 45% with an average of 40% under rainfed condition. Maximum harvest index was recorded for genotypes CIM-23 under irrigated and CIM-16 and CIM-20 in rainfed environments, respectively whereas minimum for harvest index was recorded for wheat genotype CIM-12 under irrigated and CIM-08 rainfed environments (Table 7). Harvest index measures the ability of total dry matter to be converted into economic yields (Akhtar *et al.,* 2001). The harvest index is among one the most important attributes that influences grain yield more than biological yield in different wheat varieties (Kobata *et al.*, 2018). Similar results of significant differences among wheat genotypes for harvest index were earlier reported by Tsenov *et al.,* (2022) and Baye *et al.*, (2020). Our results of significant G × E interaction for harvest index is in contrast with previous outcomes of Balkan, (2018) and Kumar *et al.*, (2014) who reported significant G × E interaction for the studied trait.

Table 1: Mean squares of 15 wheat genotypes for studied parameters across environments at Peshawar during 2021-22.

SOV	Env	Rep (Env)	Genotypes	G × E	Error	CV%
Df	1	1	14	14	29	-
Days to 50% headings	952.01**	1.7 NS	165.1**	35.23 NS	39.5	1.0
Days to maturity	1242.1 NS	10.8 **	80.4**	31.6 NS	49.9	0.8
Plant height	1234.9 NS	56.0 NS	282.9 NS	259.7 NS	561.0	4.9
Spikes meter^{-2}	332646.1 NS	2812.0 **	40801.9 **	35883.8**	624.7	1.4
Spike length	8.7 NS	0.2 NS	12.7 NS	7.8 NS	15.7	6.4
Spikelets spike^{-1}	139.5 **	0.3 NS	39.9 **	9.7 NS	24.3	4.6
Grains spike^{-1}	1450.4 **	5.7 **	600.1**	441.6 **	30.8	2.2
Grain weight spike^{-1}	4.9 NS	0.5 NS	2.2 NS	2.2 NS	15.2	36.8
1000-grain weight	16.9 **	0.1 NS	121.2**	95.0**	23.0	1.7
Biological yield	267154148.1 **	1833060.2**	13205530.9 **	32265984.5 **	3726972.1	3.0
Grain yield	37375970.3 NS	941963.9 **	7419102**	2376528.8**	1724998.3	5.3
Harvest index	8.0 NS	57.3 **	422.4**	429.7**	227.5	7.1

**: highly significant, NS: non-significant

Table 2: Means for days to heading and days to maturity of 15 wheat genotypes evaluated across two environments at The University of Agriculture, Peshawar during 2021-22. Wadan-17: Local Check, IR: Irrigated, RF: Rain fed.

	Days to 50% heading			Days to maturity		
Genotypes	**IR**	**RF**	**MEAN**	**IR**	**RF**	**MEAN**
CIM-01	121	114	118	161	153	157
CIM-04	125	118	121	163	153	158
CIM-06	122	113	117	159	151	155
CIM-08	123	114	119	162	151	156
CIM-09	122	116	119	164	153	158
CIM-10	118	111	114	160	154	155
CIM-11	119	112	115	163	156	158
CIM-12	122	117	120	162	153	159
CIM-13	123	125	119	160	151	157
CIM-16	124	115	119	161	154	156
CIM-19	124	113	117	153	152	158
CIM-20	121	113	118	162	152	157
CIM-21	123	123	118	161	154	156
CIM-23	123	114	118	160	152	157
Wadan-17	121	114	118	162	152	157
Mean	122	114	118	161	152	157
LSD(0.05)	4.5	2.9	0.62	3.2	3.4	0.69

Table 3: Means for plant height and tillers meter^{-2} of 15 wheat genotypes evaluated across two environments at The University of Agriculture, Peshawar during 2021-22.

	Plant height (cm)			Spikes meter^{-2}		
Genotypes	**IR**	**RF**	**MEAN**	**IR**	**RF**	**MEAN**
CIM-01	91	80	86	342	243	292
CIM-04	92	90	91	355	247	301
CIM-06	94	84	89	364	245	305
CIM-08	98	85	92	468	253	360
CIM-09	93	87	90	411	245	328
CIM-10	92	81	87	393	254	323
CIM-11	103	85	94	469	259	364
CIM-12	90	86	88	385	250	317
CIM-13	92	87	89	429	251	340
CIM-16	95	86	90	468	244	356
CIM-19	93	85	89	425	254	340
CIM-20	94	82	88	313	244	278
CIM-21	94	84	89	338	249	294
CIM-23	100	87	93	355	250	303
Wadan-17	92	88	90	446	239	342
Mean	94	85	90	397	248	323
LSD (0.05)	5.2	3.4	2.32	27.4	14.2	2.45

Wadan-17: Local Check, IR: Irrigated, RF: Rain fed, LSD at 5%

Table 4: Means for spike length and spikelets spike^{-1} of 15 wheat genotypes evaluated across two environments at The University of Agriculture, Peshawar during 2021-22.

	Spike length (cm)			Spikelets spike^{-1}		
Genotypes	**IR**	**RF**	**MEAN**	**IR**	**RF**	**MEAN**
CIM-01	12	11	11	22	19	21
CIM-04	12	11	11	21	20	21
CIM-06	13	11	12	22	19	20
CIM-08	12	11	11	21	18	19
CIM-09	11	11	11	21	19	20
CIM-10	13	11	12	23	20	21
CIM-11	14	12	13	23	19	21
CIM-12	12	11	12	21	18	19
CIM-13	12	11	12	22	18	20
CIM-16	12	12	12	21	17	19
CIM-19	11	11	11	21	16	18
CIM-20	11	11	11	21	20	20
CIM-21	11	11	11	21	17	19
CIM-23	12	12	12	21	18	19
Wadan-17	11	11	11	21	18	19
Mean	12	11	12	21	18	20
LSD (0.05)	0.9	0.7	0.39	1.9	1.8	0.48

Wadan-17: Local Check, IR: Irrigated, RF: Rain fed, LSD at 5%

Table 5: Means for grains spike^{-1} and grain weight spike^{-1} of 15 wheat genotypes evaluated across two environments at The University of Agriculture, Peshawar during 2021-22.

	Grains spike^{-1}			Grain weight spike^{-1} (g)		
Genotypes	**IR**	**RF**	**MEAN**	**IR**	**RF**	**MEAN**
CIM-01	52	41	47	2.26	1.43	1.84
CIM-04	47	42	45	2.10	1.79	1.95
CIM-06	50	39	44	1.93	1.77	1.85
CIM-08	50	47	48	2.18	1.94	2.06
CIM-09	42	40	41	2.10	1.91	2.01
CIM-10	55	43	49	2.32	1.65	1.98
CIM-11	52	41	46	2.30	1.28	1.79
CIM-12	50	41	46	2.35	1.85	2.10
CIM-13	50	46	48	2.54	2.17	2.35
CIM-16	57	43	50	2.35	1.29	1.82
CIM-19	56	40	48	2.11	1.44	1.78
CIM-20	56	50	53	1.70	1.78	1.74
CIM-21	57	34	46	2.44	1.03	1.74
CIM-23	52	40	46	2.64	1.85	2.24
Wadan-17	57	51	54	2.43	2.01	2.22
Mean	52	43	47	2.25	1.68	1.96
LSD (0.05)	3.1	2.4	0.54	0.5	0.6	0.38

Wadan-17: Local Check, IR: Irrigated, RF: Rain fed, LSD at 5%

Table 6: Means for 1000 grain weight and biological yield of 15 wheat genotypes evaluated across two environments at The University of Agriculture, Peshawar during 2021-22.

	1000 grain weight (g)			Biological yield (kg ha^{-1})		
Genotypes	**IR**	**RF**	**MEAN**	**IR**	**RF**	**MEAN**
CIM-01	54	55	55	11917	9480	10698
CIM-04	49	51	50	13417	10483	11950
CIM-06	49	50	50	12417	10433	11425
CIM-08	51	52	51	12583	10217	11400
CIM-09	51	51	51	13667	9583	11625
CIM-10	49	54	51	14167	9400	11783
CIM-11	49	50	50	14667	9517	12092
CIM-12	49	54	52	15383	9733	12558
CIM-13	49	50	50	12833	10183	12625
CIM-16	51	54	52	15300	8900	11508
CIM-19	50	49	50	14667	9267	12100
CIM-20	53	53	53	14833	8967	11967
CIM-21	50	53	53	13500	8733	11900
CIM-23	54	49	51	13633	10633	11117
Wadan-17	53	53	52	15267	9417	12342
Mean	51	52	53	13883	9663	11773
LSD (0.05)	2.7	1.7	0.47	1084.2	1106.2	189.31

Wadan-17: Local Check, IR: Irrigated, RF: Rain fed, LSD at 5%

Table 7: Means for grain yield and harvest index of 30 wheat genotypes evaluated across two environments at The University of Agriculture, Peshawar during 2021-22.

	Grain yield (kg ha^{-1})			Harvest Index (%)		
Genotypes	**IR**	**RF**	**MEAN**	**IR**	**RF**	**MEAN**
CIM-01	4083	3333	3708	34	35	35
CIM-04	5233	3667	4450	39	35	37
CIM-06	5583	4433	5008	45	43	44
CIM-08	5500	3517	4508	44	34	39
CIM-09	5433	3933	4683	40	41	40
CIM-10	5550	4050	4800	39	43	41
CIM-11	5800	3917	4858	40	41	40
CIM-12	4900	3672	4286	32	38	35
CIM-13	5583	4017	4800	43	40	41
CIM-16	5583	3967	4775	37	45	41
CIM-19	5467	3733	4600	37	40	39
CIM-20	6100	4067	5083	41	45	43
CIM-21	5417	3533	4475	40	40	40
CIM-23	6317	4050	5183	46	38	42
Wadan-17	4967	3950	4458	33	42	37
Mean	5434	3856	4645	39	40	40
LSD (0.05)	802.7	752.9	128.79	6.7	8.4	1.48

Wadan-17: Local Check, IR: Irrigated, RF: Rain fed, LSD at 5%

Conclusions and recommendations

Analysis of variance disclosed significant genotype by environment interaction for majority traits except spike length, spikelets weight spike^{-1}. More rainfall during crucial stages could help meet the crop's water need. Low rainfall throughout the cropping season contributed to significant G × E interaction for most of the traits. Wheat genotypes CIM-10 appeared as early heading genotypes hence these genotypes can be utilized to develop early maturing varieties in future to avoid high temperature stresses and disease outbreak. Based on performance, wheat genotype CIM-23 in irrigated and CIM-06 was found superior for grain yield in rainfed environmental conditions. Hence these genotypes should be given preference in further breeding programs for development of high-yielding wheat variety.

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