GENETIC IMPROVEMENT IN YIELD RELATED TRAITS OF WHEAT UNDER IRRIGATED AND RAINFED CONDITIONS

Hamid Ullah Khan[1]. Aizaz akbar[2]. Aftab Jehan[3]. Shahab Ahmad. Sultan Akbar Jadoon[1]. Muhammad Anas[1]. Zohaib Khan. Hamza Jamil. Waseem Ullah Shah. Shehryar Khan. Hakim Ullah. Muhammad Ikram. Muhammad Ilyas. Maaz Khan. Saima

Department of Plant Breeding and Genetics. The University of Agriculture Peshawar Pakistan.

Department of Entomology. The University of Agriculture Peshawar Pakistan.

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 except spike length, spikelet's spike^{-1} and grain weight spike^{-1}. Performance of wheat genotypes ranged from 115 to 124 days for days to headings, 154 to 158 days for days to maturity, 85.98 to 88.95 cm for plant height, 268 to 363 for spikes meter^{-2}, 11.25 to 12.65 cm for spike length, 19.70 to 21.05 for spikelet's spike^{-1}, 39.68 to 50.30 for grains spike^{-1}, 1.34 to 2.19 g for grain weight spike^{-1}, 49.24 to 54.40 g for 1000-grain weight, 9792 to 12783 kg ha^{-1} for biological yield, 3183 to 5025 kg ha^{-1} for grain yield and 30.37 to 42.35% for harvest index across both environments. Best performing genotypes were CIM-21 for days to headings, CIM-10, CIM-13, CIM-20, CIM-21 and CIM-23 for days to maturity, CIM-21 for plant height, CIM-23 for spikes m^{-2}, CIM-09 for spike length, CIM-20 and CIM-21 for spikelet's spike^{-1}, CIM-12 for grains spike^{-1}, CIM-01 for grain weight spike^{-1}, CIM-13 for 1000-grain weight, CIM-01 for biological yield, CIM-01 for grain yield, CIM-08 harvest index under irrigated and rainfed environments, respectively. These results suggested that selection could be delayed to later generations. Wheat genotype CIM-08 was found superior for grain yield and is recommended for irrigated as well as rainfed environmental conditions.

Keywords: Bread wheat (*Triticum aestivum*), rain-fed and irrigated conditions, genetic improvement, SAS analysis,

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 conditions also estimate heritability and genetic gain for grain yield and its components traits across two environments and identify stable wheat genotypes for the two tested environments.

Methodology

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 15 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.

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

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

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

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

12. Harvest index (%)

Harvest index was calculated using the following formula.

Harvest index (%) = (Grain yield plot^{-1}/ Biological yield plot^{-1}) × 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 115 to 124 days with an average of 119 days where genotype CIM-12 took minimum days to reach 50% headings while maximum days were recorded for genotype CIM-21 (Table 2). Similarly, heading days ranged from 118 to 124 days with an average of 122 days under irrigated and 112 to 126 days with an average of 116 days under rainfed environment. CIM-12 appeared as early heading genotype under irrigated as well as rainfed environments while maximum days to headings were taken by genotype CIM-01, CIM-06, CIM-20 and Khaista-17 under irrigated and CIM-21 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, environment and genotype by environment interaction (Table 1). These results depicted that genotypes remained stable across two studied environments. The reason behind similar performance of genotypes could be the result of change in weather as well as enhanced amount of rain fall. Overall mean for days to maturity ranged from 154 to 158 days with an average of 157 days across both studied environments. Wheat genotypes CIM-08 took minimum days to reach physiological maturity while maximum days were recorded for genotype CIM-10, CIM-13, CIM-20, CIM-21 and CIM-23 (Table 2). Similarly, mean performance of wheat genotypes ranged from 158 to 164 days with an average of 161 days under irrigated condition while 150 to 155 days with an average of 152 days under rainfed condition. Maximum days to maturity were recorded for genotype CIM-11 while minimum days were taken by genotype CIM-08 under irrigated condition. Likewise, genotype CIM-21 took maximum days to maturity while minimum days were exhibited by genotypes CIM-06 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 in 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 significant variations among genotype by environment interaction (Table 1). Significant differences for G × E interaction indicated varied performance of wheat genotypes across both irrigated and rainfed environments. Mean for plant height ranged from 85.98 to 88.95 cm with an average of 88.17 cm across two environments. Maximum height was depicted by genotype CIM-11 and Khaista-17 while minimum plant height was recorded for CIM-20 (Table 3). Likewise, mean of wheat genotypes ranged from 88.70 to 98.00 cm with an average of 94.22 cm under irrigated environment. Minimum plant height was attributed to genotype CIM-19 while maximum to wheat genotype Khaista-17. Similarly, mean performance of genotypes ranged from 76.80 to 86.50 cm with an average height of 82.12 cm under rainfed environment. Maximum plant height was measured for genotype CIM-19 while minimum plant height was taken by genotype CIM-06 (Table

3). Plant height play 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 286 to 363 with an average of 333.51 across two tested conditions. Similarly, mean values for spikes meter^{-2} ranged from 321 to 494 with an average of 416.86 and 231 to 259 with an average of 250.16 under irrigated and rainfed conditions, respectively (Table 3). Minimum spikes meter^{-2} were exhibited by genotype CIM-10 under irrigated as well as across environments whereas CIM-23 recorded minimum spikes meter^{-2} under rainfed condition. Moreover, maximum spikes meter^{-2} were noted for genotype CIM-23 under irrigated and across environments while for CIM-13 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 breeder 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 11.25 to 12.65 cm with an average of 11.89 cm across two environments.

Likewise, mean values for spike length ranged from 11.40 to 13.30 cm with an average length of 12.35 cm under irrigated whereas 10.50 to 12.30 cm with an average of 11.43 cm under rainfed environment (Table 4). Maximum spike length was recorded for wheat genotype CIM-01 under irrigated and across environments whereas CIM-09 under rainfed environment. Minimum spike length was measured for genotype Khaista-17 under irrigated, CIM-20 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 spikelets 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 non-significant variations for genotypes, and environment as well as genotype by environment interaction (Table 1). Means of wheat genotypes for spikelet's spike^{-1} ranged from 19.70 to 21.05 with an average of 19.8 across irrigated and rainfed environments. Likewise, mean for spikelet's spike^{-1} ranged from 20.70 to 22.50 with an average of 21.64 under irrigated environment and 17.50 to 20.00 with an overall mean value of 19.03 under rainfed environment, respectively. Minimum spikelet's spike^{-1} were produced by genotype CIM-11 under irrigated, whereas CIM-12 under rainfed environment while maximum spikelets spike^{-1} were recorder for genotype CIM-08 under irrigated, CIM-09 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 39.68 to 50.30 with an average of 45.54

across both environmental conditions, 42.55 to 60.25 with an average of 49.65 under irrigated condition and 33.70 to 48.90 with an overall mean of 41.43 under rainfed condition (Table 5). Minimum grains spike^{-1} was recorded in CIM-06 under irrigated environment whereas CIM-10 exhibited maximum grains spike^{-1} under rainfed environment. Moreover, maximum grains spike^{-1} were obtained for genotypes CIM-10 and CIM-23 under irrigated and 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 more 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 1.34 to 2.19 g with an overall mean value of 1.83 g across studied environments. Likewise, mean performance of wheat genotypes ranged from 1.58 to 2.39 g with an average of 2.08 g under irrigated and 0.96 to 2.13 g with an average of 1.57 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-21 under irrigated condition. However, maximum grain weight spike^{-1} was expressed by genotype CIM-09 while minimum by genotype CIM-06 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 49.24 to 54.40 g with an overall mean weight of 52.72 g across both environments. Similarly, means of wheat genotypes ranged from 48.18 to 56.93 g with an average of 53.37 g under irrigated condition and 48.88 to 54.45 g with an average value of 52.06 g under rainfed condition (Table 6). Maximum 1000-grain weight was exhibited by wheat genotype CIM-23 under irrigated environment whereas CIM-13 obtained maximum 1000-grain weight under rainfed condition. However, minimum value was recorded for genotype CIM-10 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). Thousand grain weight 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 9792 to 12783 kg ha^{-1} with an overall mean of 11586.7 kg ha^{-1} across two environments, 10833 to 15000 kg ha^{-1} with an average of 13341.1 kg ha^{-1} under irrigated condition and 8433 to 11317 kg ha^{-1} with an average biological yield of 9832.22 kg ha^{-1} under rainfed condition (Table 6 and Figure 1). Maximum biological yield was produced by wheat genotypes Khaista-17 under irrigated environmental conditions whereas genotype CIM-19 attained maximum biological yield under rainfed conditions. Similarly, minimum biological yield was recoded for genotype CIM-19 under irrigated and CIM-20 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 3183 to 5025 kg ha^{-1} with an overall mean of 4460.44 kg ha^{-1}. Likewise, means of wheat genotypes ranged from 3350 to 6000 kg ha^{-1} with an average of 5235 kg ha^{-1} and 3017 to 4167 kg ha^{-1} with an average of 3685.89 kg ha^{-1} under irrigated and rainfed conditions, respectively. Maximum grain yield was recorded for wheat genotype CIM-06 and Khaista-17 while minimum for genotype CIM-21 under irrigated environment. Genotypes CIM-11 recorded maximum grain yield under rainfed conditions, whereas wheat genotype CIM-21 exhibited minimum grain yield under rainfed conditions (Table 8 and Figure 2). Grain yield is 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 to enhance 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 due to fact that harvest index is less affected by growing conditions. Means for harvest index across environments ranged from 30.37 to 42.35% with an overall average value of 38.49%. Means of wheat genotypes ranged from 28.68 to 47.52% with an average of 39.32% under irrigated condition. Similarly, means of studied genotypes ranged from 32.05 to 43.06% with an average of 37.66% under rainfed condition. Maximum harvest index was recorded for genotypes CIM-04 and CIM-11 under irrigated and rainfed environments, respectively whereas minimum for harvest index was recorded for wheat genotype CIM-21 under irrigated and CIM-11 rainfed environments (Table 7). Harvest index measures the ability of total dry matter to be converted into economic yields (Akhtar *et al.,* 2001). 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 are 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	540**	0.5 NS	262.6**	171**	39.5	1.0
Days to maturity	1372.8**	2.8 NS	9.0**	171**	2.3	1.0
Plant height	2196.1 NS	113.6 **	4.3 NS	24.7**	7.8	3.2
Spikes meter^{-2}	416817.5 NS	7551.8 **	1727.3**	1877.9**	40.5	1.9
Spike length	12.5 NS	0.7 NS	0.8 NS	0.3 NS	0.7	6.8
Spikelets spike^{-1}	101.9 NS	1.2 NS	1.0 NS	0.7 NS	1.0	4.9
Grains spike^{-1}	1011.9 NS	7.9 NS	36.5**	64.8**	1.3	2.5
Grain weight spike^{-1}	3.9 NS	0.4 **	0.3 NS	0.1 NS	0.5	38.5
1000-grain weight	25.7 NS	1.0 **	9.0**	10.5**	1.4	2.3
Biological yield	184684518.5 NS	3456074.1 NS	2695309.4 **	2334798.6 **	165512.5	3.5
Grain yield	35996178.5NS	1797360.7 **	1331610.7**	427001.9**	49902.0	5.0
Harvest index	41.3 NS	238.8 **	40.4**	38.2**	9.5	8.0

**: highly significant, NS: non-significant

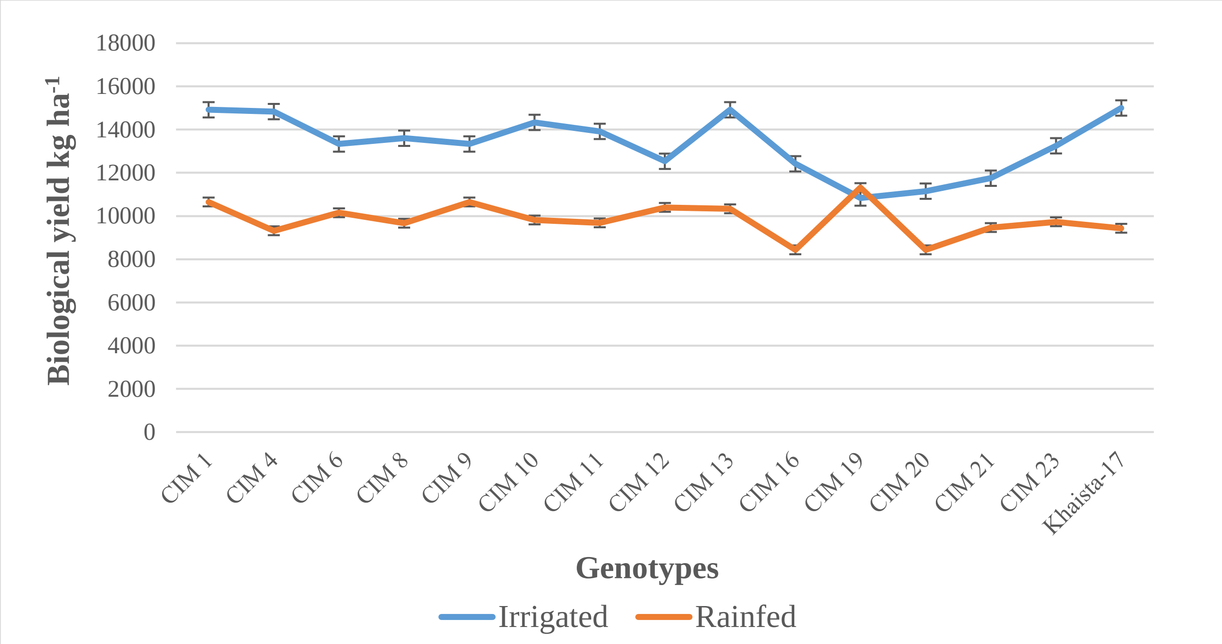

Figure 1: Biological yield kg ha^{-1} of 15 genotypes evaluated under Irrigated and Rain fed environment at The University of Agriculture, Peshawar during 2021-22 cropping season.

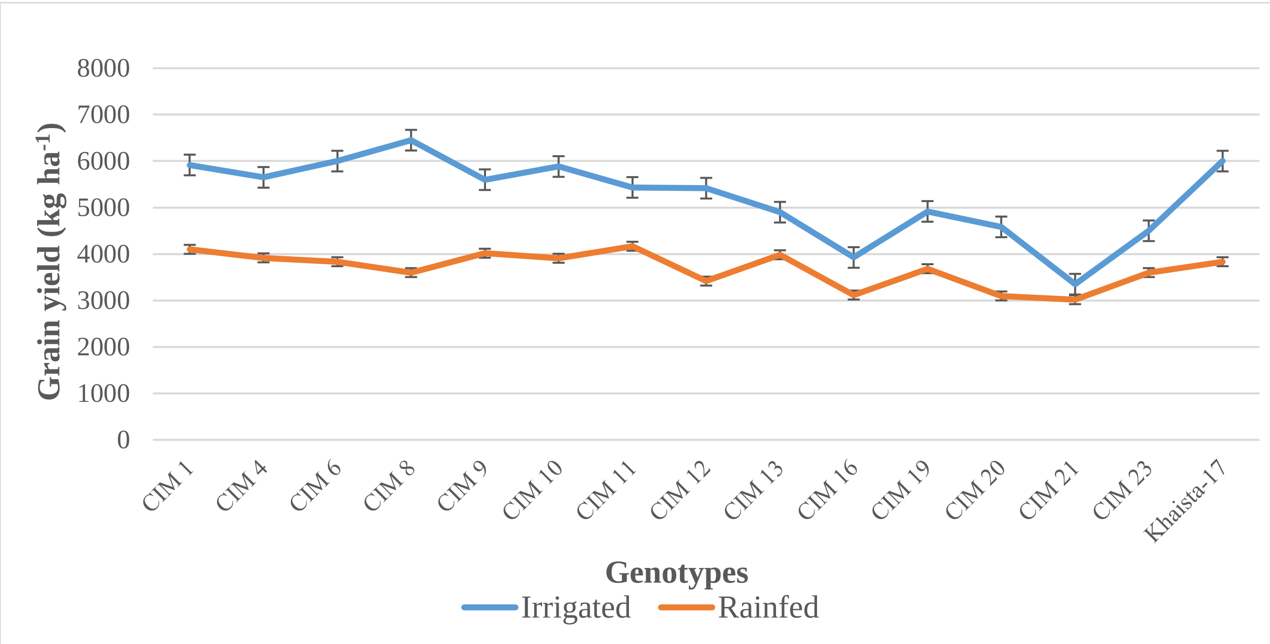

Figure 2: Grain yield kg ha^{-1} of 15 genotypes evaluated under Irrigated and Rain fed environment at The University of Agriculture, Peshawar during 2021-22 cropping season.

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

	Days to 50% heading			Days to maturity		
Genotypes	**IR**	**RF**	**MEAN**	**IR**	**RF**	**MEAN**
CIM-01	124	115	120	160	152	156
CIM-04	122	116	119	162	152	157
CIM-06	124	116	120	159	150	155
CIM-08	123	117	120	158	151	154
CIM-09	122	113	117	161	151	156
CIM-10	122	117	119	163	153	158
CIM-11	121	112	117	164	151	157
CIM-12	119	112	115	161	152	156
CIM-13	122	121	121	163	154	158
CIM-16	120	115	117	160	153	156
CIM-19	122	118	120	159	151	155
CIM-20	124	118	121	162	154	158
CIM-21	123	126	124	162	155	158
CIM-23	122	116	119	163	153	158
Khaista-17	124	116	120	162	153	157
Mean	122	116	119	161	152	157
LSD (0.05)	4.1	2.9	2.50	4.4	4.2	3.28

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	96.80	80.05	88.43	466	249	358
CIM-04	94.70	81.00	87.85	387	240	313
CIM-06	97.20	76.80	87.00	442	246	344
CIM-08	95.40	81.65	88.53	448	252	350
CIM-09	97.10	80.45	88.78	388	255	322
CIM-10	91.40	85.75	88.58	321	251	286
CIM-11	95.80	82.10	88.95	433	257	345
CIM-12	95.30	83.45	89.38	442	247	344
CIM-13	92.50	81.80	87.15	403	259	331
CIM-16	90.80	83.75	87.28	429	249	339
CIM-19	88.70	86.50	87.60	412	248	330
CIM-20	92.60	79.35	85.98	388	255	321
CIM-21	94.00	85.85	89.93	376	248	312
CIM-23	93.10	83.50	88.30	494	231	363
Khaista-17	98.00	79.90	88.95	424	255	340
Mean	94.22	82.12	88.17	416.86	250.16	333.51
LSD (0.05)	5.2	8.4	6.00	18.02	19.05	13.65

Khaista-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	13.30	11.50	12.40	22.10	19.30	20.70
CIM-04	12.10	11.40	11.75	21.40	18.70	20.05
CIM-06	12.90	11.40	12.15	21.70	18.40	20.05
CIM-08	12.10	11.20	11.65	22.50	19.50	21.00
CIM-09	13.00	12.30	12.65	21.70	20.00	20.85
CIM-10	12.60	12.20	12.40	21.70	19.70	20.70
CIM-11	11.90	11.20	11.55	20.70	19.70	20.20
CIM-12	12.60	11.40	12.00	22.20	17.50	19.85
CIM-13	12.10	11.10	11.60	20.90	18.50	19.70
CIM-16	12.90	11.50	12.20	21.70	18.70	20.20
CIM-19	11.90	10.70	11.30	21.20	18.60	19.90
CIM-20	12.00	10.50	11.25	22.20	19.90	21.05
CIM-21	12.10	11.90	12.00	22.40	19.70	21.05
CIM-23	12.30	12.00	12.15	21.20	18.80	20.00
Khaista-17	11.40	11.30	11.35	21.10	18.50	19.80
Mean	12.35	11.43	11.89	21.64	19.03	19.8
LSD (0.05)	1.1	1.03	1.74	1.4	2.2	2.12

Khaista-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	44.20	48.25	46.23	2.31	2.06	2.19
CIM-04	43.75	40.85	42.30	2.33	1.96	2.14
CIM-06	42.55	36.80	39.68	1.71	0.96	1.34
CIM-08	58.05	37.45	47.75	2.27	1.99	2.13
CIM-09	45.15	39.80	42.48	1.80	2.13	1.97
CIM-10	60.25	33.70	46.98	1.69	1.49	1.59
CIM-11	56.75	40.65	48.70	2.37	1.35	1.86
CIM-12	56.55	44.05	50.30	2.26	1.58	1.92
CIM-13	50.70	44.10	47.40	2.18	1.54	1.86
CIM-16	45.15	42.50	43.83	2.22	1.76	1.99
CIM-19	48.55	41.85	45.20	2.27	1.45	1.86
CIM-20	44.40	40.65	42.53	1.87	1.06	1.46
CIM-21	53.05	40.65	46.85	1.58	1.18	1.38
CIM-23	49.40	48.90	49.15	2.39	1.56	1.98
Khaista-17	46.25	41.35	43.80	2.06	1.56	1.81
Mean	49.65	41.43	45.54	2.08	1.57	1.83

LSD (0.05)	5.7	2.7	2.41	0.5	0.4	1.51

Khaista-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	53.15	49.94	51.55	14917	10650	12783
CIM-04	55.58	50.28	52.93	14833	9317	12075
CIM-06	54.55	53.03	53.79	13333	10150	11742
CIM-08	53.25	51.63	52.44	13600	9667	11633
CIM-09	52.18	53.40	52.79	13333	10650	11992
CIM-10	48.18	50.30	49.24	14333	9817	12075
CIM-11	50.90	54.14	52.52	13917	9683	11800
CIM-12	48.65	51.85	50.25	12533	10400	11467
CIM-13	54.35	54.45	54.40	14917	10333	12625
CIM-16	55.65	51.75	53.70	12417	8433	10425
CIM-19	54.32	49.67	52.00	10833	11317	11075
CIM-20	54.63	54.15	54.39	11150	8433	9792
CIM-21	53.98	53.15	53.56	11750	9467	10608
CIM-23	56.93	48.88	52.90	13250	9733	11492
Khaista-17	54.38	54.40	54.39	15000	9433	12217
Mean	53.37	52.06	52.72	13341.1	9832.22	11586.7
LSD (0.05)	2.6	3.0	2.55	1121.4	1255.8	872.57

Khaista-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	5917	4100	5008	39.70	38.56	39.13
CIM-04	5650	3917	4783	38.10	42.02	40.06
CIM-06	6000	3833	4917	45.04	38.02	41.53
CIM-08	6450	3600	5025	47.52	37.17	42.35
CIM-09	5600	4017	4808	42.05	37.86	39.96
CIM-10	5883	3908	4896	41.00	40.04	40.52
CIM-11	5433	4167	4800	39.13	43.06	41.09
CIM-12	5417	3417	4417	43.31	33.01	38.16
CIM-13	4900	3983	4442	33.22	38.82	36.02
CIM-16	3925	3117	3521	31.59	36.94	34.26
CIM-19	4917	3683	4300	45.24	32.51	38.88
CIM-20	4583	3097	3840	41.11	36.70	38.90
CIM-21	3350	3017	3183	28.68	32.05	30.37
CIM-23	4500	3600	4050	34.18	37.37	35.77
Khaista-17	6000	3833	4917	40.00	40.84	40.42
Mean	5235	3685.89	4460.44	39.32	37.66	38.49
LSD (0.05)	1033.3	689.6	479.12	7.6	9.3	6.60

Khaista-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 to meet water need of the crop. Low rainfall throughout the cropping season contributed to significant G × E interaction for most of the traits. Wheat genotypes CIM-12, CIM-16 and CIM-11 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-06 was found superior for grain yield across two tested environmental conditions. Hence this genotype should be given preference in further breeding programs for development of high yielding wheat variety.

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AUTHORS

First author: Hamid Ullah Khan. Ms. Department of Plant Breeding and Genetics. The University of Agriculture Peshawar Pakistan.

Aizaz Akbar Ms. Department of Plant Breeding and Genetics. The University of Agriculture Peshawar Pakistan.

Aftab jehan Ms. Department of Plant Breeding and Genetics. The University of Agriculture Peshawar Pakistan.

Shahab Ahmad. Ph.D. North Dakota state University USA.

Sultan Akbar Jadoon. Assistant Professor. Department of Plant Breeding and Genetics. The University of Agriculture Peshawar Pakistan.

Muhammad Anas. Ms. Department of Plant Breeding and Genetics. The University of Agriculture Peshawar Pakistan.

Zohaib Khan. Ms. Department of Plant Breeding and Genetics. The University of Agriculture Peshawar Pakistan.

Hamza Jamil. Ms. Department of Entomology. The University of Agriculture Peshawar Pakistan.

Waseem Ullah Shah. Ms. Department of Plant Breeding and Genetics. The University of Agriculture Peshawar Pakistan.

Shehryar Khan. Bs. Department of Plant Breeding and Genetics. The University of Agriculture Peshawar Pakistan.

Hakim Ullah. Ms. Department of Plant Breeding and Genetics. The University of Agriculture Peshawar Pakistan.

Muhammad Ikram. Bs. Department of Plant Breeding and Genetics. The University of Agriculture Peshawar Pakistan.

Muhammad Ilyas. Bs. Department of Plant Breeding and Genetics. The University of Agriculture Peshawar Pakistan.

Maaz Khan. Ms. Department of Plant Breeding and Genetics. The University of Agriculture Peshawar Pakistan.

Saima. Ms. Department of Agricultural and Biochemistry. The University of Agriculture Peshawar Pakistan.