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Original Research Article

COMPARATIVE CHARACTERIZATION OF WHEAT VARIETIES FOR YIELD AND RELATED TRAITS UNDER DROUGHT STRESS

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Abstract: *This study aims to evaluate the performance of selected wheat varieties under the world's most prevalent and increasing drought conditions and to recommend suitable drought-resistant varieties to the farming community to increase yields even under stressful conditions to meet growing food needs. For this purpose, seven wheat genotypes were grown in sandy loam soil at the experimental field area of the College of Agriculture, Bahauddin Zakariya University, Bahadur sub-campus Layyah, during 2020-21. Data were collected for the number of tillers, spikelets, flag leaf length, plant height, thousand-grain weight, spike length, and grain yield per plant. The results showed variation in the production level of wheat genotypes under control and different drought stress levels. Analysis of variance exhibited highly significant differences for all the seven characters studied. Based on mean performance Fakhar-e-Bhakkar, Gold, and Faisalabad may be top contributors to grain yield. The highest positive correlation indicates a highly significant and positive correlation between all measured morphological parameters of wheat genotypes. Path coefficient analysis recommended maximum positive direct and indirect effects on yield except for spike length. All of the genotypes performed well, even in drought conditions. However, all genotypes have some excellent features producing genetic diversity in germplasm. Therefore, these traits may be helpful for wheat breeding programs in the future.*

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Introduction

Wheat is a significant cereal worldwide and a staple food in many countries, providing more than half the calories and protein for more than one-third of the world's population (Dhakal, 2021). The growing world population has increased the demand for wheat, and it is projected that wheat production will need to increase by 60% by 2050 to feed around 9 billion people (Borisjuk et al., 2019). Over 2,000 plant species have been developed, domesticated, and cultivated throughout history, including cereals, legumes, fruits, and herbs (Ghahremaninejad et al., 2021). Wheat is mainly used as a source of energy (carbohydrates) and is essential as it represents 20-28% of a person's food energy (Shewry and Hey, 2015). It also contains significant amounts of other essential nutrients such as protein, fiber, and other components such as lipids, vitamins, minerals, and phytochemicals that can support healthy eating. It is the second most important food crop in developing countries after rice (Curtis and Halford, 2014). Due to rapid climate change and increasing global food demand, breeding wheat for superior quality, high yield potential, and resistance or tolerance to abiotic and biotic stresses is often necessary (Ladha et al., 2016; Masood et al., 2014ab). In 2020, Pakistan's wheat production was expected to reach 24.95 million tons. Pakistan's wheat production has increased from 6.48 million tons in 1971 to 24.95 million tons in 2020 at an annual growth rate of 3.11%. The global wheat production for the 2019-2020 marketing year is around 765 MMT. This increase of more than 30 million tons compared to the previous campaign. It ranks second in overall productivity but first in arable land (FAO, 2021).

Several factors can affect the productivity of significant crops, but drought is one of the most critical environmental factors affecting crop yield. Drought is divided into four types: agricultural, meteorological, hydrological, and socio-economic drought. Rainfall, river flow, and soil moisture deficiency cause the former. However, the latter is caused by the supply and demand of the region's food, water, and population, leading to migration and target population shortages (Ali et al., 2015; Farooq et al., 2011; Mutafa et al., 2013; Torabi et al., 2020). Harvesting patterns can be affected by the conditional impact of drought. Drought threatens the environment and adversely affects yield in agriculture (Ali et al., 2011; Ali et al., 2016; Ali et al., 2017; Seleiman et al., 2021). It also affects the natural and artificial characteristics of the area, as well as the basic needs of climatic conditions and water scarcity problems. Agriculture is the sector most affected by the onset of the dry season. Drought in agriculture is defined as a decrease in crop profitability due to erratic rainfall, rising temperatures, and other variables that result in decreased soil moisture (Habib-Ur-Rahman et al., 2022). Water scarcity will become a significant global problem by 2025, especially in densely populated areas (Hussain et al., 2020). Abiotic variables such as drought, salinity, and heat stress rather than biotic factors are the primary cause of wheat yield loss (Abhinandan et al., 2018). Water stress is a natural phenomenon that significantly impacts wheat yield. Climate change also plays a role in droughts, which are becoming more frequent and severe worldwide due to rising temperatures and changing rainfall patterns (Ahmed et al., 2020). Furthermore, the frequency and intensity of these events are expected to increase due to global climate change (Farooq et al., 2009). Many studies have shown that wheat is susceptible to osmotic stress, which can lead to yield losses of up to 90%, depending on the genotype, stage of plant growth, intensity, and duration of drought periods (Wang et al., 2020). Drought inhibits the ability of plants to fix carbon by reducing the amount of carbon dioxide entering mesophyll cells (Chaves et al., 2003; Flexas et al., 2004). Reduces the quantity and availability of regenerative ribulose 1, 5-bisphosphate carboxylase/oxygenase (Rubisco), and ribulose bisphosphate (RuBP), which has a direct impact on metabolic activity. In addition, it reduces the production of ATP (Bota et al., 2004). Wheat produces sterile pollen when water becomes scarce during meiosis at the early microspore stage of pollen production, reducing the number of grains produced (Ji et al., 2010). As the origin of wheat, Pakistan has abundant wheat germplasm resources. However, most studies have used commercial wheat cultivars to study or develop their traits, with only a rudimentary understanding of drought tolerance in local cultivars. Therefore, this study aimed to screen several Pakistani wheat germplasm resources using various indicators and select different drought-tolerant and drought-sensitive genotypes for future drought control programs. On the other hand, this field trial aimed to evaluate wheat genotypes' physiological and phenotypic characteristics under water stress conditions to identify the most drought-tolerant wheat genotypes for widespread adoption in the region.

Material and method

Plant material

Table ***1***). Plant height was taken in centimeters with the help of measuring tape. Table 1 shows that the

The experiment was conducted at the experimental field area of Bahauddin Zakariya University, Bahadur Sub-Campus, District Layyah, Punjab, Pakistan (30.90^{O} N and 70.96^{O} E) in 2021. The soil texture was sandy loam, and the soil pH was around 8. The soil structure was sand 61.4%, silt 21.3%, clay 16.3%, and bulk density 1.28 gcm^{-3}. Seven cultivars of wheat were selected for the experiment (Faisalabad, Gold, Anaj, Fakher-e-Bhakar, Miraj-2008, Syn-50, and As-2002).

Experimental design and treatments

The experiment was conducted as a randomized complete block design with three blocks and three replications in each block. Each replication has an area of about 24.34 ft^2. The row-to-row distance was kept at 20cm. As the experiment was divided into three blocks, the first block remained under normal conditions, and the second was treated with drought stress at tillering stage. The third was treated with drought at the booting stage. Plant production and safety precautions were implemented.

Data collection

Data were collected from each plant in the field. The number of tillers, spikelets, plant height, flag leaf lengths, and spike length were manually measured from each wheat plant in the experimental field area. These parameters were taken in centimeters (cm), including the roots. 1000-grain weight was taken in grams (g) on an electronic weighing balance, and the following formula found yield:

Yield per plant = grain weight per plant x *number of spikelets per plant*

The collected data were examined for statistical analysis of the measured parameters. Microsoft Excel 2016 was used to find the correlation between different traits and path analysis to find the direct and indirect effects of different traits on yield, while Statistix 8.1 was used for the analysis of variance (ANOVA) and probability values at 5%, which helped to find out the significance of data.

Results and discussion

It is difficult to distinguish the wheat varieties from their physical appearance. The results were obtained from different morphological parameters taken during the experimentation. Wheat production is low under drought conditions, but some varieties performed well under drought conditions compared to others. For the number of tillers, the results indicated that all varieties performed well under normal conditions, but the variety that contained most tillers under drought stress was Fakhar-e-Bhakkar and Miraj-2008 (3.56 and 3.44 avg tillers, respectively). For the number of spikelets, most spikelets were found in Fakhar-e-Bhakkar and Gold (16.44 and 13.67 avg spikelets, respectively) under drought stress (

best-performing varieties under drought stress in terms of plant height were Fakhar-e-Bhakkar and

Miraj-2008 (69.89 cm and 67.44 cm). Regarding flag leaf length, the best-performing varieties under drought stress were Fakhar-e-Bhakkar and Gold (11.5 cm and 10.89 cm). The results indicated that the best-performing variety under drought stress for spike length was Fakhar-e-Bhakkar and Anaj (13 cm and 11.3 cm, respectively). 1000-grain weight was taken in grams (g) with the help of weighing balance. The results showed that the best-performing varieties under drought stress were Fakhar-e-Bhakkar and Faisalabad (261 g and 230 g, respectively). The yield was the main focus object of the study and was measured by the product of grain weight/plant and the number of spikelet/plants. The results showed that the best-yielding variety under drought stress was Fakhar-e-Bhakkar, Gold, and Faisalabad (13.5g, 12.2g, and 11.5g per plant, respectively), as shown in Table ***1***.

Table 1. Mean comparison of different morphological traits of wheat

Genotypes	Treatments	Not	Nos	P.H	F.L	S.L	G.W	Yield/plant
V1	Control	4.33^{bc}	17.89^{bcd}	77.44^{bcd}	15.33^{cde}	14.5^{cde}	485^{a}	16.5^{cd}
V1	T1	3.67^{cd}	16.11^{ef}	71.56^{efg}	13.33^{fg}	12.8^{ghi}	286.6^{fg}	14^{ef}
V1	T2	2.61^{fg}	13.22^{h}	64^{hi}	9.33^{jk}	9^{mn}	230^{hij}	11.6^{h}
V2	Control	4.23^{bc}	17.00^{cde}	80.05^{bc}	15.83^{cde}	15.2^{bcd}	283.3^{fgh}	19^{ab}
V2	T1	2.67^{fg}	15.11^{fg}	76.22^{cde}	14.72^{def}	11.5^{jkl}	246.7^{ghi}	15.4^{de}
V2	T2	2.05^{h}	13.67^{h}	63.11^{hi}	10.89^{hi}	10.3^{lm}	180^{jk}	12.2^{gh}
V3	Control	3.67^{cd}	18.56^{bc}	67.33^{gh}	16.72^{bc}	13.9^{def}	504^{a}	15.9^{d}
V3	T1	2.44^{h}	13.33^{h}	61.44^{i}	14.33^{ef}	12.4^{hij}	263.3^{fgh}	12.7^{gh}
V3	T2	2.11^{h}	12.44^{hi}	54.22^{j}	8.67^{jk}	11.3^{kl}	220^{ij}	8.8^{i}
V4	Control	5.67^{a}	20.67^{a}	83.33^{a}	18.17^{ab}	16.6^{a}	494.3^{a}	19.9^{a}
V4	T1	5.00^{ab}	17.99^{bcd}	77.22^{cd}	14.72^{def}	15^{bcd}	352^{de}	18.3^{ab}
V4	T2	3.56^{cd}	16.44^{cde}	69.89^{fg}	11.5^{gh}	13^{f-i}	261^{fgh}	13.6^{fg}
V5	Control	4.33^{bc}	18.44^{bcd}	82.44^{ab}	16.78^{bc}	14.2^{cde}	430.3^{b}	18^{bc}
V5	T1	3.67^{cd}	16.33^{def}	74^{def}	11.48^{gh}	12^{ijk}	314.3^{ef}	13.7^{fg}
V5	T2	3.44^{de}	12.33^{hi}	67.44^{gh}	9.22^{jk}	11.2^{kl}	181^{jk}	9.7^{i}
V6	Control	3.78^{cd}	18.56^{bc}	80.39^{bc}	18.28^{a}	15.2^{bc}	395^{bcd}	18.7^{ab}
V6	T1	3.56^{cd}	15.00^{fg}	78^{bcd}	9.67^{j}	13.6^{efg}	268^{fgh}	11.9^{h}
V6	T2	2.56^{gh}	13.67^{h}	60.67^{i}	8.22^{k}	8.72^{n}	150^{k}	9^{i}
V7	Control	4.33^{bc}	18.67^{ab}	74^{def}	16.33^{bcd}	16.3^{ab}	414.7^{bc}	18.4^{ab}
V7	T1	3.38^{ef}	13.33^{h}	70.05^{fg}	13^{fg}	13.1^{f-i}	366.6^{cde}	12.1^{gh}
V7	T2	2.50^{h}	10.44^{i}	62.56^{hi}	7.72^{k}	10.6^{l}	153.3^{k}	8.8^{i}

V1; Faisalabad, V2; Gold, V3; Anaj, V4; Fakher-e-Bhakar, V5; Miraj-2008, V6; Syn-50, V7; As-2002, T1; drought at tillering stage, T2; drought at booting stage, Not; number of tillers, Nos; number of spikelet, F.L; flag leaf length, P.H; plant height, G.W; 1000-grain weight; S.L; spike length

Correlation

Correlation is an important term in plant breeding that tells about the relationship (either positive or negative) between two physiological or morphological traits. Correlation analysis is also used to find the significant differences between two traits. According to Table ***2***, the correlation analysis indicated that yield per plant has the highest positively correlated with flag leaf length (0.921) and spike length (0.843). At the same time, all the other traits were highly significant and positively correlated.

Table 2. Correlation analysis for different tarits of wheat under drought stress conditions

Traits	F.L	G.W	Nos	Not	P.H	S.L
G.W	0.826**					
Nos	0.829**	0.831**				
Not	0.658**	0.731**	0.799**			
P.H	0.698**	0.621**	0.752**	0.787**		
S.L	0.806**	0.783**	0.793**	0.811**	0.743**	
Y/P	0.921**	0.768**	0.891**	0.771**	0.811**	0.843**

**=highly significant, *=significant, F.L: Flag leaf length, G.W: 1000-grain weight, Nos: number of spikelets, Not: numbers of the tiller, P.H: plant height, S.L: spike length, Y/P: yield per plant

Path coefficient analysis

Path analysis is a statistical way to determine the direct and indirect effects of yield-related parameters on crop plant yield. In

Table ***3***, all traits positively affect yield except spike length (-0.237). Similarly, all traits have positive indirect effects on yield except spike length. The number of tillers has the highest direct effect on yield (0.603), and grain weight with the number of tillers has the highest indirect effect on yield.

Table 3. Path coefficient analysis for direct and indirect effects

Traits	G.W	Nos	F.L	S.L	Not	P.H	Y/P
G.W	0.322	0.071	0.082	-0.197	0.500	0.110	0.890
Nos	0.257	0.089	0.084	-0.173	0.397	0.115	0.771
F.L	0.255	0.072	0.103	-0.185	0.487	0.109	0.842
S.L	0.267	0.065	0.081	-0.237	0.498	0.091	0.767
Not	0.267	0.059	0.083	-0.195	0.603	0.102	0.920
P.H	0.242	0.070	0.077	-0.147	0.421	0.147	0.811

Diagonal line; direct effects, F.L; Flag leaf length, G.W; 1000-grain weight, Nos; number of spikelets, Not; number of the tiller, P.H; plant height, S.L; spike length, Y/P; yield per plant

Discussion

This study aims to select some wheat varieties for the most widespread and increasingly severe drought conditions in the world, which are highly beneficial to farmers and for breeding purposes to increase the yield and income of farmers. The early stages of seed germination are susceptible to water stress. Seeds need enough water to germinate. However, when there is a lack of water, the seeds cannot absorb enough water and, therefore, cannot germinate. Water stress reduces turgor pressure, inhibiting cell growth and expansion (Jaleel et al., 2009). Water stress has been reported to negatively affect the yield of cereal components such as grain weight, biomass, and cobs per square meter (Farnia and Tork, 2015). As these are susceptible, water stress significantly reduced wheat yield during the reproduction and grain-filling stages. Flag leaves are an essential source of assimilates during wheat grain development, contributing 30% to 50% of all assimilates in wheat plants (Dhakal, 2021). This is mainly due to a decline in wheat production. Premature senescence is caused by water stress during the grain-filling period, and the grain-filling time can be shortened (Plaut et al., 2004). The above results showed variation among the mean expression of morphological traits such as the number of tillers, spikelet, plant height, flag leaf lengths, spike length, plant weight, and yield per plant. Obsa et al., (2018) found the same results. This suggests considerable diversity in the material selected for this study, which is essential for some breeding programs. The statistical analysis of the data (correlations and path coefficients analysis) can be used as a critical tool to obtain evidence on relevant effects and causal associations between performance and specific performance components (Khan et al., 2019). In this study, yield per plant was significantly and positively correlated with flag leaf length, spike length, and grain weight. Obsa et al. (2018) describe a positive correlation between yield and thousand-grain weight. These results indicated that the yield of the extended spike genotype was higher than that of the short spike genotypes under drought conditions. In comparison, the yield of the genotype with the most considerable 1000-grain weight was higher than that of the low 1000-grain weight genotype. Increased production will also increase food production. Therefore, breeding for these traits will lead to increased crop feed yield.

Conclusion

This experiment showed variation in the production level of wheat genotypes under control and different drought stress levels during the cropping season in 2021. Statistical analysis exhibited highly significant differences for all the seven characters studied and demonstrated the existence of substantial variability amongst wheat genotypes. Based on mean performance Fakhar-e-Bhakkar may serve as a supreme contributor to grain yield. All genotypes perform well under control conditions. Therefore, the traits studied will be useful for developing improved wheat variety in future breeding programs.

Conflict of interest

The authors declared the absence of a conflict of interest.

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