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COMPARATIVE ANALYSIS OF WHEAT (*TRITICUM AESTIVUM* L.) VARIETIES FOR DROUGHT TOLERANCE

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Abstract *This study was designed to evaluate some wheat varieties against the most prevailing and increasing drought conditions worldwide and recommend suitable drought-resistant varieties to the farmer communities so that the yield can be increased even in stressful conditions to meet the increasing demand for food. For this purpose, seven wheat genotypes were grown in the sandy loam soils at the experimental research area of the College of Agriculture, BZU Bahadur sub-campus Layyah, during the wheat season of 2020-2021. Data were collected for plant height, number of tillers per plant, number of spikelets per spike, spike length of mother tiller, thousand grain weight, number of flag leaf sizes and grain yield per plant. In breeding for drought tolerance, grain yield is the idea for selection; however, it's a complicated, late-degree trait tormented by many elements other than drought. An approach that evaluates genotypes for physiological responses to drought at advanced increase ranges can be extra centered to drought and time efficient. Such a method can be enabled through current advances in excessive-throughput phenotyping platforms. In addition, the fulfilment of the latest genomic and molecular techniques depends on the best of phenotypic facts applied to dissect the genetics of complicated developments, including drought tolerance. Therefore, the primary goal of this assessment is to explain the increase-degree primarily based physio-morphological developments that would be centered through breeders to increase drought-tolerant wheat genotypes. The 2nd goal is to explain current advances in excessive throughput phenotyping of drought tolerance associated physio-morphological developments in the main below discipline conditions. We talk about how those techniques may be included in a complete breeding application to mitigate the influences of weather change. The assessment concludes that there may be a need for excessive throughput phenotyping of physio-morphological developments; this is increased degree-primarily basedto enhance the performance of breeding drought-tolerant wheat.*

Keywords*:* *drought tolerance; wheat yield; food security; phenotyping; morphology; physiology*

Introduction

Wheat, scientifically known as *Triticum aestivum* L., is the foremost cereal crop globally, a staple food for most of the world's population (Abhinandan, 2018). Forecasts indicate a 60% surge in wheat consumption by 2050 to meet the needs of an anticipated population of nine billion. This necessitates a remarkable increase in annual global average wheat yields by at least 1.6 percent, a leap from the current 1 percent, as suggested by OECD in 2018. Across history, over 2,000 plant species, including cereals, legumes, fruits, and herbs, have been cultivated, yet only a few, notably wheat, have significantly influenced and intertwined with human existence (Ahmed et al., 2020). The domestication of wheat reshaped civilizations, enabling settled living, fostering scientific advancements, accelerating the development of communities, and forming kingdoms, empires, and modern nations (GhahremaniNejad and Hoseini, 2015). Wheat is significant in human nutrition, contributing to 20 to 28 percent of an individual's dietary energy (Ghahremaninejad et al., 2021). It serves as a crucial global source of nutrition, supporting approximately 4.5 billion people. With fast-paced climate change and heightened global food demands, there's an urgent need for wheat breeding that prioritizes superior quality, higher yield potential, and resilience to both abiotic and biotic stressors (Tubeillo et al., 2016). Pakistan, a crucial center for wheat production with a wealth of wheat germplasm, has seen substantial growth in wheat production (Sallam et al., 2019). Despite being ranked second in overall productivity, the country leads in cultivable land, per FAO's 2021 data. However, various factors, primarily drought, significantly affect wheat productivity (Wang et al., 2020). Water scarcity, expected to become a critical global issue by 2025, poses a substantial challenge, particularly in densely populated regions (Farooq et al., 2011).

Drought, alongside other abiotic factors such as salt and heat stress, remains a leading cause of yield loss in wheat (Crespo et al., 2017). The increasing frequency and severity of droughts globally, attributed to climate change, are affecting wheat cultivation (Hussain et al., 2020). Osmotic stress resulting from drought can lead to significant yield reductions, varying by genotype, growth stage, and the intensity and duration of dry periods (Ladha et al., 2016). The detrimental impact of drought is diverse, affecting crop patterns, agricultural output, and environmental conditions and creating challenges related to water scarcity (Li et al., 2020). Agricultural drought, driven by erratic precipitation and rising temperatures, reduces soil moisture and impacts crop profitability (Curtis and Halford, 2014). Considering Pakistan's rich wheat germplasm, efforts to study drought tolerance mostly involve commercial wheat cultivars, lacking a comprehensive understanding of local cultivar responses to drought (Ahmed et al., 2020). Consequently, ongoing research aims to assess various Pakistani wheat germplasm to identify drought-tolerant genotypes for future initiatives to manage drought stress. Current field experiments evaluate physiological and phenological traits in wheat genotypes under drought stress to pinpoint the region's most resilient varieties for widespread adoption.

Material and Methods

This research experiment was conducted at the experimental field area of Bahauddin Zakariya University, Bahadur Sub-Campus Layyah, Punjab, to analyse the diversity of wheat genotypes under the effect of drought. The soil texture was sandy loam, with a pH of 6.5 to 7.5, a structure of 61.4 percent sand, 21.3 percent silt, and 16.3 percent clay, and a bulk density of 1.28 gcm^{-3}. The climate in the region is subtropical, with warm summers and mild winters, with long-term average rainfall of less than 200mm. The investigation included seven distinct wheat genotypes (Chakwal, Ujala, Johar, Akbar-19, Sehar, Galaxy, and Ghazi). Different drought stress (Control, semi-drought, and Drought) was applied to wheat's tillering and booting stage. The experiment utilized the Randomized Complete Block Design (RCBD) layout in the experimental field area. The experiment was split into three sections, each being reproduced three times with complete randomization. Plant-to-plant spacing was maintained at 15 cm, while row-to-row spacing was maintained at 25 cm. In each block, 5 plants were planted in each row of each replication. Irrigation, plant production, and safety procedures were all followed in the letter.

Block 1	Block 2	Block 3
Rep 1 Control 7 rows 5 plants in each row	Rep 1 Semi drought 7 rows 5 plants in each row	Rep 1 Drought 7 rows 5 plants in each row
Rep 2 Semi drought 7 rows 5 plants in each row	Rep 2 Drought 7 rows 5 plants in each row	Rep 2 Control 7 rows 5 plants in each row
Rep 3 Drought 7 rows 5 plants in each row	Rep 3 Control 7 rows 5 plants in each row	Rep 3 Semi drought 7 rows 5 plants in each row

Randomized Complete Block Design (RCBD)

The following yield-related parameters i.e., Plant height, No. of Tillers, Spike length, Flag leaf size, No. of spikes, Grain weight, and Yield were recorded.

Statistical analysis

Microsoft excel 2016 was used for the graphical representation of data, correlation, and path analysis, while Statistix 8.1 was used to analyse variance (ANOVA) and probability values.

Results and Discussion

The results showed that all varieties are responsive to drought regarding the following parameters. The plant height shows significant differences in the performance of wheat genotypes. Under drought stress, Ghazi has the maximum plant height among all wheat genotypes, followed by Akbar-2019 and Galaxy, while Johar and Sehar have the lowest plant height. The analysis of variance showed significant differences. Different drought conditions have a significant effect on the tiller capacity of plants. Likewise, wheat genotypes Akbar-19, Ghazi, and Galaxy have the highest tillers under drought stress, while the lowest numbers were recorded in Johar and Chakwal. Different drought conditions had a significant effect on the numbers of spikelet of plants. Ghazi, Akbar-19, and Galaxy have the most spikelet under drought conditions, while the least spike was noticed in Sehar. Spike length has significant differences among all genotypes. Results showed that Ghazi, Akbar-19, and Galaxy have the highest spike length, while Johar has the smallest spikes among the seven genotypes under drought stress (Table 1). In wheat, the flag leaf and the ear above it contribute 75% of the final yield. Akbar-19, Ghazi, and Ujala genotypes have the highest flag leaf length under the control condition, while Akbar-19, Ghazi and Sehar performed well under drought stress (Ali et al., 2015; Ali et al., 2016; Ali et al., 2013; Ali et al., 2010ab; Ali et al., 2011; Ali et al., 2014). Galaxy and Ujala have the lowest flag leaf length under drought stress. Different drought stress and wheat genotypes had a significant effect on grain weight. Akbar-19, Ghazi, and Galaxy have the highest grain weight under drought stress, while Johar and Sehar have the lowest grain weight under drought stress. Analyzed data showed that different drought conditions had a significant effect on yield. Wheat sown in control conditions has the highest yield, while Ghazi, Akbar-19, and Sehar were performing well under drought conditions (Asif et al., 2020; Balqees et al., 2020; Ghafoor et al., 2020; Iqbal et al., 2021; Iqra et al., 2020ab; Naveed et al., 2012; Naseem et al., 2020; Waseem et al., 2014; Saeed et al., 2012). The lowest yield was noticed in Johar and Chakwal. Drought affected the morphological characteristics of wheat, causing lower yields (Figure 1).

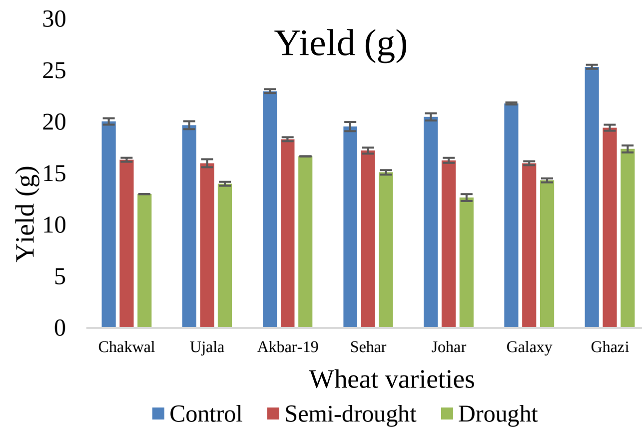

Figure 1. Graphical differences of seven wheat genotypes for Yield

Table 1. Mean comparison of different genotypes

Genotypes	Treatment	Grain weight	No. of Spike	Flag leaf length	Spike length	No. of Tillers	Plant Height	Yield
Chakwal	Control	493.33	13.67	17.00	16.61	3.27	70.67	20.06
Ujala	Control	545.00	13.33	17.78	16.44	3.33	72.67	19.69
Akbar-19	Control	593.33	15.47	18.67	18.22	3.89	78.00	23.00
Sehar	Control	450.00	14.11	16.78	17.22	3.33	71.00	19.56
Johar	Control	556.67	13.78	16.89	16.44	3.33	73.00	20.50
Galaxy	Control	583.33	15.08	16.94	17.11	3.67	75.00	21.81
Ghazi	Control	621.67	16.12	18.22	18.22	4.05	79.00	25.36
Chakwal	T1	366.67	12.33	15.50	15.11	2.83	65.33	16.33
Ujala	T1	393.33	11.56	15.44	15.44	2.94	68.67	16.00
Akbar-19	T1	460.00	13.94	16.78	15.00	3.67	72.67	18.33
Sehar	T1	326.67	12.50	15.22	15.45	3.00	65.33	17.22
Johar	T1	286.67	11.89	15.11	14.28	2.78	64.67	16.28
Galaxy	T1	380.00	13.39	14.78	15.17	3.24	70.67	15.55
Ghazi	T1	440.00	13.67	15.94	15.72	3.61	74.33	19.44
Chakwal	T2	273.33	10.33	13.67	13.22	2.27	61.33	13.00
Ujala	T2	273.33	10.11	13.56	13.44	2.34	62.67	14.00
Akbar-19	T2	320.00	12.50	15.17	13.78	3.11	68.00	16.67
Sehar	T2	180.00	9.27	13.78	13.67	2.47	61.00	15.11
Johar	T2	256.67	10.30	13.67	12.33	2.33	60.67	12.67
Galaxy	T2	293.33	11.00	13.56	14.00	2.70	66.00	13.33
Ghazi	T2	316.67	12.39	14.56	14.67	3.00	69.00	17.39

Correlation Analysis

It is particularly useful in breeding because genotypic and phenotypic correlations establish the influence of environmental factors on characteristics and offer the link between variables, which is extremely useful for directly selecting high-yielding varieties and other key qualities (Aaliya et al., 2016; Ahmad et al., 2012; Ahmad et al., 2021; Ali et al., 2015; Ali et al., 2017).

Yield has a positive and highly significant correlation with grain weight, flag leaf size, spike length, spikelet numbers, tiller, and plant height. Grain weight has a positive and highly significant correlation yield, flag leaf size, spike length, spikelet numbers, tiller, and plant height. Flag leaf size has a positive and highly significant correlation yield, grain weight, spike length, spikelet numbers, tiller, and plant height. Spikelet numbers have a positive and highly significant correlation yield, grain weight, spike length, flag leaf size, numbers of tiller, and plant height. Spike length has a positive and highly significant correlation yield, grain weight, number of spikelets, flag leaf size, number of tiller, and plant height. Numbers of tiller has a positive and highly significant correlation yield, grain weight, numbers of spikelet, flag leaf size, spike length, and plant height. Plant height has a positive and highly significant correlation yield, grain weight, spikelet numbers, flag leaf size, spike length, and tiller numbers (Table 2).

Table 2. Correlation analysis between different qualitative parameters of wheat genotypes

Traits	FLL	GW	NOS	NOT	PH	SL
GW	0.8958**					
NOS	0.8403**	0.8892**				
NOT	0.7509**	0.7973**	0.8476**			
PH	0.7774**	0.8386**	0.8429**	0.8528**		
SL	0.8392**	0.8556**	0.8317**	0.7463**	0.7626**	
Y/P	0.8883**	0.8953**	0.8882**	0.8202**	0.8379**	0.8639**

**=highly significant, FLL: flag leaf length, GW: grain weight, NOS: numbers of spikelet, NOT: numbers of tiller, PH: plant height, SL: spike length, Y/P: yield per plant

Path Analysis

According to Table 3, path coefficient analysis showed that all measured traits' direct and indirect effects positively affect yield.

Table 3. Path coefficient analysis for various traits of wheat

Traits	GW	NOS	FLL	SL	NOT	PH	Yield
GW	0.123	0.175	0.259	0.164	0.076	0.096	0.895
NOS	0.109	0.197	0.243	0.160	0.081	0.096	0.888
FLL	0.110	0.165	0.289	0.161	0.072	0.089	0.888
SL	0.105	0.164	0.242	0.192	0.071	0.087	0.863
NOT	0.098	0.167	0.217	0.143	0.096	0.097	0.820
PH	0.103	0.166	0.225	0.146	0.081	0.114	0.837

Diagonal line: direct effects, FLL: flag leaf length, GW: grain weight, NOS: numbers of spikelet, NOT: numbers of tiller, PH: plant height, SL: spike length, Y/P: yield per plant

Conclusion

The primary aim of the current study was to assess various wheat varieties' performance under prevailing drought conditions worldwide, explicitly focusing on Akbar-19 and Ghazi, which exhibited the highest yields in Layyah's arid region, indicating their potential benefit for farmers and breeding programs aiming to enhance wheat crop yield. The analysis of variance highlighted significant differences among the studied traits, indicating substantial genetic variation among the wheat genotypes, as observed in prior studies. Characteristics such as plant height, tillers per plant, spikelets per spike, spike length, flag leaf size, thousand grain weight, and grain yield showed variability among genotypes, aligning with findings from previous research. Correlation and path coefficient analyses revealed significant positive associations between grain yield and certain yield components, such as spike length and thousand grain weight. This implies that genotypes with longer spikes and higher grain weights tend to yield more. The selection of these traits could potentially boost crop yield. Furthermore, while thousand grain weight displayed significant positive correlations with several yield-related factors, there were varying associations, indicating the diverse relationships among yield components. Ultimately, the study suggested that some wheat genotypes, notably Ghazi and Akbar-19, performed better under drought stress, leading to their designation as drought-tolerant varieties and their inclusion in breeding programs to develop drought-resistant wheat genotypes.

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Declaration

Conflict of interest

There is no conflict of interest among the authors.

Data Availability statement

All authenticated data have been included in the manuscript.

Ethics approval and consent to participate

These aspects are not applicable in this paper.

Consent for publication

Not applicable

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