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Research Article

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EVALUATION OF SPRING WHEAT GENOTYPES UNDER WATER STRESSED CONDITION

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ABSTRACT

Pakistan faces severe challenges in wheat production annually due to the devastating effects of drought stress. Therefore, present research was carried out to evaluate 15 exotic bread wheat genotypes along with the local check variety, Khirman for their performance under drought stress. Analysis of variance revealed that all the traits were significantly different (P<0.01) among the cultivars. Based on mean performance, genotype V-18 showed better performance for all the studied characters, while genotype V-14 showed desirable performance for different traits such as early growth vigor, number of grains spikelet^{-1}, number of grains spike^{-1}, number of spikelets spike^{-1}, spike length, peduncle length, and grain yield plant^{-1}. The local check Khirman also produced desirable values for four different traits, namely early growth vigor, number of grains spike^{-1}, peduncle length, and grain yield plant^{-1}. The cluster analysis divided all the genotypes into three distinct clades. The first cluster comprises V-14, V-18, and the local check Khirman, which performed very well under drought conditions compared to the other genotypes. The presence of these genotypes with the local check Khirman is regarded as indicative of drought-tolerant genotypes. The second cluster comprises nine genotypes, namely V-10, V-11, V-12, V-13, V-16, V-19, V-20, and V-23, which performed moderately compared to the genotypes found in the drought-tolerant cluster. The last cluster comprises four genotypes, namely V-09, V-15, V-17, and V-22, which performed very poorly under drought conditions. Overall, the two exotic lines, V-14 and V-18, which were in the cluster with the drought-tolerant variety Khirman, performed very well and can be considered as drought-tolerant genotypes.

Keywords: Screening, Wheat, Genotypes, Yield, Drought

INTRODUCTION

Drought is a major abiotic stress that affects the growth and yield of all types of agricultural crops. Globally, drought cuts off around 50% of wheat production annually (Regmi *et al.*, 2021). In Pakistan, 20% of the land has very limited water sources. Specifically, in the Balochistan province, which has 34.72 million hectares of land and an irrigated area of about 2.09 million hectares, constituting about 6% of the total land (Mustafa and Qazi, 2018). This water scarcity will impact agricultural productivity in the future and may lead to food shortages. Wheat grains contain more protein among cereals like maize, rice, and/or any other grain crop in the world. It is also an important source of vitamins and minerals and a primary food, used to make flour and other bakery items (Sial *et al.*, 2022). Wheat production stood at 31.4 million tonnes compared to 28.2 million tonnes last year, and a growth of 11.6 was observed in wheat production (GOP, 2024).

Drought is a polygenic stress by nature. It directly affects crop yield, especially in semi-arid and arid regions where there is insufficient rainfall to cultivate crops properly. Wheat is a water-intensive crop and requires five to six irrigations (Rawtiya and Kazaly, 2021). When drought stress occurs during the growth and development phases, it significantly reduces wheat yield. Therefore, drought is a key factor that directly affects the growth and greatly reduces the yield of wheat crops (Poudel *et al.*, 2020). When drought stress occurs during the heading, flowering, or soft dough stages, it leads to a significant reduction in wheat yield. Early season drought stress can result in a 22% decrease in yield, while mid-season drought stress can lead to a 50% reduction. When drought stress occurs during anthesis, yield loss can be high as 72% (Regmi *et al.*, 2021). It has been observed that moderate drought stress during the vegetative phase has minimal to no impact on wheat yield, whereas drought stress during the maturity stage leads to about a 10% decrease in wheat yield (Chowdhury *et al.*, 2021).

Plant breeders primarily focus on developing and screening high-yield cultivars under drought conditions. However, their success has been limited due to the complex genetic mechanisms controlling plant responses and the unpredictable nature of drought

(Ahmed *et al.*, 2022). Considering this, various morphological and physiological traits have been suggested for selecting drought-resistant wheat types. For screening drought-resistant cultivars, several morphological parameters, such as spikelets spike^{-1}, grains spike^{-1}, seed index, grain yield plant^{-1}, and grain yield plot^{-1}, are crucial to study as they contribute to the drought stress tolerance of the wheat plant (Khadka *et al*., 2020). Therefore, the current study was designed to assess the yield potential of 15 new advanced wheat lines under drought conditions compared to a local check.

MATERIALS AND METHODS

The study was conducted at the Nuclear Institute of Agriculture (NIA), Tandojam, during Rabi wheat cropping season 2021-22 to evaluate advanced bread wheat lines for various yield and yield-related traits under drought stress conditions. The genotypes used in this study were received from International Center for Agriculture Research in Dry Areas (ICARDA) (Figure 1). Only a single irrigation was applied at the early seedling stage, with no additional water provided throughout its life. The experimental design was Randomized Complete Block Design (RCBD) with four rows, and each row was 3.5 meters long. Seeds were sown using a drilling method with 30 cm spacing between rows and 20 cm spacing between plants. Data was collected from ten randomly selected plants from each replication. Essential practices, such as weed control and removal of off-types, were carried out manually and on schedule. Analysis of variance and Duncan's Multiple Range Test were performed using Statistix 8.1 software, while cluster analysis was done by using Minitab 17 software (Duncan, 1955; Kovach, 2005).

Figure 1. Pedigree chart of drought spring wheat yield trail (DSBWYT) received from ICARDA.

Genotype	Pedigree record	Selection history	Origin
V-09	KAUZ//ALTAR84/AOS/3/MILAN/DUCULA	AISBW05-103-7AP-0AP-0AP-8AP-0AP-0TR	Lebanon
V-10	ATTILA*2/PBW65//PFAU/MILLAN	ICW05-0450-8AP-0AP-0AP-2AP-0SD-0TR	Lebanon
V-11	SERI.1B//KAUZ/HEVO/3/AMAD/4/PFAU/MILAN	ICW06-00151-8AP-0AP-03SD-0TR	Lebanon
V-12	ATTILA*2/PBW65//PFAU.MILAN	ICW05-0450-8AP-0AP-0AP-3AP-0SD-0TR	Lebanon
V-13	KAUZ//ALTAR84/AOS3/KAUZ/3/ATTILA50Y//ATTILA/BCN/4/PASTOR-6	ICW06-50246-7AP-0AP-0AP-1 –SD-0TR	Lebanon
V-14	OPATA/RAYON//KAUZ/3/2*MILLAN/DUCULA	ICW06-50333-4AP-0AP-0AP-1 SD-0TR	Lebanon
V-15	ANGI-1	ICW92-0326-12AP-0L-7AP-0L-2AP-0AP-0TR	Lebanon
V-16	WEAVER/WL3928//SW89/3064/3/SHUHA-4//NS732-HER	ICW05-0469-7AP-0AP-0AP-3AP-0AP-0TR	Lebanon
V-17	SHUHA-4//NS732/HER/3/QAFZAH-33	ICW05-0600-4AP-0AP-0AP-1AP-0AP-0TR	Lebanon
V-18	ATTILA-50Y//ATTILA/BCN/3/PFAU/MILAN	ICW05-0632-12AP-0AP-0AP-1AP-0AP-0TR	Lebanon
V-19	JAWAHIR-1/3/PASTOR/SERI//PFAU	ICW05-0668-17AP-0AP-0AP-11AP-0AP-0TR	Lebanon
V-20	JAWAHIR-1/GIRWILL-5	ICW05-0669-15AP-0AP-0AP-2AP-0AP-OTR	Lebanon
V-21	SERI.1B//KAUZ/HEVO/3/AMAD/4/FLAG-2	ICW06-00141-18AP/0KUL-0DZ/0AP-0DZ/0AP-2AP-0AP-0TR	Lebanon
V-22	ENKOY/FLAG-5	ICW06-00434-13AP/0KUL-0DZ/0AP-0DZ/0AP-1AP-0AP-0TR	Lebanon
V-23	ICARDA-SRRL-9/JAWAHIR-22	ICW06-00504-4AP/0KUL-0DZ/0AP-0DZ/0AP-0AP-4AP-0AP-0TR	Lebanon
V-24	Local Check (Khirman)		

RESULTS

The analysis of variance revealed that all genotypes exhibited significant differences (P≤0.01) in early ground cover, early growth vigor, number of grains spikelet^{-1}, number of grains spike^{-1}, number of spikelets spike^{-1}, spike length, peduncle length, thousand-grain weight, and grain yield plant^{-1} (Table 1 and 2). This suggests that genotypes performed variably to the drought stress and studied genotypes possess valuable genetic diversity for these traits, making them well-suited for addressing future breeding challenges

.**Table 1:** ANOVA for 5 plant traits of 16 genotypes grown under water stress condition

Source	DF	Mean squares				
		EGC	EGV	GPSLT	NOGPS	NSPS
Replication	2	0.0208	0.2067	0.03106	2.4565	0.11357
Genotype	15	13.9542**	17.6695**	0.13831**	71.2451**	4.88516**
Error	30	0.0208	0.1087	0.02019	3.6060	0.11775
C.V.	-	2.61	2.09	4.90	3.43	1.8

** =1% level of significance; EGC= early ground cover, EGV= early growth vigor, GPSLT= grains per spikelets, NOGPS= number of grains per spike, NSPS= number of spikelets per spike

Table 2: ANOVA for 4 plant traits of 16 genotypes grown under water stress condition

Source	DF	Mean squares			
		SL	PL	TGW	PYG
Replication	**2**	0.00269	0.3599	1.2093	0.0021
Genotype	**15**	1.77160**	20.8386**	28.4848**	15.8987**
Error	**30**	0.10563	0.4003	1.3810	0.0404
C.V.		3.39	1.93	3.86	1.04

** = 1% level of significance; SL= spike length, PL= peduncle length, TGW= thousand grain weight, PYG= grain yield per plant

Mean performance data presented in Tables 3 and 4 showed significant differences among the genotypes under study. The genotype V-18 quickly covered the ground compared to the local check Khirman and the other genotypes, whereas the highest early growth vigor was achieved by the local check Khirman. However, V-13 and V-14 also showed good early growth vigor (Table 3).

Table 3: Mean value of 16 wheat genotypes for 5 traits studied in the experiment

Genotypes	EGC	EGV	GPSLT	NOGPS	NSPS
V-09	5.0000E	11.527H	2.7733EFG	51.287GH	17.787G
V-10	6.0000D	15.287F	2.8067EFG	55.093EF	17.913FG
V-11	7.0000C	17.623B	2.9900BCDE	57.523CDE	19.857CD
V-12	6.0000D	16.703C	2.8667DEF	52.477FG	18.563E
V-13	6.0000D	17.953AB	2.9433CDEF	55.000EF	18.117EFG
V-14	7.0000C	17.923AB	3.1433ABC	60.580ABC	20.563B
V-15	1.0000H	9.277I	2.5000H	46.190I	16.610H
V-16	4.0000F	16.380CD	2.8367DEF	56.020DE	19.383D
V-17	2.0000G	14.713G	2.5933GH	48.097I	17.780G
V-18	9.0000A	17.603B	3.3000A	60.703AB	20.527B
V-19	7.0000C	16.497C	3.2133AB	62.377A	21.190A
V-20	4.0000F	15.867DE	2.8900DEF	56.583DE	19.337D
V-21	7.0000C	16.617C	2.7067FGH	58.810BCD	19.523D
V-22	4.0000F	14.667G	2.7967EFG	49.050HI	8.4770EF
V-23	5.0000E	15.477EF	2.9567CDE	55.827DE	18.233EFG
Khirman	8.3333B	18.383A	2.7733EFG	60.903AB	20.380BC
LSD $_{0.05}$	0.24	0.54	0.23	3.166	0.57

EGC= early ground cover; EGV= early ground vigor; NSPS= number of spikelet spike; GPSLT^{-1}= Number of grain spikelet^{-1}; NOGPS= number of grains spike^{-1}

The results depicted in Table 3 showed that V-18, V-19, and V-14 produced more grains spikelet^{-1} compared to the local check Khirman and all other genotypes, which produced fewer grains spikelet^{-1} (Table 3). Similarly, V-19, the local check Khirman, V-18, and V-14 produced more grains spike^{-1} in comparison to the other genotypes analyzed (Table 3). The results regarding the number of spikelet's spike^{-1} indicated that V-19 produced a high number of spikelet's spike^{-1}, followed by V-14, V-18, and the local check Khirman (Table 3).

The results presented in Table 4 show that V-18 had the longest spike length, followed by V-14 and the local drought-tolerant cultivar Khirman, which also had relatively longer spikes compared to the other genotypes. The highest peduncle length was observed in the drought-tolerant check variety Khirman, followed by V-14 and V-18, which also had relatively longer peduncles. Significant variation in TGW (thousand-grain weight) was noted among the genotypes, with V-18 having the highest TGW, followed by V-14, which also had a higher thousand-grain weight than the rest of the genotypes. Regarding grain yield plant^{-1}, V-18, the drought-tolerant variety Khirman, and V-14 produced the highest yields compared to the other genotypes (Table 4).

Table 4: Mean value of 16 wheat genotypes for 5 traits studied in the experiment

Genotypes	SL	PL	TGW	GYP
V-09	8.287F	30.333FG	28.900EF	17.737HI
V-10	9.190DE	32.143DE	31.183CD	18.217G
V-11	9.663CD	32.853CD	28.870EF	19.750D
V-12	9.717CD	33.320C	26.910GH	18.867F
V-13	9.810C	33.353C	32.837BC	19.203E
V-14	10.487B	37.243A	33.470B	22.457C
V-15	8.093F	29.477G	31.953BCD	16.487K
V-16	9.570CD	32.047DE	25.673GH	18.350G
V-17	9.237DE	29.477G	30.957CD	17.247J
V-18	11.333A	36.360AB	36.160A	24.520A
V-19	9.647CD	32.190DE	25.017H	19.570D
V-20	9.617CD	31.240EF	27.237FG	18.257G
V-21	9.907C	35.323B	30.657DE	19.600D
V-22	8.953E	30.283FG	32.883BC	17.463IJ
V-23	9.620CD	30.477FG	32.817BC	18.017GH
Khirman	10.053BC	37.407A	28.900EF	23.657B
LSD $_{0.05}$	0.54	1.05	1.95	0.33

SL= spike length; PL= peduncle length; TGW= thousand grain weight; GYP= grain yield plant^{-1}.

The results of the multivariate cluster analysis are presented in Figure 2 which reveals that the genotypes can be categorized into three distinct groups; The first cluster comprises V-14, V-18, and the local check Khirman, which performed better under drought conditions compared to the other genotypes. The presence of these genotypes with the check variety is regarded as indicative of drought-tolerant genotypes. The second cluster comprises nine genotypes, namely V-10, V-11, V-12, V-13, V-16, V-19, V-20, and V-23, which performed moderately drought tolerant compared to the genotypes found in the drought-tolerant cluster. The last cluster comprises four genotypes, namely V-09, V-15, V-17, and V-22, which performed very poorly under drought conditions.

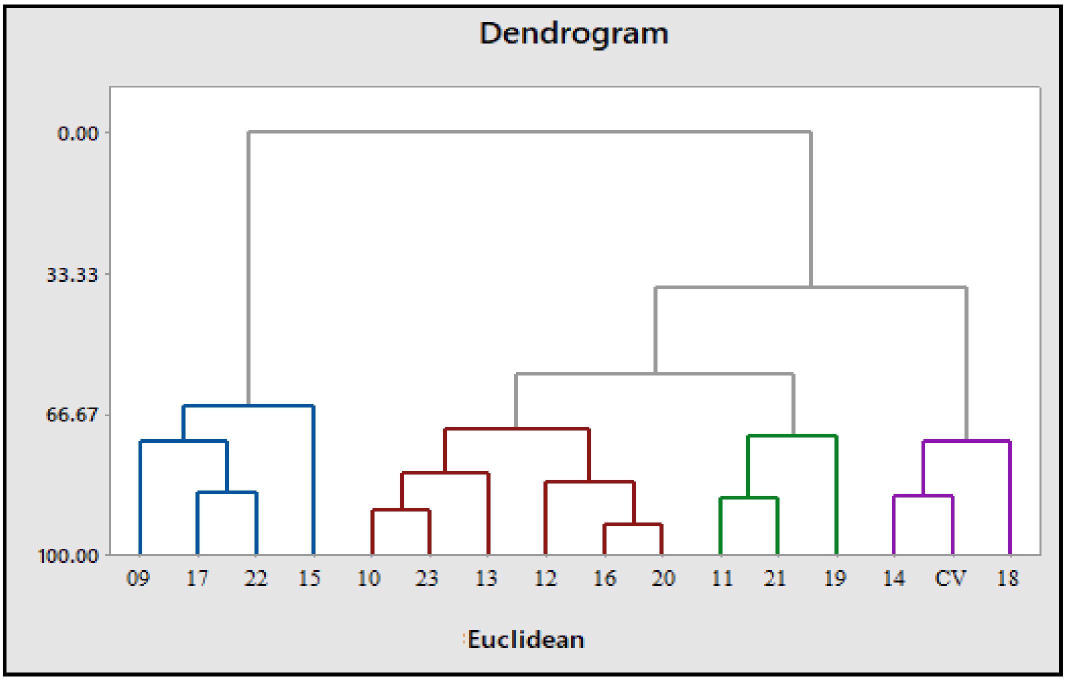

Figure 2. Dendrogram based cluster analysis for yield and yield associated traits in wheat.

DISCUSSION

Global wheat production faces significant threats due to climate change and ongoing decreases in water availability for the agriculture sector (Sial *et al*., 2022). Wheat breeders are working to protect wheat from the detrimental impacts of drought by employing novel screening strategies for drought tolerance. These efforts extend beyond traditional phenotyping methods to include robust, newly developed high-throughput technologies (Memon *et al*., 2022). In this study, fifteen spring wheat candidate lines were evaluated under drought conditions alongside the widely grown drought-tolerant cultivar Khirman to investigate various growth and yield-related traits. The results revealed that some genotypes exhibited notably greater early growth vigor and covered the ground more rapidly than Khirman. Early ground coverage and vigorous early growth are important traits for breeding drought-tolerant varieties, as they indicate a genotype's ability to compete effectively with weeds for land, water, and nutrients, key factors for establishing a strong crop stand.

The yield and yield-associated data indicate that under drought conditions, the V-18 genotype outperformed both the local check variety and the other genotypes, showing higher grain yield plant^{-1} and thousand-grain weight. It has been noted that genotypes exhibiting greater numbers of grains spikelet^{-1}, grains spike^{-1}, spikelets spike^{-1}, and thousand-grain weight demonstrate good performance in drought conditions. These observations align with previous studies' findings, indicating that drought affects the thousand-grain weight, number of grains spikelet^{-1}, number of grains spike^{-1}, number of spikelets spike^{-1}, and peduncle length (Arain *et al*., 2022). Furthermore, compelling evidence indicates that under drought conditions, long spike length and the number of grains spike^{-1} contribute significantly more to grain yield compared to other yield-associated traits. This occurs because the decrease in seed weight caused by stress is compensated by the higher number of grains plant^{-1} or seed spike^{-1} (Faheem *et al*., 2023). Hence, genotypes that consistently uphold these traits under water-stress conditions can be selected as drought-tolerant varieties.

The cluster analysis results showed that the genotypes V-14 and V-18 were grouped in the same clade as the drought-tolerant cultivar Khirman. This indicates that these genotypes perform well under drought conditions, as supported by the agronomic and yield-related data. Specifically, V-14 demonstrated superior agronomic and growth characteristics, including early growth vigor, grains spikelet^{-1}, grains spike^{-1}, peduncle length, thousand-grain weight, and grain yield plant^{-1}, although it produced slightly less than V-18. On the other hand, V-18 outperformed all other genotypes in yield and yield-related traits, such as early ground cover, grains spikelet^{-1}, grains spike^{-1}, spike length, peduncle length, thousand-grain weight, and grain yield plant^{-1}.

CONCLUSIONS

Considering the study's aims, it was observed that genotypes V-14 and V-18 are suitable for drought conditions based on their performance under drought stress conditions and hence can be considered as drought tolerant. These genotypes can be crossed to improve drought resistance to improve drought tolerance of existing gene pools.

AUTHORS' CONTRIBUTION

NYS drafted the manuscript, MAS designed the experiment, GF and AAM helped in data collection, AAK performed statistical analysis, MA and Su critically revised and improved English of the manuscript, SAS and BK helped in experimental set up and data collection.

AUTHORS CONFLICT

Authors declares there is no conflict of interest, all the authors have read MS and are agreed to publish in the journal.

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