RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
54 (2) 297-304, 2022
http://doi.org/10.54910/sabrao2022.54.2.8
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

EXOTIC WHEAT GENOTYPES RESPONSE TO WATER-STRESS CONDITIONS

N.Y. SIAL[1*], M. FAHEEM[2], M.A. SIAL[2], A.R. ROONJHO[3], F. MUHAMMAD[3], A.A. KEERIO[1], M. ADEEL[1], S. ULLAH[1], Q. HABIB[3], and M. AFZAL[3]

[1]Department of Agriculture, University College of Dera Murad Jamali, Naseerabad, Balochistan, Pakistan
[2]Nuclear Institute of Agriculture, Tando Jam, Sindh, Pakistan
[3]Lasbela University of Agriculture, Water and Marine Sciences, Uthal, Balochistan, Pakistan
[*]Corresponding author: naveedyaseen786@hotmail.com
E-mail addresses of coauthors: mlofaheem@gmail.com, Mahboobali.sial@gmail.com, fateh.shahwani@gmail.com, rehmanroonjha@gmail.com, ayazalikeerio@outlook.com, m.adeel@ucdmj.luawms.edu.pk, sanasajid54@gmail.com, qeasarhabib@gmail.com, Afzalroonjha139@gmail.com

SUMMARY

Drought is the most devastating abiotic stress which has significantly threatened global wheat production. The recent study was designed to evaluate the performance of eight exotic wheat lines through the Drought Spring Bread Wheat Yield Trial (DSBWYT), along with a local drought-tolerant check cultivar, Khirman, under water-stressed conditions based on agronomic and yield-related traits. The experiment was conducted during cropping season 2019–2020 in a randomized complete block design with three replications at the Nuclear Institute of Agriculture (NIA), Tando Jam, Pakistan. The analysis of variance revealed that there was a significant difference among the genotypes for all studied traits. The genotype DSBWYT-8 possessed better agronomic traits and growth features like early growth vigor and early ground cover. On the other hand, the genotype DSBWYT-4 performed better in yield and yield-related traits like main spike yield, grains per spike, and 1000-grains weight. Both genotype revealed excellent plot grain yield and harvest index and were not significantly different from each other. The cluster analysis grouped all the genotypes into three clades. The drought-tolerant local check cultivar Khirman clustered with genotypes DSBWYT-2, DSBWYT-4, and DSBWYT-8 thus, this clade can be regarded as drought tolerant. The second cluster comprised of two genotypes, i.e., DSBWYT-1 and DSBWYT-5, which performed relatively low as compared to genotypes present in the drought-tolerant cluster, whereas the genotypes DSBWYT-3, DSBWYT-6, and DSBWYT-7 clustered together to represent low yielding genotypes under drought condition as compared with the check cultivar Khirman. Based on these results, the genotypes DSBWYT-2, DSBWYT-4, and DSBWYT-8 can be recommended as the drought-tolerant genotypes.

Keywords: Spring wheat, drought, yield components, agronomic traits

Key findings: Wheat genotypes DSBWYT-2, DSBWYT-4, DSBWYT-8, and local check cultivar Khirman performed well for different yield and yield associated traits and were grouped in the same category during cluster analysis, indicating that these genotypes possess good genotypic resource.

Communicating Editor: Dr. Aris Hairmansis
Manuscript received: April 9, 2022; Accepted: May 25, 2022.

To cite this manuscript: Sial NY, Faheem M, Sial MA, Roonjho AR, Muhammad F, Keerio AA, Adeel M, Ullah S, Habib Q, Afzal M (2022). Exotic wheat genotypes response to water-stress conditions. *SABRAO J. Breed. Genet.* 54(2): 297-304. http://doi.org/10.54910/sabrao2022.54.2.8

INTRODUCTION

Drought is known as one of the most devastating abiotic stresses which limits the overall crop yield of almost all agricultural crops. It is estimated that by the end of 2025, 1.8 billion people around the globe will face an acute shortage of water supply, while about 65% of the total world's population will be living under water-stressed conditions (Nezhadahmadi *et al.,* 2013). In Pakistan, one-fifth of the available arable land, i.e., 4.9 million ha is prone to water deficiency (Munir *et al.,* 2007). This shortage of water supply will threaten agricultural productivity and hence, will create food security issues.

Wheat (*Triticum aestivum* L.) is the most important cereal grain crop and widely cultivated in various climatic conditions in the world. It is the main source of food and provides the major portion of calories to more than 1.5 billion people (Mursalova *et al*., 2015). Drought, being the polygenic stress in nature, has also affected wheat production worldwide especially in arid and semiarid areas (Darzi-Ramandi *et al*., 2016; Kilic and Yagbasanlar, 2010). Insufficient rainfall in these areas results in less water supply to wheat plants which affects all the growth development stages and physiological processes significantly reducing the yield (Reynolds *et al*., 2005; Zulkiffal *et al*., 2022).

In Pakistan, a vast area has arid to semiarid climatic conditions where wheat is cultivated and hence. its production is always threatened by water scarcity. Additionally, insufficient rainfall and lack of irrigation are the main constraints for higher yield. On the other hand, climate change has worsened the scenario as the summers are getting hotter and drier due to which very little surface water, as well as. soil moisture, is available to cultivate wheat (Munir *et al*., 2007; Dwivedi *et al*., 2018).

To cope with the drought stress, breeding of drought-tolerant cultivar is deemed the best solution to get a higher yield from water-deficient areas. Wheat breeders use a multilayer approach to breed drought-tolerant genotypes by characterizing the available genetic diversity and phenotyping the traits related to yield under water stressed conditions to develop a better understanding of the physiological and genetic basis of drought tolerance (Mwadzingeni *et al*., 2016a). Among these approaches, phenotyping of morpho-physiological traits, including yield and yield components, always remains the key benchmark to screen breeding material against drought (Mwadzingeni *et al*., 2016b; Shaukat *et al*., 2021).

Selection based on such traits as plant height, reduced days to anthesis and maturity, root architecture, and high root density, has significantly improved the wheat productivity in optimal and water-deficient conditions (Blum, 2011; Ehdaie *et al*., 2012). Short plant height results in a high harvest index whereas, a reduced number of days to anthesis and maturity is important to avoid terminal drought (Slafer *et al*., 2005; Lopes *et al*., 2012). Similarly, the yield components, which are usually considered as the most important for drought screening, are spikelets per spike, productive tillers per plant, grains per spike, and 1000-grain weight (Passioura, 2012; Mwadzingeni *et al*., 2016b).

In general, such genotypes are selected which yield comparatively well in both the optimum and stressed conditions. Moreover, during screening and phenotyping, breeders tend to select these genotypes which have good agronomic traits, coupled with high yield, to get better yield under drought conditions. This selection technique has resulted in a significant improvement in wheat productivity, not only in optimal water conditions, but also under water-stressed conditions (Tardieu, 2012). Based on these facts, the recent study was designed to evaluate the performance of eight candidate lines under water-stressed conditions based on agronomic and yield-related traits.

MATERIALS AND METHODS

Plant material and experimental design

The experimental plant material comprised of eight exotic wheat lines which were received from ICARDA (International Center for Agricultural Research in the Dry Areas), along with one drought-tolerant cultivar cv. Khirman, to be evaluated under drought conditions (Table 1). The experiment was conducted under water stressed condition at the wheat breeding field of the Nuclear Institute of Agriculture (NIA), Tando Jam, Pakistan. The experiment was laid out in randomized complete block design with three replications during cropping season 2019–2020. Each wheat genotype was sown with four rows, 3 m long and 30 cm apart between rows. To impose severe moisture stress, the experiment was applied with only a single irrigation during seedling stage after 21 days of sowing; no further irrigation was applied to the crop during

Table 1. Pedigree of the wheat genotypes used in the study.

No.	Line code	Pedigree	Selection history	Origin
1	DSBWYT-1	P1.861/RDWG/4/SERI.1B//KAUZ/HEVO/3/AMAD	AISBW05-0041-3AP-0AP-0AP-2AP-0SD-0TR	Lebanon
2	DSBWYT-2	SERI.1B//KAUZ/HEVO/3/AMAD/4/ESDA/SHWA//BCN	AISBW05-0153-11AP-0AP-0AP-2AP0SD-0TR	Lebanon
3	DSBWYT-3	SERI.18//KAUZ/HEVO/3/AMAD/4/KAUZ/PASTOR	AISBW05-0347-14AP-0AP-0AP-2AP-0SD-0TR	Lebanon
4	DSBWYT-4	WEAVER/WL3928//SW89/3064/3/KAUZ//MON/CROW'S'	ICW05-0513-10AP-0AP-0AP-2AP-0SD-0TR	Lebanon
5	DSBWYT-5	KAUZ//MON/CROW?S?/4?SERI.1B.KAUZ/HEVO/3/AMAD	ICW05-0534-22AP-0AP-0AP-2AP-0SD-0TR	Lebanon
6	DSBWYT-6	SERI.1B//KAUZ/HEVO/3/AMAD/4/PFAU/MILAN	ICW06-00151-9AP-0AP-04 SD-0TR	Lebanon
7	DSBWYT-7	ATTILA50Y//ATTILA/BCN/3/PFAU/MILAN	ICW05-0632-12AP-0AP-0AP-2AP-0AP-0TR	Lebanon
8	DSBWYT-8	CHILERO1/4/VEE'S'/3/HORK/4MH//KAL-BB/S/PFAU/MILAN	ICW05-0634-11AP-0AP-0AP-2AP-0AP-0TR	Lebanon
9	Khirman (Check)	Local drought resistant cultivar	-	NIA, Tando Jam - Pak.

NIA: Nuclear Institute of Agriculture, Tando Jam - Pakistan

the entire crop season. The experimental site had highly fertile clay loam soil with 7.5 pH. The recommended chemical fertilizers applied to the trial were 100N:50 P2O5 kg/ha.

Data collection and analysis

To determine the effect of severe water stress on genotypic potential, the data on various yield associated traits were recorded *viz*., early growth vigor (cm), early ground cover, days to booting, days to heading, days to 75% maturity, days to grain filling, tiller plant^{-1}, plant height (cm), nodes plant^{-1}, peduncle length (cm), spike length (cm), spikelets spike^{-1}, grains spike^{-1}, grains spikelets^{-1}, main spike yield (g), 1000-grain weight, biological yield plot^{-1}, grain yield plot^{-1} (g), and harvest index (%). The data were subjected to analysis of variance and the means were compared through Duncan's multiple range test as suggested by Duncan (1955) using statistical software Statistix 8.1. The means data of all the parameters were utilized for cluster analysis using Euclidean distance matrix with the un-weighted pair group method based on arithmetic averages (UPGMA) to construct the dendrogram keeping default setting of computer software Multivariate Statistical Package V. 3.13p (Kovach, 2005).

RESULTS

All the data recorded against different parameters were subjected to analysis of variance (ANOVA) to determine the significant differences among the genotypes based on observed parameters. The results of ANOVA and the least significance difference (LSD) among means for agronomic traits *viz.,* early ground cover (EGC), early ground vigor (EGV), days to booting (DB), days to grain filling (DGF), days to heading (DH), days to physiological maturity (DM), nodes per plant (NOP), plant height (PH), and tillers per plant (TP) are represented in Tables 2 and 4, while the results of ANOVA and LSD related to yield and yield components *viz.,* spike length (SL), peduncle length (PL), main spike yield (MSY), spikelets per spike (SPS), grains per spike (GPS), grains per spikelets (GPSLT), 1000-grain weight (TGW), biological yield per plot (BYPP), grain yield per plot (GYP), and harvest index (HI) are represented in Tables 3 and 5, respectively.

The results showed that there was a significant difference among the genotypes for all the agronomic traits (Table 2). The genotype DSWBYT-1 and DSWBYT-8 quickly cover the ground as compared to the rest of the genotypes whereas, the highest EGC was achieved by DSWBYT-8, followed by DSWBYT-3, and DSWBYT-4 which were statistically at par with the drought-tolerant check cultivar Khirman (Table 4). The results indicated that DSWBYT-3, DSWBYT-7, and cv. Khirman took minimum DB as compared with other genotypes which took more days to boot. Similarly, DSWBYT-7 and DSWBYT-3 took minimum DH as compared with the rest of the genotypes and statistically at par with the cv. Khirman. However, the genotype DSWBYT-8 took maximum DH as compared with the check

Table 2. Analysis of variance for agronomic traits in wheat genotypes.

Source	d.f.	Mean squares									
		EGC	EGV	DB	DH	DM	DGF	PH	NOP	TP	SL
Replications	2	0.78	0.62	38.11	12.44	7.26	41.93	4.74	0.02	0.04	0.07
Genotypes	8	13.25**	4.19**	33.25**	36.25**	39.37**	56.34**	34.10**	0.27**	1.29**	1.44**
Error	16	0.28	0.64	6.90	4.61	6.30	4.84	5.95	0.01	0.28	0.05
C.V.	-	10.54	4.90	4.30	2.80	2.23	4.22	2.81	2.07	8.57	2.27

d.f. = Degree of freedom; C.V. = coefficient of variance; EGC = early ground cover; EGV = early ground vigor; DB = days to booting; DH = days to heading; DM = days to physiological maturity; DGF = days to grain filling; PH = plant height; NOP = nodes per plant; TP = tillers per plant; SL = spike length

Table 3. Analysis of variance for grain yield and its related traits in wheat genotypes.

Source	d.f.	Mean squares								
		PL	MSY	SPS	GPS	GPSLT	TGW	BYPP	GYP	HI
Replications	2	1.91	0.00	0.78	6.56	0.06	5.21	725.90	337.00	1.06
Genotypes	8	46.26**	0.18**	3.24**	78.42**	0.25**	86.18**	98571.80**	13303.00**	43.73**
Error	16	5.69	0.02	0.32	9.93	0.03	7.95	2545.70	626.60	1.40
C.V.	-	6.85	8.11	2.86	5.74	6.65	7.86	2.42	4.96	4.85

d.f. = degree of freedom; C.V. = coefficient of variance; PL = peduncle length; MSY = main spike yield; SPS = spikelets per spike; GPS = grains per spike; GPSLT = grains per spikelets; TGW = 1000-grain weight; BYPP = biological yield per plot; GYP = grain yield per plot; HI = harvest index

Table 4. Mean performance of the wheat genotypes for various agronomic traits.

Genotypes	EGC	EGV	DB	DH	DM	DGF	PH	NOP	TP
DSBWYT-1	7.67a	16.90abc	60.33bcd	76.00bc	110.00d	52.67bcd	82.81e	4.38a	6.72a
DSBWYT-2	6.33b	15.52c	64.67ab	81.67a	119.00a	54.33abc	84.33cde	3.57d	5.52cd
DSBWYT-3	1.67f	17.10ab	58.67d	74.00cd	116.67ab	58.00a	87.43bcd	4.00c	5.45d
DSBWYT-4	2.67e	16.76abc	64.00abc	79.67ab	112.67bcd	51.67cd	89.67ab	4.43a	6.48ab
DSBWYT-5	3.67d	16.95ab	60.67bcd	76.67bc	110.67cd	52.67bcd	83.00e	4.00c	6.86a
DSBWYT-6	5.67bc	16.00bc	60.00cd	75.67c	115.00abc	49.33d	88.52abc	4.43a	5.68bcd
DSBWYT-7	4.33d	13.57d	56.33d	71.33d	109.00d	52.67bcd	84.19de	4.48a	6.38abc
DSBWYT-8	7.67a	17.48a	66.67a	81.33a	108.33d	42.67e	90.19ab	4.00c	5.38d
Khirman	5.33e	16.28abc	58.67d	74.67cd	112.33bcd	55.67ab	91.76a	4.19b	7.03a
$LSD_{0.05}$	0.91	1.38	4.55	3.72	4.34	3.80	4.22	0.15	0.92

LSD = least significance difference; EGC = early ground cover; EGV = early ground vigor; DB = days to booting; DH = days to heading; DM = days to physiological maturity; DGF = days to grain filling; PH = plant height; NOP = nodes per plant; TP = tillers per plant

Table 5. Mean performance of the wheat genotypes for yield and its related traits.

Genotypes	SL	PL	MSY	SPS	GPS	GPSLT	TGW	BYPP	GYP	HI
DSBWYT-1	10.95ab	36.52bc	1.82bc	20.86ab	53.75b	2.58cd	36.89bc	2361.70a	510.00b	21.60c
DSBWYT-2	9.38d	41.57a	1.82bc	18.81de	54.54b	2.90ab	31.68d	2000.00c	480.00bc	23.99b
DSBWYT-3	9.66cd	32.67cd	2.22a	20.67ab	52.81bc	2.56cd	35.07bcd	2183.30b	401.67e	18.39d
DSBWYT-4	10.62b	36.38bc	2.10a	20.09bc	60.48a	3.02ab	48.56a	2096.70b	585.00a	27.92a
DSBWYT-5	9.76cd	34.90bcd	2.04ab	19.19cd	61.43a	3.20a	33.14cd	2300.00a	553.33a	24.07b
DSBWYT-6	9.81c	31.57de	1.66c	19.29cd	47.91c	2.48d	34.89bcd	2128.30b	426.67de	20.05cd
DSBWYT-7	9.52cd	27.86e	1.59c	20.29ab	48.05c	2.37d	33.30cd	1785.00d	460.00 cd	25.80b
DSBWYT-8	9.81c	34.00bcd	1.69c	18.10e	54.85b	3.03ab	30.72d	1935.00c	570.00 a	29.45a
Khirman	11.33a	37.67ab	2.21a	21.19a	60.70a	2.87bc	38.71b	1991.70c	560.00a	28.10a
$LSD_{0.05}$	0.40	4.13	0.27	0.98	5.45	0.32	4.88	87.33	43.33	2.05

LSD = least significance difference; SL = spike length; PL = peduncle length; MSY = main spike yield; SPS = spikelets per spike; GPS = grains per spike; GPSLT = grains per spikelets; TGW = 1000-grain weight; BYPP = biological yield per plot; GYP = grain yield per plot; HI = harvest index

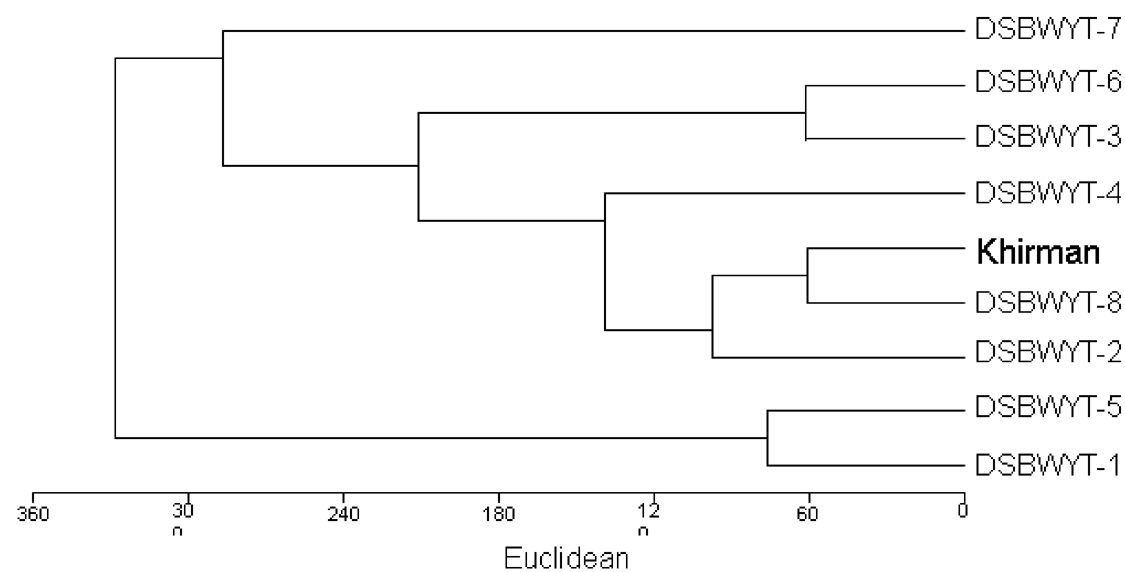

Figure 1. Dendrogram based on the agronomic and yield-related traits in wheat genotypes.

cv. Khirman and other genotypes. The results regarding DM depicted that DSWBYT-8 mature more rapidly as compared with the rest of genotypes, while DSWBYT-1 and DSWBYT-7, which had minimum times span of booting, matured relatively late.

In wheat the days to grains filling is very crucial in determining the grain yield, as well as, act as the main indicator for drought escape. The result regarding this parameter showed that genotype DSWBYT-8 had the shortest period for DGF as compared with the rest of the genotypes and check cv. Khirman whereas, genotype DSWBYT-3 took maximum DGF (Table 4). The data regarding PH showed that the genotypes DSWBYT-1 and DSWBYT-5 were significantly shorter as compared with the check cultivar and other genotypes. It is noteworthy that all the genotypes, except DSWBYT-8, were smaller in stature than cv. Khirman.

The results presented that the highest reproductive tillers per plant under drought conditions was recorded in cv. Khirman and statistically at par for genotypes DSWBYT-1 and DSWBYT-5, while the rest of the genotypes produced less TP (Table 4). Maximum SL was observed in cv. Khirman, followed by genotype DSWBYT-1 and DSWBYT-4 which had relatively longer spikes as compared with the rest of the genotypes. The highest PL was recorded for DSWBYT-2 which had the lowest spike length as compared with the other genotypes. On the other hand, minimum PD was observed in genotype DSWBYT-7. The result regarding MSY showed that drought-tolerant check cv. Khirman had the highest MSY, which is statistically similar to genotypes DSWBYT-3, DSWBYT-4, and DSWBYT-5, while the DSWBYT-8 had the minimum MSY. No genotype could beat the cv. Khirman in terms of NOSPS which was recorded to be the maximum. However, genotypes DSWBYT-1, DSWBYT-4, and DSWBYT-7 had relatively high NOSPS than other genotypes and were comparable with cv. Khirman.

A maximum grains per spike was observed in genotypes, DSWBYT-4 and DSWBYT-5 which was statistically at par with cv. Khirman. Though not much variation was observed for grains per spikelets among the genotypes, yet it was maximum in genotype DSWBYT-5 (Table 5). TGW, which is considered as the key trait in screening the drought-tolerant genotypes, a significant variation was observed among the studied genotypes for this trait. The results showed that the genotype DSWBYT-4 had maximum TGW, followed by cv. Khirman. All the rest of the genotypes had significantly less TGW as compared with the drought-tolerant check. The results of biological yield per plot indicate that the genotypes, DSWBYT-1, DSWBYT-5, DSWBYT-3, DSWBYT-4. and DSWBYT-6 performed better than the drought-tolerant check cv. Khirman. Maximum BYPP was recorded in genotype DSWBYT-1, followed by DSWBYT-5. Two genotypes, DSWBYT-4 and DSWBYT-8 outclass the cv. Khirman for GYP whereas. the genotype DSWBYT-5 has statistically similar GYP as compared with the check.

Significantly, the genotype DSWBYT-1, which had the highest BYPP, produced the low grain yield as compared with the high yielding genotypes (DSWBYT-4, DSWBYT-5, and DSWBYT-8) (Table 5). The harvest index is a good indicator to depict the translocation of bio-synthates to the grains during water stress, as well as, under optimal conditions. The result showed that the genotype DSWBYT-8 had the highest HI as compared with the rest of all the genotypes and cv. Khirman. Interestingly, the genotype DSWBYT-8 has significantly very less BYPP as compared with other high BYPP genotypes. Moreover, the HI of genotype DSWBYT-4 was also statistically the same as compared with cv. Khirman and genotype DSWBYT-8.

The result of multivariate cluster analysis of genotypes based on recorded agronomic and yield-related parameters is shown in Figure 1. It is evident that the studied genotypes can be separated into three groups. The drought-tolerant cv. Khirman clustered with genotypes DSWBYT-2, DSWBYT-4, and DSWBYT-8 can be regarded as drought tolerant cluster having genotypes which overall, performed quite well under water-stressed conditions. The second cluster comprised of two genotypes, i.e., DSWBYT-1 and DSWBYT-5 which can be regarded as moderately tolerant for the overall performance of these genotypes were relatively low as compared with the genotypes present in the drought-tolerant cluster. The third cluster comprised of three genotypes, i.e., DSWBYT-3, DSWBYT-6, and DSWBYT-7, which yielded quite low under drought condition as compared with cv. Khirman and the other genotypes.

DISCUSSION

Climatic change and continuous reduction in water availability to the agriculture sector have significantly threatened global wheat production (Li *et al*., 2009). Wheat breeders are investing great efforts to safeguard the wheat from the adverse effect of drought by deploying new strategies of screening for drought tolerance, not only through conventional phenotyping, but also through robust newly evolved high-throughput technologies (Xu and Crouch, 2008; Araus and Cairns, 2014). In this study, different growth and yield-related traits were investigated in eight candidate lines of spring wheat in comparison with the widely grown drought-tolerant cv. Khirman under drought conditions.

The results showed that some genotypes exhibited excellent early growth vigor and cover the ground more quickly as compared with the check cultivar. EGC and EGV are desirable traits for drought tolerance breeding as these traits are the indicators that genotypes can compete well with weeds in utilizing land, water and nutrient resources which is essential for a good crop stand. Similarly, some genotypes like DSWBYT-7 took minimum days for heading and maturity. Early heading and maturity in wheat is very beneficial to escape the drought and heat stress and enables the wheat genotypes to invest more water and nutrients at a critical stage (Blum, 2011). Interestingly, the genotype DSWBYT-8 rapidly filled the grains as compared with the rest of the genotypes without compromising the yield. This shows that the genotype has much potential to tolerate the drought by abruptly translocating the biosynthates to the grains, which is a highly desirable and heritable trait.

Plant height is the key factor to determine the harvest index of cereal crops. The findings of this study revealed that the genotypes like DSWBYT-4, DSWBYT-8 and the local check, having high plant height, produce more grains as compared with short stature genotypes. For drought tolerance, tall wheat cultivars are usually selected as these genotypes have more capacity to assimilate photosynthates to the grains (Mwadzingeni *et al*., 2016a). However, some studies argued that the short stature wheat genotypes also have a good harvest index especially under water-stressed conditions (Slafer *et al*., 2005; Blum, 2011).

The data regarding yield and yield components suggest that the genotypes DSWBYT-4, DSWBYT-5, and DSWBYT-8 produced higher grain yield under drought conditions as compared with the local check. It has been observed that the genotypes which have more reproductive tillers, grains per spike, and 1000-grain weight performed very well under the drought conditions. These findings are in accord with the previous studies, which reported that the drought affects the fertile tillers per plant, 1000-grain weight, grain number per spike, spike weight, peduncle length, and grain weight per spike (Plaut *et al*., 2004; Kilic and Yagbasanlar, 2010).

Moreover, convincing evidence showed that the highest number of productive and fertile tiller per plant, and grains per spike participate more toward the grain yield as compared with the rest of the yield components when assessed under drought conditions. This is because the reduction in the seed weight due to stress is compensated by more grains per plant or per spike (Slafer *et al*., 2014). Therefore, the genotypes which tend to maintain these traits under water deficit conditions can be selected as drought-tolerant genotypes. The cluster analysis used in this study also helped to identify the drought-tolerant genotypes.

The results of cluster analysis revealed that the genotypes DSWBYT-2, DSWBYT-4, and DSWBYT-8 clustered in the same clade where the drought-tolerant cv. Khirman was present. This shows that these genotypes have good performance under drought condition as confirmed by the agronomic and yield-related data. Critically, the genotype DSWBYT-8 possessed better agronomic and growth features like early growth vigor and ground cover, and also has excellent grain yield and harvest index. On the other hand, the genotype DSWBYT-4 outclassed all the other genotypes for yield and yield-related traits like main spike yield, grains per spike, 1000-grains weight, plot grain yield. and harvest index.

CONCLUSIONS

Keeping the objectives of the study in view, it can be concluded that the genotypes DSWBYT-2, DSWBYT-4 and DSWBYT-8 can be recommended as the drought-tolerant genotypes. The other genotypes, which are good in one trait or another, can be crossed with each other to develop better genotypes for drought-prone regions.

REFERENCES

Araus JL, Cairns JE (2014). Field high-throughput phenotyping: The new crop breeding frontier. *Trends in Plant Sci*. 19(1): 52-61.

Blum A (2011). Plant water relations, plant stress and plant production. In: Plant Breeding for Water-Limited Environments. Springer, New York. pp. 11-52.

Darzi-Ramandi H, Najafi-Zarini H, Shariati V, Razavi K, Kazemitabar SK (2016). Screening Iranian bread wheat lines under different water regimes using yield based drought tolerance indices. *SABRAO J. Breed. Genet.* 48(4): 491-503.

Dwivedi SK, Kumar G, Basu S, Kumar S, Rao KK, Choudhary AK (2018). Physiological and molecular aspects of heat tolerance in wheat. *SABRAO J. Breed. Genet.* 50(2): 192-216.

Ehdaie B, Layne AP, Waines JG (2012). Root system plasticity to drought influences grain yield in bread wheat. *Euphytica* 186(1): 219-32.

Kilic H, Yağbasanlar T (2010). The effect of drought stress on grain yield, yield components and some quality traits of durum wheat (*T. turgidum* ssp. durum) cultivars. *Not. Bot. Hort. Agrobot. Cluj-Napoca*. 38(1): 164-70.

Li Y, Ye W, Wang M, Yan X (2009). Climate change and drought: A risk assessment of crop-yield impacts. *Climate Res.* 39(1): 31-46.

Lopes MS, Reynolds MP, Jalal-Kamali MR, Moussa M, Feltaous Y, Tahir IS, Barma N, Vargas M, Mannes Y, Baum M (2012). The yield correlations of selectable physiological traits in a population of advanced spring wheat lines grown in warm and drought environments. *Field Crops Res*. 128: 129-36.

Munir M, Chowdhry MA, Ahsan M (2007). Generation means studies in bread wheat under drought condition. *Int. J. Agric. Biol*. 16(1): 44-51.

Mursalova J, Akparov Z, Ojaghi J, Eldarov M, Belen S, Gummadov N, Morgounov A (2015). Evaluation of drought tolerance of winter bread wheat genotypes under drip-irrigation and rain-fed conditions. *Turk. J. Agric. For*. 39(5): 817-24.

Mwadzingeni L, Shimelis H, Dube E, Laing MD, Tsilo TJ (2016a). Breeding wheat for drought tolerance: Progress and technologies. *J. Integr. Agric.* 15(5): 935-43.

Mwadzingeni L, Shimelis H, Tesfay S, Tsilo TJ (2016b). Screening of bread wheat genotypes for drought tolerance using phenotypic and proline analyses. *Front. Plant Sci*. 25(7): 12-76.

Nezhadahmadi A, Prodhan ZH, Faruq G (2013). Drought tolerance in wheat. *The Scien. World J*. https://doi.org/10.1155/2013/610721.

Passioura JB (2012). Phenotyping for drought tolerance in grain crops: When is it useful to breeders? *Funct. Plant Biol.* 1(11): 25-39.

Plaut Z, Butow BJ, Blumenthal CS, Wrigley CW (2004). Transport of dry matter into developing wheat kernels and its contribution to grain yield under post-anthesis water deficit and elevated temperature. *Field Crops Res.* 86(2): 185-98.

Reynolds MP, Mujeeb-Kazi A, Sawkins M (2005). Prospects for utilizing plant-adaptive mechanisms to improve wheat and other crops in drought and salinity prone environments. *Ann. Appl. Biol.* 146(2): 239-259.

Shaukat S, Kousar I, Fatima S, Shukat R, Ali A, Ahmad J, Akhtar N, Nadeem M, Farooq J, Ramzan M (2021). Evaluation of spring wheat genotypes for terminal heat stress. *SABRAO J. Breed. Genet.* 53(2): 239-247.

Slafer GA, Araus JL, Royo C, Del-Moral LF (2005). Promising eco-physiological traits for genetic improvement of cereal yields in Mediterranean environments. *Ann. Appl. Biol.* 146(1): 61-70.

Slafer GA, Savin R, Sadras VO (2014). Coarse and fine regulation of wheat yield components in response to genotype and environment. *Field Crops Res.* 157(15): 71-83.

Tardieu F (2012). Any trait or trait-related allele can confer drought tolerance: Just design the right drought scenario. *J. Expt. Bot.* 63(1): 25-31.

Xu Y, Crouch JH (2008). Marker-assisted selection in plant breeding: From publications to practice. *Crop Sci.* 48(2): 391-407.

Zulkiffal M, Ahmed J, Riaz M, Ramzan Y, Ahsan A, Kanwal A, Ghafoor I, Nadeem M, Abdullah M (2022). Response of heat-stress tolerant and susceptible wheat lines in diverse planting environments by using parametric stability models. *SABRAO J. Breed. Genet.* 54(1): 127-140. http://doi.org/ 10.54910/sabrao 2022.54.1.12.