Biological and Clinical Sciences Research Journal
eISSN: 2708-2261; pISSN: 2958-4728
www.bcsrj.com
DOI: https://doi.org/10.54112/bcsrj.v2023i1.188
*Biol. Clin. Sci. Res. J., Volume, **2023**: 188*
Original Research Article

SELECTION OF DROUGHT TOLERANT WHEAT GENOTYPES BASED ON MEAN PERFORMANCE AND BIPLOT ANALYSIS

AFZAL M[1], *KHALID MN[1], IMTIAZ M[1], NASIR B[1], SHAH SAH[2], NAWAZ M[3], NAYAB SF[4], MALIK SN[5], MAJEED T[6], MAQBOOL R[1]

[1]*Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan*
[2]*Soil and Water Testing Laboratory, Mianwali, Pakistan*
[3]*Agronomy Forage Production Section, Faisalabad, Pakistan*
[4]*Sorghum Research Sub Station Dera Ghazi Khan, Pakistan*
[5]*Soil and Water Conservation Research Institute Chakwal, Pakistan*
[6]*Soil and Water Testing Laboratory for Research Thokar Naiz Baig Lahore, Pakistan*
**Correspondence author email address: noumankhalidpbg@pgmail.com*

(Received, 21th October 2022, Revised 6th January 2023, Published 15th January 2023)

Abstract: *The effect of water deficiency was assessed on the productivity of different wheat genotypes viz., Pasban-90, T-11, C-271, LU-26, Seher-06, AARI-11, Maxi-Pak 1965, Ujala-16, Chakwal-50 and Anaj-17 using triplicate Randomized Complete Block Design under two environmental conditions, i.e., normal and drought. The trials were planted in the experimental field area of University of Agriculture Faisalabad, Pakistan. Four irrigations were applied to normal condition trials while drought one depended only on natural precipitation. All characters showed highly significant results for irrigation except for spike length and grains per spike. Mean values were computed from raw data and represented by graphs in which values for each trait were compared separately for drought and normal irrigation conditions. Under drought conditions of irrigation, the maximum grain yield mean value was Ujala-16, while the minimum grain yield value was Seher-06. Biplots were plotted from the mean values of each trait for both irrigation conditions separately to analyze the performance of each genotype individually. The genotype which performed best under both conditions for grain yield per plant was Anaj-17. The most susceptible genotype to drought was Seher-06. Under drought conditions, the genotypes which performed best were Ujala-16, C-271 and Chakwal-50. The -performing genotype under normal irrigation conditions was C-271 for grain yield per plant. The results could help to select the best wheat genotypes for improving breeding programs to increase the average production of the economically important crop.*

Keywords: wheat, drought, yield, mean performance, biplot

Introduction

Drought remains the most devastating factor among abiotic factors responsible for reducing wheat production. Other environmental factors such as insects, diseases, heat and salinity also affect crop productivity, but drought causes more loss (Sallam et al., 2019). The reduction in wheat productivity because of drought stress is less elongation of the stem, limited photosynthesis and no proper functioning of enzymes (Zahra et al., 2021). Grain weight and grain yield are also affected by water deficiency. On the other hand, pre-anthesis stress potentially amend source-sink associations for drought-tolerant and drought-sensitive wheat genotypes (Anwaar et al., 2020).

The extreme water shortage leads to changes in morpho-physiological and metabolic parameters of plants. Consequently, it reduces yield of crops and affects their quality (Dorostkar et al., 2015). It is observed that the process of photosynthesis, plant morphological features, anti-oxidant enzymes and different substances for osmotic adjustment are adversely affected under drought stress conditions. The severity of water deficit stress depends upon a plant's growth stage (Farshadfar & Elyasi, 2012). However, root organ performs beneficial role under drought stress because it is the only source of absorbing nutrients and water from soil (Mohammadi & Abdulahi, 2017). Hence, it is vital in developing plant drought tolerance (El Sabagh et al., 2019). Under water deficit conditions, a plant's leaf could also play a key role in water conservation and improving its utilization. Decisively, the morphology of a plant plays an important role in the survival, adaptation and growth of a crop under drought conditions (Khayatnezhad & Gholamin, 2020; Pequeno et al., 2021).

[Citation: Afzal, M., Khalid, M.N., Imtiaz, M., Nasir, B., Shah, S.A.H., Nawaz, M., Nayab, S.F., Malik, N.S., Majeed, T., Maqbool, R. (2023). Selection of drought tolerant wheat genotypes based on mean performance and biplot analysis. *Biol. Clin. Sci. Res. J.*, **2023***: 188*. doi: https://doi.org/10.54112/bcsrj.v2023i1.188]

The average yield of the crops grown under unfavorable conditions such as water deficit stress could be increased either by improving agronomic cultural practices or by introducing such varieties which could perform better under moisture stress (Gholamin & Khayatnezhad, 2020). So, there is a direst need for such genotypes better adapted to semi-arid regions. Moreover, it is also widely accepted by scientists, but there is no consensus of plant breeders on the crucial issue. Some plant breeders believe that tolerance to stress can be achieved by simply selecting of wheat genotypes for higher grain yield (Tofig, 2015). In this case, it is assumed that wheat genotypes that give high yields under normal conditions can also perform better than others under low moisture conditions (Sattar et al., 2020). On another approach, superior yield varieties for semi-arid regions should be developed, selected and tested in moisture-stress environment. Improving the grain yield of genotypes is regarded as the most desirable objective of breeders for low soil moisture regions. Selection of higher-yield varieties should be practiced under optimum and moisture stress conditions (Sharifi & Mohammadkhani, 2016).

There is a need for such study programs which could help in developing tolerant genotypes (Ahmad et al., 2018). The efficiency of selection criteria can be enhanced by focusing on physiological characteristics positively associated drought tolerance (Wang et al., 2016). The productivity of wheat crops can be enhanced by identifying such genotypes which can perform well under drought stress. It can be achieved by exploring the maximum genotypes from the germplasm of wheat available worldwide (Naeem et al., 2015). Considering the abovementioned facts, the current study was conducted 1) to screen out drought-tolerant varieties which could be useful in the future to bear the water deficit stress resulting in increased cultivated area 2) to investigate the association of physiological traits with low moisture stress in different genotypes of wheat.

Materials and methods

Screening

Experimental material

The experiment was performed to investigate the effect of water deficiency on the production of different bread wheat genotypes. The experimental field area of the department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan, was utilized to experiment (November 10, 2021). Ten high yielding genotypes of wheat crop viz., Pasban-90, T-11, C-271, LU-26, Seher-06, AARI-11, Maxi-Pak 1965, Ujala-16, Chakwal-50 and Anaj-17 were grown on normal wheat growing season. Triplicate Randomized Complete Block Design was used for the plantation of the experiment under two trials, i.e., normal and drought conditions. Dibbler was used for seed sowing. On one hill, two seeds were sown while maintaining a distance of 15 centimeters within rows. Also, thinning of plants was completed so that one plant per hill could be obtained. At both ends of each replication, extra non-experimental genotypes were also grown to eliminate border effects. Irrigation of about 8 cm was applied as a soaking dose in drought and normal condition trials. Four irrigations were applied to the normal irrigated experiment, while the drought experiment was only dependent on natural precipitation. The recommended production technology of bread wheat was used to analyze the effects of water deficiency on desired traits. Data were recorded from five guarded plants of each genotype in each replication. At full maturity, the crop was harvested, and phenotyping was completed for the following desired traits: Plant height, number of tillers, flag leaf area, spike length, peduncle length, water content %, number of grains spike^{-1}, number of spikelets spike^{-1}, 1000-grain weight, grain yield plant^{-1}.

Statistical Analysis

After collecting data of all desired traits from both experimental trials, it was subjected for analysis of variance by using Statistix 8.1 to evaluate genotypic differences. For the selection of genotypes, Biplot analysis was performed by XLSTAT.

Results and discussions

Significance and mean performance of different wheat genotypes

Analysis of variance is a technique that uses statistical models, and their associated estimation methods to observe variation present among the group means in a desired sample. Analysis of variance was introduced by well-known statistician and biologist Ronald Fisher. The data was collected from the field and exposed to the analysis of variance to check the significance of water, genotypes and their interaction, that is, water x genotypes. It was concluded that all characters showed highly significant irrigation results except spike length and grains per spike. Water x genotype interactions for plant height, spike length, peduncle length and grains per spike were non-significant, while it was significant for flag leaf area, the total number of tillers, relative water contents, spikelets per spike, 1000-grain weight and grain yield per plant. Similar results related to the significance of different traits for wheat genotypes were also observed by (Bányai et al., 2020; Roostaei et al., 2021; Shirvani et al., 2022).

Table 1: Analysis of variance for all the genotypes

[Citation: Afzal, M., Khalid, M.N., Imtiaz, M., Nasir, B., Shah, S.A.H., Nawaz, M., Nayab, S.F., Malik, N.S., Majeed, T., Maqbool, R. (2023). Selection of drought tolerant wheat genotypes based on mean performance and biplot analysis. *Biol. Clin. Sci. Res. J.*, **2023***: 188*. doi: https://doi.org/10.54112/bcsrj.v2023i1.188]

SOV	DF	Flag leaf area	Number of tillers	Plant height	Spike length	Peduncle length	Water content %	Number of grains spike^{-1}	Number of spikelets spike^{-1}	1000 Grain weight	Grain yield plant^{-1}
Replication	2	0.49	2.44	12.92	634.3	2.92	4.13	3798.8	2.08	1.15	0.93
Treatment (T)	1	1277.8**	309.5**	1689**	285.9**	523.3**	4417.2**	6780**	55.54**	1693.3**	940.5**
Genotypes (G)	9	148.3**	45.02**	273.6**	2.40	13.95*	591.2**	129.78	10.67**	128.7**	167.1**
T×G	9	20.71**	7.49**	53.61	1.042	7.69	107.3**	16.18	1.83*	12.30*	32.52**
Error	38	0.55	2.33	19.67	32.03	3.96	1.96	207.1	0.44	1.34	0.83
Total	59										

Graphical representation of means for two conditions of irrigation, i.e., normal and drought of 10 genotypes of wheat for yield-related traits

Mean values were computed from the data measured from 10 different genotypes of wheat grown in the field under two conditions of irrigation, i.e., normal and drought. This data was collected for yield, and 9 different yield-attributed traits. Graphs represented mean values to analyze the variability present for the traits according to their significance.

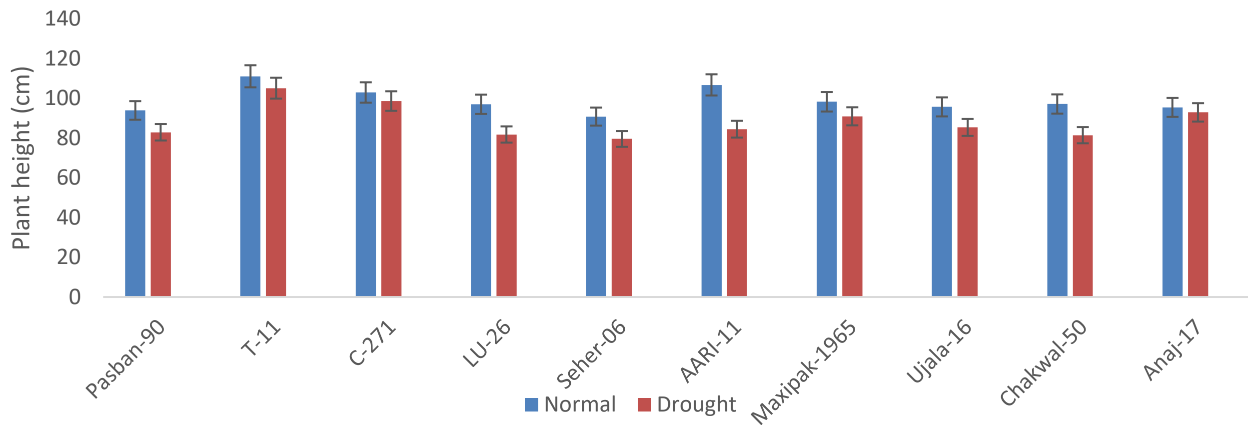

Figure 1: Average values of 10 genotypes of wheat under two levels of irrigation, i.e. normal and drought for Plant height under randomized complete block design in the field of the university of Agriculture

The mean comparison of 10 genotypes of wheat under two conditions of irrigations, i.e., normal and drought, for plant height, is given in Fig. 1. Under drought conditions, plant height varied from 789.53 to 105.06 cm. Maximum plant height was observed under drought conditions for T-11 (105.06 cm) followed by C-271(98.6 cm), Anaj-17(92.90 cm) and Maxi-Pak 1965(90.93 cm) while minimum plant height was observed for Seher-06 (79.53 cm) followed by Chakwal-50 (81.43 cm), LU-26 (81.76 cm) and Pasban-90 (82.90 cm). The total no. of tillers ranged from 4.99 to 12.52 under drought conditions (Fig. 2). Values of flag leaf area ranged from 13.44 to 27.80 cm under drought conditions (Fig. 3). Minimum value for flag leaf area was observed for AARI-11 (13.44 cm) followed by Pasban-90 (17.30 cm), LU-26 (17.65 cm) and Maxi-Pak 1965 (17.75 cm) while the maximum value for flag leaf area was observed for Anaj-17 (27.80 cm) followed by Chakwal-50 (27.79 cm), Ujala-16 (27.78 cm) and C-271 (24.44 cm). Under normal conditions, spike length varied from 10.3 to 12.26 cm (Fig. 4). Spike length ranged from 7.43 to 10.36 cm under drought conditions. Maximum peduncle length was observed under normal conditions for T-11 (36.56 cm) followed by LU-26 (36.36 cm), Maxi-Pak 1965 (36.23 cm) and AARI-11 (34.53 cm), while minimum peduncle length was observed for Anaj-17 (30.63 cm) followed by Seher-06 (31.50 cm), Chakwal-50 (32.76 cm) and Ujala-16 (33.81 cm) as presented in Fig. 5. Relative water contents were ranges from 27.45 to 53.33 under drought condition (Fig. 6). Under normal condition, grains per spike varied from 51.44 to 69.21. Maximum grains per spike were observed under normal conditions for Maxi-Pak 1965 (69.21) followed by AARI-11 (67.99), Chakwal-50 (67.21) and Ujala-16 (64.88) (Fig. 7). Spikelets per spike were ranges from 15.77 to 20.66 under drought condition (Fig. 8). Under normal condition, 1000-grain weight varied from 27.15 to 42.97 g. Maximum 1000-grain weight was observed under normal conditions for LU-26 (42.97 g) followed by Ujala-16 (40.95 g), Chakwal-50 (40.83 g) and Seher-06 (40.55 g) (Fig. 9). Grain yield per plant ranged from 9.09 to 20.62 g under drought condition. Minimum grain yield per plant was observed for Seher-06 (9.09 g) followed by Pasban-90 (10.82 g), Maxi-Pak 1965 (14.81 g) and T-11 (15.33 g), while maximum grain yield per plant was observed for Ujala-16 (20.62 g) followed by C-271 (20.52 g), AARI-11(19.87 g), Anaj-17 (19.87 g) and Chakwal-50 (19.51 g) (Fig. 10).

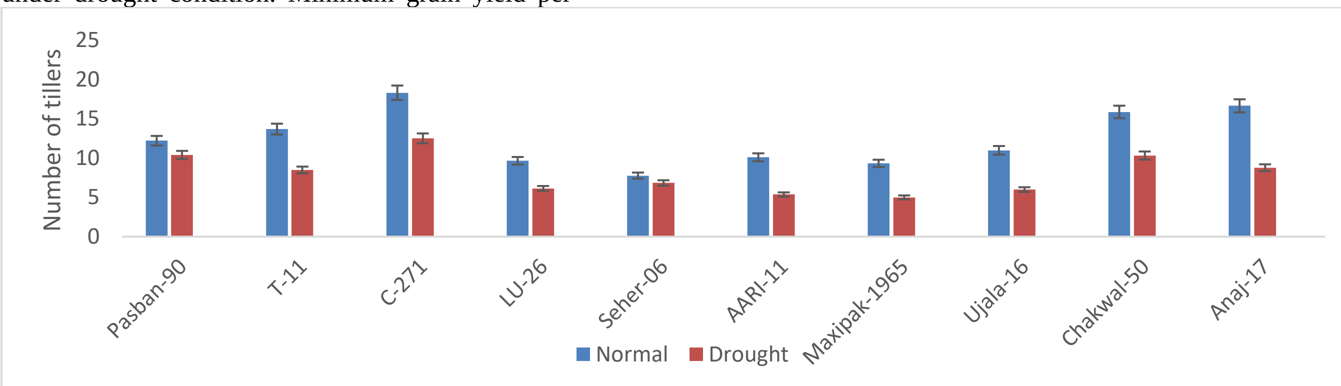

Figure 2: Average values of 10 genotypes of wheat under two levels of irrigation, i.e. normal and drought, for a number of tillers per plant.

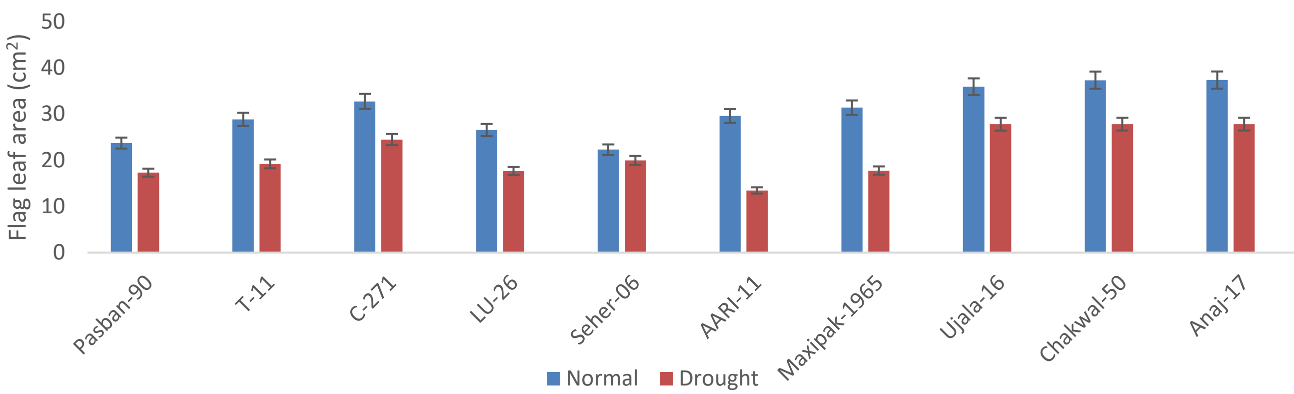

Figure 3: Average values of 10 genotypes of wheat under two conditions of irrigation i.e. normal and drought for flag leaf area

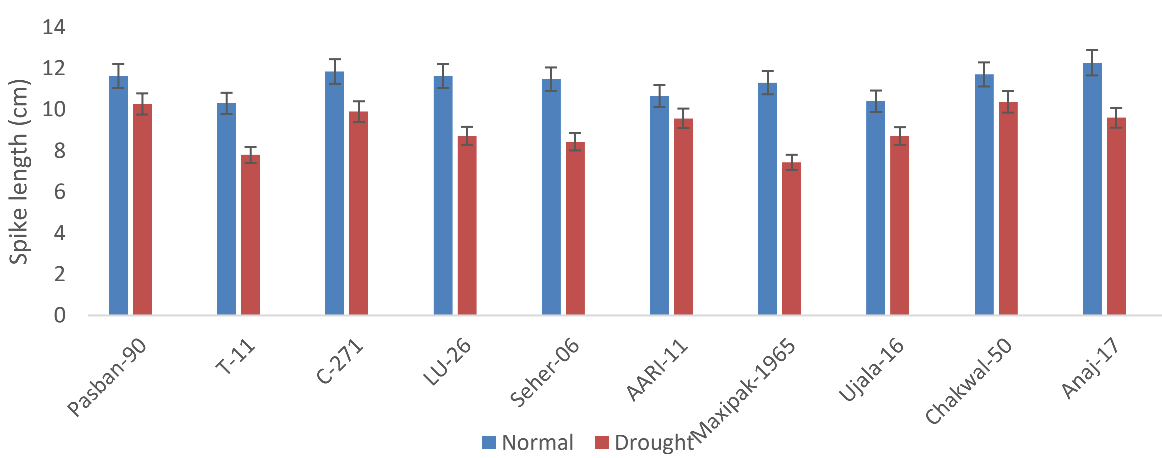

Figure 4: Average values of 10 genotypes of wheat under two levels of irrigation i.e. normal and drought for Spike length.

[Citation: Afzal, M., Khalid, M.N., Imtiaz, M., Nasir, B., Shah, S.A.H., Nawaz, M., Nayab, S.F., Malik, N.S., Majeed, T., Maqbool, R. (2023). Selection of drought tolerant wheat genotypes based on mean performance and biplot analysis. *Biol. Clin. Sci. Res. J.*, **2023***: 188*. doi: https://doi.org/10.54112/bcsrj.v2023i1.188]

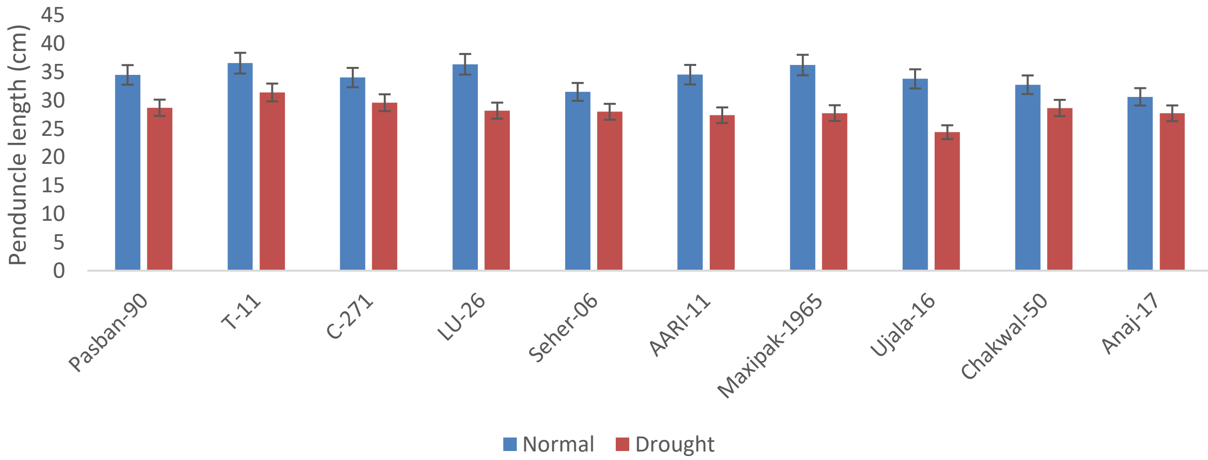

Figure 5: Average values of 10 genotypes of wheat under two levels of irrigation i.e. normal and drought for Peduncle length.

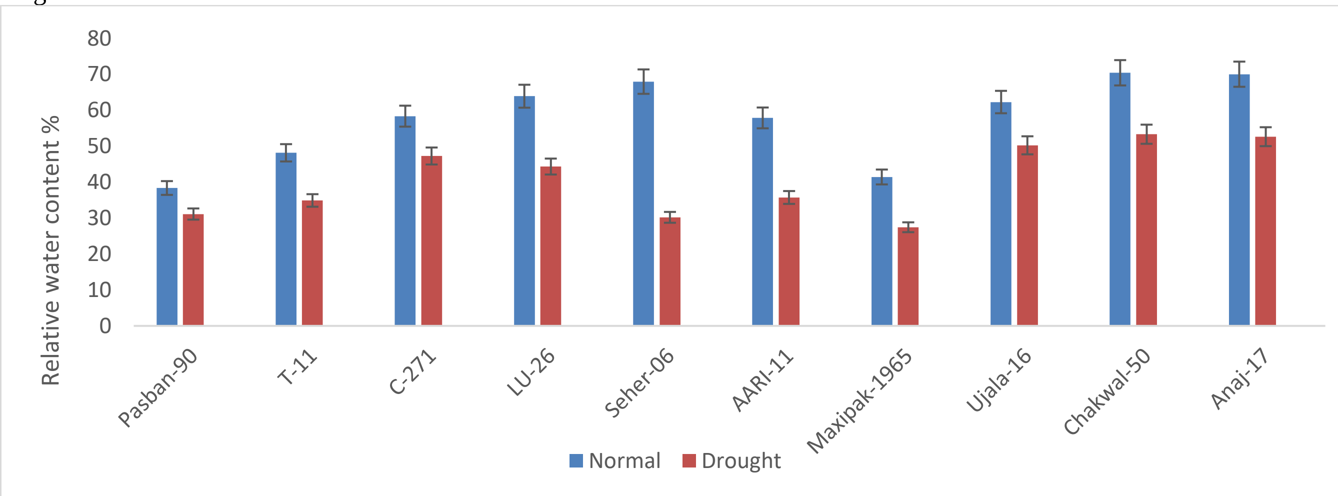

Figure 6: Average values of 10 genotypes of wheat under two levels of irrigation i.e. normal and drought for relative water contents.

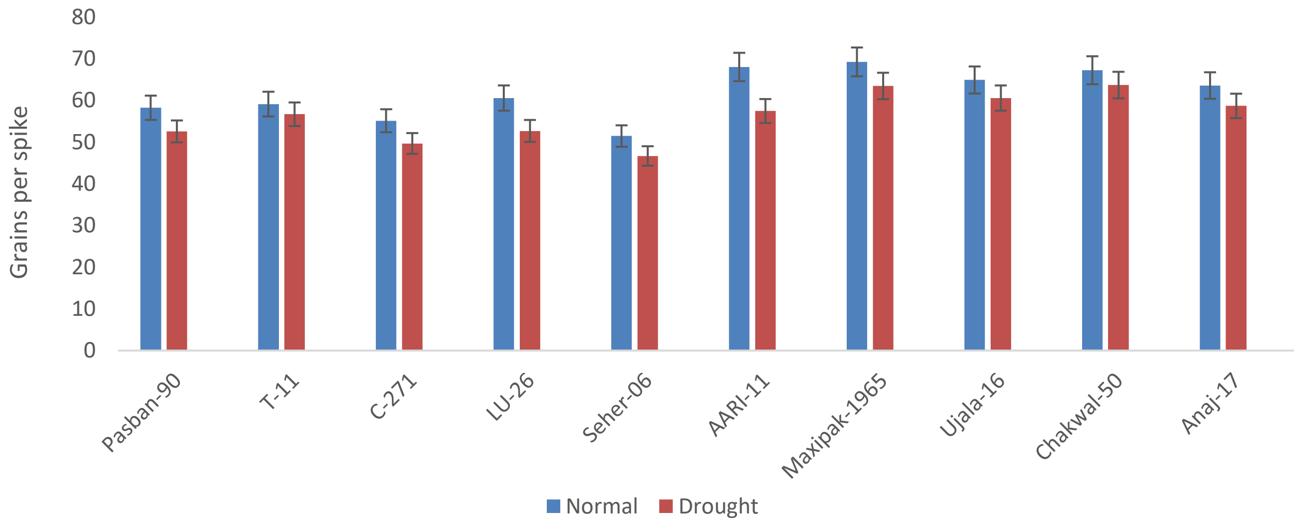

Figure 7: Average values of 10 genotypes of wheat under two levels of irrigation i.e. normal and drought for number of grains per spike.

[Citation: Afzal, M., Khalid, M.N., Imtiaz, M., Nasir, B., Shah, S.A.H., Nawaz, M., Nayab, S.F., Malik, N.S., Majeed, T., Maqbool, R. (2023). Selection of drought tolerant wheat genotypes based on mean performance and biplot analysis. *Biol. Clin. Sci. Res. J.*, **2023***: 188*. doi: https://doi.org/10.54112/bcsrj.v2023i1.188]

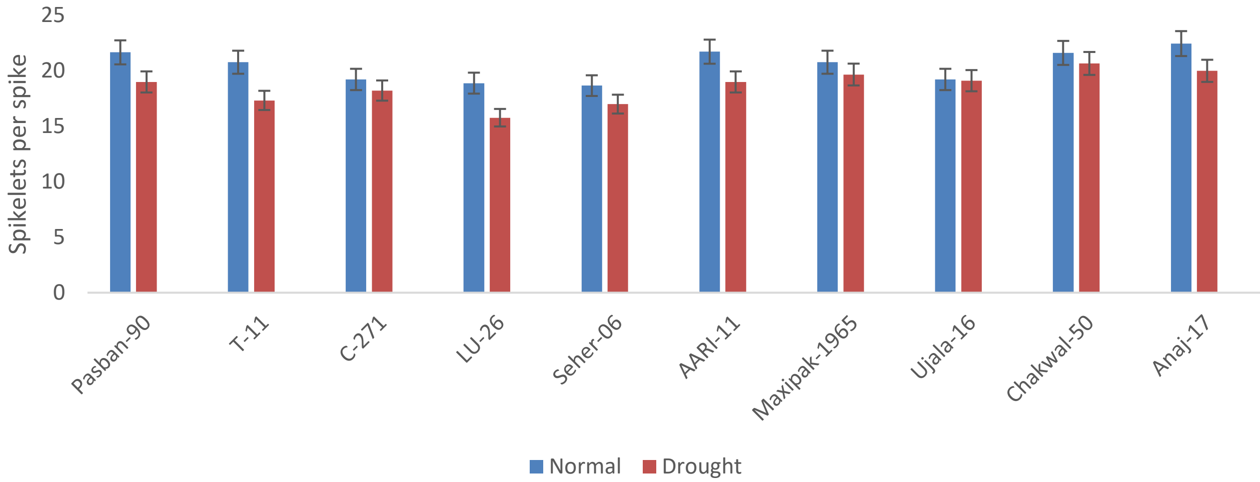

Figure 8: Average values of 10 genotypes of wheat under two levels of Irrigation i.e. Normal and drought for Spikelets per spike.

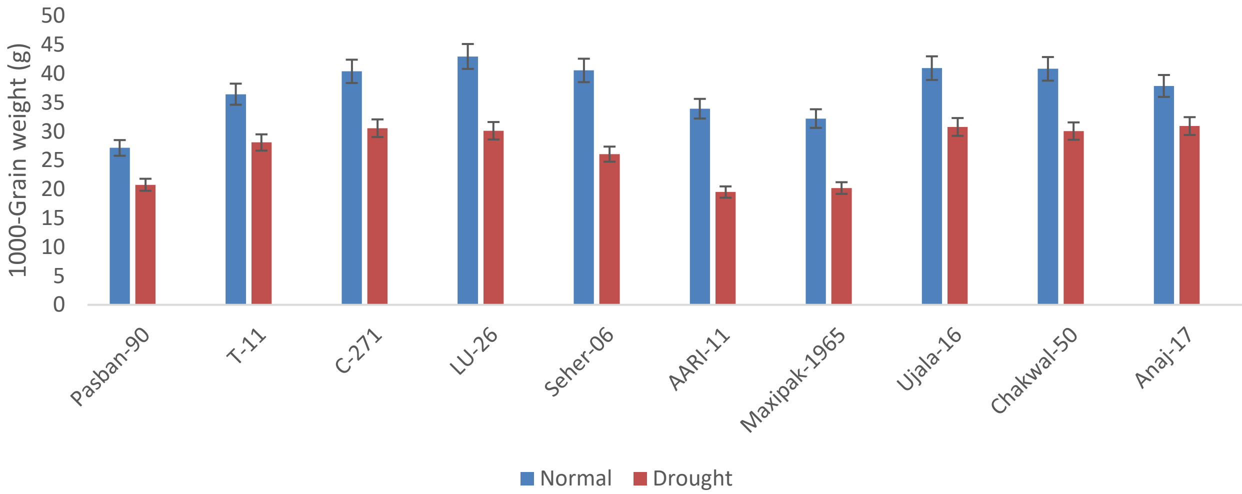

Figure 9: Average values of 10 genotypes of wheat under two levels of irrigation i.e. Normal and Drought for 1000-grain weight

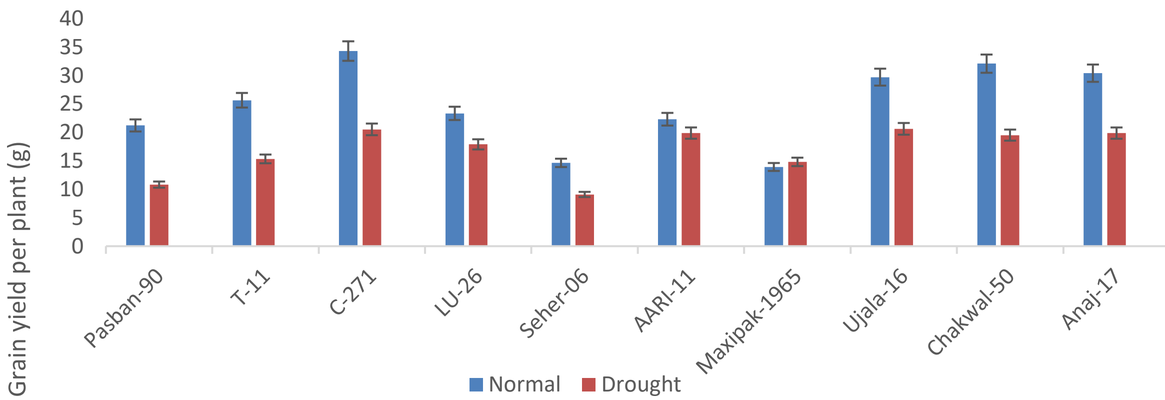

Figure 10: Average value of 10 genotypes of wheat under two levels of irrigation i.e. Normal and drought for Grain yield per plant

Biplot analysis of 10 wheat genotypes under two irrigation conditions i.e. normal and drought, for different yield-related attributes.

In this field experiment, 10 genotypes of wheat was screened out under two different conditions of irrigation, i.e. normal and drought.

Several studies have also been performed for selecting tolerant genotypes by using biplot analysis (Ajayi et al., 2020; Aminpanah et al., 2018; Karaman, 2019). Data for different yield-attributed traits were collected and exposed to Biplot analysis. The main objective of this analysis was to check out the performance of each genotype individually under both irrigation conditions.

Biplot analysis of 10 genotypes of wheat under two conditions of irrigation, i.e., normal and drought for plant height, is given in figure 11. The genotype which had made the longest OP vector was T-11 and performed best under both levels of irrigation, i.e., normal and drought, followed by AARI-11, LU-26 and Chakwal-50. C-271 performed better than other genotypes under drought conditions of irrigation for plant height. Comparable results were also found by (Eztollah Farshadfar et al., 2012; Kaya et al., 2006; Mohammadi et al., 2009; Rad et al., 2013). Biplot analysis of 10 genotypes of wheat under two conditions of irrigation i.e. normal and drought for a total number of tillers is given in figure 12. It was analyzed that Anaj-17 performed best for no. of tillers under normal conditions followed by Chakwal-50 and T-11. Under drought conditions, the performance for tillers per plant of C-271 was better than all other genotypes followed by Pasban-90 and Chakwal-50. It was also observed that under drought conditions of irrigation, the best performance was given by Ujala-16, followed by Chakwal-50 and C-271. The least performed under drought conditions was by AARI-11 for the flag leaf area (Fig. 13). Under normal conditions, Anaj-17 proved to be better than others regarding spike length, while in the case of drought conditions, the performance of Chakwal-50 and Pasban-90 was best as compared to other genotypes (Fig. 14). The best performance for peduncle length under drought condition was T-11 followed by C-271 while genotype LU-26 and Maxi-Pak 1965 performed best under normal condition of irrigation (Fig. 15). The most susceptible genotype to drought was Maxi-Pak 1965 for relative water contents but under normal condition Ujala-16 and C-271 also performed better than remaining genotypes (Fig. 16). These results were correlated with (Farshadfar & Sutka, 2006; Yildirim et al., 2018). The best performance for grains per spike under both conditions was by Maxi-Pak 1965. Under drought conditions, the genotypes which performed best regarding grains per spike were Chakwal-50 followed by Ujala-16 and Anaj-17. The most susceptible genotype to water deficit was Seher-06. The wheat genotype which performed better than others under normal conditions was also Chakwal-50 followed by AARI-11 (Fig. 17). The best performance for spikelets per spike under drought conditions was Chakwal-50 followed by Maxi-Pak 1965 while genotype LU-26 was followed by Seher-06 were most susceptible to drought followed by 17(Aas-11×9515) and 13(10065) were susceptible for drought (Fig. 18). The best-performing genotype under each condition was Chakwal-50 regarding 1000-Grain weight (Fig. 19). The genotype which performed best under each condition was Anaj-17 regarding grain yield per plant. The most susceptible genotype to drought was Seher-06. Under drought conditions, the genotypes performed were Ujala-16, C-271 and Chakwal-50. These findings were also correlated with (Ezatollah Farshadfar et al., 2012; Kendal & Sener, 2015; Malik et al., 2014). The best-performing genotype under normal conditions of irrigation was C-271 (Fig. 20). Similar results were found by Arain et al. (2022).

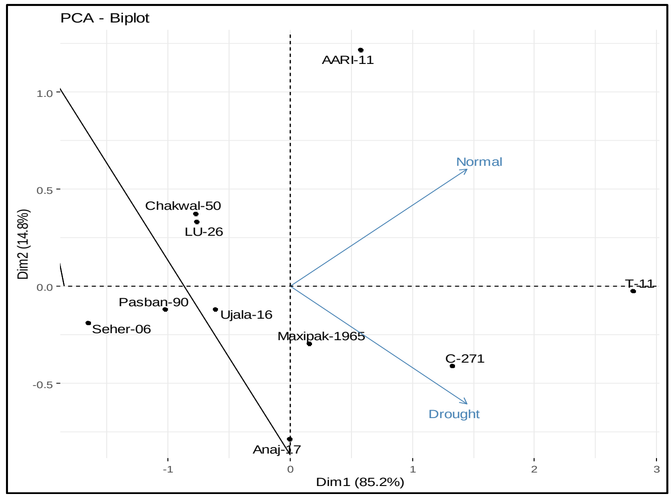

Figure 11: Biplot analysis of 10 genotypes of wheat under two conditions of irrigation i.e., normal and drought for Plant height

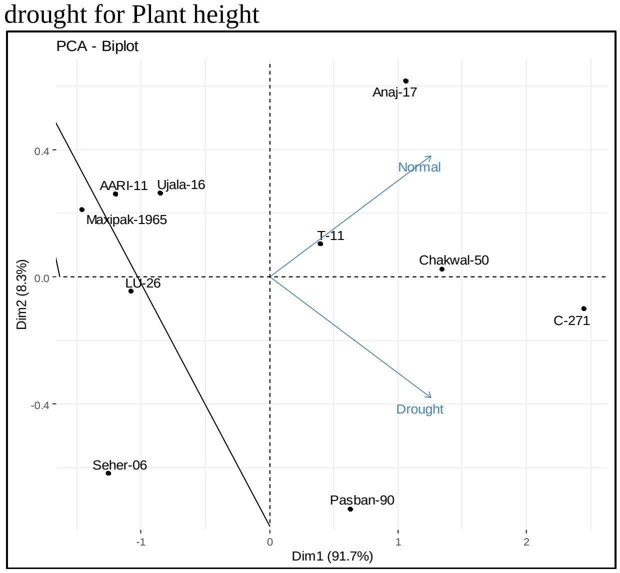

Figure 12: Biplot analysis of 10 genotypes of wheat under two conditions of irrigation i.e., normal and drought for number of tillers per plant

[Citation: Afzal, M., Khalid, M.N., Imtiaz, M., Nasir, B., Shah, S.A.H., Nawaz, M., Nayab, S.F., Malik, N.S., Majeed, T., Maqbool, R. (2023). Selection of drought tolerant wheat genotypes based on mean performance and biplot analysis. *Biol. Clin. Sci. Res. J.*, **2023***: 188*. doi: https://doi.org/10.54112/bcsrj.v2023i1.188]

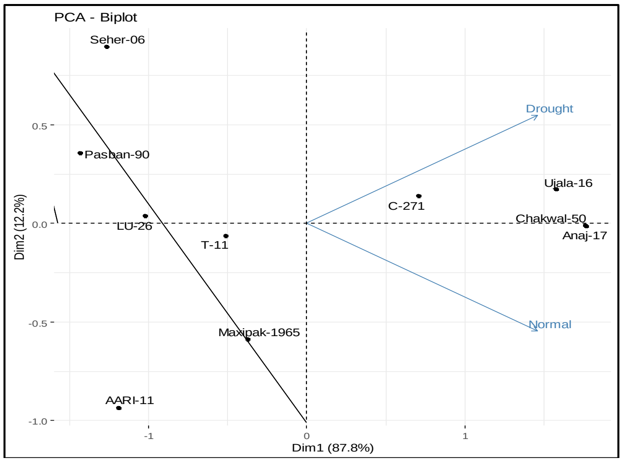

Figure 13: Biplot analysis of 10 genotypes of wheat under two conditions of irrigation i.e., normal and drought for Flag leaf area

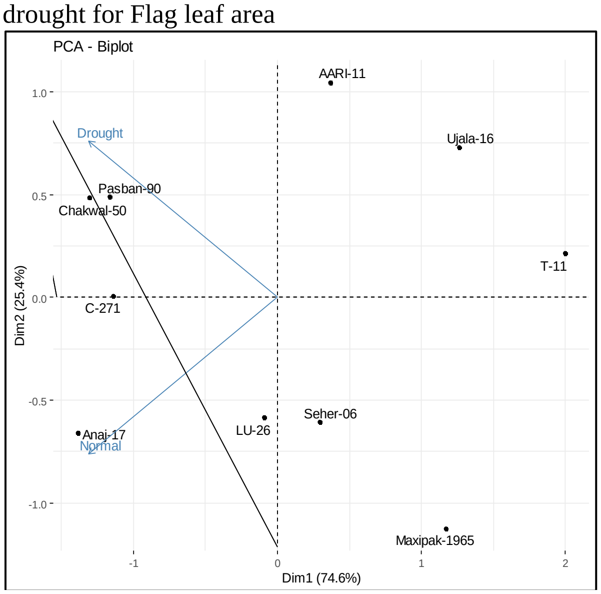

Figure 14: Biplot analysis of 10 genotypes of wheat under two conditions of irrigation i.e., normal and drought for Spike length

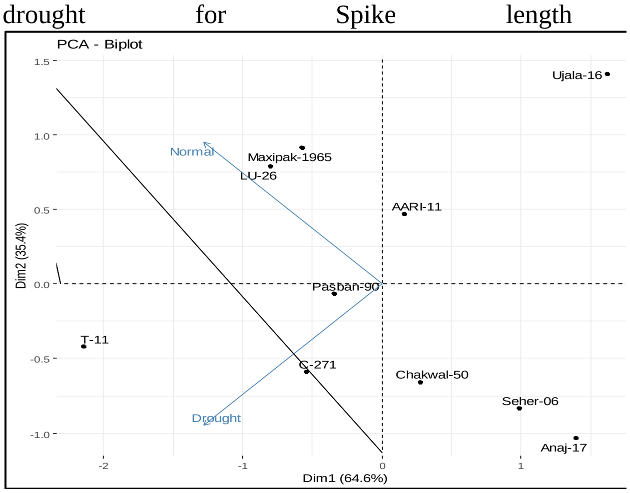

Figure 15: Biplot analysis of 10 genotypes of wheat under two conditions of irrigation i.e., normal and drought for Peduncle length

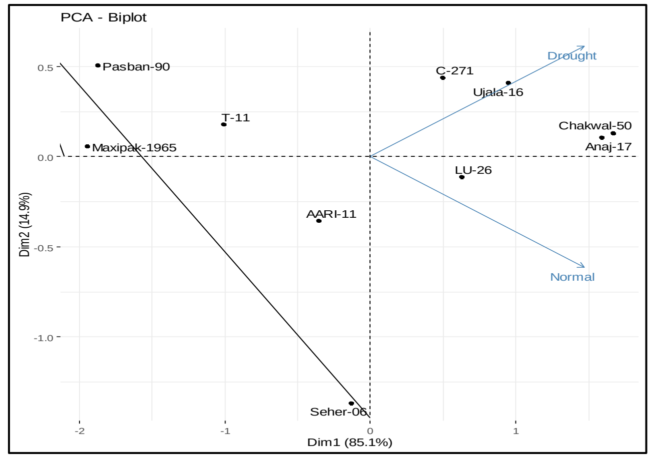

Figure 16: Biplot analysis of 10 genotypes of wheat under two conditions of irrigation i.e., normal and drought for Relative water contents

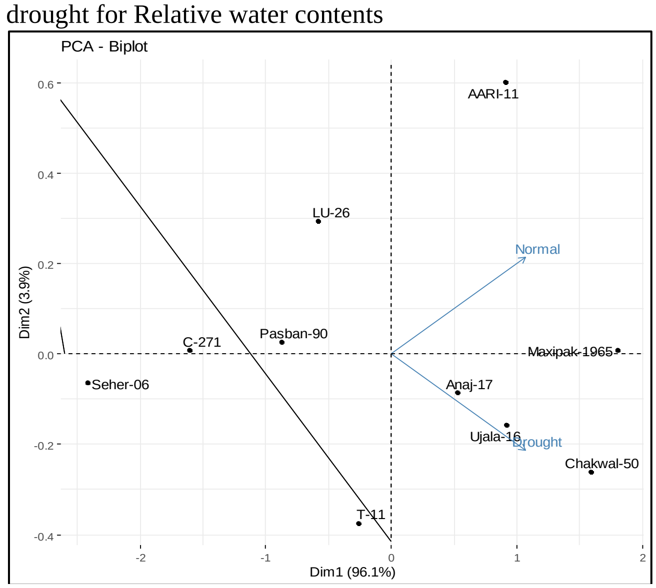

Figure 17: Biplot analysis of 10 genotypes of wheat under two conditions of irrigation i.e., normal and drought for number of grains per spike

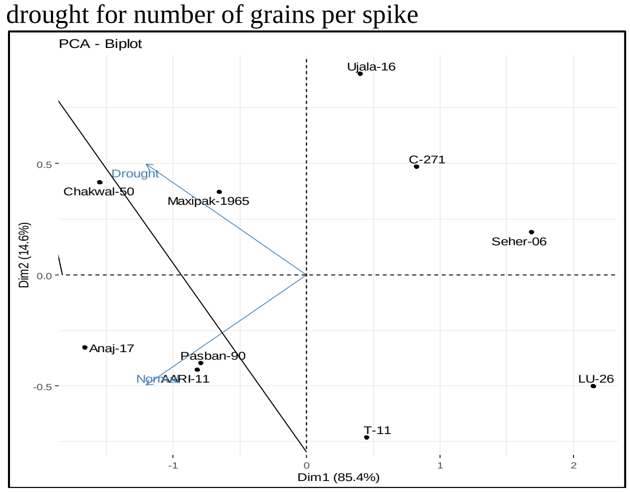

Figure 18: Biplot analysis of 10 genotypes of wheat under two conditions of irrigation i.e., normal and drought for Spikelets per spike

[Citation: Afzal, M., Khalid, M.N., Imtiaz, M., Nasir, B., Shah, S.A.H., Nawaz, M., Nayab, S.F., Malik, N.S., Majeed, T., Maqbool, R. (2023). Selection of drought tolerant wheat genotypes based on mean performance and biplot analysis. *Biol. Clin. Sci. Res. J.*, **2023***: 188*. doi: https://doi.org/10.54112/bcsrj.v2023i1.188]

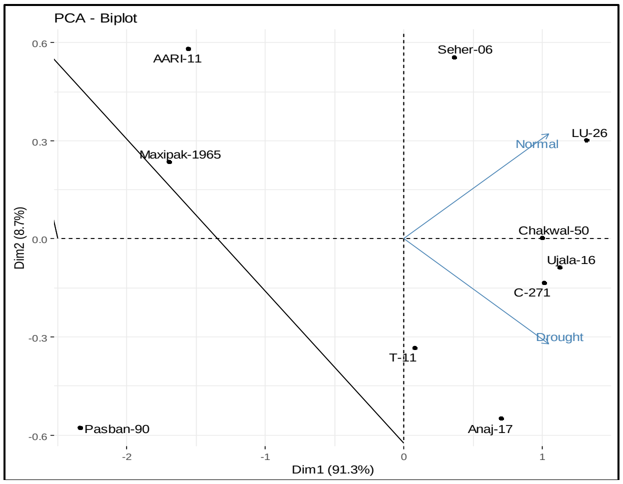

Figure 19: Biplot analysis of 10 genotypes of wheat under two conditions of irrigation i.e., normal and drought 1000-Grain weight

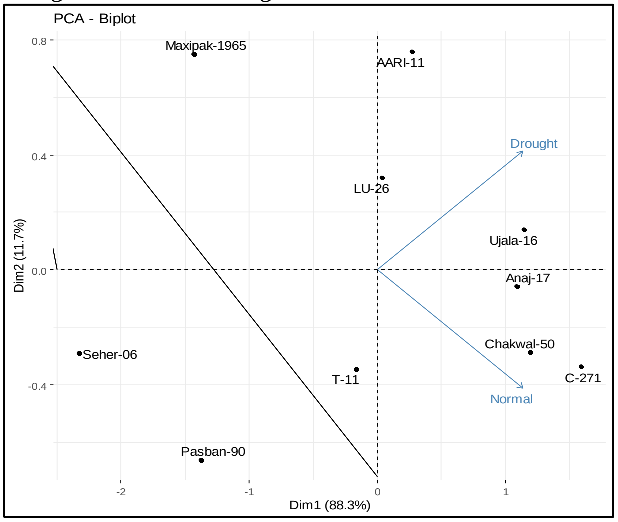

Figure 20: Biplot analysis of 10 genotypes of wheat under two conditions of irrigation i.e., normal and drought for Grain yield per plant

Conclusion

It is the direst need time to manipulate wheat genotypes genetically on a sustained basis so that new and advanced genotypes can be introduced to fulfill the demand for wheat with the increasing population of the World. Among all these stresses, water deficit is one of the most devastating abiotic stresses that decrease the yield. Therefore, it is necessary to understand the genetic makeup and mechanisms occurring in the wheat crops so that this information can be used in the future to improve grain yield. Under the normal conditions of irrigation, the maximum grain yield per plant was computed for C-271 while the minimum yield was observed for Maxi-Pak 1965. Under drought conditions of irrigation, the maximum grain yield mean value was of Ujala-16, while the minimum grain yield value was Seher-06. According to Biplot analysis, the genotype which performed best under both conditions for grain yield per plant was Anaj-17. The most susceptible genotype to drought was Seher-06. Under drought conditions, the genotypes which performed best were Ujala-16, C-271 and Chakwal-50. The best-performing genotype under normal conditions of irrigation was C-271 for grain yield per plant.

References

Conflict of interest

The authors declared absence of conflict of interest.

Ahmad, Z., Waraich, E. A., Akhtar, S., Anjum, S., Ahmad, T., Mahboob, W., Hafeez, O. B. A., Tapera, T., Labuschagne, M., & Rizwan, M. (2018). Physiological responses of wheat to drought stress and its mitigation approaches. *Acta Physiologiae Plantarum* **40**, 1-13.

Ajayi, A. T., Gbadamosi, A. E., Olumekun, V. O., & Nwosu, P. O. (2020). GT biplot analysis of shoot traits indicating drought tolerance in cowpea [Vigna unguiculata (L.) Walp] accessions at vegetative stage. *International Journal of BioSciences & Technology* **13**.

Aminpanah, H., Sharifi, P., & Ebadi, A. A. (2018). Evaluation of rice genotypes based on yield and yield components under complete irrigation and drought stress conditions and drought tolerance indices using biplot analysis. *Cereal Research* **8**, 169-183.

Anwaar, H. A., Perveen, R., Mansha, M. Z., Abid, M., Sarwar, Z. M., Aatif, H. M., ud din Umar, U., Sajid, M., Aslam, H. M. U., & Alam, M. M. (2020). Assessment of grain yield indices in response to drought stress in wheat (Triticum aestivum L.). *Saudi Journal of Biological Sciences* **27**, 1818-1823.

Arain, S. M., Sial, M. A., & Jamali, K. D. (2022). Identification of wheat mutants with improved drought tolerance and grain yield potential using biplot analysis. *Pak. J. Bot* **54**, 45-55.

Bányai, J., Kiss, T., Gizaw, S., Mayer, M., Spitkó, T., Tóth, V., Kuti, C., Mészáros, K., Láng, L., & Karsai, I. (2020). Identification of superior spring durum wheat genotypes under irrigated and rain-fed conditions. *Cereal research communications* **48**, 355-364.

Dorostkar, S., Dadkhodaie, A., & Heidari, B. (2015). Evaluation of grain yield indices in hexaploid wheat genotypes in response to drought stress. *Archives of Agronomy and Soil Science* **61**, 397-413.

El Sabagh, A., Hossain, A., Barutcular, C., Islam, M. S., Awan, S., Galal, A., Iqbal, M., Sytar, O., Yildirim, M., & Meena, R. (2019). Wheat (Triticum aestivum l.) production under drought and heat stress–adverse effects, mechanisms and mitigation: A review.

Farshadfar, E., & Elyasi, P. (2012). Screening quantitative indicators of drought tolerance in

[Citation: Afzal, M., Khalid, M.N., Imtiaz, M., Nasir, B., Shah, S.A.H., Nawaz, M., Nayab, S.F., Malik, N.S., Majeed, T., Maqbool, R. (2023). Selection of drought tolerant wheat genotypes based on mean performance and biplot analysis. *Biol. Clin. Sci. Res. J.*, **2023***: 188*. doi: https://doi.org/10.54112/bcsrj.v2023i1.188]

bread wheat (Triticum aestivum L.) landraces. *European Journal of Experimental Biology* **2**, 577-584.

Farshadfar, E., & Sutka, J. (2006). Biplot analysis of genotype-environment interaction in durum wheat using the AMMI model. *Acta Agronomica Hungarica* **54**, 459-467.

Farshadfar, E., Jamshidi, B., & Aghaee, M. (2012). Biplot analysis of drought tolerance indicators in bread wheat landraces of Iran. *International Journal of Agriculture and Crop Sciences* **4**, 226-233.

Farshadfar, E., Mohammadi, R., Aghaee, M., & Vaisi, Z. (2012). GGE biplot analysis of genotype x environment interaction in wheat-barley disomic addition lines. *Australian Journal of Crop Science* **6**, 1074-1079.

Gholamin, R., & Khayatnezhad, M. (2020). Study of bread wheat genotype physiological and biochemical responses to drought stress. *Helix-The Scientific Explorer| Peer Reviewed Bimonthly International Journal* **10**, 87-92.

Karaman, M. (2019). Evaluation of bread wheat genotypes in irrigated and rainfed conditions using biplot analysis. *Applied Ecology and Environmental Research* **17**, 1431-1450.

Kaya, Y., Akçura, M., & Taner, S. (2006). GGE-biplot analysis of multi-environment yield trials in bread wheat. *Turkish Journal of Agriculture and Forestry* **30**, 325-337.

Kendal, E., & Sener, O. (2015). Examination of genotype× environment interactions by GGE biplot analysis in spring durum wheat. *Indian J. Genet* **75**, 341-348.

Khayatnezhad, M., & Gholamin, R. (2020). Study of durum wheat genotypes' response to drought stress conditions. *Helix-The Scientific Explorer| Peer Reviewed Bimonthly International Journal* **10**, 98-103.

Malik, R., Sharma, H., Sharma, I., Kundu, S., Verma, A., Sheoran, S., Kumar, R., & Chatrath, R. (2014). Genetic diversity of agro-morphological characters in Indian wheat varieties using GT biplot. *Australian Journal of Crop Science* **8**, 1266-1271.

Mohammadi, R., & Abdulahi, A. (2017). Evaluation of durum wheat genotypes based on drought tolerance indices under different levels of drought stress. *Journal of Agricultural Sciences, Belgrade* **62**, 1-14.

Mohammadi, R., Haghparast, R., Amri, A., & Ceccarelli, S. (2009). Yield stability of rainfed durum wheat and GGE biplot analysis of multi-environment trials. *Crop and Pasture Science* **61**, 92-101.

Naeem, M. K., Ahmad, M., Kamran, M., Shah, M. K. N., & Iqbal, M. S. (2015). Physiological responses of wheat (Triticum aestivum L.) to drought stress. *International Journal of Plant and Soil Science* **6**, 1-9.

Pequeno, D. N., Hernandez-Ochoa, I. M., Reynolds, M., Sonder, K., MoleroMilan, A., Robertson, R. D., Lopes, M. S., Xiong, W., Kropff, M., & Asseng, S. (2021). Climate impact and adaptation to heat and drought stress of regional and global wheat production. *Environmental Research Letters* **16**, 054070.

Rad, M. N., Kadir, M. A., Rafii, M., Jaafar, H. Z., Naghavi, M., & Ahmadi, F. (2013). Genotype environment interaction by AMMI and GGE biplot analysis in three consecutive generations of wheat (Triticum aestivum) under normal and drought stress conditions. *Australian Journal of Crop Science* **7**, 956.

Roostaei, M., Rajabi, R., Jafarzadeh, J., & Mohammadi, R. (2021). Assessment of drought tolerance and grain yield stability of rainfed winter bread wheat (Triticum aestivum L.) genotypes. *Crop breeding journal* **11**, 25-44.

Sallam, A., Alqudah, A. M., Dawood, M. F., Baenziger, P. S., & Börner, A. (2019). Drought stress tolerance in wheat and barley: advances in physiology, breeding and genetics research. *International journal of molecular sciences* **20**, 3137.

Sattar, A., Sher, A., Ijaz, M., Ul-Allah, S., Rizwan, M. S., Hussain, M., Jabran, K., & Cheema, M. A. (2020). Terminal drought and heat stress alter physiological and biochemical attributes in flag leaf of bread wheat. *PloS one* **15**, e0232974.

Sharifi, P., & Mohammadkhani, N. (2016). Effects of drought stress on photosynthesis factors in wheat genotypes during anthesis. *Cereal research communications* **44**, 229-239.

Shirvani, F., Mohammadi, R., Daneshvar, M., & Ismaili, A. (2022). Genetic variability, response to selection for agro-physiological traits, and traits-enhanced drought tolerance in durum wheat. *Acta Ecologica Sinica*.

Tofig, A. (2015). Effect of drought stress on some physiological traits of durum (Triticum durum Desf.) and bread (Triticum aestivum L.) wheat genotypes. *Journal of Stress Physiology & Biochemistry* **11**, 29-38.

Wang, J. Y., Turner, N. C., Liu, Y. X., Siddique, K. H., & Xiong, Y. C. (2016). Effects of drought stress on morphological, physiological and biochemical characteristics of wheat species differing in ploidy level. *Functional Plant Biology* **44**, 219-234.

Yildirim, M., Barutcular, C., Koc, M., Dizlek, H., Hossain, A., Islam, M. S., Toptas, I., Basdemir, F., Albayrak, O., & Akinci, C. (2018). Assessment of the grain quality of wheat genotypes grown under multiple environments using GGE biplot analysis. *Fresenius Environmental Bulletin* **27**, 4830-4837.

Zahra, N., Wahid, A., Hafeez, M. B., Ullah, A., Siddique, K. H., & Farooq, M. (2021). Grain development in wheat under combined heat and drought stress: Plant responses and management. *Environmental and Experimental Botany* **188**, 104517.

[Citation: Afzal, M., Khalid, M.N., Imtiaz, M., Nasir, B., Shah, S.A.H., Nawaz, M., Nayab, S.F., Malik, N.S., Majeed, T., Maqbool, R. (2023). Selection of drought tolerant wheat genotypes based on mean performance and biplot analysis. *Biol. Clin. Sci. Res. J.*, **2023***: 188*. doi: https://doi.org/10.54112/bcsrj.v2023i1.188]