

Research Article



Characterization of Wheat Genotypes for Sustainable Production in the Face of Changing Climatic Conditions

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ABSTRACT One of the many challenging abiotic factors affecting wheat growth and yield in arid and semiarid regions is drought. This research conducted during the years 2022-2023, involved the evaluation of 100 wheat genotypes. In this experiment, explored the seedling-stage responses, revealing that genotypes such as G33, G68, and G29 demonstrated superior growth and water regulation under normal and drought conditions in most of the studied traits. Conversely, G99, G84, and G91 exhibited lower mean values, indicating these genotypes as a drought susceptible. The results emphasized the importance of selecting genotypes with favorable traits for enhanced drought tolerance and improved yield potential. The study's importance lies in the identification of genotypes with resilient traits under water stress, providing valuable insights for breeding programs aimed at developing drought-tolerant spring wheat varieties. The results and discussions presented the genetic variability in wheat and offer practical implications for sustainable crop production in the face of changing climatic conditions.

Keywords: *Wheat; Drought; Genetics; Plant; Yield; Seedling*

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INTRODUCTION Drought is a formidable environmental stress that significantly impacts the growth, development, and productivity of wheat plants. The effects of drought are multifaceted, affecting various physiological and biochemical processes crucial for optimal wheat growth. One of the primary consequences of drought stress is water scarcity, leading to reduced cell turgor pressure and impaired cell expansion. As a result, wheat plants often exhibit wilting, leaf rolling, and a general decline in overall turgidity (Chowdhury et al., 2021). Wheat, a major staple crop, faces increasing challenges from climate change, with drought being a primary threat to its productivity. In response to water scarcity, wheat plants activate a series of adaptive mechanisms to ensure survival and maintain essential physiological processes. One critical strategy involves osmotic adjustment, where the plant accumulates compatible solutes like proline and sugars to sustain cell turgor and osmotic potential. This osmoregulation aids in preserving cellular integrity under water-deficit conditions (Habibpor et al., 2011). Trait selection is a fundamental aspect of breeding programs aimed at enhancing drought tolerance in wheat. The

identification and incorporation of specific traits related to water-use efficiency and stress adaptation play a pivotal role in developing wheat varieties resilient to water scarcity. Wheat, a crucial staple crop globally, faces increasing challenges due to climate change, with drought being a significant threat to its productivity (Iqbal, 2019). To address this, breeding strategies for drought tolerance in wheat necessitate the careful selection of traits that enable the crop to withstand water scarcity. Here, we explore key traits crucial in wheat breeding programs focused on enhancing drought tolerance. Root architecture is a critical trait that profoundly influences a plant's ability to access water resources. Breeding for drought tolerance involves selecting wheat genotypes with deep and extensive root systems (Arifuzzaman et al., 2020). Deep roots enable plants to explore soil depths, accessing water stored at lower levels during periods of water scarcity. The selection of genotypes with enhanced root traits contributes to improved water uptake efficiency. Wheat varieties with extensive and deep root systems are prioritized in breeding efforts. Deep roots allow plants to access moisture stored in deeper soil layers during periods of drought. Varieties

exhibiting superior root traits contribute to improved water uptake efficiency, enhancing the plant's ability to withstand water stress (Ishaq et al., 2023). Within genetically diverse wheat populations, there exists a spectrum of traits related to drought tolerance. These traits may include variations in root architecture, leaf morphology, flowering time, and molecular markers associated with stress response. Exploring and understanding this diversity enable researchers to pinpoint adaptive traits that contribute significantly to drought resilience (Noorka; Teixeira da Silva, 2014). Physiological screening extends to below-ground traits, especially root characteristics. Root traits, including depth, length, and architecture, profoundly influence a plant's ability to access soil moisture. Screening for root traits assists in identifying wheat genotypes with adaptive root systems capable of efficient water extraction from deeper soil layers (Grzesiak et al., 2019).

Drought-tolerant genotypes often possess deep and extensive root systems, allowing for efficient water uptake from deeper soil layers. Holistic breeding approaches represent a dynamic and integrated framework for enhancing drought tolerance in spring wheat. By combining traditional breeding methods with state-of-the-art technologies, considering multi-trait selection, and engaging stakeholders, holistic breeding ensures a more resilient and adaptive wheat crop (Abdelghany et al., 2023). The incorporation of adaptive strategies and continuous improvement aligns with the objectives of the thesis, contributing to the development of spring wheat genotypes that can thrive under challenging water-deficient conditions.

MATERIAL AND METHODS

The experimental material was comprised of 100 wheat genotypes. These genotypes were collected from different wheat Breeding Institutes. The experiment was conducted in wire house under both normal and drought conditions to check the performance of the germplasm at seedling stage. Two seeds of each genotype were sown in polythene bags filled by sandy loam soil under complete randomized design (CRD) with three replications. The reason to sow seeds in sandy loam soil was to save roots from damage. After germination, only one plant per bag was kept for eighty genotypes under both conditions. The bags kept under drought condition were not watered after their complete germination till the development of three leaves. The bags under normal condition were watered regularly to their field capacity till the development of three leaves. In each replication, twelve seedlings of each genotype were kept. After twenty-one days of sowing, at three leaves stage, data were recorded for these traits namely root length, shoot length, root shoot ratio, leaf relative water content and excised leaf water loss. On the basis of studied traits, the three genotypes were selected showing tolerance to drought stress as lines and three genotypes which showed the susceptibility against the drought stress were selected as testers. The data was subjected to Analysis of Variance (ANOVA) (Steel et al., 1980) for different morphological traits and mean comparison using radar graph analysis under normal and drought conditions.

RESULTS AND DISCUSSION

This study focuses on the assessment of genetic variability and relatedness among 100 spring wheat genotypes under both normal and drought conditions. Various morphological attributes, including root length (RL), shoot length (SL), root-to-shoot ratio (R/S), relative water content (RWC), and excised leaf water loss (ELWL), were evaluated to understand the genotypic responses to water stress.

Root Length (RL)

The depth and extent of root development are indicative of a genotype's ability to explore the soil for water resources. A longer root length suggests improved drought tolerance as the plant can access water from deeper soil layers, ensuring sustained growth and development during water scarcity. The analysis of variance (ANOVA) for root length (RL) in wheat genotypes exposed to normal and drought conditions demonstrated significant variability attributed to genotypes, environments, and their interaction (Table 1). The genotype effect was highly significant, indicating substantial genetic diversity in root length among the studied wheat genotypes. The environmental effect was also highly significant, underscoring the substantial impact of growth conditions on RL. This interaction highlights the importance of understanding how genotypes respond to varying environmental stresses, especially under drought conditions. The observed genetic variability in RL among wheat genotypes signifies the potential for selecting varieties with optimal root characteristics for improved water and nutrient uptake, particularly in drought-prone environments. These findings contribute valuable insights into the genetic basis of root traits, facilitating targeted breeding efforts to enhance the drought resilience of wheat varieties (Ahmad, et al., 2022).

Under normal conditions, the root length (RL) of the 100 wheat genotypes displayed a diverse range, with values ranging from 14.15 to 29.15 cm and a mean of 18.37 cm. This variability, highlighted by a moderate standard deviation (SD) of ± 3.32 and a coefficient of variation (CV) of 18.05%, emphasizes the potential for selecting genotypes with desirable root length characteristics (Table 2). Under drought conditions, RL ranged from 9.28 to 23.79, presenting a mean of 17cm. The SD was ± 3.29 , and the CV was 19.35%, indicating higher variability under stress (Table 2). Mean values for 100 studied wheat genotypes about this trait mentioned in Figure 1 and Figure 2 under normal and drought conditions respectively in this study. The genotypes G99 (14.15), G84 (14.65), and G91 (14.95) exhibited the lowest mean values for root length under normal conditions. In contrast, G33 (29.15), G68 (27.81), and G29 (28.09) displayed the upper mean values, indicating superior performance in root development. Under drought conditions, wheat genotypes with lower mean values for root length included G99 (9.28), G84 (9.36), and G91 (9.66). In contrast, those with upper mean values were G33 (23.79), G68 (23.46), and G29 (22.74) indicating variations in drought tolerance and root development.

Shoot length (SL)

The shoot length is vital for assessing the overall growth and development of wheat genotypes, especially under drought

conditions. A well-developed shoot system is crucial for capturing sunlight and facilitating photosynthesis. In the context of drought tolerance, genotypes with optimal shoot lengths may demonstrate better adaptation to water-limited environments, contributing to enhanced grain yield (Ahmad et al., 2014). The analysis of variance (ANOVA) for shoot length (SL) in wheat genotypes exposed to normal and drought conditions revealed significant variability attributed to genotypes, environments, and their interaction. The environmental effect was also highly significant emphasizing the considerable influence of growth conditions on SL (Table 1). This interaction underscores the importance of understanding the genotype-specific responses to different environmental stresses, particularly under drought conditions (Farshadfar et al., 2014). The observed genetic variability in SL among wheat genotypes highlights the potential for selecting varieties with optimal shoot characteristics, which is crucial for overall plant development and yield. These findings contribute valuable insights into the genetic basis of shoot traits, providing a basis for targeted breeding efforts to enhance the adaptability and performance of wheat varieties under varying environmental conditions (Bukhari et al., 2021).

Shoot length (SL) exhibited variations among the wheat genotypes under normal conditions. The SL ranged from 22.99 to 32.38 cm, with an average of 27.67 cm. The relatively lower CV of 6.97% and SD was ± 1.93 for SL indicates a more consistent trait among the studied genotypes (Table 2).

SL had a minimum of 17.11cm, a maximum of 26.49cm, and a mean of 21.81cm, with an SD of ± 1.94 and a CV of 8.91, suggesting moderate variability compared to normal conditions (Table 2).

Mean values for 100 studied wheat genotypes about this trait mentioned in Figure 1 and Figure 2 under normal and drought conditions respectively in this study. Wheat genotypes with lower mean shoot lengths under normal conditions included G99 (22.99), G84 (23.82), and G91 (24.1). On the other hand, G29 (31.06), G68 (31.32), and G33 (32.38) demonstrated superior shoot length performance. The genotypes G91 (17.11), G84 (17.94), and G99 (18.22) exhibited lower mean shoot lengths under drought conditions. Conversely, G68 (25.17), G29 (25.43), and G33 (26.49) displayed higher mean shoot lengths, suggesting differences in response to water scarcity (Chowdhury et al., 2021).

Root-to-shoot ratio (R/S)

The root-to-shoot ratio is a key morphological trait that provides insights into the biomass allocation strategy of wheat genotypes. An increased root-to-shoot ratio under drought conditions may indicate a genotype's ability to prioritize root growth, allowing for efficient water uptake and utilization. This trait is essential for characterizing the drought tolerance mechanisms of wheat genotypes.

The analysis of variance (ANOVA) for root-to-shoot ratio (R/S) in wheat genotypes subjected to normal and drought conditions demonstrated significant variation attributed to genotypes, environments, and their interaction. Genotypic differences were highly significant, indicating substantial genetic diversity in the root-to-shoot ratio among the studied wheat genotypes. The

environment effect was also highly significant underscoring the pronounced influence of growth conditions on the R/S ratio (Table 1). This interaction emphasizes the need to consider genotype-specific responses to environmental stresses, particularly in the context of R/S ratio.

The significant genetic variability observed in R/S ratio among wheat genotypes highlights the potential for selecting varieties with optimized root-to-shoot characteristics. This trait plays a crucial role in resource utilization and stress adaptation. These findings provide valuable insights for wheat breeding programs aiming to develop varieties with improved root-to-shoot ratios, contributing to enhanced drought tolerance and overall plant performance (Kumar et al., 2016).

The root-to-shoot ratio (R/S) demonstrated considerable variability among the wheat genotypes under normal conditions. With values ranging from 43.69 to 98.27 and an average of 66.81, the genotypes displayed distinct patterns in allocating resources between roots and shoots. The moderate CV of 19.59% and SD value ± 13.09 suggests potential avenues for selecting genotypes with optimized root-to-shoot ratio (Table 2).

R/S ratio ranged from 35.03 to 98.24, with a mean of 80 and a CV of 19.9, indicating significant variability in the root-to-shoot ratio. The SD value was ± 15.92 under drought condition (Table 2). Mean values for 100 studied wheat genotypes about this trait are mentioned in Figure 1 and Figure 2 under normal and drought conditions respectively in this study. The genotypes G99 (43.69), G84 (46.76), and G91 (49.02) exhibited lower mean values for root-to-shoot ratio under normal conditions. In contrast, G68 (97.06), G33 (97.51), and G29 (98.27) displayed higher mean values, indicating a more balanced distribution of biomass between roots and shoots. Lower mean values for root-to-shoot ratio under drought conditions were observed in G99 (35.03), G84 (36.82), and G91 (39.28). On the other hand, genotypes with upper mean values included G29 (97.55), G33 (97.95), and G68 (98.24), indicating diverse strategies in biomass allocation during drought stress.

Relative water contents (RWC)

Relative water content is a critical parameter for evaluating the water status of wheat genotypes. It reflects the ability of plant tissues to retain water, which is crucial for withstanding drought stress. Genotypes with higher relative water content under drought conditions were likely to exhibit improved water retention capacities, contributing to enhanced drought tolerance (Grzesiak et al., 2019).

The analysis of variance (ANOVA) for relative water contents (RWC) in wheat genotypes exposed to normal and drought conditions revealed significant variation attributable to genotypes and environments (Table 1). Despite this, the significant genetic variability observed in RWC among wheat genotypes underscores the importance of genetic factors in determining water retention capacity (Amare et al., 2019).

Wheat genotypes exhibiting higher RWC values under drought conditions were indicative of enhanced drought tolerance. These findings offer valuable insights for wheat breeding efforts focused on developing varieties with improved water-use efficiency and resilience to water scarcity. The identification of

genotypes with superior RWC provides a foundation for targeted breeding strategies aimed at improving drought adaptation in wheat crops.

Under normal conditions, the relative water content (RWC) of the 100 wheat genotypes ranged from 69.13 to 83.15, with a mean of 73.7. The low CV of 2.98% and SD was ± 2.19 indicated a more uniform response among genotypes, highlighting the importance of this trait in maintaining water balance (Table 2). RWC showed a minimum of 65.08, a maximum of 79.17, a mean of 69.78, an SD of ± 2.22 , and a CV of 3.19, showcasing stability in this trait under stress (Table 2).

Mean values for 100 studied wheat genotypes about this trait are mentioned in Figure 1 and Figure 2 under normal and drought conditions respectively in this study. Lower mean values for relative water content under normal conditions were observed in G99 (69.13), G84 (70.13), and G91 (70.79). Conversely, genotypes with upper mean values included G29 (80.15), G68 (82.15), and G33 (83.15), indicating better water retention. The genotypes G99 (65.08), G84 (66.08), and G91 (66.73) showed lower mean values for relative water content under drought conditions. In contrast, G29 (76.17), G33 (78.17), and G68 (79.17) demonstrated higher mean values, suggesting differences in water retention abilities (Chowdhury et al., 2021). Excised leaf water loss (ELWL)

Excised leaf water loss is a valuable morphological marker for assessing the leaf-level water regulation mechanisms in wheat genotypes. Lower leaf water loss indicates better water use efficiency and adaptive mechanisms to reduce transpiration under drought conditions. Understanding this trait contributes to characterizing the drought tolerance mechanisms of spring wheat genotypes (Barakat et al., 2010).

The analysis of variance (ANOVA) for excised leaf water loss (ELWL) in wheat genotypes exposed to normal and drought conditions revealed significant variation attributed to both genotypes and environments (Table 1). This indicates that some

genotypes may exhibit altered water loss rates under drought stress, emphasizing the need for comprehensive assessments of ELWL in breeding programs (Ibrahim et al., 2012).

Wheat genotypes with lower ELWL values under drought conditions were indicative of reduced transpiration rates and improved water-use efficiency. These findings provide valuable information for breeding programs aiming to develop wheat varieties with enhanced drought tolerance. Identifying genotypes with superior ELWL characteristics was crucial for advancing breeding strategies focused on improving the water-use efficiency of wheat crops under water-limiting conditions (Kim et al., 014). Excised leaf (EL) traits also exhibited variability under normal conditions, with values ranging from 2.24 to 4.64 and a mean of 3.59. The moderate CV of 13.42% and SD ± 0.48 suggested diverse responses among wheat genotypes in terms of excised leaf water loss. These findings provide insights into the inherent variability of key seedling traits under normal conditions, crucial for understanding the potential performance of wheat genotypes in varying environmental conditions (Table 2). ELWL mean values varied from 2.2 to 4.6, with a mean of 3.56, a CV of 13.52, and SD of ± 0.48 indicating moderate variability in the response to drought stress (Table 2).

Mean values for 100 studied wheat genotypes about this trait mentioned in Figure 1 and Figure 2 under normal and drought conditions respectively in this study. Genotypes G91 (2.24), G84 (2.34), and G99 (2.44) demonstrated lower mean values for excised leaf water loss under normal conditions. In contrast, G29 (4.24), G68 (4.44), and G33 (4.64) displayed higher mean values, suggesting increased resistance to water loss through leaves. Genotypes G84 (2.2), G99 (2.3), and G91 (2.4) displayed lower mean values for excised leaf water loss under drought conditions. Conversely, G68 (4.2), G33 (4.4), and G29 (4.6) exhibited higher mean values, indicating variations in the ability to minimize water loss through leaves during drought stress.

Table 1: Mean Square values of Analysis of variances (ANNOVA) for studied traits

Source	DF	RL	SL	R/S	RWC	ELWL
Replications	2	3.06	18.34	0.00	152.42	0.05
Genotypes	99	68.09**	21.47**	0.14**	27.77**	1.45**
Environments	1	4214.37*	5160.97**	0.71*	2308.88**	0.09**
Genotypes*Environments	99	0.02*	0.02*	0.24**	0.26**	0.03*
Error	398	1.09	1.17	0.11	0.28	0.02
Total	599					

** = highly significant, * = significant

Table 2: Summary statistics of 100 wheat genotypes studied under normal and drought conditions using seedling traits

Traits	RL-N	RL-D	SL-N	SL-D	R/S-N	R/S-D	RWC-N	RWC-D	ELWL-N	ELWL-D
Minimum	14.15	9.28	22.99	17.11	43.69	35.03	69.13	65.08	2.24	2.2
Maximum	29.15	23.79	32.38	26.49	98.27	98.24	83.15	79.17	4.64	4.6
Mean	18.37	17	27.67	21.81	66.81	80	73.7	69.78	3.59	3.56
SD	3.32	3.29	1.93	1.94	13.09	15.92	2.19	2.22	0.48	0.48
CV	18.05	19.35	6.97	8.91	19.59	19.9	2.98	3.19	13.42	13.52

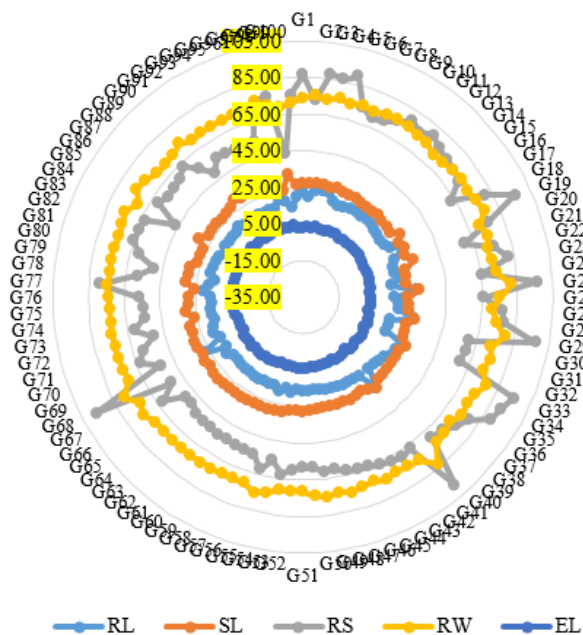


Figure 1: RADAR Graph for mean values of studied traits in 100 wheat genotypes under normal conditions

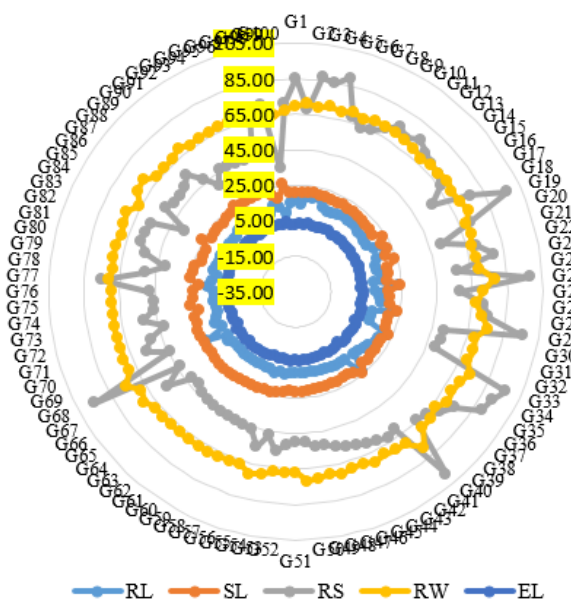


Figure 2: RADAR Graph for mean values of studied traits in 100 wheat genotypes under drought conditions

CONCLUSION

This study focused on germplasm screening at the seedling stage, involving the assessment of root length, shoot length, root/shoot ratio, leaf relative water content, and excised leaf water loss (ELWL) under both normal and drought conditions.

From the results of experiment, under normal conditions, genotypes such as G33, G68, and G29 exhibited superior performance in RL, SL, R/S, RWC and ELWL, showed their robust growth and efficient water regulation. In contrast, G99, G84, and G91 demonstrated lower mean values, suggesting potential areas for improvement in these genotypes. In drought conditions, the genotypes G33, G68, and G29 also maintaining their prominence in RL, SL, R/S, RWC, and ELWL. These genotypes displayed adaptive traits, such as increased root length and reduced excised leaf water loss, indicative of their drought tolerance. Conversely, G99, G84, and G91 continued to exhibit lower mean values, signifying potential susceptibility to water stress. The comprehensive summary highlights the importance of these morphological indices in characterizing the drought tolerance of spring wheat genotypes. The identified genotypes with superior traits serve as potential characteristics for further investigations and incorporation into breeding initiatives for enhanced drought tolerance in spring wheat.

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