*Biological and Clinical Sciences Research Journal*
*eISSN: 2708-2261; pISSN: 2958-4728*
*www.bcsrj.com*
DOI: https://doi.org/10.54112/bcsrj.v2023i1.506
*Biol. Clin. Sci. Res. J., Volume, **2023**: 506*
*Original Research Article*

# RICE RESILIENCE IN THE FACE OF CLIMATE CHALLENGES EXPLORING DROUGHT RESPONSE IN RICE GENOTYPES

***AYUB MA[1], IJAZ M[1], BANO M[2], BIBI A[3], BIBI T[3], GULNAZ S[4], KHAN RAR[3], MALLHI AR[5], SARFRAZ S[3], AHSAN A[4], ANWAR MR[1], LATIF A[6], NAZAR MZK[7], SHAFIQUE MT[2]**

[1]*Rice Research Station, Bahawalnagar, Pakistan*
[2]*Research Laboratory of Agriculture and Agri-Product Safety of the Ministry of Education, Yangzhou University, China*
[3]*Rice Research Institute, Kala Shah Kaku, Lahore-39018, Pakistan*
[4]*Wheat Research Institute, Ayub Agricultural Research Institute, Faisalabad, Pakistan*
[5]*Maize Research Station Faisalabad, Ayub Agricultural Research Institute, Faisalabad, Pakistan*
[6]*Vegetable Research Institute, Ayub Agricultural Research Institute Faisalabad, Pakistan*
[7]*Soil and Water Testing Laboratory Bahawalnagar, Pakistan*
**Corresponding author email address: ahsinyub@gmail.com*

*(Received, 14th May 2023, Revised 26th October 2023, Published 28th October 2023)*

**Abstract** *Climate change is posing significant challenges to agriculture, threatening global food security. Among these challenges, drought stress is a formidable obstacle to rice production, a staple food for billions. Drought stress disrupts vital physiological processes, causing yield losses and impacting grain quality. Developing drought-tolerant rice varieties is essential to ensure food production and farmers' livelihoods. This study explores the drought tolerance potential of six Basmati rice genotypes: Basmati 198 (G1), Basmati 385 (G2), Rachna basmati (G3), Super Basmati (G4), Shaheen basmati (G5), and Basmat 2000 (G6). These genotypes have previously demonstrated submergence tolerance. By subjecting them to drought stress, we aim to assess their adaptability to multiple stressors, crucial in changing climates. A Randomized Complete Block Design was employed, ensuring methodological rigor. Seedlings were transplanted into the field, and drought stress was induced during the booting stage. We monitored various traits, including plant height, productive tillers, panicle length, spikelet numbers, fertility, branches, biological yield, grain yield, and harvest index. Statistical analyses revealed significant genotype-specific responses to drought. Results showed significant differences among genotypes under both control and drought conditions, underscoring genetic variability. Drought stress significantly impacted most traits. Basmat 2000 (G6) demonstrated superior performance under drought conditions. Clustering analysis revealed genetic diversity among genotypes, offering insights for breeding programs. Correlation analysis highlighted the importance of specific traits for grain yield. In conclusion, this study contributes to understanding genetic diversity among Basmati rice genotypes under drought stress. The findings emphasize the need for developing drought-tolerant rice varieties and offer valuable insights for sustainable rice cultivation in changing climates*.

**Keywords:** climate change, drought stress, Basmati rice, genetic diversity, drought tolerance, sustainable agriculture

## Introduction

Climate change is transforming ecosystems and challenging various sectors, including agriculture. Rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events pose significant threats to global food security (Kim et al., 2020). Agricultural systems are particularly susceptible to these changes due to their reliance on stable climatic conditions for crop growth and productivity. As climate change intensifies, developing resilient crop varieties becomes paramount (Venuprasad et al., 2007). Drought stress is one of the most formidable challenges faced by rice production worldwide. Rice, a staple food for billions, is often cultivated in regions prone to erratic rainfall patterns and prolonged dry spells. Drought stress detrimentally affects rice at various growth stages, disrupting physiological processes essential for growth and yield (Pandey & Shukla, 2015). Reduced water availability leads to wilting, decreased photosynthesis, and impaired nutrient uptake, culminating in yield losses and compromised grain quality. Addressing drought stress in rice cultivation is pivotal to ensuring stable food

[Citation Ayub, M.A., Ijaz, M., Bano, M., Bibi, A., Bibi, T., Gulnaz, S., Khan, R.A.R., Mallhi, A.R., Sarfraz, S., Ahsan, A., Anwar, M.R., Latif, A., Nazar, M.Z.K., Shafique, M.T. (2023). Rice resilience in the face of climate challenges exploring drought response in rice genotypes. *Biol. Clin. Sci. Res. J.*, **2023***:* 506. doi: https://doi.org/10.54112/bcsrj.v2023i1.506]

production and safeguarding the livelihoods of millions of farmers (Singh et al., 2012).

Plants, including rice, exhibit a remarkable diversity in their responses to drought stress. This natural variation arises from the intricate interplay of genetic, physiological, and biochemical mechanisms (Nahar et al., 2016). Some rice genotypes demonstrate an inherent ability to tolerate drought by modulating their water use efficiency, altering root architecture to explore deeper soil layers, and adjusting their osmotic balance to prevent cellular damage. Understanding these diverse strategies can offer insights into identifying and harnessing genetic resources that confer drought tolerance (Shehab et al., 2010). Drought tolerance is a polygenic trait influenced by a network of genes that collectively govern the plant's response to water deficit. The genetic basis of drought tolerance involves regulatory genes that orchestrate stress-related gene expression, genes responsible for synthesizing protective molecules like Osmo protectants and antioxidants, and those that regulate stomatal closure to reduce water loss. Furthermore, the genetic pathways governing drought tolerance can intersect with other stress response pathways, underscoring the complexity of plant stress adaptation (Upadhyaya & Panda, 2019).

The overarching objective of this study is to explore the drought tolerance potential of rice genotypes that have previously demonstrated submergence tolerance. By subjecting these genotypes to drought stress, we aim to assess their adaptability to multiple stressors, which is paramount in changing climates (Ali et al., 2016; Ali et al., 2014ab; Khalid and Amjad, 2018; Raman et al., 2012). Our experimental approach involves carefully selected rice genotypes with established submergence tolerance, which we hypothesize might share certain underlying mechanisms with drought tolerance. Drought stress will be induced using controlled conditions, and physiological and morphological parameters will be measured to gauge the genotypes' response to water deficit (Aaliya et al., 2016; Ahsan et al., 2013; Ali et l., 2017; Ali et al., 2015; Ali et al., 2013; Iqbal et al., 2017; Salekdeh et al., 2002). In conclusion, the complex interplay between climate change, drought stress, and rice production necessitates the development of resilient rice genotypes that can thrive under challenging conditions. This study seeks to contribute to this goal by investigating the drought tolerance potential of rice genotypes known for submergence tolerance. Through a comprehensive understanding of how these genotypes respond to drought stress, we aim to shed light on novel stress adaptation mechanisms and offer valuable insights for sustainable rice cultivation in the face of evolving climatic patterns.

## Materials and Methods

**Plant Materials:** Six distinct rice types, namely Basmati 198 (G1), Basmati 385 (G2), Rachna basmati (G3), Super Basmati (G4), Shaheen basmati (G5), and Basmat 2000 (G6)**,** were utilized for the investigation. These rice types were selected to examine the response to drought stress.

**Experimental Design:** A Randomized Complete Block Design (RCBD) was employed to ensure methodological rigor and reliability. This facilitated a structured comparison of the rice types across different conditions. The experiment was implemented within the field environment, partitioning the rice into designated sections known as plots and sub-plots.

**Planting and Transplanting:** The process commenced by sowing rice seeds onto suitably moist raised beds. After a growth period of 35 days, the juvenile plants were transplanted to the main field with meticulously prepared soil. A standardized spacing of 9 inches between rows and individual plants was maintained. In spatial gaps, supplementary plants were introduced to ensure comprehensive coverage.

**Drought Stress:** At the specific developmental stage denoted as the "booting stage," drought stress was deliberately induced upon the rice plants. This entailed purposefully reducing the water supply to the plants over 30 days. This facilitated the observation of the different reactions of the distinct rice types to water scarcity.

**Data Collection:** Throughout the drought stress period, a meticulous monitoring of the rice plants was conducted. Factors such as plant height (PH), productive tillers per plant (PT), panicle length (PL), total spikelets per panicle (TS), sterile spikelets per panicle (SS), fertile spikelets per panicle (FS), fertility percentage ( FP), number of primary branches per panicle (PB), biological yield per plant (BY), grain yield per pant (GYP) and harvest index (HI) were taken at maturity. These observations facilitated a nuanced comprehension of each rice type's varying levels of drought resilience.

**Statistical Analysis:** Following the accumulation of data, statistical methodologies like ANOVA and dendrogram were employed using STATISTIX 8.1 to assess the genetic variability. Heat map analysis and correlation analysis was performed by using R software. The disparities between rice types under normal and drought conditions were scrutinized. This process yielded valuable insights into identifying rice types that demonstrated enhanced resistance to drought stress

## Results

The results of ANOVA under control conditions revealed that all the genotypes were highly significant for all the traits under study except

[Citation Ayub, M.A., Ijaz, M., Bano, M., Bibi, A., Bibi, T., Gulnaz, S., Khan, R.A.R., Mallhi, A.R., Sarfraz, S., Ahsan, A., Anwar, M.R., Latif, A., Nazar, M.Z.K., Shafique, M.T. (2023). Rice resilience in the face of climate challenges exploring drought response in rice genotypes. *Biol. Clin. Sci. Res. J.*, **2023***:* 506. doi: https://doi.org/10.54112/bcsrj.v2023i1.506]

biological yield (table 1). While in drought conditions, all the attributes showed highly significant results against genotypes except harvesting index and biological yield. The significance of the results showed that genetic variability was present among all genotypes under both conditions. Thus, the data was further analyzed for detailed studies. Drougt stress affected the performance of rice genotypes for most of the traits. The response of rice genotypes under control and drought stress is illustrated in figure 1 and 2 for all the parameters under study.

Heat map analysis was used to assess the mean performance of cotton genotypes. Under control conditions, G6 performed best for plan followed by G5 and G4, while G5 showed maximum values under drought stress. For productive tillers per plant, G2 showed maximum values under control while G5 showed maximum numbers of productive tillers per plant under drought stress. For panicle length, total spikelets and sterile spikelets per plant G6 performed best among all genotypes under both conditions. Under drought conditions, maximum fertile spikelets per plant were also exhibited by G6. For fertility %, G5 showed maximum values under control while G4 showed maximum values under drought stress. G1 showed maximum values for primary branches per plant under both conditions. G6 exhibited highest biological yield and grain yield per plant under drought stress. G4 showed highest values for harvest index under drought stress. The dendrograms under control (figure 5) and drought stress (figure 6) are representing the genetic diversity of all genotypes by dividing them into six different clusters.

Correlation analysis was performed to determine the association of different attributes with grain yield per plant under control and drought conditions. The results of correlation analysis are presented in the form of collarograms. Under control conditions, grain yield per plant had a significant and positive association with fertile spikelets per panicle, fertility percentage, primary branches per panicle, and harvest index, while significant and negative correlation was observed with sterile spikelets per panicle, panicle length, and plant height.

Under drought stress, plant height, biological yield per plant, fertile spikelets per panicle, total spikelets per panicle, panicle length, fertility percentage, and productive tillers per plant showed significant and positive associations with grain yield.

**Discussion**

In this study, we investigated the response of six distinct Basmati rice genotypes, namely Basmati 198 (G1), Basmati 385 (G2), Rachna basmati (G3), Super Basmati (G4), Shaheen basmati (G5), and Basmat 2000 (G6), to both control and drought stress conditions. The ANOVA results indicate significant differences among these genotypes for most studied traits under both conditions. This underscores the presence of genetic variability among these rice genotypes, aligning with prior research (Ahmad et al., 2022; Bhutta et al., 2019; Qureshi et al., 2018). The diverse genetic backgrounds among these genotypes can lead to distinct responses to environmental stressors.

Drought stress pronouncedly affected the performance of these rice genotypes across most of the measured traits. The adverse impact of drought stress on yield-related traits is well-documented (Aslam et al., 2022; Haider et al., 2012). The observed reductions in grain yield, panicle length, and fertile spikelets per panicle, among others, emphasize the challenges these genotypes face, consistent with previous findings. Such impacts necessitate the development of drought-tolerant varieties to ensure food security in water-scarce regions (Akram et al., 2013; Farooq et al., 2010).

Heat map analysis visually represented trait performance among these rice genotypes. The differential response of G6 (Basmat 2000) to drought stress, showcasing superior performance for several traits, underscores the potential for developing drought-resilient cultivars. These results align with studies emphasizing the significance of selecting appropriate genotypes tailored to specific agroclimatic conditions (Majeed et al., 2011).

The clustering analysis demonstrated the genetic diversity among these rice genotypes. The distinct clusters provide valuable insights for breeding programs, as diverse genetic backgrounds facilitate the development of hybrids with improved tolerance to environmental stressors (Ghouri et al., 2022). This approach aligns with established breeding strategies that aim to broaden the genetic base of cultivated rice varieties (Mostajeran & Rahimi-Eichi, 2008).

Correlation analysis revealed trait associations with grain yield, an essential consideration in crop improvement programs (Hanif et al., 2021). Under control conditions, the positive correlation between grain yield and fertile spikelets per panicle, fertility percentage, primary branches per panicle, and harvest index reinforces the importance of these traits for achieving optimal yields (Farooq et al., 2009). Under drought stress, traits such as plant height, biological yield per plant, fertile spikelets per panicle, total spikelets per panicle, panicle length, fertility percentage, and productive tillers per plant exhibited positive associations with grain yield. These associations highlight the significance of these traits for mitigating the yield-reducing effects of drought (Mumtaz et al., 2020; RASHEED et al., 2021).

**Conclusion**

[Citation Ayub, M.A., Ijaz, M., Bano, M., Bibi, A., Bibi, T., Gulnaz, S., Khan, R.A.R., Mallhi, A.R., Sarfraz, S., Ahsan, A., Anwar, M.R., Latif, A., Nazar, M.Z.K., Shafique, M.T. (2023). Rice resilience in the face of climate challenges exploring drought response in rice genotypes. *Biol. Clin. Sci. Res. J.*, **2023**: 506. doi: https://doi.org/10.54112/bcsrj.v2023i1.506]

In conclusion, the findings of this study contribute to our understanding of the genetic variability among Basmati rice genotypes in response to drought stress. The pronounced effects of drought on yield-related traits underscore the necessity for developing drought-tolerant varieties. The differential performance of specific genotypes and the genetic diversity among them provide valuable insights for breeding programs to enhance resilience to environmental stressors and improve overall crop productivity.

**Table 1: One-way ANOVA for control**

| Source | BY | FP | FS | GYP | HI | PB | PH | PL | PT | SS | TS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Rep** | 581.9 | 430.3 | 818.9 | 0.1 | 14.1 | 1.0 | 22.0 | 6.2 | 15.2 | 604.6 | 49.3 |
| **Geno** | 4184.5** | 2664.3** | 1999.6** | 8.0** | 92.0** | 4.2** | 475.6** | 44.5** | 68.5** | 3309.3** | 2939.8** |
| **Error** | 104.8 | 324.5 | 780.9 | 0.1 | 9.2 | 1.0 | 15.3 | 6.8 | 3.8 | 522.8 | 229.9 |

**Table2: One-way ANOVA for drought**

| Source | BY | FP | FS | GYP | HI | PB | PH | PL | PT | SS | TS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Rep** | 158.0 | 5.2 | 2296.6 | 8.2 | 73.8 | 0.0 | 31.0 | 0.2 | 0.5 | 7.5 | 2522.0 |
| **Geno** | 3481.4** | 127.3** | 5557.5** | 218.9** | 322.5* | 6.2** | 1903.4** | 42.7** | 44.4** | 246.7** | 5481.5** |
| **Error** | 55.6 | 9.8 | 3032.4 | 1.6 | 21.9 | 0.5 | 14.0 | 1.5 | 2.9 | 22.1 | 3100.6 |

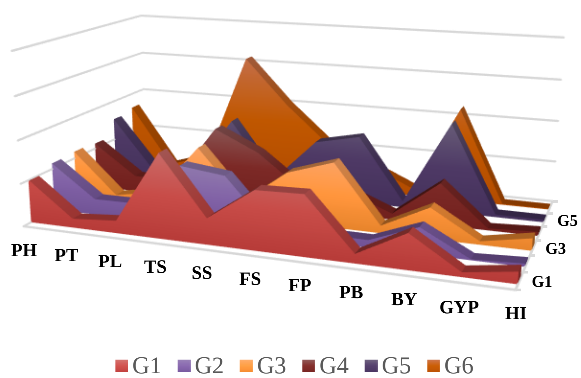


**Figure 1: Response of genotypes for all the studied traits in control conditions**

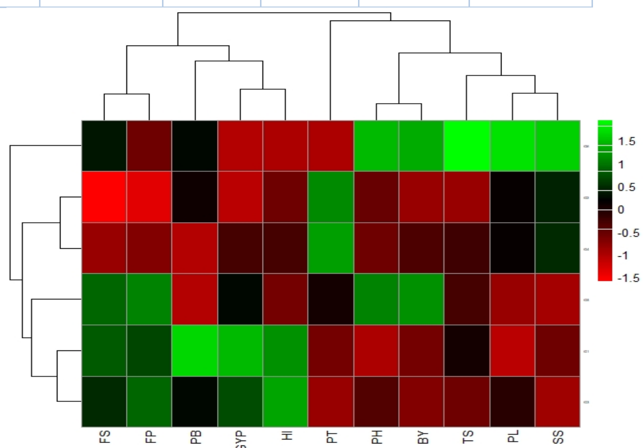


**Figure 3: Heatmap analysis of rice genotypes for all the attributes under control**

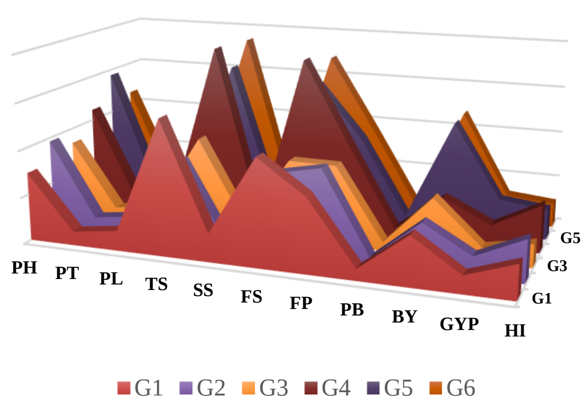


**Figure 2: Response of genotypes for all the studied traits in drought conditions**

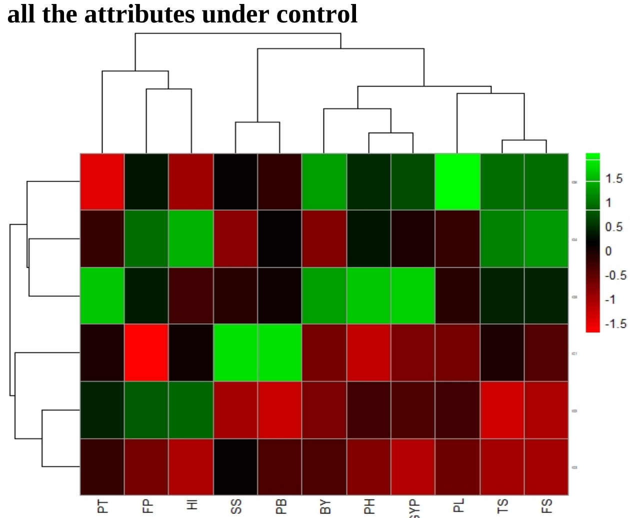


**Figure 4: Heatmap analysis of rice genotypes for all the attributes under drought**

[Citation Ayub, M.A., Ijaz, M., Bano, M., Bibi, A., Bibi, T., Gulnaz, S., Khan, R.A.R., Mallhi, A.R., Sarfraz, S., Ahsan, A., Anwar, M.R., Latif, A., Nazar, M.Z.K., Shafique, M.T. (2023). Rice resilience in the face of climate challenges exploring drought response in rice genotypes. *Biol. Clin. Sci. Res. J.*, **2023***:* 506. doi: https://doi.org/10.54112/bcsrj.v2023i1.506]

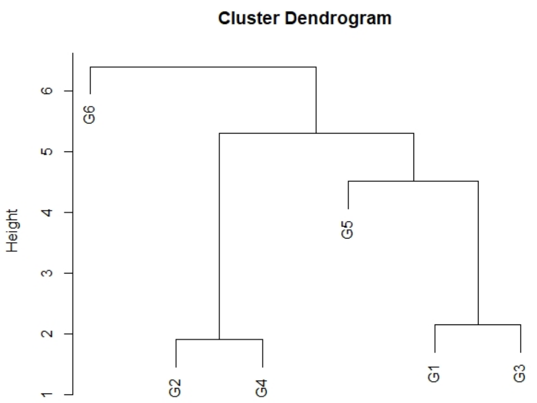


**Figure 5: Dendrogram chart presenting clustering of rice genotypes under control**

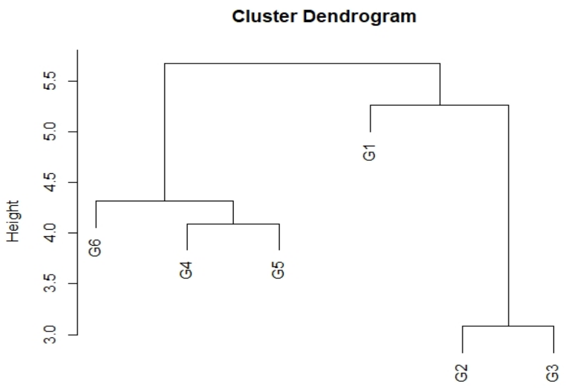


**Figure 6: Dendrogram chart presenting clustering of rice genotypes under drought**

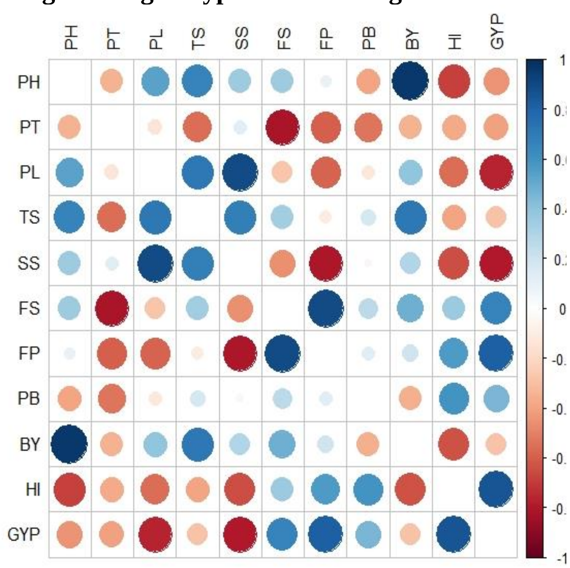


**Figure 7: Correlogram presenting correlation of all traits with grain yield in control conditions**

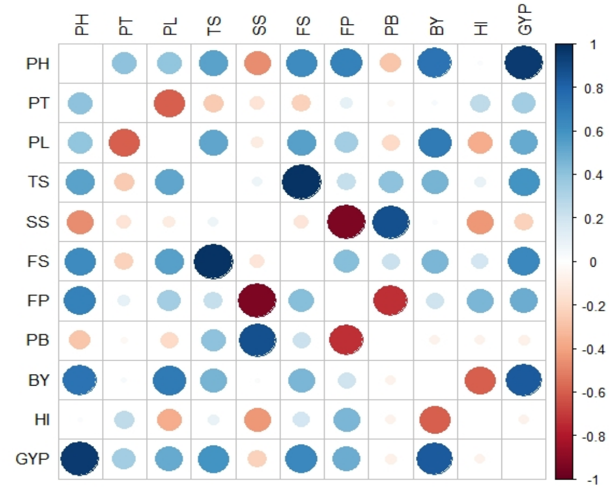


**Figure 8: Correlogram presenting correlation of all traits with grain yield in drought conditions**

**References**


Aaliya, K., Qamar, Z., Ahmad, N. I., Ali, Q., Munim, F. A., & Husnain, T. (2016). Transformation, evaluation of gtgene and multivariate genetic analysis for morpho-physiological and yield attributing traits in Zea mays. *Genetika*, **48**(1), 423-433.

Ahsan, M., Farooq, A., Khaliq, I., Ali, Q., Aslam, M., & Kashif, M. (2013). Inheritance of various yield contributing traits in maize (Zea mays L.) at low moisture condition. *African Journal of Agricultural Research*, **8**(4), 413-420.

Ali, F., Ahsan, M., Ali, Q., & Kanwal, N. (2017). Phenotypic stability of Zea mays grain yield and its attributing traits under drought stress. *Frontiers in plant science*, **8**, 1397.

Ali, F., Kanwal, N., Ahsan, M., Ali, Q., Bibi, I., & Niazi, N. K. (2015). Multivariate analysis of grain yield and its attributing traits in different maize hybrids grown under heat and drought stress. *Scientifica*, **2015**.

Ali, Q., Ahsan, M., Ali, F., Aslam, M., Khan, N. H., Munzoor, M., ... & Muhammad, S. (2013). Heritability, heterosis and heterobeltiosis studies for morphological traits of maize (Zea mays L.) seedlings. *Advancements in Life sciences*, **1**(1): 53-62.

Ali, Q., Ahsan, M., Kanwal, N., Ali, F., Ali, A., Ahmed, W., ... & Saleem, M. (2016). Screening for drought tolerance: comparison of maize hybrids under water deficit condition. *Advancements in Life Sciences*, *3*(2), 51-58.

Ali, Q., Ali, A., Ahsan, M., Nasir, I. A., Abbas, H. G., & Ashraf, M. A. (2014a). Line× Tester analysis for morpho-physiological traits of Zea


[Citation Ayub, M.A., Ijaz, M., Bano, M., Bibi, A., Bibi, T., Gulnaz, S., Khan, R.A.R., Mallhi, A.R., Sarfraz, S., Ahsan, A., Anwar, M.R., Latif, A., Nazar, M.Z.K., Shafique, M.T. (2023). Rice resilience in the face of climate challenges exploring drought response in rice genotypes. *Biol. Clin. Sci. Res. J.*, **2023***:* 506. doi: https://doi.org/10.54112/bcsrj.v2023i1.506]

mays L seedlings. *Advancements in Life sciences*, **1**(4), 242-253.

Ali, Q., Ali, A., Awan, M. F., Tariq, M., Ali, S., Samiullah, T. R., ... & Hussain, T. (2014b). Combining ability analysis for various physiological, grain yield and quality traits of Zea mays L. *Life Sci J*, **11**(8s), 540-551.

Ahmad, H., Zafar, S. A., Naeem, M. K., Shokat, S., Inam, S., Naveed, S. A., Xu, J., Li, Z., Ali, G. M., & Khan, M. R. (2022). Impact of pre-anthesis drought stress on physiology, yield-related traits, and drought-responsive genes in green super rice. *Frontiers in Genetics*, 256.

Akram, H., Ali, A., Sattar, A., Rehman, H., & Bibi, A. (2013). Impact of water deficit stress on various physiological and agronomic traits of three basmati rice (Oryza sativa L.) cultivars. *J Anim Plant Sci* **23**, 1415-1423.

Aslam, M. M., Rashid, M. A. R., Siddiqui, M. A., Khan, M. T., Farhat, F., Yasmeen, S., Khan, I. A., Raja, S., Rasool, F., & Sial, M. A. (2022). Recent insights into signaling responses to cope drought stress in rice. *Rice science* **29**, 105-117.

Bhutta, M. A., Munir, S., Qureshi, M. K., Shahzad, A. N., Aslam, K., Manzoor, H., & Shabir, G. (2019). Correlation and path analysis of morphological parameters contributing to yield in rice (Oryza sativa) under drought stress. *Pak J Bot* **51**, 73-80.

Farooq, M., Wahid, A., & Basra, S. (2009). Improving water relations and gas exchange with brassinosteroids in rice under drought stress. *Journal of Agronomy and Crop Science* **195**, 262-269.

Farooq, M., Wahid, A., Lee, D. J., Cheema, S., & Aziz, T. (2010). Drought stress: comparative time course action of the foliar applied glycinebetaine, salicylic acid, nitrous oxide, brassinosteroids and spermine in improving drought resistance of rice. *Journal of Agronomy and Crop Science* **196**, 336-345.

Ghouri, F., Ali, Z., Naeem, M., Ul-Allah, S., Babar, M., Baloch, F. S., Chattah, W. S., & Shahid, M. Q. (2022). Effects of silicon and selenium in alleviation of drought stress in rice. *Silicon* **14**, 5453-5461.

Haider, Z., Khan, A. S., & Zia, S. (2012). Correlation and path coefficient analysis of yield components in rice (Oryza sativa L.) under simulated drought stress condition. *American-Eurasian Journal of Agricultural & Environmental Sciences* **12**, 100-104.

Hanif, S., Saleem, M. F., Sarwar, M., Irshad, M., Shakoor, A., Wahid, M. A., & Khan, H. Z. (2021). Biochemically triggered heat and drought stress tolerance in rice by proline application. *Journal of Plant Growth Regulation* **40**, 305-312.

Iqbal, M. S., Jabbar, B., Sharif, M. N., Ali, Q., Husnain, T., & Nasir, I. A. (2017). In silico MCMV silencing concludes potential host-derived miRNAs in maize. *Frontiers in plant science*, **8**, 372.

Khalid, M., & Amjad, I. (2018). Study of the genetic diversity of crops in the era of modern plant breeding. *Bulletin of Biological and Allied Sciences Research* **2018**, 14-14. Kim, Y., Chung, Y. S., Lee, E., Tripathi, P., Heo, S., & Kim, K.-H. (2020). Root response to drought stress in rice (Oryza sativa L.). *International journal of molecular sciences* **21**, 1513.

Majeed, A., Salim, M., Bano, A., Asim, M., & Hadees, M. (2011). Physiology and productivity of rice crop influenced by drought stress induced at different developmental stages. *African Journal of Biotechnology* **10**, 5121-5136.

Mostajeran, A., & Rahimi-Eichi, V. (2008). Drought stress effects on root anatomical characteristics of rice cultivars (Oryza sativa L.). *Pakistan Journal of Biological Sciences* **11**, 2173-2183.

Mumtaz, M. Z., Saqib, M., Abbas, G., & Ul-Qamar, Z. (2020). Drought stress impairs grain yield and quality of different rice genotypes under field conditions by impaired photosynthetic attributes and K nutrition. *Rice Sci* **27**, 5-9.

Nahar, S., Kalita, J., Sahoo, L., & Tanti, B. (2016). Morphophysiological and molecular effects of drought stress in rice. *Ann Plant Sci* **5**, 1409-1416.

Pandey, V., & Shukla, A. (2015). Acclimation and tolerance strategies of rice under drought stress. *Rice science* **22**, 147-161.

Qureshi, M. K., Munir, S., Shahzad, A. N., Rasul, S., Nouman, W., & Aslam, K. (2018). Role of reactive oxygen species and contribution of new players in defense mechanism under drought stress in rice. *Int J Agric Biol* **20**, 1339-1352.

Raman, A., Verulkar, S., Mandal, N., Variar, M., Shukla, V., Dwivedi, J., Singh, B., Singh, O., Swain, P., & Mall, A. (2012). Drought yield index to select high yielding rice lines under different drought stress severities. *Rice* **5**, 1-12.

RASHEED, R., IQBAL, M., ANWAR, S., SHEREEN, A., & KHAN, M. A. (2021). Assessment of rice (Oryza sativa L.)

[Citation Ayub, M.A., Ijaz, M., Bano, M., Bibi, A., Bibi, T., Gulnaz, S., Khan, R.A.R., Mallhi, A.R., Sarfraz, S., Ahsan, A., Anwar, M.R., Latif, A., Nazar, M.Z.K., Shafique, M.T. (2023). Rice resilience in the face of climate challenges exploring drought response in rice genotypes. *Biol. Clin. Sci. Res. J.*, **2023**: 506. doi: https://doi.org/10.54112/bcsrj.v2023i1.506]

genotypes for drought stress tolerance using morpho-physiological indices as a screening technique. *Pak. J. Bot* **53**, 45-58.

Salekdeh, G. H., Siopongco, J., Wade, L. J., Ghareyazie, B., & Bennett, J. (2002). Proteomic analysis of rice leaves during drought stress and recovery. *PROTEOMICS: International Edition* **2**, 1131-1145.

Shehab, G. G., AHMED, O. K., & El-Beltagi, H. S. (2010). Effects of various chemical agents for alleviation of drought stress in rice plants (Oryza sativa L.). *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* **38**, 139-148.

Singh, C. M., Binod, K., Suhel, M., & Kunj, C. (2012). Effect of drought stress in rice: a review on morphological and physiological characteristics. *Trends in Biosciences* **5**, 261-265.

Upadhyaya, H., & Panda, S. K. (2019). Drought stress responses and its management in rice. In *Advances in rice research for abiotic stress tolerance* (pp. 177-200). Elsevier.

Venuprasad, R., Lafitte, H. R., & Atlin, G. N. (2007). Response to direct selection for grain yield under drought stress in rice. *Crop Science* **47**, 285-293.

**Declarations**

**Data Availability statement**

All data generated or analyzed during the study are included in the manuscript.

**Ethics approval and consent to participate**

Not applicable

**Consent for publication**

Not applicable

**Funding**

Not applicable

**Conflict of Interest**

Regarding conflicts of interest, the authors state that their research was carried out independently without any affiliations or financial ties that could raise concerns about biases.

**Authors contributions**: All authors contribute equally.



[Citation Ayub, M.A., Ijaz, M., Bano, M., Bibi, A., Bibi, T., Gulnaz, S., Khan, R.A.R., Mallhi, A.R., Sarfraz, S., Ahsan, A., Anwar, M.R., Latif, A., Nazar, M.Z.K., Shafique, M.T. (2023). Rice resilience in the face of climate challenges exploring drought response in rice genotypes. *Biol. Clin. Sci. Res. J.*, **2023***:* 506. doi: https://doi.org/10.54112/bcsrj.v2023i1.506]