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

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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 production.

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 (Upadhya & 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 understanding of how these genotypes respond to submergence tolerance. Through a comprehensive coverage.

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), fertile 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...
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. Drought 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 panicle length, total spikelets per panicle, fertile spikelets per panicle, and fertile spikelets per panicle. 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 per plant, fertile spikelets per panicle, and fertile spikelets per panicle 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, 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 Basmati 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

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

<table>
<thead>
<tr>
<th>Source</th>
<th>BY</th>
<th>FP</th>
<th>FS</th>
<th>GYP</th>
<th>HI</th>
<th>PB</th>
<th>PH</th>
<th>PL</th>
<th>PT</th>
<th>SS</th>
<th>TS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rep</td>
<td>581.9</td>
<td>430.3</td>
<td>818.9</td>
<td>0.1</td>
<td>14.1</td>
<td>1.0</td>
<td>22.0</td>
<td>6.2</td>
<td>15.2</td>
<td>604.6</td>
<td>49.3</td>
</tr>
<tr>
<td>Geno</td>
<td>4184.5</td>
<td>*</td>
<td>2664.3*</td>
<td>*</td>
<td>1999.6*</td>
<td>*</td>
<td>8.0*</td>
<td>92.0*</td>
<td>4.2*</td>
<td>475.6*</td>
<td>44.5*</td>
</tr>
<tr>
<td>Error</td>
<td>104.8</td>
<td>324.5</td>
<td>780.9</td>
<td>0.1</td>
<td>9.2</td>
<td>1.0</td>
<td>15.3</td>
<td>6.8</td>
<td>3.8</td>
<td>522.8</td>
<td>229.9</td>
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</tbody>
</table>

Table 2: One-way ANOVA for drought

<table>
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<th>Source</th>
<th>BY</th>
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<th>FS</th>
<th>GYP</th>
<th>HI</th>
<th>PB</th>
<th>PH</th>
<th>PL</th>
<th>PT</th>
<th>SS</th>
<th>TS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rep</td>
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<td>5.2</td>
<td>229.6</td>
<td>8.2</td>
<td>73.8</td>
<td>0.0</td>
<td>31.0</td>
<td>0.2</td>
<td>0.5</td>
<td>7.5</td>
<td>2522.0</td>
</tr>
<tr>
<td>Geno</td>
<td>3481.4</td>
<td>*</td>
<td>127.3*</td>
<td>*</td>
<td>5557.5*</td>
<td>*</td>
<td>218.9*</td>
<td>*</td>
<td>322.5</td>
<td>*</td>
<td>1903.4*</td>
</tr>
<tr>
<td>Error</td>
<td>55.6</td>
<td>9.8</td>
<td>3032.4</td>
<td>1.6</td>
<td>21.9</td>
<td>0.5</td>
<td>14.0</td>
<td>1.5</td>
<td>2.9</td>
<td>22.1</td>
<td>3100.6</td>
</tr>
</tbody>
</table>

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

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

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

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


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**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**


https://doi.org/10.54112/bcsfr.v2023i1.506


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.

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