Comparative Analysis of Drought Stress Tolerance in bread wheat and Spelt Wheat Based on Morphological and Physiological Traits

# ABSTRACT

To assess the morphological and physiological traits of bread wheat and spelt wheat, a field experiment was carried out. Drought stress significantly impacts wheat production, particularly affecting the morphological and physiological traits determining drought tolerance. This study evaluated the drought responses of three wheat genotypes-WH 1080, British Spelt, and Romanian Spelt by analysing their morphological (plant height, number of spikes per plant, spike length, spike weight, and 100-grain weight) and physiological parameters (chlorophyll content, relative leaf water content (RLWC), water use efficiency (WUE), and relative stress injury (RSI)) under controlled and drought-stressed conditions. The findings demonstrated that drought stress significantly decreased grain weight, spike characteristics, and plant height in all genotypes. WH 1080 exhibited the greatest sensitivity to drought, with pronounced reductions in chlorophyll content, RLWC, and spike weight, along with a significant increase in RSI. British Spelt demonstrated superior drought tolerance, maintaining higher chlorophyll levels, RLWC, and WUE under drought conditions, while showing a lower rise in RSI, indicating better membrane stability. Romanian Spelt displayed intermediate responses, with moderate reductions in chlorophyll content and RLWC but a relatively stable WUE and higher RSI than British Spelt. Overall, British Spelt emerged as the most sdrought-resilient genotype, exhibiting better water retention, efficient photosynthetic performance, and reduced stress injury under water-deficit conditions. These results imply that British Spelt has the potential for growing in drought-prone areas, and more research into the mechanisms behind its drought tolerance may help with breeding initiatives meant to increase wheat's resistance to water stress.

Key words: spelt wheat, spike, water use efficiency, relative stress injury

# INTRODUCTION

# Among the world's most vital crops, wheat (Triticum aestivum L.) thrives in various kinds of climates (Filip et al., 2023). Nearly720 million tons produced worldwide, making it one of the main basic crops but recurrent droughts linked to climate change are expected to reduce its output throughout the continent (Knox et al., 2012). To satisfy the expanding population's requirement for food, its yields must be raised (Ray et al., 2013). Climate change, agricultural practices, and groundwater depletion issues are all over globe, but they are particularly severe in developing countries of Asia, where they cause water shortages for crop production, particularly during dry seasons (Mukherjee et al., 2023). Lack of water encourages plants to downregulate several physio-chemical functions, which damages cellular activity through oxidative stress with loss of yield (Ullah et al. 2019; Panda et al. 2021). Moreover, excellent source of nutrition, spelt (Triticum spelta) is an ancestral cousin of wheat (Campbell, 1997, Salamon et al.,2020). Spelt excellent nutritional value and abundance of ancient genes have rekindled consumer, farmer, and breeder interest in recent years (Alvarez, 2021).

# On the contrary, Bread wheat, a widely cultivated cereal, plays a pivotal role in ensuring global food security and exerts a substantial influence on the world economy. (Bapela et al. 2022). Despite production interest in running years, there is limited knowledge regarding the contrast analysis of spelt and bread wheat in response to drought stress. Only some work has been done in past years focusing on tiller production (Cabeza et al., 1993). Similarly, a few research have studied the physiological response to drought of bread wheat (Delperee et al., 2003, Germ et al., 2013, Aubert et al., 2020). Therefore, a huge gap exists regarding the drought resistance mechanisms of alternative crops. Drought stress negatively impacts wheat growth and productivity at all stages of development- heading, anthesis and grain filling (Khadka et al. 2020 and Zhang et al. 2018). Occurrence of drought stress during periods surrounding anthesis and grain filling stages leads to a reduction in nutrient uptake and photosynthetic efficiency, abortion of ovules, reduction in number of grains per spike, production of shrunken kernels, reduction in grain weight and finally, loss in grain yield (Pradhan et al. 2012; Iqbal 2019; Bapela et al. 2022). In short, drought stress retards plant growth, development and yield by altering the connection between grain yield and its components (Afzal et al. 2017). In wheat, grain yield reduction due to drought stress could be as high as 65% (Bennett et al. 2012). Different wheat and spelt cultivars may develop different stress resistance strategies so to preserve growth and productivity, there is a need to enhance information to cope with drought stress (Radzikowska et al., 2022).

# This study sought to evaluate the relative suitability of specific spelt wheat cultivars for growing under conditions that are drought stressed in contrast to bread wheat. The underlying study posited that certain spelt wheat cultivars among those examined might exhibit enhanced resilience to stress produced by drought. The differential responses to drought stress were assessed through the analysis of several key physiological metrics, including the relative water content (RWC) in the leaves and water use efficiency (WUE). Therefore, research trial was conducted for evaluation of spelt wheat and bread wheat for morphological and physiological traits

#  MATERIAL AND METHOD

In the winter period of 2021 and 2022, a pot experiment was set up at the Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu's Division of Plant Physiology, Faculty of Basic Sciences, (J&K) to evaluate spelt wheat and bread wheat for morphological and physiological traits. A soil combination made of soil, cow dung, and sand was placed inside the pot, which was 25 cm deep, 30 cm broad, and 10 mm thick. Two genotypes of spelt wheat: ‘British’ and ‘Romanian’ were evaluated with reference to one common bread wheat WH 1080. WH-1080 seeds were obtained from Mega seed section, Division of Plant Breeding and Genetics, SKUAST-Jammu, Main campus Chatha. The seeds of *Triticum spelta* were collected from Australia.

Five grains of bread wheat and spelt wheat were planted in every pot. All of these plant growing operations were carried out using a totally randomized design and maintained under identical growth circumstances. Following seed germination (14 days), the three seedlings that were most aligned were kept in each container. In order to evaluate the potential drought resistance of spelt cultivars, plants were exposed to two different circumstances: drought (soil water deficit) and irrigation conditions (control) for ten days. At the conclusion of the drought period, the physiological condition of the control and drought-stressed plants was assessed. Morphological traits like plant height, number of spikes/plants, spike length, spike weight,100 grain weight were taken.

Using dimethyl sulfoxide (DMSO), the non-destructive technique outlined by Gunes et al. (2007) was used to extract chlorophyll. The top completely formed leaves of the plant was collected in order to calculate the relative leaf water content (RLWC). They were then placed in polythene bags and kept in an ice box to prevent moisture loss. Twenty leaf discs were immediately weighed using an electronic balance to record their fresh weight (FW). The discs were then kept in distilled water in a petri dish overnight to allow them to reach full turgidity. Afterward, they were gently blotted dry and weighed again to obtain their turgid weight (TW). The discs were then dried in an oven for 48 hours at 80°C to find their dry weight (DW). Weatherly's (1950) formula was used to determine RLWC:

**RLWC (%) = Fresh weight (g)– Dry weight (g) X 100**

 **Turgid weight (g)– Dry weight(g)**

The Sullivan (1972) approach was used to assess the relative stress injury (RSI%) in leaves.

RSI (%) = ECa /ECb X 100

WUE was determined using Giuliani et al. (2017)'s formula.

WUE (g per litre) = Total grain yield produced by plants (g)/total water consumed by plants(litre)

**Statistical analysis**

The means of the observable parameters were compared at the 5% confidence level using the Shapiro-Wilk normality test. The gathered data was statistically analyzed using R Studio program.

Table:1"Effect of Drought Stress on morphological parameters of Wheat Genotypes"

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Genotype | Plant height | NO. OF SPIKES/ PLANT | Spike length | Spike weight | 100 grain weight |
|  | control | treated | control | treated | control | treated | control | treated | control | treated |
| WH 1080 | 76.46± 3.43a | 69.36 ± 0.92b | 8.00± 0.57c | 7.00 ± 0.57c | 10.40 ± 0.05c | 9.56 ± 0.20d | 2.37 ± 0.10a | 1.91 ± 0.14b | 4.43 ± 0.12a | 3.67 ± 0.09b |
| British spelt | 66.13 ± 2.16bc | 65.63 ± 0.43bc | 21.66 ± 1.20a | 20.33 ± 0.33a | 13.83 ± 0.34a | 12.73 ± 0.27b | 1.87 ± 0.19bc | 1.73 ± 0.15bcd | 3.48 ± 0.14b | 3.37 ± 0.06b |
| Romanian spelt | 65.60 ± 0.75bc | 62.50 ± 0.62c | 17.00 ± 1.00b | 15.66 ± 0.88b | 12.53 ± 0.28b | 10.83 ± 0.17c | 1.57 ± 0.02cd | 1.48 ± 0.05d | 2.81 ± 0.12c | 2.76 ± 0.01c |
| C.D at 5% | 3.09 | 1.45 | 0.43 | 0.22 | 0.18 |

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Table:2 Effect of Drought Stress on physiological parameters of Wheat Genotypes"

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Genotype | Chl a (mg/g F.W) | Chl b (mg/g F.W) | RLWC (%) | RSI (%) | WUE (g/L) |
|  | control | treated | control | treated | control | treated | control | treated | control | treated |
| WH 1080 | 1.95± 0.01c | 1.41 ± 0.07d | 0.52 ± 0.003c | 0.36 ± 0.02d | 71.45 ± 0.80c | **66.21 ± 0.61d** | 33.77 ± 0.85a | 24.19± 0.19bc b | 1.29± 0.008b | 1.37 ± 0.008a |
| British spelt | 2.56 ± 0.03a | 2.30 ± 0.04b | 0.71 ± 0.01a | 0.64 ± 0.008b | 80.19 ± 0.44a | 75.51 ± 0.66b | 23.29 ± 1.00c | 17.22 ± 0.98d | 0.97 ± 0.012d | 1.08 ± 0.014c |
| Romanian spelt | 2.32 ± 0.02b | 2.04 ± 0.01c | 0.64 ± 0.008b | 0.55 ± 0.004c | 76.55 ± 0.51b | 70.90 ± 0.41c | 25.78 ± 0.26b | 19.27 ± 0.51d | 0.96 ± 0.008d | 1.08 ± 0.02c |
| C.D at 5% | 0.07 | 0.02 | 1.05 | 1.43 | 0.02 |

# RESULTS AND DISCUSSION

# In this study, as shown in Table 1, the reduction in plant height, number of spikes per plant, spike length, spike weight, and 100-grain weight under drought conditions showed the impact of water stress on plant growth and yield components.

# Plant Height

# Plant height decreased in all three genotypes under drought conditions (Fig 1). WH 1080 exhibited a significant reduction in height from 76.46 cm under control conditions to 69.36 cm under drought stress. British Spelt and Romanian Spelt showed a similar trend, with slight variations. Romanian Spelt showed the least height reduction (62.50 cm under stress), which could suggest a better ability to maintain growth under limited water availability. However, all genotypes showed a statistically significant reduction in plant height, indicating that stress due to shortage of water adversely impact the vegetative development of wheat plants. In response to drought stress, plant height decreased in all kinds, mostly as a result of protoplasmic dryness and decreased relative turgidity. This phenomenon is linked to the loss of turgor pressure, resulting in constrained cell expansion and inhibited cell division, as described by Mehraban et al. (2019). These findings underscore the substantial impact of drought conditions on plant height.

#  Number of Spikes per Plant

# Number of Spikes per plant was significantly affected by drought stress (Sher et al.,2017). British Spelt showed a higher spike number than the other two genotypes, though there was still a minor decrease (21.66 to 20.33 spikes per plant). The ability of British Spelt to maintain a relatively higher spike number under drought stress may reflect its tolerance to water deficit, suggesting this variety's potential for better productivity under dry conditions.

# Spike Length

# WH 1080 showed a significant decrease from 10.40 cm in control to 9.56 cm under drought. British Spelt showed the highest spike length in both conditions but also experienced a considerable reduction from 13.83 cm to 12.73 cm. Romanian Spelt, while exhibiting the shortest spike length, followed the same reduction pattern. These results indicate that drought stress limits spike elongation, thereby influencing the reproductive growth of wheat (Abbasi et al.,2014).

# Spike Weight

# Spike weight is significantly influenced by drought stress, which is directly correlated with yield. In wheat, the application of drought stress during the grain-filling period typically results in a decrease in grain weight, which ultimately leads to a loss in the overall grain yield (Tian et al., 2006). The primary factor contributing to this decline in grain weight under water-limiting circumstances is the reduced proliferation of endosperm cells, which culminates in a diminished sink capacity per kernel (Wajid et al., 2011; Naroui et al., 2012). WH 1080 displayed the highest spike weight under control conditions (2.37 g), but this value dropped to 1.91 g under drought stress. British Spelt and Romanian Spelt exhibited smaller reductions, with the latter showing the lowest spike weight in both control and stress conditions. Despite this reduction, British Spelt and Romanian Spelt were able to retain more spike weight under stress, which could indicate better resilience in context of grain development and yield retention under water-limited conditions.

# 100-Grain Weight

# The 100-grain weight, a crucial yield indicator, was also reduced under drought stress across all genotypes. It is because of the lack of water which make the plant to complete grain formation in a comparatively shorter amount of time (Riaz and Chowdary 2003). WH 1080 had the highest grain weight under both conditions (4.43 g and 3.67 g), but the reduction was significant. British Spelt and Romanian Spelt showed smaller reductions, with Romanian Spelt being least affected (2.81 g to 2.76 g), possibly due to its better adaptability to drought conditions. This suggests that Romanian Spelt may be more efficient in maintaining grain filling under drought stress, contributing to a more stable yield.

# Physiological Data of Wheat Genotypes under Drought Stress

Physiological responses of three wheat genotypes (WH 1080, British Spelt, and Romanian Spelt) under drought stress are outlined in Table 2. Parameters such as chlorophyll content (Chl a and Chl b), relative leaf water content (RLWC), water use efficiency (WUE), and relative stress injury (RSI) provide important insights into the drought tolerance mechanisms of these genotypes.

**Chlorophyll a (Chl a) and Chlorophyll b (Chl b) Content**

Drought stress led to a notable drop in chlorophyll content across all three genotypes, affecting their photosynthetic efficiency. Under drought conditions WH 1080 exhibited a significant decline in Chl a from 1.95 mg/g FW under control conditions to 1.41 mg/g FW. Similarly, Chl b content of WH 1080 decreased from 0.52 mg/g FW to 0.36 mg/g FW, indicating a higher susceptibility to chlorophyll degradation under stress. This reduction in chlorophyll levels suggests a compromised photosynthetic capacity, limiting the plant's ability to convert light into energy efficiently under water-deficit conditions.

British Spelt exhibited the highest retention of chlorophyll piments under stress, with smaller declines from 2.56 mg/g FW to 2.30 mg/g FW for Chl a, and 0.71 mg/g FW to 0.64 mg/g FW for Chl b. This ability to maintain higher chlorophyll levels under drought conditions may contribute to its superior drought tolerance, allowing it to sustain higher photosynthetic rates compared to the other genotypes. Romanian Spelt also experienced a reduction in chlorophyll content, but the decline was less severe than in WH 1080, reflecting its moderate drought tolerance. Chlorophyll content exhibited a marked reduction under stress conditions, with the most pronounced declines observed in the more sensitive cultivars. Specifically, genotypes WH 1080 showed a significant decrease in chlorophyll levels, as illustrated in table 2. This decrease is likely due to the impairment of the light-dependent processes in photosynthesis, as noted by Rong-hua (2006). Furthermore, the data supported the conclusions of Condon et al. (2002) by showing a significant decrease in net photosynthetic activity under water-poor circumstances.

 **Relative Leaf Water Content (RLWC)**

RLWC, a crucial measure of plant water status, was dramatically decreased by drought stress. WH 1080 displayed a considerable reduction in RLWC from 71.45% under control conditions to 66.21% under drought stress, suggesting that this genotype struggled to retain water in its tissues, leading to increased vulnerability to water loss and dehydration. The decrease in RLWC reflects reduced cell turgor, which can negatively impact metabolic processes and growth. The decline in relative water content (RWC) in plants experiencing drought stress may be attributed to a reduction in overall plant vigor, a phenomenon widely documented across numerous plant species (Liu et al.,2002). Under conditions of water stress, the cell membrane undergoes significant alterations, including increased permeability and a reduction in structural integrity (He etal.,1995). British Spelt had the highest RLWC under both control (80.19%) and drought conditions (75.51%), indicating a more efficient mechanism for conserving water under stress. Romanian Spelt also showed a significant decrease in RLWC, but it retained a relatively high value (70.90%) under drought, highlighting its capacity to maintain cellular water content better than WH 1080. These results suggest that both British Spelt and Romanian Spelt are more resilient in preserving water within their tissues, which is essential for sustaining physiological functions under drought stress.

**Water Use Efficiency (WUE)**

WUE improved across all three genotypes under drought stress. An enhancement in water use efficiency (WUE) has been postulated to arise from a disproportionately greater decline in both transpiration and photosynthetic rates as a consequence of water deficit (Chen et al., 2009). WH 1080, for instance, increased from 1.29 g/L under control conditions to 1.37 g/L under drought. This increase indicates that WH 1080 is able to adjust its water use efficiency in response to drought, likely through mechanisms that optimize water uptake and minimize water loss. British Spelt and Romanian Spelt also showed improvements in WUE under stress, both increasing from approximately 0.97-0.96 g/L to 1.08 g/L. Although the increase in WUE is notable in WH 1080, British Spelt and Romanian Spelt consistently displayed higher efficiency, suggesting that these genotypes are more efficient in utilizing water for biomass production under water-limited conditions.

**Relative Stress Injury (RSI)**

All genotypes showed a considerable rise in RSI, a measure of cell membrane integrity and plant damage under stress, during drought (Almeselmani et al., 2011). WH 1080 exhibited a sharp rise in RSI from 24.19% under control conditions to 33.77% under drought, indicating that it experienced the highest level of cellular injury and membrane damage due to drought stress. This suggests a high level of stress susceptibility in WH 1080, with its tissues being more prone to oxidative damage and cellular disruption under water stress.

In contrast, British Spelt showed a more moderate increase in RSI from 17.22% to 23.29% under drought stress. This lower level of stress injury reflects better ability of British spelt to maintain stability of cell membrane and reduce the damaging effects of drought. Romanian Spelt also exhibited an increase in RSI from 19.27% to 25.78%, but the rise was less pronounced compared to WH 1080, indicating moderate drought tolerance. Both British Spelt and Romanian Spelt showed a better ability to mitigate cellular injury under drought conditions, which contributes to their overall drought resilience.

**Correlation analysis**

The study of Pearson's correlation between physiological and morphological attributes were conducted under drought conditions. There was significant relation observed between plant height and spike weight (r = 0.96) and between spike weight and 100 grain weight (r = 0.94). Chlorophyll a and Chlorophyll b showed a strong positive association (r = 0.95), as did RWC and Chlorophyll b (r = 0.97) (Fig-3).

Under drought stress, WUE showed a strong negative correlation with number of spikes per plant (r = -0.91) and Chlorophyll b (r = -0.90), but a positive association with spike length (r = 0.62). RSI had a positive correlation with spike weight (r = 0.69), highlighting stress-adaptive traits.

**CONCLUSION**

#  The observed reduction in the morphological parameters under drought stress reflects the susceptibility of wheat plants to water limitation, which impacts their ability to grow vegetatively and reproduce. WH 1080, despite showing the highest values in most parameters under control conditions, experienced the most significant reductions under drought conditions, indicating relative sensitivity to water stress. In contrast, British Spelt exhibited greater resilience, maintaining higher spike numbers, lengths, and spike weights under stress, which may make it a more suitable variety for drought-prone environments. Romanian Spelt, though displaying lower values in general, demonstrated a relatively stable 100-grain weight and minimal reductions in plant height and spike length, suggesting a strong adaptability to drought stress.

The physiological data clearly show that drought stress adversely affects chlorophyll content, RLWC, and increases RSI in all three genotypes. WH 1080 is the most sensitive to drought, as reflected by significant reductions in chlorophyll content and RLWC, and a sharp increase in relative stress injury. Although WH 1080 showed a slight improvement in WUE, it’s higher RSI suggests that it experiences more severe cellular damage under drought stress, making it less drought-tolerant overall.

British Spelt, on the other hand, exhibited the most resilience, maintaining higher chlorophyll levels, RLWC, and a lower increase in RSI. Its ability to efficiently manage water use and minimize stress injury makes it the most drought-tolerant genotype in this study. Romanian Spelt showed moderate responses, with relatively stable WUE and less severe reductions in RLWC, but a notable increase in RSI, suggesting it has moderate drought tolerance.

These findings highlight the importance of selecting genotypes like British Spelt that exhibit superior physiological adaptations to drought stress. Future studies could focus on exploring the molecular mechanisms behind these traits, potentially informing breeding programs aimed at enhancing drought tolerance in wheat.

# Fig 1-Effect of drought stress on plant height, no. of spikes/plant, spike length, spike weight, 100 grain weight

**Fig 2-effect of drought stress on Chl a, Chl b, RLWC, RSI, WUE.**



**Fig-3-Correlation analysis of morphological and physiological traits of wheat genotypes under control and drought conditions**

**Data availability:** According to the author, the information will be made provided upon a fair request.

## Declarations

. Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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