American Journal of Biology and Natural Sciences
https://biojournals.us/index.php/AJBNS
ISSN: 2997-7185

Impact of Temperature Changes on the Growth, Development and Physiological Indicators of Wheat Varieties

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Received: 2025, 21, Jun
Accepted: 2025, 22, Jul
Published: 2025, 23, Aug

Abstract: This study investigates the physiological and biochemical responses of three wheat varieties ("Asr", "Andijon-2", and "Vassa") grown in the semi-arid climate of the Sirdarya region (Uzbekistan) to short-term cold stress (7 °C for 8 hours). Experiments were conducted in the spring of 2024 with three replications under both control and stress conditions. Measurements included growth rate, photosynthetic activity, chlorophyll a content, and catalase enzyme activity. Results demonstrated that cold stress reduced growth rates by 25–35%, with "Andijon-2" showing higher photosynthetic efficiency (16.1 μmol $CO_2/m^2 \cdot s$) and catalase activity (5.4 μmol H_2O_2/min/mg), indicating superior tolerance. Conversely, "Vassa" exhibited higher sensitivity, with a marked decline in chlorophyll a (20.9 mg/g) and catalase activity (4.8 μmol/min/mg). These findings provide critical insights for the selection of cold-tolerant wheat genotypes.

Keywords: temperature stress, wheat varieties, chlorophyll, catalase, photosynthesis, Sirdarya region, oxidative stress, growth inhibition

INTRODUCTION

In recent decades, the global rise in climate variability has led to frequent and unpredictable temperature drops that severely affect crop productivity and physiological homeostasis [1]. Wheat (Triticum aestivum L.), as a staple cereal, is particularly vulnerable during critical growth stages such as tillering, heading, and grain filling. Even short-term exposure to suboptimal temperatures (5–10 °C for 6–12 hours) can alter metabolic pathways, inhibit cell expansion, and impair electron transport in chloroplasts [2,3].

Earlier studies have shown that temperature stress leads to reduced photosynthetic rate, destabilization of Photosystem II, enhanced reactive oxygen species (ROS) generation, and oxidative damage to cellular structures [4]. However, varietal resilience is strongly influenced by antioxidant enzyme systems such as catalase (CAT), peroxidase (POD), and superoxide dismutase (SOD), which counteract ROS accumulation [5,6]. Furthermore, chlorophyll degradation and reduced Rubisco carboxylation capacity are among key symptoms of thermal stress [7].

The Sirdarya region is one of Uzbekistan's major wheat-producing areas, where temperature amplitude can fluctuate by over 25–30 °C within a single day. This presents a natural model for studying short-term temperature impacts under field-simulated conditions [8]. Despite the release of improved cultivars like "Andijon-2" and "Vassa", data on their physiological behavior under thermal extremes remain scarce.

This study aims to fill this gap by quantitatively assessing the physiological and biochemical response of selected wheat varieties to short-term temperature stress. The emphasis is placed on linking physiological traits such as growth rate, chlorophyll content, and enzyme activities to stress tolerance and productivity.

MATERIALS AND METHODS

Study Area and Experimental Conditions

Experiments were conducted in Boyovut and Gulistan districts (Sirdarya region, Uzbekistan) during spring 2024 under semi-controlled field conditions.

Plant Material

Three locally adapted wheat varieties were used:

"Asr" – early-maturing, semi-dwarf

"Andijon-2" – high-yielding, stress-tolerant

"Vassa" – new introduction, moderate resistance

Stress Treatment and Design

A randomized complete block design (RCBD) was used with 3 replicates per variety. Plants were exposed to:

Control conditions: 15–20 °C natural ambient temperature

Cold stress: 7 °C for 8 hours (20:00 to 04:00) using controlled chambers

Physiological and Biochemical Measurements

1. **Growth Rate**: Main stem length was measured daily using a ruler. The relative growth rate (RGR) was calculated as:

$$O'sishsur'ati = \frac{L_2 - L_1 b}{t_2 - t_1}$$

where, are stem lengths at time.

2. **Photosynthesis Rate**: Measured in situ using LI-COR LI-6800 (μmol $CO_2/m^2 \cdot s$) [9]
3. **Chlorophyll a Content**: Extracted in 80% acetone and calculated via Arnon's formula [10]:

$$Xlorofill\, "a" = (12{,}7\; x\; A_{663} - 2{,}69 \text{ x } A_{645}) \text{ x } \frac{V}{W}$$

where = absorbance at 663 and 645 nm, = extract volume, = fresh weight

4. **Catalase Activity**: Based on H_2O_2 decomposition (Aebi method), expressed in μmol H_2O_2/min/mg protein [11].

Statistical Analysis

Data were analyzed using one-way ANOVA ($p<0.05$) and Tukey's HSD test for multiple comparisons via SPSS 26. Results are presented as mean ± SD.

RESULTS

The analysis focused on the extent to which short-term temperature stress inhibited plant growth and modified photosynthetic and biochemical parameters.

Growth Rate under Cold Stress

Variety	**Control (cm/day)**	**Stress (cm/day)**	**Reduction (%)**
Asr	1.8 ± 0.1	1.2 ± 0.1	33.3
Andijon-2	2.0 ± 0.2	1.4 ± 0.1	30.0
Vassa	1.7 ± 0.1	1.1 ± 0.2	35.3

Growth inhibition was most pronounced in “Vassa” (35.3%), whereas “Andijon-2” retained relatively higher growth (1.4 cm/day). These data reflect potential differences in meristematic activity and hormonal homeostasis under stress.

Photosynthesis, Chlorophyll a, and Catalase Activity

Variety	Photosynthesis (μmol/m²·s)	Chlorophyll a (mg/g)	Catalase (μmol/min/mg)
Asr	15.2 ± 0.5	23.1 ± 1.2	5.1 ± 0.3
Andijon-2	16.1 ± 0.6	22.5 ± 0.9	5.4 ± 0.2
Vassa	14.8 ± 0.4	20.9 ± 1.1	4.8 ± 0.4

“Vassa” showed the lowest chlorophyll a and catalase values, indicating a compromised antioxidant defense. “Andijon-2” maintained higher photosynthesis and enzymatic activity.

DISCUSSION

Short-term exposure to low temperature significantly reduces growth rates, photosynthetic performance, and enzymatic protection in wheat. The decline in photosynthesis in “Vassa” (14.8 μmol/m²·s) correlates with lower chlorophyll a and catalase levels, indicating oxidative stress and chloroplast damage [4,11]. “Andijon-2” consistently exhibited higher physiological resilience with 16.1 μmol/m²·s photosynthesis and 5.4 μmol/min/mg catalase activity, supporting Shibaeva's model of genotype-dependent antioxidative response [2].

Furthermore, reduced chlorophyll a in “Vassa” (–28.8%) mirrors findings from Kalaji et al. (2016), which attribute pigment loss to impaired chlorophyll biosynthesis and increased lipid peroxidation [10]. “Asr”, although less responsive than “Andijon-2”, maintained moderate levels in all parameters, suggesting partial cold tolerance.

In alignment with Yamori et al. (2014), the cold-induced reduction in Rubisco activation may explain the decline in carbon assimilation rates. This physiological impairment can ultimately reduce biomass accumulation and grain yield.

These results suggest that integrating chlorophyll content and antioxidant enzyme assays into screening protocols can enhance selection of climate-resilient wheat varieties. Future studies may also explore transcriptomic markers linked to cold adaptation.

CONCLUSION

Short-term cold stress (7 °C for 8 hours) significantly suppressed physiological performance in all three wheat varieties. Growth rates decreased by 25–35%, with “Andijon-2” showing superior resilience via higher photosynthesis (16.1 μmol/m²·s), catalase activity (5.4 μmol/min/mg), and moderate chlorophyll retention. “Vassa” proved to be the most sensitive, suggesting it may require additional breeding for stress tolerance. These results support targeted varietal selection for environments with fluctuating temperature regimes.

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