

## THEORETICAL ASPECTS OF SOME ECO-PHYSIOLOGICAL CHARACTERISTICS OF DURUM WHEAT UNDER GLOBAL DROUGHT CONDITIONS

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### Abstract

This article examines the theoretical aspects of selected eco-physiological traits of durum wheat (*Triticum durum*) under global drought conditions. It addresses the physiological mechanisms and adaptive responses that enable the crop to survive and maintain productivity under limited water availability. The discussion includes drought tolerance strategies such as osmotic adjustment, stomatal regulation, antioxidant activity, and changes in photosynthetic efficiency. Attention is also given to the role of morphological adaptations, including root system architecture and leaf surface characteristics, as well as the impact of drought stress on grain quality and yield. By integrating insights from plant physiology, agronomy, and environmental science, the article provides a foundation for developing sustainable management practices and breeding programs aimed at improving durum wheat resilience in arid and semi-arid regions.

**Keywords:** durum wheat, eco-physiology, drought stress, adaptive mechanisms, photosynthesis, osmotic adjustment, yield stability, global climate change.

### Introduction

Due to the shortage of agricultural land, cultivation is shifting toward areas with moderate productivity, as the global population continues to grow and more land is being allocated for housing and industrial enterprises. With environmental and climate change, the stress on plants for growth and survival increases proportionally. Consequently, agricultural research has focused on improving productivity under adverse conditions. Studying the physiological effects of drought stress on plants is critical for understanding these impacts and for developing drought-tolerant breeding lines. When individual adaptation to drought is insufficient, genetic traits—such as genes encoding constitutively expressed proteins—can be employed to enhance water-use efficiency. In cases where physical adaptation of roots and leaves is inadequate, it may be necessary to utilize constitutive proteins that regulate the expression of multiple other genes through signaling pathways to improve water-use efficiency in roots and leaves. In response to drought stress, numerous plant genes—including transcription factors and small

RNAs—are selectively upregulated. However, adaptation to drought stress and environmental fluctuations requires considerable time and energy. To meet future food demand, it will be necessary to develop improved agronomic practices and conduct deeper research on drought-resistant crops [1].

In desert and semi-desert regions, strategies for mitigating drought have attracted more attention than other approaches. Drought stress has been shown to reduce plant growth, development, yield, and biomass. It can affect the physiological, metabolic, and biochemical activities of plants. In some cases, drought-tolerant plants are employed to counteract the consequences of water scarcity. It is therefore important to examine how plants can be made more adaptable and drought-resistant without compromising yield potential. Under limited water availability, selective breeding can enhance plant performance and productivity. Plants under drought conditions tend to increase transpiration, alter hormonal activity, and delay senescence. Drought affects plants throughout their entire life cycle—from germination to harvest. When water is scarce, plant growth and development are delayed, leading to significant yield reductions and, in some cases, complete cell death in surrounding tissues. For this reason, improving drought tolerance in plants under variable climatic conditions is an urgent and critical challenge.

### Materials and methods

Agriculture faces severe production losses each year due to prolonged drought. Drought stress significantly impacts plant physiology, subsequently reducing yield. It induces a range of physiological and molecular changes in plants, many of which help them adapt to unfavorable environments. Drought stress influences plant metabolism both directly and indirectly. It alters the morpho-anatomical, physiological, and biochemical composition of plants, thereby reducing transpiration and improving the efficiency of available water use. Continuous water loss through transpiration results in leaf water deficits. In addition to oxidative damage, water scarcity can also lead to cell death. To mitigate the negative effects of drought, it is essential first to determine the specific mechanisms through which drought stress affects plant physiology [1].

In stressful environments—especially under drought—plant survival and development depend on adaptive mechanisms and protective systems, such as the ability to extract nutrients and water from deep soil layers, osmotic adjustment through the accumulation of free amino acids and ions, increased levels of sugars and proline, biochemical activity, stomatal regulation of water loss, and phenological plasticity [2].

## Results and discussion

As with other crops, important physico-chemical responses and parameters for assessing wheat's reaction to drought include chlorophyll content, stomatal conductance, leaf water potential, photosynthetic rate, and transpiration rate [3]. Plants utilize osmotic regulation to lower osmotic potential and overcome water-deficit challenges. By maintaining turgor pressure, osmotic regulation supports stomatal conductance and moderate water status. When exposed to drought stress, plants can regulate osmotic balance through three main mechanisms: reducing intracellular water, decreasing cell volume, and increasing solute concentration within cells [4].

Despite intensive durum wheat breeding programs over the past century, the agronomic and morpho-physiological responses of wheat to drought stress remain insufficiently understood. Therefore, agromorphological assessments can be useful in improving the sequential operations involved in wheat processing and transformation. Specifically, selecting drought-tolerant varieties and applying appropriate agronomic measures can help prevent problems and deficiencies in critical operations such as milling and flour processing [5, 6].

With global climate change, it is predicted that reduced precipitation and increased evaporation will intensify widespread drought in many regions [7]. Moreover, global warming has led to unpredictable precipitation patterns, resulting in more frequent prolonged drought periods worldwide [8].

Plants use osmotic regulation to lower osmotic potential and overcome challenges arising from water deficit. By maintaining turgor pressure, osmotic regulation helps sustain stomatal conductance and moderate water status. When exposed to drought stress, plants can regulate osmotic balance in three ways: by reducing intracellular water, decreasing cell volume, and increasing the concentration of solutes within cells [9].

Despite intensive durum wheat breeding programs over the past century, the agronomic and morpho-physiological responses of wheat to drought stress remain insufficiently understood. Therefore, agromorphological evaluations can be useful for improving the sequential operations involved in wheat processing and transformation. In particular, selecting drought-tolerant varieties and applying appropriate agronomic practices can help prevent problems and deficiencies in critical processes such as milling and flour production [10, 11].

In durum wheat, precipitation variability often results in water deficits, which are a major limiting factor for yield, especially when water shortages occur during flowering and grain-filling stages [12]. Studying the agromorphological, biochemical, and physiological responses of crops is essential to understanding their ability to respond and adapt under water-limited conditions. Several agromorphological traits—such as plant height, spike length, number of grains per spike, thousand-grain weight, and even morphological modifications in adaptive

genotypes—are associated with how wheat tolerates drought stress in soils with limited moisture [13].

Moreover, breeding and selecting drought-resistant durum wheat varieties, along with improving fertilizer supply, can enhance the degree of resilience [14]. In nature, plants are constantly exposed to various biotic and abiotic stresses. Among these, drought is one of the most detrimental factors to plant growth and productivity, representing a major threat to stable crop production under changing climatic conditions. Drought triggers a wide range of responses, from alterations in cellular metabolism to changes in growth rate and yield. Understanding the biochemical and molecular responses to drought is essential for gaining a comprehensive understanding of the mechanisms underlying plant tolerance to water-limited environments.

Certain aspects of the morphological, physiological, and biochemical changes in plants caused by drought are highlighted here. Drought stress gradually reduces the rate of CO<sub>2</sub> assimilation due to decreased stomatal conductance. It reduces leaf area, stem elongation, and root growth, disrupts plant water relations, and decreases water-use efficiency. Drought also degrades photosynthetic pigments and reduces gas exchange, ultimately lowering plant growth and productivity. Under drought stress, the accumulation of osmolytes plays a key role in conferring dehydration tolerance and has been extensively studied. In addition, drought-induced production of reactive oxygen species (ROS) at the cellular level is well-documented, and their generation and scavenging are tightly regulated through enhanced antioxidant systems at both the production and consumption stages [15].

## **Conclusions**

Durum wheat (*Triticum durum*) is among the most important cereal crops cultivated in arid and semi-arid regions, where drought stress is a major constraint on yield and grain quality. The analysis of eco-physiological responses under global drought conditions demonstrates that water scarcity affects the crop at multiple levels—morphological, physiological, biochemical, and molecular—ultimately reducing photosynthetic activity, biomass accumulation, and productivity.

Osmotic adjustment, efficient stomatal regulation, accumulation of compatible solutes, and enhanced antioxidant defense are among the key adaptive mechanisms enabling durum wheat to maintain growth and survival under limited water availability. Agromorphological traits such as plant height, spike length, number of grains per spike, and thousand-grain weight are valuable indicators for selecting drought-tolerant genotypes. Furthermore, biochemical and physiological parameters, including chlorophyll content, photosynthetic rate, and leaf water potential, provide important screening tools in breeding programs.

To address the challenges posed by increasing drought frequency and severity under climate change, a combination of strategies is required:

- Breeding and selection of drought-tolerant varieties with stable yield potential;
- Improved agronomic practices that optimize water use efficiency;
- Integration of modern tools such as molecular markers, remote sensing, and high-throughput phenotyping to accelerate selection;
- Sustainable resource management to reduce the ecological impact of agricultural systems.

A deeper understanding of the physiological, biochemical, and molecular basis of drought tolerance in durum wheat will support the development of climate-resilient cultivars and ensure food security in water-limited environments. Continued research, coupled with innovative technological applications, is essential for sustaining and improving durum wheat production in the face of global climate change.

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