16-18 February 2026

9th National and 1st International Conference of Plant Physiology

University of Guilan, Rasht, Guilan, Iran

# Nanoparticles in Alleviating Abiotic Stresses in Plants: Mechanisms and Future Prospects

**Fatemeh Amini**

Associate Professor, Department of Agronomy and Plant Breeding Sciences, Faculty of Agricultural Technology (Abouraihan), University of Tehran, Tehran, Iran. E-mail: aminif@ut.ac.ir

## Abstract

Abiotic stresses, such as drought, salinity, temperature extremes, and heavy metal toxicity, are significant limiting factors for plant growth and agricultural productivity worldwide. With climate change exacerbating the frequency and intensity of these stresses, innovative solutions are urgently needed to enhance plant resilience. Nanotechnology, particularly the use of metal oxide nanoparticles (NPs), has emerged as a promising strategy for improving plant tolerance to abiotic stresses. This review discusses the potential of nanoparticles, specifically titanium dioxide ($TiO_2$) and zinc oxide (ZnO) nanoparticles, in mitigating the effects of environmental stressors. These nanoparticles exert their effects through various mechanisms, including enhancing water and nutrient uptake, modulating plant hormone levels, boosting antioxidant defenses, and improving root growth. The review also highlights the application of $TiO_2$ and ZnO nanoparticles in alleviating specific stresses, such as salinity, drought, and heat, while addressing the challenges associated with their use in agriculture.

## Introduction

Abiotic stresses such as drought, salinity, temperature extremes, and heavy metal toxicity are among the leading causes of reduced crop productivity globally. The increasing severity of these stresses, driven by climate change, threatens food security, making it crucial to explore sustainable agricultural solutions. Plant responses to abiotic stresses typically involve oxidative damage, ion imbalance, and disrupted cellular processes (Dumani et al., 2022). While traditional agricultural techniques have had limited success in mitigating these effects, nanotechnology, particularly the use of nanoparticles (NPs), is emerging as a promising strategy for enhancing plant resilience under such adverse conditions (Farahi et al., 2023). Nanoparticles, especially metal oxide nanoparticles are being studied for their potential to mitigate abiotic stresses (Amini 2025, Alibabaie and Amini 2019). In this review, we will explore how $TiO_2$ and ZnO nanoparticles function to alleviate environmental stress in plants, examining their physiological, biochemical, and molecular mechanisms of action.

## Results and discussion

The alleviation of abiotic stress by nanoparticles should not be viewed as the outcome of isolated physiological processes, but rather as the result of a coordinated network of responses operating at morphological, biochemical, and molecular levels. Enhanced water and nutrient uptake mediated by $TiO_2$ and ZnO nanoparticles establishes the foundation for improved plant performance under stress by maintaining cellular hydration and metabolic activity. This improved resource availability directly influences hormonal balance and stress signaling pathways, particularly those involving abscisic acid and auxins.

Improved ABA-mediated signaling under drought and salinity stress contributes to optimized stomatal regulation, reducing water loss while sustaining photosynthetic capacity. Concurrently, nanoparticle-induced modulation of auxin signaling promotes root elongation and lateral root formation, enabling more efficient soil exploration. These morphological adaptations further reinforce water and nutrient acquisition, creating a positive feedback loop that enhances stress resilience.

At the cellular level, the activation of antioxidant defense systems plays a critical role in preventing oxidative damage caused by stress-induced ROS accumulation.

## References

Alibabaie, F., Amini, F. (2019) Investigation of Drought Stress effects on Germination of *Festuca ovina* in the present of ZnO Nanoparticles. *16 th agronomy and plant breeding congress, Ahvaz, Iran.*

Al-Khayri, J. M., Rashmi, R., Surya Ulhas, R., Sudheer, W. N., Banadka, A., Nagella, P., Aldaej, M. I., Rezk, A. A.-S., Shehata, W. F., & Almaghasla, M. I. (2023). The Role of Nanoparticles in Response of Plants to Abiotic Stress at Physiological, Biochemical, and Molecular Levels. *Plants*, *12*(2), 292.

Amini F (2025) Effect of Zinc Oxide (ZnO) Nanoparticles on In Vitro Regeneration of Petunia hybrida under the Influence of Growth Regulators. The 6rd International and 12th National Conference on Biotechnology, Tehran, Iran.