Comparison of Ascorbic Acid with Other Vitamins in Drought Stress Tolerance

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Abstract

Drought stress is a major environmental factor affecting plant growth and productivity. Plants employ various biochemical and physiological mechanisms to mitigate drought-induced oxidative damage, including the production of antioxidant vitamins. Among these, ascorbic acid (AsA) plays a crucial role in regulating reactive oxygen species (ROS), enhancing photosynthesis, and improving water-use efficiency. Other vitamins, such as vitamin E, B-complex vitamins, and vitamin K, also contribute to drought tolerance but differ in their specific functions and effectiveness. This review compares the role of AsA with other vitamins in drought stress tolerance, highlighting why AsA is the most effective vitamin for drought adaptation.

1. Introduction

Drought stress triggers oxidative stress in plants due to excessive ROS accumulation. To counteract this, plants synthesize various antioxidants, including vitamins, to protect cellular structures and maintain physiological functions. Among these, AsA is recognized as one of the most efficient antioxidants. However, other vitamins also contribute to plant stress tolerance in different ways. This review provides a comparative analysis of AsA with other vitamins to understand their relative importance in drought stress adaptation.

2. Role of Ascorbic Acid in Drought Stress Tolerance

Ascorbic acid (AsA) is a water-soluble antioxidant that plays multiple roles in plant drought stress tolerance:

- **ROS Scavenging:** AsA directly detoxifies ROS, preventing cellular damage.
- **Photosynthesis Protection:** AsA maintains chlorophyll stability and stabilizes photosystem II (PSII) under drought conditions.
- **Stomatal Regulation:** It modulates abscisic acid (ABA) signaling, optimizing stomatal closure and reducing water loss.
- **Enzyme Activation:** AsA participates in the ascorbate-glutathione (AsA-GSH) cycle, enhancing redox homeostasis.
- **Gene Regulation:** It influences drought-responsive genes and metabolic pathways.

3. Comparison of AsA with Other Vitamins

3.1 Ascorbic Acid (AsA) vs. Vitamin E (Tocopherols)

Feature	AsA	Vitamin E
Solubility	Water-soluble	Lipid-soluble
Function	ROS scavenger, redox regulator, photosynthesis protector	Lipid peroxidation prevention, membrane stability
Drought Role	Detoxifies ROS, regulates ABA, stabilizes chloroplasts	Protects membranes but lacks direct ROS scavenging
Effectiveness	High	Moderate

◆ **Conclusion:** AsA is more effective than vitamin E due to its direct involvement in ROS detoxification and stomatal regulation.

3.2 Ascorbic Acid (AsA) vs. B Vitamins (B1, B6, B9)

Feature	AsA	B Vitamins (B1, B6, B9)
Function	Antioxidant, stress regulator	Metabolic coenzyme, enzyme activator
Drought Role	Enhances stress signaling, stabilizes photosynthesis	Supports metabolism but lacks direct ROS detoxification
Photosynthesis Protection	Maintains chlorophyll, stabilizes PSII	No direct role
Effectiveness	High	Low to Moderate

◆ **Conclusion:** B vitamins play a supporting role in metabolism, but AsA is more critical for direct drought stress response.

3.3 Ascorbic Acid (AsA) vs. Vitamin K

Feature	AsA	Vitamin K
Function	Antioxidant, redox homeostasis	Electron transport in photosynthesis
Drought Role	Protects chloroplasts, reduces oxidative stress	Supports electron transport but lacks ROS detoxification
Water Use Efficiency	Regulates ABA, improves osmotic balance	No direct role
Effectiveness	High	Low to Moderate

◆ **Conclusion:** Vitamin K supports electron transport but lacks the broader stress-response functions of AsA.

4. Conclusion

Among all vitamins, ascorbic acid (AsA) emerges as the most effective in conferring drought tolerance due to its multifunctional role in:

- ROS detoxification and oxidative stress management
- Photosynthesis stabilization and chloroplast protection
- Hormonal regulation, especially ABA-mediated stomatal control
- Gene expression modulation in response to drought

Other vitamins such as vitamin E, B-complex vitamins, and vitamin K contribute to stress tolerance but lack the comprehensive protective mechanisms offered by AsA. Therefore, enhancing AsA content in crops through genetic and agronomic interventions can be a promising strategy for improving drought resilience.

5. Future Perspectives

Further research is needed to explore:

- Genetic engineering approaches to increase AsA biosynthesis in drought-prone crops.
- Synergistic interactions between AsA and other vitamins in stress adaptation.
- The role of AsA-enriched biofortification strategies in improving crop yield under water-limited conditions.

By integrating AsA-focused strategies into crop breeding and management, sustainable solutions for mitigating drought stress can be developed, ensuring food security in a changing climate.

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