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Drought Tolerance in Crops

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Abstract: -

Drought is one of the most severe abiotic stresses limiting global crop productivity, affecting approximately 26% of the world's arable land. Climate change has increased the frequency and severity of drought events, threatening food security in many regions. Drought stress in plants leads to physiological water deficiency, disrupting growth, photosynthesis, nucleic acid and protein synthesis, and nitrogen metabolism. To cope with drought conditions, plants employ multiple resistance strategies, including drought escape, dehydration avoidance, and dehydration tolerance. Morphological adaptations such as enhanced root systems, reduced leaf area, and stomatal modifications, along with physiological and biochemical mechanisms like osmotic adjustment, antioxidant activity, and stress protein synthesis, contribute to drought tolerance. Addressing drought stress in agriculture requires an integrated approach combining molecular tools, morpho-physiological analyses, and conventional breeding strategies to develop drought-resistant crop varieties and ensure food security in the face of global climate change.

Introduction:

Stress in plants refers to any external condition that adversely affects growth, metabolism, development, or productivity. **Stress can be classified into two main types**:

- **Biotic stress:** Caused by living organisms (e.g., pathogens, pests).
- **Abiotic stress:** Resulting from environmental factors such as extreme

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temperatures, moisture deficiency or excess, mineral toxicity or deficiency, salinity, soil pH, and air pollution (Taiz et al., 2015).

Drought is one of the most severe abiotic stresses affecting crops globally. It is defined as a period or condition of unusually dry weather within a geographic area, marked by a prolonged lack of precipitation. Drought stress is characterized by **low water potential** in plant tissues due to high solute concentration, leading to water scarcity for cellular processes.

Global climate change is exacerbating the frequency and severity of drought events, threatening crop productivity and global food security. Currently, approximately **26% of the world's arable land is subject to drought stress** (FAO, 2021).

Definition of Drought

- **Drought** is a prolonged dry period in the natural climate cycle that can occur anywhere in the world.
- It is a **global problem**, particularly prevalent in arid and semi-arid regions.
- Contemporary drought events are often accompanied by **extreme temperatures**, further worsening their impact on agriculture.

Improving crop yield under these conditions is essential to meet the **food security demands** of an increasing global population.

Drought Stress

Drought stress refers to **physiological water deficiency** that limits plant growth, development, and productivity. It results from natural variability and **anthropogenic climate change**, which alters precipitation patterns and increases evaporation rates.

Major Causes of Drought

1. **Atmospheric Factors**
   - ✓ High temperatures
   - ✓ Strong winds
   - ✓ Air pollution
2. **Soil Factors**
   - ✓ Low soil temperature
   - ✓ Excessive soil salinity
   - ✓ Low residual soil water content

Types of Drought

A. Meteorological Drought

- Prolonged periods with less than average precipitation.
- Typically defined as rainfall **<25%** of the regional average.

B. Agricultural Drought

- Affects crop production and ecosystem functioning.
- Results from soil moisture deficits that harm plant growth.

C. Hydrological Drought

- Occurs when water reserves in lakes, reservoirs, and aquifers fall below average levels.
- Typically follows extended dry periods.

Effects of Drought Stress on Plants Growth

- Reduction in **turgor pressure**.
- Decrease in **cell expansion**, leading to smaller cells and stunted growth.

Photosynthesis

- Reduced photosynthetic efficiency due to:
  - Stomatal closure limiting CO_2 uptake.
  - Disruption of **Photosystem II**.
  - Decreased electron transport rates.

Nucleic Acid and Protein Synthesis

- Increased **protease and RNase activity**.
- RNA hydrolysis and decline in DNA content.

Nitrogen Metabolism

- Impaired translocation of **starch and carbohydrates**.
- Disruption of nitrogen assimilation pathways.

Drought Resistance

Drought resistance refers to the **ability of plants to minimize yield loss under drought conditions** compared to optimal, well-watered environments. It encompasses multiple strategies that help plants cope with water scarcity.

Mechanisms of Drought Tolerance

1. **Drought Escape**
   - Completing the life cycle before soil moisture is depleted.
   - Examples: Early flowering, seed dormancy.
2. **Dehydration Avoidance**
   - Maintaining favorable water balance despite low soil moisture.
   - Mechanisms:
     - ✓ Stomatal regulation
     - ✓ Enhanced water uptake via deep root systems
3. **Dehydration Tolerance**
   - Withstanding low tissue water potential while maintaining cellular function.
   - Key features:
     - ✓ Reduced chemical activity of water
     - ✓ Accumulation of solutes
     - ✓ Membrane stabilization
     - ✓ Maintenance of protein structure

Management of Dehydration Tolerance

- Maintenance of **membrane integrity**
- Protection of **cellular macromolecules**
- Osmotic adjustment through **solute accumulation**

Morphological Responses to Drought

- Increased **root-to-shoot ratio** for better water uptake.
- Well-developed root systems.
- Thick, small leaf area to reduce transpiration.
- Developed leaf veins and bundles.

- Smaller, more numerous stomata.

Physiological and Biochemical Basis of Drought Tolerance

- Increased **dehydration resistance** of cytoplasm.
- Synthesis of **Late Embryogenesis Abundant (LEA) proteins**.
- Reduced accumulation of **Reactive Oxygen Species (ROS)**.
- Enhanced activity of **antioxidative enzymes**.
- Modified **Rubisco efficiency** under stress.

Conclusion

Global warming is intensifying the impacts of drought on crop productivity, making effective management of drought stress essential to ensure food security for a growing population. Integration of molecular approaches, morpho-physiological analyses, and conventional breeding strategies will accelerate the development of drought-resistant crops needed for sustainable agricultural production.