



Dry or Drowned: Management Strategies for Water Stress in Maize

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Maize (*Zea mays L.*) is an important cereal crop cultivated worldwide for food, feed and industrial purposes. One of the key elements influencing its growth and productivity is the availability of water. Both inadequate and excessive water can adversely affect maize. Drought limits water availability to plants, while waterlogging restricts oxygen supply to the roots. Despite being opposite forms of water stress, both conditions can severely impair plant growth, reproductive development and ultimately reduce grain yield. As climate variability intensifies, maize crops are facing more frequent periods of drought, heavy rainfall and temporary flooding. Understanding how maize responds physiologically to these contrasting water stresses is essential for developing effective management practices and building more resilient maize production systems.

Drought Stress: When Water Becomes Limiting

Drought occurs when soil moisture becomes insufficient to meet crop water requirements. Maize is especially vulnerable to water shortage during tasseling, silking, pollination and grain filling, as these stages require substantial water and are critical for successful reproduction and yield formation. As soil moisture declines, plant water status decreases and stomata close to reduce water loss. However, stomatal closure also restricts carbon dioxide entry into leaves, resulting in reduced photosynthesis. Prolonged drought can further accelerate leaf senescence and reduce the photosynthetically active leaf area.

Drought Effects on Reproductive Development

Water stress around flowering can disturb the synchronization between pollen shedding and silk emergence, resulting in poor pollination and fewer kernels per cob. Drought during grain filling reduces the supply of photosynthetic assimilates to developing kernels, resulting in incomplete grain filling and lighter grains. Drought can also increase the formation of reactive oxygen species (ROS), which may damage cellular membranes and proteins when their accumulation exceeds the plant's antioxidant capacity. Enzymes such as superoxide dismutase, catalase and peroxidases help protect plants against such oxidative damage.

Managing Drought Stress

Effective drought management should focus on conserving soil moisture and protecting the crop during critical growth stages.

- **Timely sowing:** Proper sowing time helps the crop utilize available rainfall and may reduce exposure to drought during flowering.
- **Stress-tolerant varieties:** Drought-tolerant hybrids or varieties can maintain better water status, root growth, photosynthesis and reproductive performance under water deficit.
- **Soil-moisture conservation:** Mulching, residue retention and conservation tillage can reduce evaporation and improve soil-water retention.

- **Efficient irrigation:** Where irrigation is available, priority should be given to critical stages such as tasseling, silking and early grain development.
- **Balanced nutrition:** Adequate and balanced nutrient supply supports root growth, photosynthesis and stress tolerance.

Waterlogging Stress: When Too Much Water Becomes a Problem

Waterlogging occurs when excess water saturates the soil, filling the air spaces between soil particles and severely limiting oxygen supply to the root zone. It commonly develops after heavy or prolonged rainfall, particularly in low-lying areas and poorly drained fields. Unlike drought, where plants struggle to obtain sufficient water, waterlogging creates a shortage of oxygen around the roots. Since roots depend on oxygen for aerobic respiration and energy production, reduced oxygen availability can suppress root respiration, limit energy generation and impair normal root function. As waterlogging persists, these effects can restrict nutrient uptake, root growth and overall plant performance.

Physiological effects of waterlogging

Waterlogging inhibits root growth and activity and can cause root injury when prolonged. Reduced root function affects the uptake and transport of essential nutrients, particularly nitrogen and other nutrients required for active growth. The effects are subsequently reflected in the shoots. Reduced nutrient uptake and impaired root function can cause chlorosis, reduced photosynthesis and restricted plant growth. Prolonged waterlogging can also interfere with reproductive development and grain formation. Under oxygen-deficient conditions, roots increasingly depend on anaerobic metabolism, which produces much less energy than normal aerobic respiration. Metabolites such as ethanol and lactate may accumulate during prolonged stress, contributing to metabolic injury.

Managing Waterlogging

The key to waterlogging management is rapid removal of excess water and improvement of root-zone aeration.

- **Proper drainage:** Surface drainage channels can quickly remove excess water from fields prone to water stagnation.
- **Raised beds or ridge-and-furrow systems:** These systems can improve drainage and maintain better aeration around roots.
- **Appropriate sowing time:** Planting should be planned according to local rainfall patterns to minimize exposure to prolonged waterlogging.
- **Improved soil structure:** Suitable soil-management practices and adequate organic matter can improve infiltration and root-zone conditions.
- **Waterlogging-tolerant genotypes:** Tolerant varieties or hybrids can maintain better root function and recover more rapidly after temporary flooding.

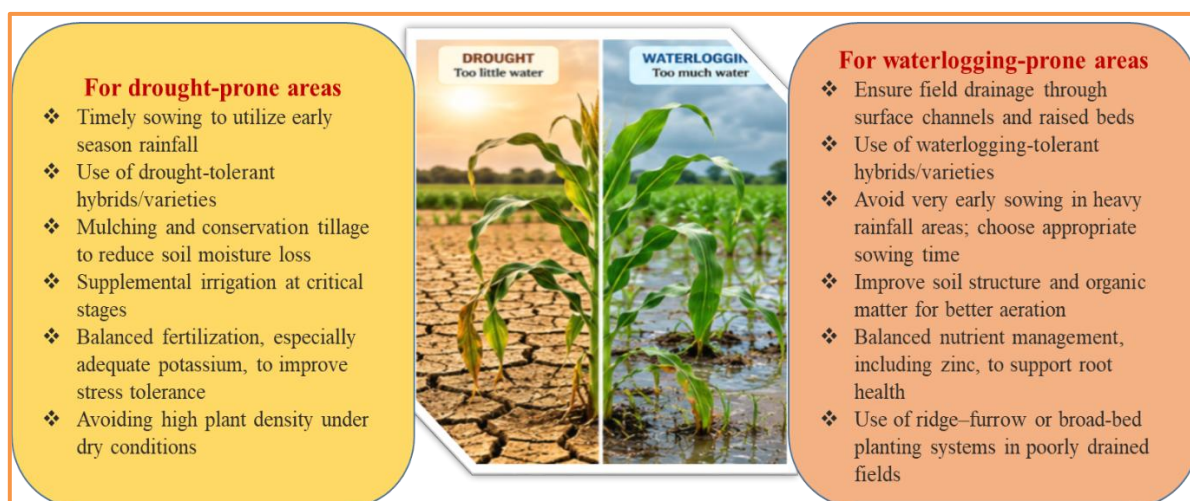


Figure: Management strategies for drought and waterlogging stress in maize

Towards Water-Resilient Maize

Increasing climate variability requires maize varieties and production systems capable of tolerating both water deficit and excess water. From a physiological perspective, drought-resilient maize should maintain root growth, leaf water status, photosynthesis and reproductive performance under limited water. Waterlogging-tolerant maize should maintain root activity, tolerate temporary oxygen deficiency and recover rapidly after drainage. Traits such as root architecture, water-use efficiency, photosynthetic stability, membrane integrity, antioxidant capacity and reproductive-stage stress tolerance can therefore be useful in identifying resilient genotypes. Integrating physiological screening with breeding, improved phenotyping and appropriate agronomic practices can contribute to the development of maize better adapted to variable environments.

Conclusion

Drought and waterlogging are two sides of the same water-management challenge in maize. While drought limits water availability, waterlogging limits oxygen availability to roots. Both stresses can disturb photosynthesis, nutrient uptake, reproduction and grain filling, ultimately reducing yield. Effective management requires an integrated approach involving timely sowing, stress-tolerant varieties, soil-moisture conservation, efficient irrigation, balanced nutrition and proper drainage. As climate variability increases, sustainable maize production will depend not simply on supplying more water, but on maintaining an optimum soil-water environment throughout crop growth.

References

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