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Physiological Responses of Crops to Water Deficit Induced by Partial Root-Zone Irrigation

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Abstract

Water scarcity is a major limitation to agricultural production in arid and semi-arid regions. Partial root-zone irrigation (PRD) has emerged as an effective water-saving irrigation strategy that allows plants to maintain physiological activity under reduced water supply. This review synthesizes current knowledge on crop physiological responses to water deficit induced by PRD, with particular emphasis on photosynthesis, antioxidative defense mechanisms, yield formation, and water productivity (WUE). Although PRD may slightly reduce yield or seed quality when imposed during sensitive growth stages, it generally improves WUE and system-level productivity, particularly in diversified cropping systems.

Introduction

Among various water-saving strategies, partial root-zone irrigation (PRD) has received increasing attention due to its potential to reduce irrigation water use while maintaining acceptable crop performance. PRD involves irrigating only part of the root system while the remaining portion is exposed to drying soil. This spatially heterogeneous water supply generates root-to-shoot signaling, primarily mediated by abscisic acid (ABA), leading to partial stomatal closure and reduced transpiration without severe reductions in photosynthesis. This review aims to integrate current knowledge on crop physiological responses to PRD-induced water deficit, with a special focus on findings reported in cereals, legumes, and intercropping systems

Photosynthetic Responses to PRD-Induced Water Deficit

Water deficit imposed by PRD affects photosynthesis through both stomatal and non-stomatal limitations. Partial stomatal closure reduces CO_2 diffusion into leaves, leading to lower net photosynthetic rates. In addition, prolonged water stress may impair chlorophyll synthesis and disrupt photosynthetic electron transport.

In cereal crops such as wheat, PRD-induced reductions in photosynthesis are often smaller than reductions in transpiration, resulting in improved WUE at the leaf and canopy levels (Eskandari & Alizadeh-Amraie, 2016).

Antioxidative Responses and Oxidative Stress Regulation

Plants counteract ROS accumulation through enzymatic antioxidants such as superoxide dismutase (SOD), catalase (CAT), peroxidase (POD), and ascorbate peroxidase (APX). Enhanced activity of these enzymes under PRD has been reported in several crops. Eskandari et al. (2015) demonstrated that sesame plants exposed to moderate water deficit exhibited enhanced physiological tolerance without significant deterioration in seed quality, suggesting effective antioxidant regulation.

Table 1. Physiological and antioxidative responses of crops to partial root-zone irrigation

Crop / system	Main physiological response	Antioxidant response	Reference
Wheat	Reduced photosynthesis, improved WUE	↑ SOD, CAT	Eskandari & Alizadeh-Amraie (2016)
Sesame	Stable growth under deficit	Enhanced tolerance	Eskandari et al. (2015)
Wheat-Persian clover Intercropping	Membrane peroxidation and leaf water content	SOD, MDA. POD	Eskandari et al., (2018)

References

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