8 Agricultural Applications and Comprehensive Evaluation of Drought-Resistance Regulation in Wheat

8.1 Water management and irrigation regulation

Water management in drought-prone wheat production aims to avoid severe inhibition of photosynthesis while improving water-use efficiency through controlled deficit rather than continuous full irrigation. Across irrigation-gradient studies, mild water stress generally maintained a relatively high photosynthetic rate and sometimes even improved biomass accumulation and 1 000-grain weight compared with fully irrigated controls, indicating that moderate restriction can enhance water productivity without a major physiological penalty (Zhao et al., 2020). A similar conclusion emerged from stage-based field-capacity experiments, in which mild stress around 65%-70% field capacity improved canopy photosynthesis, assimilate allocation to grain, yield, and water-use efficiency, whereas moderate and severe stress increasingly constrained these responses. These results suggest that irrigation scheduling should target the threshold at which stomatal regulation conserves water but does not yet trigger major non-stomatal damage to the photosynthetic system.

The timing and delivery mode of irrigation are as important as total water supply. Growth-stage-based deficit irrigation sustained a high photosynthetic rate when soil relative water content was maintained at 60%-75%, and the treatment irrigated from jointing to filling achieved the best balance between water saving and acceptable yield loss in Northwest China. Under drip irrigation, mild deficit imposed at tillering or jointing increased antioxidant enzyme activity, reduced ROS and lipid peroxidation, delayed flag-leaf senescence, and improved yield relative to stronger deficit treatments, with the tillering-stage mild deficit giving the clearest agronomic advantage (Che et al., 2025). Complementary field management can strengthen this effect: ridge-furrow mulching with moderate deficit irrigation improved soil water status, raised flag-leaf photosynthesis, enhanced SOD, POD, CAT, and APX activities, and reduced oxidative damage, making it a practical water-saving strategy in semi-arid systems.

8.2 Nutritional regulation and application of exogenous substances

Adequate mineral nutrition can buffer the drought-induced decline in photosynthetic and antioxidant function in wheat leaves. Nitrogen supply is especially important because drought-stressed plants receiving moderate or high N maintain higher photosynthesis and N-metabolism activity than low-N plants, while also showing stronger SOD, POD, CAT, GR, and APX responses and better osmotic adjustment (Ru et al., 2022). At vegetative stages, higher N also helped wheat sustain leaf water potential, chlorophyll and Rubisco content, and lower lipid peroxidation under drought, indicating that nutritional regulation supports both carbon assimilation and ROS detoxification. Thus, fertilizer management should be viewed as part of drought regulation rather than a separate yield-input issue.

Exogenous substances provide an additional tool for protecting wheat leaves when drought cannot be avoided. Root-applied strigolactones enhanced the expression of antioxidant-defense, chlorophyll-biogenesis, and light-harvesting genes, and this was accompanied by higher SOD, POD, and CAT activities, increased chlorophyll, and a higher photosynthetic rate under drought (Song et al., 2023). Foliar salicylic acid, zinc, and glycine betaine reduced H_2O_2, $O_2{\bullet}^-$, MDA, and lipid oxidation while promoting antioxidant enzymes, osmolyte accumulation, and grain yield under reproductive-stage drought, with glycine betaine showing the strongest overall effect in that study. Other regulators act through related mechanisms: Zn increased SPAD, Fv/Fm, ascorbate, glutathione, phenolics, and flavonoids while reducing H_2O_2 and lipid peroxidation, and GABA increased phenolic acids and antioxidant enzyme activity, further supporting the use of exogenous compounds to reinforce redox protection under water deficit.

8.3 Drought-tolerant cultivar screening and precision agriculture applications

Drought-tolerant cultivar screening is most effective when it integrates photosynthetic, antioxidant, water-status, and yield-related traits rather than relying on any single indicator. Field evaluation in the North China Plain reduced 24 conventional traits to a smaller set of practical drought indicators, identifying canopy temperature, leaf water content, photosynthetic rate, intercellular CO_2 concentration, POD, MDA, and ABA among the most