measures can complement intrinsic physiological tolerance (Irkiso et al., 2025). At the genetic level, wheat lines with tighter stomatal control, improved root development, and lower relative water loss show higher instantaneous water use efficiency and less physiological damage under water limitation. Together, these findings show that drought adaptation in wheat is best understood as coordinated regulation of water loss, water capture, and photosynthetic protection rather than as a single-trait response (Figure 1).

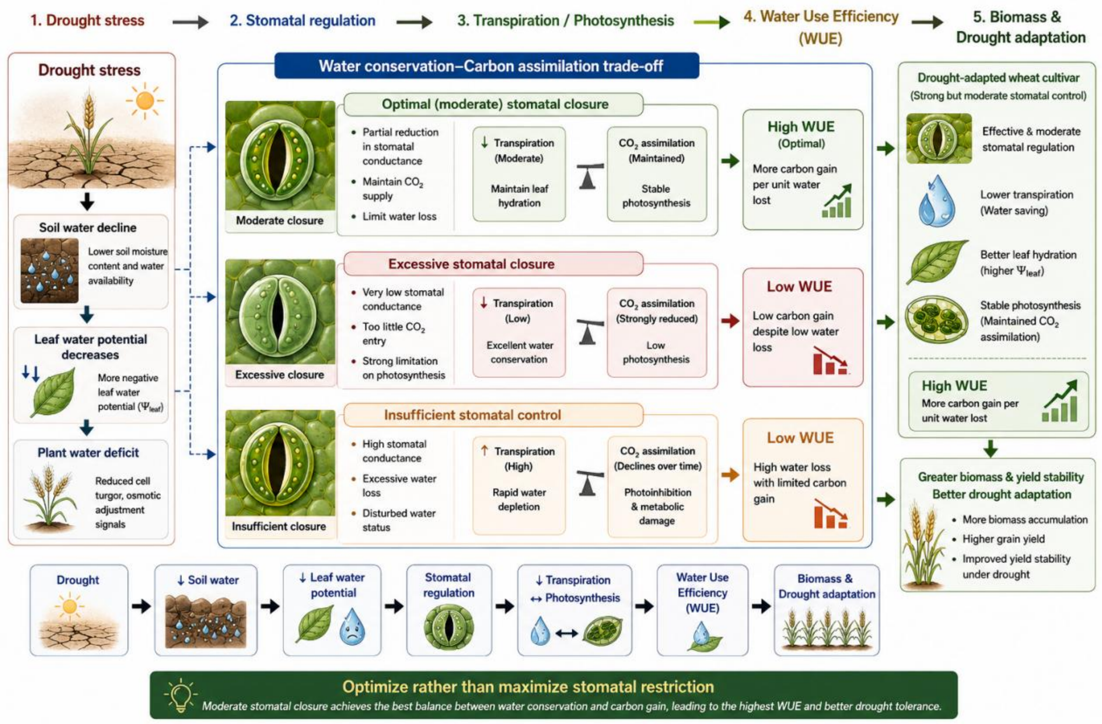

Figure 1 Trade-off between water conservation and carbon assimilation in wheat under drought stress. Moderate stomatal restriction can improve water use efficiency by reducing transpiration while maintaining relatively stable photosynthetic carbon assimilation, whereas excessive stomatal closure can restrict carbon gain and biomass accumulation. Drought-adapted wheat cultivars optimize stomatal regulation and tissue hydration to balance water conservation with productive photosynthesis

3 Changes in Leaf Photosynthetic Characteristics of Wheat under Drought Stress

3.1 Dynamic responses of gas exchange parameters

Drought stress suppresses leaf gas exchange in wheat primarily through progressive declines in net photosynthetic rate, stomatal conductance, and transpiration, and these changes often appear early during soil drying. Across experiments, stomatal conductance is typically the most sensitive gas-exchange trait, and once it falls sufficiently, limitations on CO_2 supply begin to constrain photosynthetic carbon gain more strongly (Pflüger et al., 2024). This early phase is therefore dominated by stomatal limitation rather than irreversible biochemical damage, especially under mild to moderate stress. As drought intensifies, reduced stomatal opening also weakens evaporative cooling and accelerates feedback effects on leaf metabolism, which further depresses assimilation.

With longer or more severe drought, gas-exchange inhibition becomes increasingly shaped by non-stomatal factors, including reductions in carboxylation capacity and electron transport. In wheat, this transition is often reflected by lower chlorophyll content, smaller assimilating leaf area, and rising intercellular constraints that indicate impairment beyond stomatal closure alone (Guizani et al., 2023). Genotypic differences are substantial: tolerant cultivars generally maintain higher photosynthesis and conductance under stress, whereas sensitive genotypes adopt stronger water-conserving closure at the cost of carbon uptake. After rewatering, gas exchange can recover markedly, but recovery depends on how far drought has progressed before relief.

3.2 Chlorophyll fluorescence and photosystem function

Chlorophyll fluorescence shows that drought alters the photochemical functioning of wheat leaves even when visible injury is limited. Sensitive fluorescence traits usually include declines in ΦPSII, qP, and ETR, together