

and water input level strongly affect yield and efficiency, with field evidence showing that an intermediate irrigation regime of 0.75 Epan produced the highest water use efficiency among tested treatments under semi-arid conditions (Gouthami et al., 2025).

This optimization must also consider substrate and root-zone water dynamics rather than irrigation amount alone. Simulation-based work under protected cultivation showed that a 1.0 lph emitter combined with a 48-hour interval maintained optimal root-zone moisture while limiting deep percolation, indicating that irrigation design can improve water-use efficiency by keeping water available where *Chrysanthemum* roots can use it most effectively. At the same time, excessive deficit remains risky, because garland *Chrysanthemum* exposed to strong water restriction showed leaf chlorosis, reduced fresh and dry mass, and visible drought injury, whereas a moderate deficit treatment was more compatible with maintaining yield while improving efficiency (Chang et al., 2021).

7.2 Application of biostimulants and soil improvement measures

Among biostimulant approaches, exogenous melatonin has the clearest direct evidence for improving *Chrysanthemum* drought tolerance. Under PEG-induced drought, melatonin increased net photosynthesis, transpiration, and stomatal conductance, while also reducing the decline in chlorophyll and relative water content, indicating better coordination between water status and photosynthetic performance under stress. Melatonin also enhanced osmotic adjustment and antioxidant defense by increasing soluble sugars, soluble proteins, and antioxidant enzyme activities, which helps explain its protective effect on seedling vigor under water deficit (Luo et al., 2023).

Brassinolide and rhizosphere-oriented measures provide additional routes for stress mitigation and soil-related improvement. In *Chrysanthemum*, brassinolide treatment increased relative water content, net photosynthetic rate, chlorophyll fluorescence, Rubisco activity, and enzymes of the ascorbate-glutathione cycle, while reducing hydrogen peroxide accumulation, especially under drought conditions (Yang et al., 2020). Beyond plant growth regulators, review evidence indicates that *Chrysanthemum* production can also benefit from biological soil improvement, including rhizosphere inoculation strategies and beneficial microorganisms such as *Pseudomonas putida*, which have shown potential to improve plant growth and flowering and may support more resilient production systems.

7.3 Breeding and biotechnology approaches for drought-resistant *Chrysanthemum*

Breeding drought-resistant *Chrysanthemum* remains a high priority because drought tolerance is a complex trait controlled by many genes and strongly influenced by the species' polyploid and heterozygous genome. Transcriptome profiling under dehydration identified thousands of responsive transcripts, including transcription factors and kinases, and these datasets have been proposed as candidate-gene and marker resources for future breeding of drought-tolerant cultivars. More recent reviews likewise conclude that conventional breeding now needs to be integrated with marker-assisted selection, transgenic methods, genome editing, and multi-omics approaches to accelerate stress-tolerance improvement in *Chrysanthemum*.

Functional genetics and association mapping now provide more direct routes to cultivar improvement. Several drought-related regulators have already been characterized in *Chrysanthemum*, including CmSCL4 and CmR1MYB1, which synergistically enhance drought tolerance through ABA-responsive signaling, showing that targeted manipulation of signaling genes can improve stress adaptation (Zhang et al., 2022). At the population level, GWAS and integrative mapping studies identified favorable alleles, elite donor cultivars, and co-localized loci linked to drought tolerance, providing practical pre-breeding materials and genetic markers for developing cultivars with stronger drought resistance and more efficient water use (Lu et al., 2025).

8 Conclusions and Future Perspectives

Drought stress consistently depresses core photosynthetic processes in *Chrysanthemum* leaves, including net photosynthetic rate, stomatal conductance, transpiration, chlorophyll content, and PSII-related performance, and these declines become stronger as soil water deficit intensifies. Across graded drought treatments, intercellular CO₂ commonly decreases at earlier or milder stress and then rises under more severe stress, indicating a transition