balance shifts from rapid accumulation of fresh mass toward sugar concentration, metabolic change, aroma formation, and tissue softening (Fabeiro et al., 2002; Liu et al., 2024; Wang et al., 2025).

Recent developmental studies support this stage-based view. Transcriptomic and metabolomic analyses show that melon fruit follows a strong developmental sequence in which early growth is associated with active cell division and expansion, and later stages are associated with sharp changes in sucrose, organic acids, texture-related pathways, and ripening regulation. A 2025 transcriptome-metabolome study described middle and late fruit development as a typical S-shaped growth process, while a 2024 time-series transcriptome study confirmed clear differences between earlier and later maturity stages in sugar and organic-acid metabolism. This matters for irrigation research because the same water regime cannot be expected to serve all developmental goals equally well (Liu et al., 2024; Wang et al., 2025).

2.2 Water demand during different growth stages

Melon does not demand water uniformly across the season. Early vegetative growth requires enough moisture to support establishment and leaf area development, but seasonal demand often peaks from flowering into fruit enlargement, when transpiration and sink demand are both high. Stage-based deficit irrigation experiments have repeatedly shown that water restriction during blooming or fruit set is more damaging to yield than comparable restriction imposed later. In the classic controlled-deficit study by Fabeiro and colleagues, deficits during blooming most strongly reduced production, deficits during setting affected both quantity and quality, and deficits during ripening had a stronger effect on quality than on yield (Fabeiro et al., 2002).

More recent work confirms that stage sensitivity remains a central principle. Yavuz and colleagues, working in a semi-arid environment, found the highest yields under stress-free irrigation across all stages, but they also showed that different stage combinations shifted quality and water use efficiency in different ways. Kuscu and Turhan later reported that maintaining full irrigation up to fruit ripening and then shifting to 50% ETc produced nearly the same three-year average yield as full irrigation while improving water productivity and several quality traits. In greenhouse substrate production, Xue and colleagues found that mild deficit during maturity reduced cracking and improved quality without a significant penalty in yield. Together these studies suggest that melon water demand is highest, and least negotiable, before and during early fruit growth, while the late stage offers more room for quality-oriented adjustment (Yavuz et al., 2021; Kuscu and Turhan, 2022; Xue et al., 2025).

2.3 Physiological responses of melon to water availability

When water becomes limiting, melon responds through declines in leaf water status, stomatal conductance, transpiration, and net photosynthesis. These are not abstract laboratory traits; they directly shape fruit growth because they determine how much carbon and water are available for sink tissues. Recent studies in field and greenhouse systems show that moderate water deficits can be tolerated if leaf gas exchange remains high enough and if the plant avoids prolonged turgor loss. Under severe or prolonged deficits, however, stomatal closure and reduced photosynthesis lead to smaller canopies, weaker fruit growth, and lower yield (Miceli et al., 2023; Panda et al., 2025; di Santo and Barrios-Masias, 2026).

At the same time, melon does show some capacity for acclimation. In a recent study combining deficit irrigation with biostimulant preconditioning, melon plants under a suppressed-irrigation treatment showed evidence of osmotic adjustment, and the biostimulated treatment further improved water uptake and irrigation water productivity while increasing phenolic compounds in fruit. This is important because it shows that the physiological response to irrigation frequency is not determined by water alone; root-zone conditions, stress history, cultivar traits, and biological inputs can all shift the plant's response threshold (Zapata-García et al., 2025).

2.4 Critical irrigation periods for melon production

The literature points to two especially critical periods. The first is flowering to early fruit enlargement, when water deficits can reduce fruit set, lower fruit number, and restrict the cell division and early expansion that underpin later fruit size. The second is fruit maturity, not because the plant becomes fragile in the same way, but because