showing that fruit growth and quality formation are tightly linked developmental processes (Cheng et al., 2022; Gustani et al., 2024; Wang et al., 2025).

Water management in melon has become more difficult for two reasons. The first is the broad pressure of water scarcity in many melon-producing regions, including semi-arid Mediterranean zones, northwestern China, and dry parts of North America. The second is that melon quality responds not only to total irrigation amount, but also to the timing and rhythm of water delivery. A global meta-analysis of vegetable deficit irrigation showed that mild to moderate deficit can often preserve yield better than severe deficit, but melon-specific studies make clear that the developmental stage at which the deficit occurs is just as important as the severity itself (Fabeiro et al., 2002; Singh et al., 2021; Yavuz et al., 2021). In protected systems the challenge is even more delicate. Over-irrigation can reduce water use efficiency, increase nutrient leaching, dilute sweetness, and in some cases aggravate fruit cracking, while under-irrigation can suppress canopy development, reduce leaf gas exchange, and limit fruit growth. A two-year commercial melon study in Murcia showed that sensor-guided irrigation reduced water inputs by 27%-30% without yield loss and increased both water and nitrogen productivity, which suggests that a major part of the problem is not lack of technology but lack of precise scheduling. Likewise, a recent greenhouse muskmelon study reported that mild water deficit at fruit maturity significantly lowered cracking while improving commercial quality, showing that “too much” irrigation can be harmful late in the cycle (Zapata-García et al., 2023; Xue et al., 2025).

Irrigation frequency is the temporal dimension of irrigation management. Total seasonal water amount matters, but the interval between irrigation events determines how strongly roots experience drying cycles, how much oxygen remains in the root zone, how stable nutrient transport is, and how sharply the plant alternates between high and low water status. In melon, this matters because fruit growth depends on continuous assimilate supply and sustained cell expansion, while sweetness and firmness often improve when late-season water supply becomes slightly more restrictive. For this reason, frequency should not be treated as a secondary technical detail. It is a direct regulator of source-sink relations, root uptake, and final fruit quality (Sensoy et al., 2007; Li et al., 2012; Sun et al., 2024). The evidence now comes from several kinds of systems. Open-field work has compared longer and shorter irrigation intervals across fixed water amounts. Protected-environment studies have tested pulsed irrigation several times per day, especially in drip and soilless systems. Newer precision-irrigation studies go further by combining irrigation timing with plant-based or sensor-based signals, effectively turning irrigation frequency into a variable that changes with crop stage and crop stress rather than with a fixed calendar. This shift is particularly important for melon because the sensitive phases are not identical from transplanting to ripening (Chang et al., 2019; Zapata-García et al., 2023; Fang et al., 2026).

This study examines irrigation frequency from the perspective of three connected outcomes: vegetative growth, fruit development, and fruit quality. Instead of treating water management as a purely engineering issue, the discussion follows melon development across stages and asks how irrigation rhythm changes canopy formation, root activity, fruit set, fruit enlargement, ripening, and commercial quality traits. It also considers regional case studies, with special attention to eastern China and the Zhejiang-related context, because protected melon production in those regions makes irrigation scheduling especially consequential. The study finally summarizes sustainable strategies, recent technological advances, current research limitations, and practical directions for future work.

2 Water Requirements and Growth Characteristics of Melon

2.1 Growth and development stages of melon

Melon growth is typically divided into an early vegetative stage, a flowering and fruit-set stage, a fruit enlargement stage, and a maturation or ripening stage. Although these labels are simple, the physiological meaning of each stage is different. During early vegetative growth, the plant is building photosynthetic area and root capacity. During flowering and fruit set, reproductive stability becomes critical because water stress can interfere with flower function, fruit initiation, and the early cell division processes that largely determine later fruit size. During enlargement, fruit becomes a dominant sink for water and photoassimilates. During maturation, the