accumulation, carotenoid biosynthesis, and stress and hormone signaling, all modulated as fruits pass from immature white to fully ripe red or over-ripe stages (Yu et al., 2022). Non-destructive and physiological measurements further indicate that ripening involves progressive pigment and carotenoid changes at the surface and within the flesh, along with hormone shifts typical of non-climacteric, ABA-and ethylene-modulated maturation, which together stabilize final fruit size and weight (Dhanani et al., 2022).

2.2 Mechanisms by which watermelon flesh cell division and expansion contribute to fruit weight

Fruit weight is fundamentally determined by the final number and size of flesh cells. In watermelon, cell division predominates during only the first several days after anthesis, followed by a long expansion phase in which existing cells enlarge dramatically through vacuolation and wall remodeling. Anatomical studies comparing pollinated, auxin-induced parthenocarpic, and unpollinated fruits show that early fruit growth depends on active cell division in pericarp and ovule tissues; unpollinated ovaries, which lack sustained division, rapidly cease growth, illustrating the centrality of early proliferative activity for subsequent fruit mass potential. After this brief proliferative window, increases in pulp weight from about one week onward are largely ascribed to cellular expansion, consistent with microscopic evidence that watermelon flesh cells become large and visually apparent as fruits enlarge (Kojima et al., 2020).

Cell expansion is driven by coordinated changes in cell wall architecture, hormonal signals, and metabolic status. Studies of firmness and texture reveal that differences in protopectin, cellulose, and hemicellulose contents, together with cell number, packing, and wall thickness, underlie variation in tissue density and mechanical support for expanding cells (Sun et al., 2020; Mashilo et al., 2022). Auxin- and Aux/IAA-mediated pathways modulate cell enlargement and the balance between cell size and number: high expression or allelic variants of Aux/IAA are linked to increased cell number, smaller cell size, and higher firmness, whereas reduced Aux/IAA activity is associated with larger cells and softer flesh, indicating that auxin signaling tunes the cellular composition that ultimately contributes to fruit volume and weight (Anees et al., 2023).

2.3 The impact of source-sink relationships in watermelon plants on fruit weight accumulation

Fruit growth depends on assimilate and water supply from vegetative organs, with the developing fruit acting as a strong sink whose demand changes across development. Dynamic sap-flow monitoring along fruit stalks across successive developmental stages shows that diurnal water distribution between leaves and fruit shifts markedly as fruits expand, slow growth, and reach maturity. During early expansion, nighttime inflow to the fruit dominates, correlating with rapid daily mass increase, whereas at later stages midday transpiration demand in leaves competes more strongly, shortening net inflow periods and reducing net fruit growth, before inflow and outflow balance at maturity when phenotype and weight stabilize (Zhang et al., 2024). Under low-light conditions, reduced photosynthesis and altered carbon and nitrogen metabolism associate with smaller fruits, lower soluble sugar and amino acid contents, and extensive transcriptional reprogramming, demonstrating that source capacity strongly constrains sink development during the critical 0-15 days after pollination expansion window (Gao et al., 2023).

Water supply and photosynthate partitioning also interact with environmental water availability and irrigation management to determine final fruit size and yield. Experiments manipulating drip irrigation at different fractions of crop water requirement across growth stages show that severe water deficits reduce total and marketable yield, average fruit weight, and fruit number, with vegetative growth and active fruit development phases more sensitive than the ripening phase. Deficit irrigation applied only during ripening has a comparatively smaller impact on marketable fruit weight and improves water-use efficiency, implying that the sink strength of fruits is highest and most vulnerable to water limitation during early and mid-development when rapid mass accumulation occurs. Together, these findings indicate that fruit weight formation in watermelon emerges from an integrated source-sink system, in which environmental factors such as light and water modulate assimilate production and transport to the fruit, thereby shaping the trajectory of fruit growth and final weight.

3 Key Environmental Factors Influencing Watermelon Fruit Weight

Watermelon fruit weight is shaped by a complex interaction of temperature, light, water, and nutrient status that