together regulate cell division, cell expansion, and carbohydrate supply to developing fruits. Studies in protected and open-field systems show that modifying microclimate or resource availability around the fruiting zone can substantially alter fruit volume, sugars, and final yield per plant. Temperature and light, in particular, determine photosynthetic capacity and assimilate partitioning, while water and soil factors influence canopy function, root activity, and stress responses that indirectly affect fruit growth rates (Woo et al., 2022). Understanding these key environmental drivers is essential for building predictive models of fruit weight formation and for designing precise cultivation strategies in climate-vulnerable production regions (Barros et al., 2024).

3.1 The impact of temperature variations on watermelon fruit expansion rate and final fruit weight

Targeted heating around the fruiting region clearly demonstrates that temperature during early enlargement can accelerate fruit growth and increase final fruit weight. Raising the minimum temperature around fruit-bearing shoots to 18 °C in early spring plastic-house production significantly increased fresh fruit weight per plant, soluble solids, and fruit set rate, indicating enhanced sink activity and yield potential under suboptimal ambient conditions. High night-time temperature around young fruits (approximately 6 °C above the control) similarly increased fruit length, diameter, and weight by 16 days after anthesis through accelerated cell enlargement, even though final size at harvest later converged with the control (Chamchum et al., 2023).

The timing of temperature elevation also influences internal quality and sugar accumulation associated with fruit weight formation. Heating the fruit and nearby shoots during the early cell enlargement stage (5-20 days after anthesis) increased sucrose phosphate synthase activity and led to higher sucrose content at maturity, particularly in outer flesh tissues, suggesting that warm conditions can promote both structural growth and assimilate storage capacity. When high-temperature treatments were imposed between 10 and 20 days after anthesis, cell enlargement in the central region was stimulated and sugar contents at harvest generally increased; by contrast, high temperatures applied only after 20 days enhanced cell expansion in peripheral tissues but reduced sugar levels overall, indicating that late heat can impair optimal sugar accumulation while still altering fruit morphology.

3.2 The role of light conditions in the accumulation of watermelon photosynthetic products and fruit weight formation

Light intensity and spectral composition strongly control photosynthetic production and distribution of assimilates to fruits, thereby determining fruit size. In vertically trained, high-density systems, increasing shading with planting density reduced per-plant solar radiation interception and whole-plant photosynthetic production, which was closely correlated with reduced fruit size despite little change in soluble solids, highlighting light-driven assimilate supply as a primary determinant of fruit weight. Experiments on greenhouse orientation showed that a southeast-northwest single-span greenhouse received higher integrated solar radiation and higher leaf transpiration near fruits than an east-west structure, and these microclimatic differences were associated with increased fruit volume expansion in seedless watermelon (Figure 1) (Woo et al., 2022).

Artificial supplemental lighting further illustrates the role of light in driving both biomass production and carbohydrate accumulation in fruits. In winter-grown watermelon, evening LED lighting at 900 μmol m^{-2} s^{-1} significantly increased chlorophyll content, photosynthetic rate, fruit number, fruit weight, and flesh thickness, leading to a 31% yield increase and higher fruit sugar content relative to natural-light controls (Hossain et al., 2025). Similarly, plastic-house plants receiving 6-12 h of white LED light at night produced heavier fruits with larger dimensions and thicker flesh than non-supplemented plants, confirming that extended photoperiod and elevated photon flux enhance fruit growth by bolstering daily carbon gain and translocation to reproductive sinks (Gao et al., 2023).

3.3 Regulatory mechanisms of water and soil nutrients on watermelon fruit weight formation

Water availability and root-soil interactions regulate canopy temperature, photosynthesis, and stress physiology, which in turn shape fruit development and final weight. Experiments manipulating the wetted soil area under drip irrigation (12%-22% of surface) in semi-arid Brazil showed that average leaf temperature remained below air temperature and that fruit mass and BRIX were statistically similar across treatments, suggesting that a relatively wide range of localized wetting can maintain physiological stability and high yield if overall water supply is