

with sugar and pigment metabolism. Thus, the strawberry light environment is directly relevant to both source activity in leaves and sink metabolism in fruits, making it a key target for quality-oriented crop management (Warner et al., 2021).

Research over the last decade has shown that light management can be used strategically to improve strawberry production in greenhouses and controlled environments, particularly where winter radiation is limited or canopy structure creates local shading. Supplemental LED lighting has received the greatest attention because it allows precise control of wavelength, intensity, and photoperiod, and different spectra can produce distinct outcomes. Red light often promotes productivity and anthocyanin accumulation, while blue light can enhance certain quality traits and, in some systems, increase soluble sugar content. Combined red-blue lighting has also been reported to improve soluble solids, anthocyanin concentration, and vegetative performance, although cultivar dependence remains an important limitation. In addition, newer work suggests that far-red or other spectrum adjustments can further alter flowering, biomass partitioning, fruit yield, and sweetness. Collectively, these findings indicate that light management is no longer a purely supplemental practice for maintaining growth, but an active production tool for steering fruit quality formation in strawberry (Lauria et al., 2023; Ries and Park, 2024).

Despite this progress, important gaps remain in understanding how light management specifically influences sugar accumulation while simultaneously affecting other fruit-quality components. Available studies show that supplemental lighting can increase total sugar, glucose, and fructose concentrations, and can also modify soluble solids, acidity, polyphenols, and anthocyanins, but responses vary with season, cultivar, irrigation status, and the precise light regime applied. Moreover, the physiological and molecular coordination between carbon assimilation, carbohydrate transport, ripening metabolism, and light signaling has not yet been fully resolved for strawberry production systems. Therefore, a focused synthesis of current knowledge is needed to clarify how light intensity, spectral composition, and light-management strategies shape fruit quality, with particular emphasis on sugar accumulation. The objective of this paper is to examine the influence of light management on strawberry fruit quality and sweetness-related traits, summarize current research progress, and provide a basis for optimizing lighting strategies in modern strawberry cultivation (Qiu et al., 2023; Xu et al., 2023).

2.Light Characteristics and Their Effects on Strawberry Photosynthetic Performance

2.1 Effects of light intensity on photosynthesis and carbon assimilation

Light intensity is a primary determinant of strawberry photosynthetic performance because it directly affects carbon fixation, stomatal behavior, and assimilate supply. Under greenhouse shading, reduced irradiance decreased photosynthetic rate, stomatal conductance, sugar accumulation, and marketable fruit yield, showing that inadequate light restricts both source activity and carbon allocation to developing sinks (Choi, 2021). Similar responses were observed during transplant production in LED systems, where increasing intensity within an effective range enhanced stomatal conductance, net photosynthetic rate, and dry matter accumulation, confirming that carbon assimilation improves as photon supply approaches the cultivar's physiological requirement.

However, the effect of intensity is not simply linear, because optimal ranges differ with developmental stage and production environment. During runner propagation, unrooted plants performed best at $90 \mu\text{mol m}^{-2} \text{s}^{-1}$ during rooting, whereas rooted seedlings responded positively up to $270 \mu\text{mol m}^{-2} \text{s}^{-1}$, with no further growth improvement at $360 \mu\text{mol m}^{-2} \text{s}^{-1}$, indicating saturation of biomass gain at higher irradiance. Recent controlled-environment work also showed that moderate supplemental illumination directed to the abaxial leaf surface increased CO_2 assimilation, fruit yield, and fruit quality with greater energy efficiency than equivalent adaxial lighting, emphasizing that both light dose and light distribution influence whole-canopy carbon gain (Wang et al., 2026).

2.2 Influence of photoperiod on vegetative growth and reproductive development

Photoperiod modifies strawberry growth by changing the daily duration of carbon acquisition and by regulating the timing of developmental transitions. In indoor sole-source systems, extending the photoperiod from 12 to 16 h accelerated flowering by 17-21 days, advanced first harvest, and increased fruit production by 372%–989%, while increases in PPFD mainly enhanced vegetative biomass, indicating that day length can dominate reproductive