Breaking Dawn: The twilight of starch degradation in the light

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Plants have the amazing ability to convert solar energy into sugars through photosynthesis. Photosynthesis-derived sugars, synthesized during the day, serve as building blocks for a myriad of metabolic and developmental processes in plants (i.e. respiration, cell wall biosynthesis, amino acids synthesis, and the production of secondary metabolites). Upon synthesis, these sugars can either be used right away or converted into starch to be used at night, during which starch reserves are remobilized and degraded into simple sugars (i.e. maltose), allowing plants to maintain growth until photosynthesis resumes the next day (Stitt and Zeeman, 2012). Usually, starch synthesis and degradation are assumed as two separate processes occurring either during the day (starch synthesis) or during the night (starch degradation). However, it is long known that starch degradation can occur in the light as well (Stitt and Heldt, 1981; Lu et al., 2005; Weise et al., 2006). More recent studies even demonstrated that the rate of starch degradation in the light increases as the duration of light exposure increases (Fernandez et al., 2017). Although the fact that starch degradation also occurs in the light has been observed for decades, its biological relevance for plant growth and its regulation remain unclear.

In this issue of Plant Physiology, Ishihara et al. (2022) further characterized the biological relevance of starch degradation in the light. They demonstrate that starch degradation in the light is regulated via processes similar to those occurring during the day (starch synthesis) or during the night (starch degradation). However, it is known that starch degradation can occur in the light as well (Stitt and Heldt, 1981; Lu et al., 2005; Weise et al., 2006). More recent studies even demonstrated that the rate of starch degradation in the light increases as the duration of light exposure increases (Fernandez et al., 2017). Although the fact that starch degradation also occurs in the light has been observed for decades, its biological relevance for plant growth and its regulation remain unclear.

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degradation rate in the evening). This prediction was contradicted by their physiological data showing, not a decrease but, a stabilization of starch levels before dusk. Using $^{13}$CO$_2$ labeling, the authors showed that the stabilization of starch resources was associated to the maintenance of cell wall and protein synthesis upon simulated dusk twilight. Based on these results, the authors hypothesized that decreased light intensity during evening twilight causes a dampening of photosynthesis and the associated sucrose/starch accumulation, which would in turn trigger starch degradation to maintain starch levels constant until dusk and avoid an energy crisis (Figure 1).

To test their hypothesis, Ishihara et al. (2022) investigated the role of Tre6P in regulating starch accumulation in the light. Tre6P is a sucrose sensor molecule known to regulate starch homeostasis by inhibiting starch degradation (Figueroa and Lunn, 2016). By using ethanol-inducible Tre6P synthase-overexpressing lines (displaying increased levels of Tre6P upon induction by ethanol), the authors showed that increased Tre6P levels corresponded with increased starch levels, corroborating the idea that Tre6P inhibits starch degradation.

Altogether, the authors provide evidence that decreased light intensity during evening twilight reduces photosynthesis activity and subsequent sucrose/starch synthesis, which in turn decreases Tre6P levels in plants, thereby promoting starch degradation to maintain starch levels constant until dusk (Figure 1). This increased starch degradation during evening twilight allows plants to buffer growth processes when photosynthesis efficiency declines.

Tre6P is a key regulator of starch degradation during the night as it integrates the circadian clock to set the pace at which starch must be degraded to sustain plant growth until the next day (dos Anjos et al., 2018). The authors speculate that the clock could also play a role in pacing starch degradation in the light, too. This idea would be an interesting follow-up study to confirm whether starch degradation in the light could simply be the reverse as when it occurs at night. Indeed, the fact that starch levels are barely affected by simulated twilight applied early in the day could underlie adaptive mechanisms of plants to distinguish between simple weather fluctuations (i.e. sun flecks or clouds) when compared with evening twilight. In addition, evening twilight is usually associated with cooler temperatures, which would be an interesting parameter to model and study in the context of the regulation of starch degradation in the light. In conclusion, Ishihara et al. (2022) beautifully combine model predictions with physiological data to further our understanding of starch degradation in the light and its biological and ecophysiological relevance.

Conflict of interest statement. None declared.

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