

The magnifying effect of water droplets

A window into how plants acclimate to intense light

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Who hasn't noticed those glistening dew droplets on leaves in the early morning, after rain, or even secreted by the plants themselves? Yet these droplets can play an unexpected role in plant life: acting like tiny magnifying glasses, they can focus sunlight onto small areas of the leaf, creating localized spots of intense light. This phenomenon, reminiscent of the legend of Archimedes' burning mirrors, raises a fascinating question: how do plants manage these micro-light stresses?

The magnifying effect: a tool to study light stress in plant cells

By focusing light, water droplets create areas of high light intensity on the leaf surface. This is why we drew inspiration from this natural phenomenon to study how plants respond to intense light exposure at the cellular level (Figure 1). To simulate the magnifying effect of water droplets in the lab and study its consequences, we developed two protocols: in the first one, we placed a glass bead between a leaf sample and a confocal microscope and used white light source (Figure 2); in the second, we used high intensity laser light of the confocal microscope to induce light stress. In our study, titled « The burning glass effect of water droplets triggers a high light-induced calcium response in the chloroplast stroma », published in *Current Biology*, we reported that this magnifying effect triggers a significant increase in calcium (Ca^{2+}) levels in the powerhouse of the plant cell: the chloroplast¹.



Figure 1: Illustration of the magnifying effect of water droplets on a leaf. Picture by Jenny Svénnäs-Gillner.

Why focus on calcium levels in plant cells?

Calcium is a unique mineral element that serves both as a nutrient and a cellular signalling molecule² in all eukaryotic organisms. In plants, calcium is known to regulate essential processes such as cell division, enzyme activity, and phytohormonal responses. Without sufficient calcium, plants exhibit slowed growth, develop deformities, or become more susceptible to diseases and harsh environmental conditions.

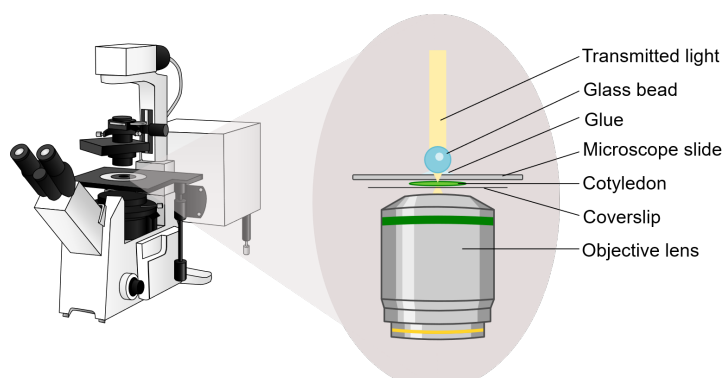


Figure 2: Diagram of the glass bead setup that was used to mimic the focus effect of water drops, on a confocal microscope. Confocal-scanning-laser-microscope (CSLM) icon by Database Center for Life Science (DBCLS) <https://togov.dbcls.jp/en/pics.html> licensed under CC-BY 4.0.

Our findings... under the microscope

By conducting experiments with different light colours or lasers (white, red, and blue), we confirmed that the increase in calcium levels in chloroplasts occurs regardless of the light source's colour and depends solely on its intensity. Reflecting on the legend of Archimedes' mirrors, we also wondered whether temperature influences this phenomenon: repeating the experiment with intense light at different temperatures, we observed that the calcium increase occurs even at low temperatures. However, we noted that combining intense light with high temperature accelerates the calcium increase in chloroplasts.

Our results also show that our experimental protocol faithfully reproduces natural photo-oxidative damage, particularly because we observed a decrease in photosynthetic efficiency during our experiments, validating its relevance for studying light stress. The calcium level increase in chloroplasts, induced by intense light, also revealed an unexpected interaction between the calcium reserves of chloroplasts and the endoplasmic reticulum (Figure 3, panel C)! Calcium, both a nutrient and a cellular signalling molecule, can be stored in different compartments of plant cells, such as the apoplast, vacuole, and endoplasmic reticulum (Figure 3, panel A and B). The release of calcium to low-concentration cellular sites, followed by active transport to storage sites, produces what are known as calcium signatures. Our study revealed a close link between the calcium reserves of the endoplasmic reticulum and chloroplasts: Indeed, we observed for the first time that these two cellular compartments exchange calcium and that this exchange is disrupted upon exposure to intense light.

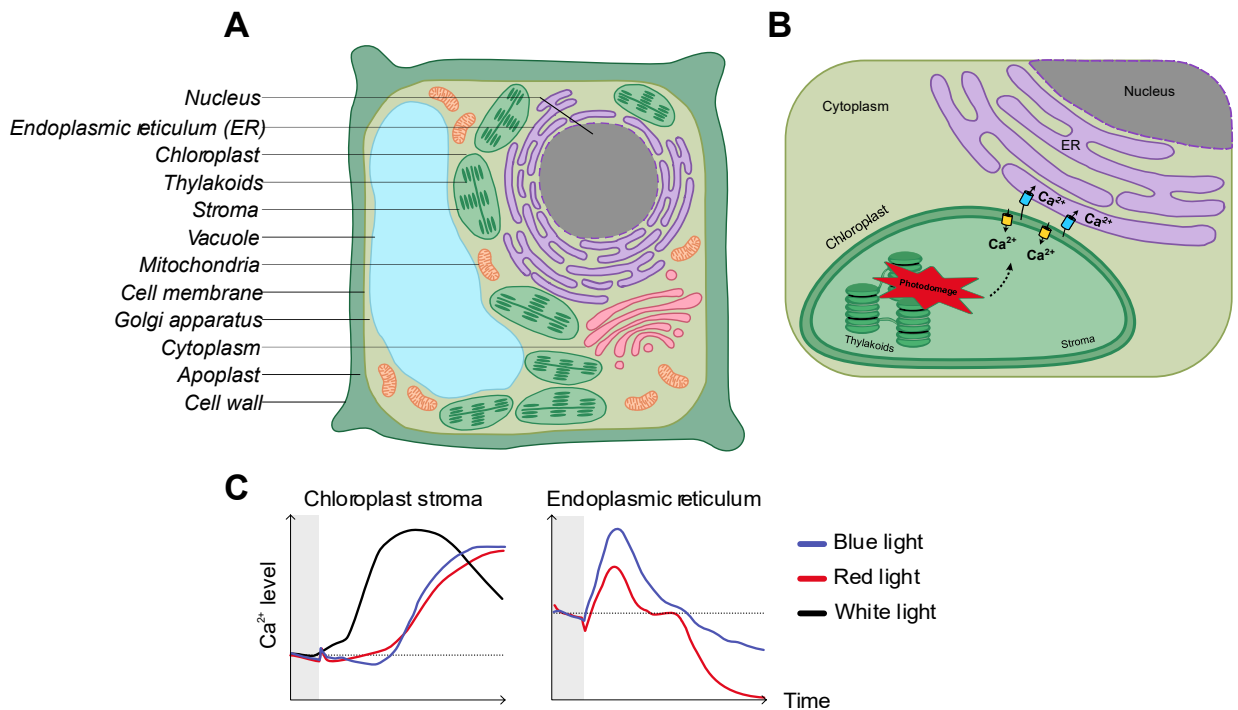


Figure 3: Our results in schematic representation. A) Simplified representation of plant cell. B) Our hypothetical model of calcium increases in the chloroplast of *Arabidopsis thaliana* when submitted to intense light, and the link with endoplasmic reticulum (ER). C) Schematic representation of the calcium level in chloroplast stroma and endoplasmic reticulum during intense light exposure (blue, red or white). The grey box represents lower intensity of light (control condition), the dotted line represents the value 0.

Why is this discovery important?

Understanding how plants manage light fluctuations is crucial for anticipating their adaptation to changing environments. As extreme climate events, such as intense light episodes and heatwaves, become more frequent, studying these stress responses is not just a fundamental research objective: it is a concrete measure to secure the future of agriculture and ecosystems. By deepening our knowledge of how plants cope with stress, we hope to develop crops that are more tolerant to climate change. Further exploring calcium signalling in plants under adverse environmental conditions and its role in acclimation is therefore our preferred approach to achieving this goal.

FAQ

Why decouple intense light and high temperature in this study?

In plant, it has been demonstrated that intense light can trigger different molecular responses than those induced by high temperatures. Additionally, these two conditions do not cause the same damage to plant cells. Another reason is that high light intensity is not always associated with heat in nature: for example, it can be very sunny in winter even though the thermometer shows rather cold temperatures.

Photosynthesis: why is it less efficient under intense light?

Photosynthesis is the process by which photosynthetic organisms (plants, algae, and some bacteria) convert the sun's light energy into chemical energy, producing sugars from carbon dioxide and water. Photosynthesis is therefore essential for plants, as it provides them with the energy needed for growth. In the case of plant exposure to intense light, the photosynthetic chain (i.e., the set of proteins that ensure the functioning of the various physicochemical steps of photosynthesis) becomes overloaded by the amount of light energy received by the plant. This leads to photo-damage and, more specifically, the destruction of certain proteins in the photosynthetic chain, resulting in a reduction in the plant's photosynthetic efficiency.

How to study variations in calcium levels in plant cells?

In this study, we used genetically modified lines of *Arabidopsis thaliana* (a model organism for plant biology studies). These lines produce so-called calcium reporter proteins: these laboratory-designed proteins include a part where calcium can bind and a fluorescent part. The binding of calcium to the reporter protein triggers a conformational change, which affects the intensity of its fluorescence. Using a confocal microscope, we can observe and quantify the fluorescence of calcium reporter proteins and thus deduce the amount of calcium present in the studied cellular compartment.

Why not use a real water droplet instead of a glass bead to reproduce this magnifying effect?

For two main reasons: the risk of evaporation of the droplet during the experiment and the fact that a water droplet placed on a microscope slide does not take the same rounded shape as it does on leaves.

REFERENCES

¹ Kuang, D. et al. The burning glass effect of water droplets triggers a high light-induced calcium response in the chloroplast stroma. *Curr Biol* 35, 2642-2658 e2647 (2025). <https://doi.org/10.1016/j.cub.2025.04.065>

² Luan, S. & Wang, C. Calcium Signaling Mechanisms Across Kingdoms. *Annu Rev Cell Dev Biol* 37, 311-340 (2021). <https://doi.org/10.1146/annurev-cellbio-120219-035210>



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