Leaf transpiration and heat protection

The leaf is a **transformer of light energy into chemical energy**. Like all energy transformers, it needs to be **cooled** for it to work properly.

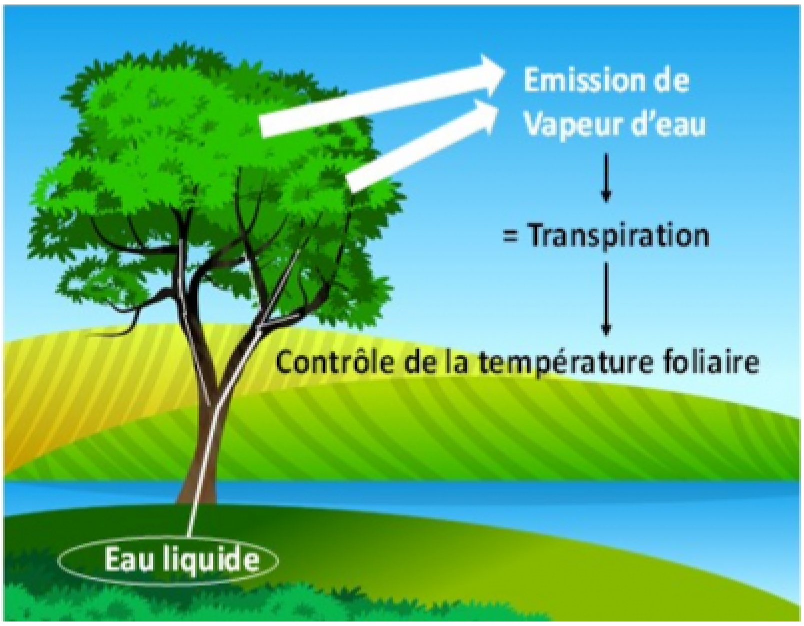

Figure 1. Under optimal conditions, liquid water drawn from the soil by plants maintains their hydration level at a level that allows all their functions (photosynthesis, growth respiration etc.) to function smoothly. The liquid water is vaporized in the leaves at the level of the cell walls. The water vapour thus formed exits leaves the leaf mainly through the stomata constituting transpiration. [Source: royalty free / Pixabay]

Water is used to accomplish this function. It is first drawn from the soil by the plant's roots and then transferred to its various organs, including the leaves, where it allows the maintenance of an active metabolism. It is at the level of the leaves that it returns to the atmosphere in the form of vapor. The vaporization of water takes place in the leaf at the level of the cell walls. The water vapour leaves the leaf mainly through the stomata (see Effects of temperature on photosynthesis): this is **transpiration** (Figure 1). Transpiration allows the continuous cooling of the leaves.

The temperature of a leaf depends on the energy it receives and that which it eliminates. The energy received comes mainly from **solar radiation**, but also from long-wave radiation emitted by surrounding objects.

Transpiration can indeed eliminate a large part of the absorbed energy: the heat of vaporization of water at 20°C is 2,452 joules per gram.

Let's assume that a leaf maintained at 20°C absorbs 300 wm^{-2} (a beautiful spring day) and loses 3 mmoles H_2O m^{-2} s^{-1} (= 3 x 18 mg H_2O = 0.054 g H_2O $m^{-2}s^{-1}$). It then eliminates by sweating 0.054 x 2 452 j m^{-2} s^{-1} = 132.4 wm^{-2}, i.e., almost half of the energy absorbed.

The rest is mainly dissipated by **conduction** in the boundary layer following a temperature gradient, then **convection** (wind action) above the boundary layer. Only a very small part of this energy, 1 to 2%, is stored in the photosynthesis.

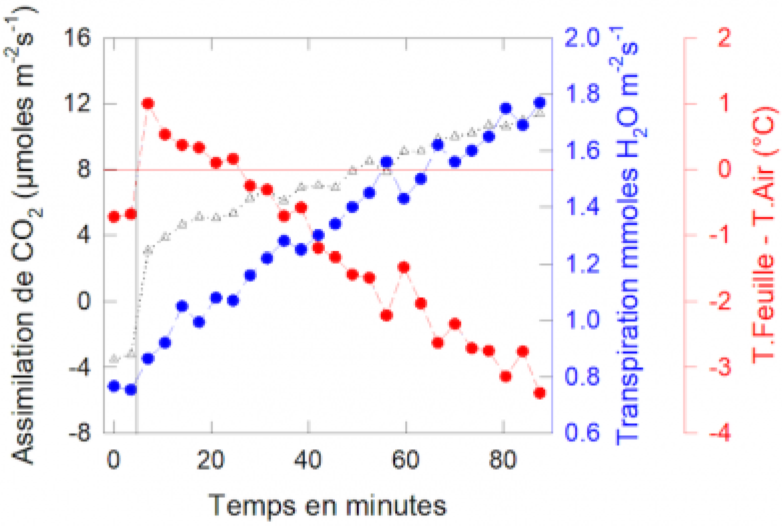

Figure 2. Variations of CO_2 assimilation (black) by a leaf, of its transpiration (blue) and of the difference of its temperature with the ambient air (red) during its passage from darkness to light (vertical line). The measurements are made on a Ranunculus glacialis leaf. The temperature (T) of the ambient air is 20°C. The horizontal red line indicates the equality between the air and the leaf temperature. The light during the measurement is close to saturation. [Source: © Cornic and Streb, unpublished]

The example shown in Figure 2, when a *Ranunculus glacialis* leaf [1] is moved from darkness to light, shows that the increase in photosynthesis is accompanied by an increase in transpiration. Stomata that were closed in the dark open in the light. **In the dark** the temperature of the leaf is slightly lower than that of the air. **It increases sharply in the light** and then decreases as transpiration increases. At the end of the observation its temperature is about 3°C lower than that of the air.

In plants that transpire abundantly the temperature of the leaves can be 1 to 2°C lower than that of the air. On the other hand, in plants suffering from drought (little transpiration) and exposed to light, the leaf temperature can be up to 10°C (or even more) higher than the air temperature.

Plants that suffer from a **lack of water** often show **thermal stress** due to high leaf temperatures.

Notes and references

Cover image. [Source: Encyclopedia of Environment]

[1] *Ranunculus glacialis*, the glacier buttercup, is a herbaceous species in the Ranunculaceae family, growing in montane and subarctic climates.
