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Image: Wilma Slegers

Plants react differently during the day

Biological clock determines many processes in the plant

The plant's biological clock plays a role in many processes. This sometimes explains why a plant does not respond as you'd expect, for example, to prolonged artificial lighting or CO_2-dosing.

Even before it gets light, processes start in the plant that normally take place when it's light. It's as though the plant 'knows' that the sun is about to rise. The trigger that sets off these processes is not the light itself, but the internal biological clock. Take another example: Lowering the temperature at the break of day can inhibit the elongation of many pot plants. This effect is called DROP. However, if this temperature reduction is given at the end of the day, the effect is much smaller or even absent. The plant's sensitivity to DROP varies throughout the day.

Circadian rhythms

It is becoming increasingly clear that very many processes in the plant are subject to a rhythm. There are so many of these processes that some researchers think that virtually everything in the plant happens rhythmically. Some of the processes are seed germination, elongation, photosynthesis, production of plant hormones, enzyme activity, opening and closing of stomata *(see figure)*, opening of flowers and secretion of fragrances. And even the translation of the genetic information on the genes has a rhythm. In Arabidopsis *(see box)* this affects at least 10% of the active genes and some researchers think it could be even 35%. The practical consequences of this are hard to explain.

This phenomenon is officially called circadian rhythms. Circadian means 'about a day'. Many rhythms do cover about 24 hours; others can be up to 30 hours. This also indicates that it is a real internal rhythm of the plant. The earth always takes 24 hours to rotate on its axis. If this is the signal, there wouldn't be any circadian rhythms only a diurnal rhythm (day-night) that covers 24 hours exactly.

Ignoring circadian rhythms

In our nurseries we try to have everything under control. We've come a long way with climate control and we're pretty good at controlling plant processes. However, the circadian rhythms sometimes throw a spanner in the works; actually quite often, because unexpected reactions take place regularly. These are easier to understand if you look at them with this in mind. For example, the absence of the DROP effect at the end of the day can be attributed to the plant being at a low point in its sensitivity cycle.

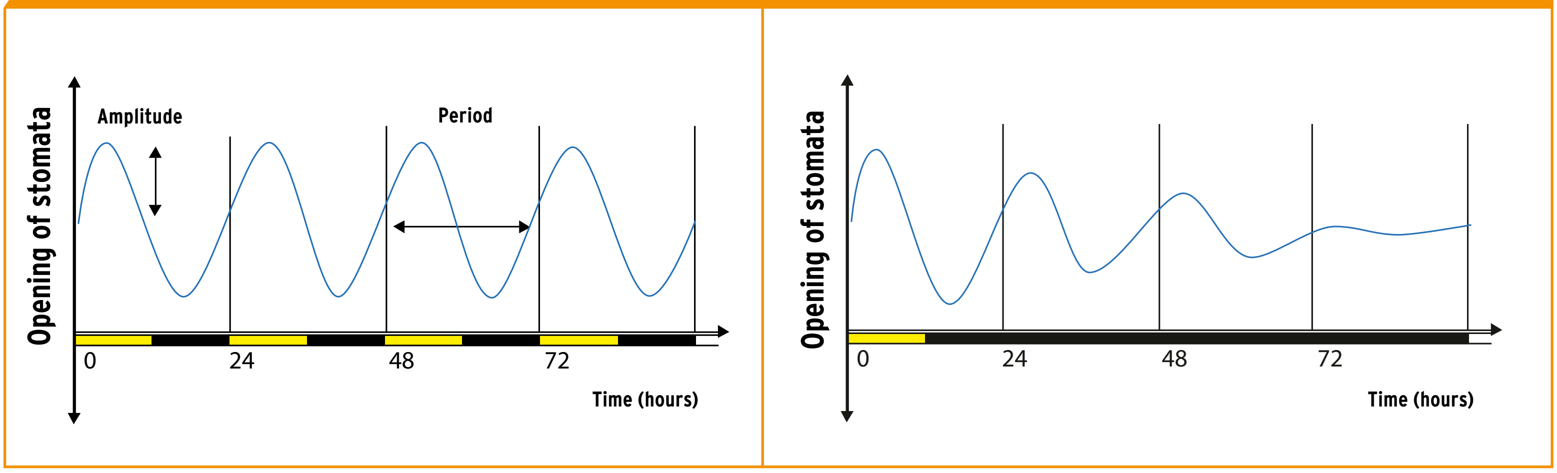
Long-term lighting has a disruptive effect on setting and the balance between vegetative and generative growth in young pepper plants.

Ignoring the circadian rhythms can lead to problems if the application of certain cultivation measures causes a plant to differ greatly from its natural rhythms. Examples are: Using artificial lighting for a long time; using different light colours; or supplying CO_2 at the wrong moment. Please note, no problems need to occur – the plant can take a lot – but if they do, the reasons can lie in the biological clock. And there's little you can do about that.

Fooling the plant

The clock can be influenced, however, and the plant has a mechanism for this. Special

Figure. Circadian rhythms



The figure on the left shows the rhythm of the opening of the stomata under normal circumstances (yellow on the horizontal bar is light, black is dark). The figure on the right shows that if you stop providing light the rhythm continues for some time with approximately the same interval but then subsides. The biological clock that regulates this process is no longer 'set' by the light.

light and temperature put the clock 'right' with the actual day rhythm. So you can fool the plant. For example, by giving a flash of light just before sunrise you can adjust the clock forwards. If you do that just after dusk the rhythm adjusts backwards. The plant 'sees' this light via pigments, such as phytochrome and cryptochrome. This could be a means of influencing the rhythm.

It could be useful when lighting over long periods. Extreme long-term lighting certainly goes against all circadian rhythms; there's no doubt about that. The plant has no opportunity to readjust its internal clock; you ignore the rhythm of the stomata, even hotosynthesis and all kinds of enzymic processes.

It would be worth investigating if it's possible to put things straight by adjusting the certain light colours that influence phytochrome and cryptochrome. This area is still very hazy, partly because it's only recently that we've realised that circadian rhythms have such an impact. A good question is, how quickly things can go wrong? If it doesn't happen in one day it might be possible to continually supply light for a few days, alternating with a period of 24-hours without artificial lighting. Then the plant again experiences a natural night and can adjust its clock.

Effect of long-term lighting

A clear indication of rhythmic sensitivity is the disruptive effect caused by long-term lighting on setting and the balance between vegetative and generative growth in young pepper plants. Also, various pot plants have a different leaf position during the day and night. The leaf position of young plants is very important because the light that lands next to the plant is simply lost. By using light colour it might be possible to steer the plant towards the ideal leaf position. This is all part of the fine-tuning. A certain light colour can be beneficial to photosynthesis but the same colour may be counterproductive to the leaf position.

Researchers come across the biological clock quite regularly, for example when trying to ammeliorate the way of supplementing CO_2. Given the nature of the orchid it's likely that six hours of day and six hours of night (twice per 24-hours) can increase production. But such a treatment wouldn't work. It would run up against a circadian rhythm.

Changing the clock by one hour already confuses the biorhythm in many people. Cultivation measures, such as lighting, can have a much greater effect on biorhythms.

More than one internal clock

It gets even more complicated because not only is there one, but several internal clocks than run next to each other. The green bean has a different rhythm for the opening of the stomata and CO_2-assimilation than for the positioning of leaves (that at night move into a sleep position). It turns out that the 'clock' is in the cells themselves and not in a plant tissue. Also the rhythm starts very early in development, usually when the seed absorbs water (imbibition) for germination.

Finally, are there more rhythms than just circadian rhythms? Hedera has a cyclical growth pattern throughout the year. Some plants flower every year at the same time. And completely fascinating is the fact that all the same kind of bamboo, all over the world, flower at the same time. This is due to a very long-term rhythm.

Useful weed

Much research has gained momentum since scientists started using the plant Arabidopsis thaliana as a model plant. It has relatively few genes and a short life cycle. The plant is quite small and is easy to change genetically.

Now that we have such a plant, everyone is using it for research and our knowledge is growing tremendously; also, for example, in the area of the biological clock. Arabidopsis is a pionier plant on sandy soils. In common language: a weed, but indeed a very useful weed for science.

Summary

It is becoming increasingly clear that the biological clock in the plant plays a role in a huge number of processes. Examples are seed germination, elongation, photosynthesis, production of plant hormones, enzyme activity, opening and closing of stomata and opening of flowers. This also means that throughout the day plants react differently to cultivation measures. It is something to consider during long-term lighting, CO_2-dosing and the application of different light colours. On this point, we still need a lot more knowledge.