Temperature control: dif, pre-night and other tricks for crop steering

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Growers with advanced computers can use very refined temperature control techniques, many of which have been discovered in the last decade. Some methods are 'dif', pre-night, and temperature integration. They are based on a good understanding of what temperature does to a plant. The discussion about advanced temperature control is complex and far from completed. Researchers are gaining new insights and growers are testing new ideas. This article deals with some effects of temperature on plants and some aspects of modern temperature control.

Temperature requirements

The temperature required by a plant depends on the many factors: species, variety, plant stage, season, overall light level. Some species require high temperature (e.g. cucumber) whereas others thrive at low temperature (e.g. lettuce). Also varieties can have specific preferences. The plant stage is very important too: whether the plant is in the young (vegetative) stage or the producing (generative) stage. In young plants, the grower aims to produce new nodes and leaves as fast as possible. Therefore young plants are grown at a higher temperature. Once the plants have sufficient leaf area and reach the generative stage, the temperature is gradually lowered and the development rate slows down. At night a low temperature is better, amongst other things to allow good fruit set.

This is all about the average temperature level in situations where temperature is determined by heating. Temperature control in its basic form is then simple: there is a flat line for day-time temperature and another flat line at a somewhat lower level for night temperature. The temperature lines may be adjusted now and then depending on conditions and plant stages. To be able to use advanced temperature control, it is important to understand how temperature works.

Temperature effects

The temperature has a large effect on basic plant processes, especially on the *rates* at which processes occur. Temperature determines the rate of development, e.g. the flowering rate. For instance in tomatoes the development of one truss with three nodes and three leaves takes 10 days at lower temperature, and takes only a week at higher temperature. Temperature also affects the rate of fruit set, rate of fruit growth (time from flowering to start of colouring) and rate of fruit ripening (colouring). This has a very strong effect on how the plant looks: tall en skinny, or very short, solid and robust.

Most processes go faster at a higher temperature. An exception is fruit set, which is favoured by fairly low temperature at night. For instance the optimal temperature for fruit set in tomatoes is 19 °C and in capsicum 18 °C. All aspects must be taken into consideration when determining the night temperature.

Unfortunately, higher temperature has a disadvantage too. At higher temperature the respiration process goes faster too. Respiration is the internal burning of assimilates (sugars). So at higher temperature more assimilates are burned, thus leaving less assimilates available for plant growth. Therefore temperature also has an effect on fruit size, albeit indirect: fruit are smaller at higher temperature.

Growth versus development

It is important to understand the difference between growth (weight gain) and development. Development is the appearance of new organs and moving into a new phase. Light and CO2 determine the growth (weight gain), because they determine how much photosynthesis there is. Temperature does not do this (or only a bit and only indirectly through increased respiration at higher temperature). Temperature controls the development rates (flowering rate, etc), or in fact the speed of all processes, as well as the shape of the plants.

Grow pipe

The assimilates (sugars) formed by photosynthesis are distributed in the plant. Assimilates are produced in the leaves throughout the day and are then transported to other plant parts, including roots, plant heads, growing leaves, flowers and growing fruit (or trusses). Now the trick is that warm plant parts attract more assimilates than cold plant parts. A small difference in temperature can already make a difference in weight gain (growth) of that plant part.
A greenhouse grower can use this fact. This is done by using a second net of heating pipes in the crop, additional to the heating pipes near the ground (e.g. the pipe rails). This second heating net is often positioned near the top of the plant. This pipe then heats the plant heads or the fruit near the top. When the heads or fruit are warmer, they will attract more assimilates. If the second net can be lifted when the plants grow, it is called ‘grow pipe’. A grow pipe is a local heat sources that brings the heat where it is needed. If there are two heating nets, the first heating net (e.g. the pipe rail system) has to run at a reduced temperature, to ensure there is not enough total heat input.

Pre-night

Another way of creating a different temperature in the plant head is by quickly dropping the air temperature. This is a trick that is understood since some years. Growers apply this at the end of the day or early night, when the leaves are full of sugars. The temperature is quickly dropped a few degrees. The leaves will quickly adopt the lower temperature. But the more solid plant parts are slow to follow. So the fruit will stay warmer than the leaves. This can last for a few hours. Due to their higher temperature they will attract more sugars, which is the purpose of this so-called pre-night temperature drop.
There is discussion about whether the heads (and stems) stay warmer and attract extra sugars too. Young fruit are massive, but a thin head has little mass. It will cool down quickly, whereas a thick head may cool down slower. In Europe a thermal screen is present and the screen is used in combination with the grow pipe for refined temperature control. The screen can be shut earlier or later, particularly for controlling temperature of the plant head.
The pre-night temperature drop works well. In order to create an even larger difference in temperature, the grower can set a higher temperature in the late afternoon by choosing a higher venting temperature. This has also another reason, namely maintaining the required 24 hour average. In this way the lower pre-night temperature is compensated by a higher late-afternoon temperature, so that the average 24 hour temperature remains the same. In addition, the temperature in the second half of the night can be set a bit higher, also to achieve the required heat-sum on a day.

Dif and average temperature

Simple temperature control works with a fixed day-time temperature and fixed night temperature. But the temperature does not have to stay at a fixed level all the time: variations in temperature are allowed. As long as the average temperature remains the same, the development rate (flowering rate) will remain the same. The main temperature variation that growers use is a difference between the day and the night temperature, called ‘dif’. For instance 12 hours 18 °C (at night) and 12 hours 22 °C (at day) results in 20 °C average, with a dif of 4 °C. A higher dif (night temperature much lower than day temperature) stimulates fruit set. It will result in a more generative plant. Lower dif (night and day temperature more similar) is used to stimulate vegetative growth, i.e. strengthening the head.

Temperature integration
Another form of variation is temperature integration. It means that the control computer aims for a certain average temperature to be achieved over a period of several days. The greenhouse is allowed to be warmer for a short while, if this is compensated by lower temperature at another moment. Both the dif and the temperature integration will be discussed later in more detail.

Summary
Plants require a certain temperature depending species, stage, and more.
'Dif' which is a difference between day and night temperature. It is used in combination with an average 24-hour temperature. Dif can be used as a tool to help fruit set (generative steering) or can help creating a stronger head (vegetative steering).
Pre-night temperature (in the evening hours) can be lower than normal, if it is compensated by a somewhat higher temperature after midnight. The lower pre-night temperature can be combined with a higher temperature in the late afternoon.
Temperature integration is a method aiming at achieving an average temperature over a period of several days.