TEMPERATURE EFFECTS ON PLANTS

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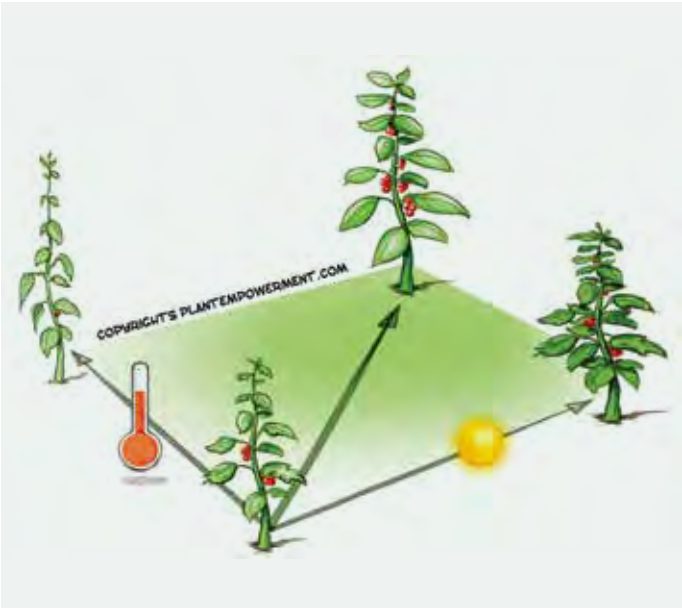

Figure 1: *The right combination of light sum and average temperature gives a tall balanced plant. Too warm but not enough light gives long and skinny plants. A lot of light but not enough warmth creates short stocky plants. Picture with permission from www.plantempowerment.com*

Temperature control in a greenhouse is a key factor for heating costs and for plant growth and fruit production.

Too high or too low temperature costs money, one way or another. By understanding the effects of temperature, we can choose better temperature settings and so improve energy efficiency. The best temperature strategy is maintaining a good balance between average temperature and prevailing light level (or light sum). In this article we describe the background of this rule, by investigating the effects of temperature on plant development, photosynthesis, respiration, assimilate transport, vegetative/generative balance and fruit ripening. The next article will give specific numbers.

Development rate

In all plants, the average temperature over 24 hours has a strong effect on the development rate, which is the speed of appearance of new internodes, leaves and flowers (or trusses in tomatoes). For instance, tomato plants at 17 degrees grow 2.5 new leaves and 0.8 new trusses per week, while at 23 degrees they throw out 3.5 leaves and 1.2 trusses each week (50% faster development). Temperature that is too low results in not enough flowers or trusses, therefore poor production later. Temperature that is too high creates too many young leaves and flowers or trusses, and there may not be enough food (sugars or assimilates) available to support them.

Sugars are produced in mature leaves (see photosynthesis, below). There must be a balance between sugar production in large leaves (called 'source') and sugar consumption in growing plant parts (called 'sink'). Sugar production is stimulated by more light, while sugar consumption is stimulated by higher temperature. The grower must maintain the right source/sink balance to build a balanced plant. This means at low average light levels, maintaining a low average temperature, while at higher average light levels, maintaining a higher temperature.

Photosynthesis and respiration

Photosynthesis is uptake of CO_2 by the leaves to produce assimilates (sugars), which are the building blocks for new plant tissue. Photosynthesis is driven by light, so it happens only during the day, or when artificial lighting is on.

There is gross and nett photosynthesis; the difference between them is the respiration. Respiration is the breakdown of sugars inside the plant to provide energy to keep the plant going. Respiration continues day and night, irrespective of light. In a nutshell:

1. gross photosynthesis is the initial production of sugars;
2. respiration then 'burns' a part of the newly formed sugars;
3. nett photosynthesis is the balance of gross photosynthesis minus respiration.

We are interested in nett photosynthesis, as that tells us the amount of assimilates (sugars) available for growth, after the respiration has taken its toll.

Nett photosynthesis

Generally speaking, photosynthesis means nett photosynthesis. It depends on light, temperature, CO_2 and more. Under perfect conditions, with CO_2 elevated to 1000 ppm, the photosynthesis increases with increasing temperature between 15 and 30 degrees Celsius. Above about 30 degrees the nett photosynthesis drops due to fast increasing respiration. (See the red line in the graph.) However, if the CO_2 concentration is below 350 ppm, temperatures above 24 degrees already reduce the nett photosynthesis. (This is because gross photosynthesis is

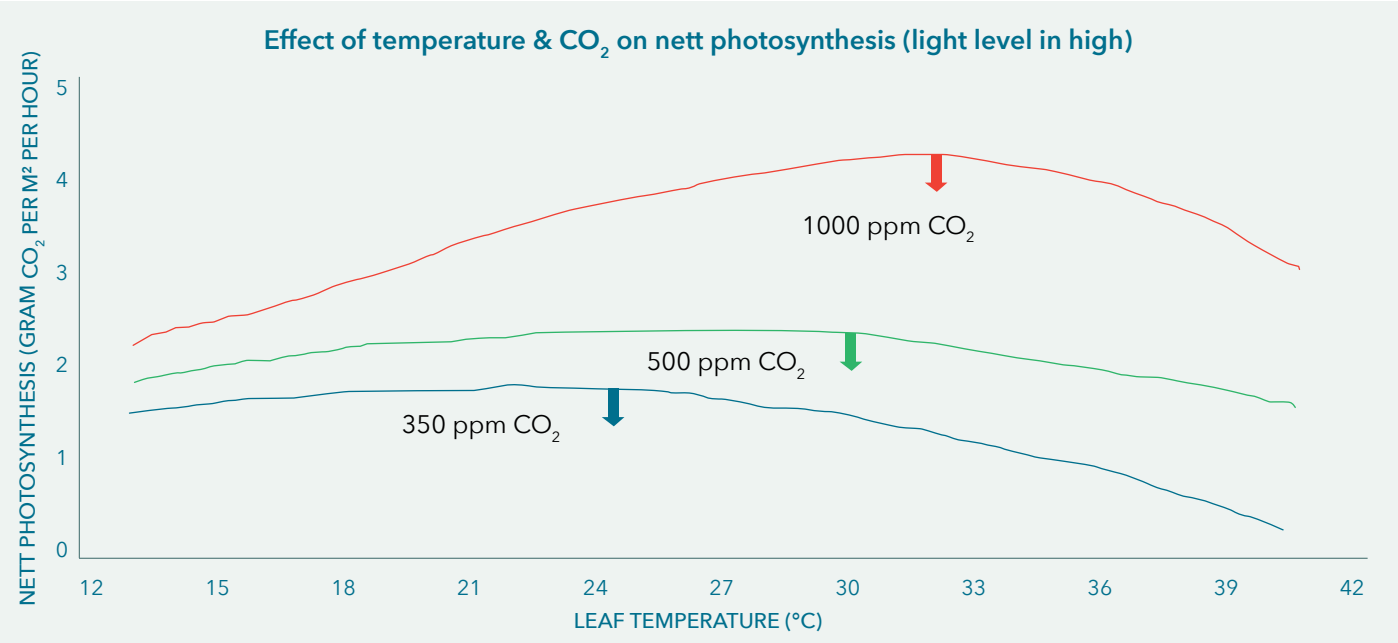

Figure 2: *Higher temperature is especially good at high light and high CO_2 levels*

restricted by low CO_2 and respiration is fuelled by high temperature.) At moderate CO_2 levels (say 450 – 600 ppm), temperatures up to 30 degrees have little effect on nett photosynthesis. (See the green line in the graph.) But there is another good reason to maintain high temperature at high light levels, namely to stimulate the transport of assimilates.

Assimilate transport

On a sunny day, leaves produce large amounts of assimilates (sugars). These must be exported out of the leaves quickly, so the leaves don't get saturated. Warmth is essential for speedy transport. In sunny weather the sun provides the necessary warmth.

After a very sunny day, the assimilate export must continue until well into the night. Therefore the night temperature must be set higher after a bright day than after a dark day. If the night temperature is too low this inhibits the export of assimilates, so the surplus sugars are converted into starch and stored in the cells. A trained eye can see if the leaves of a tomato plant are filled with starch in the morning: they are thick, firm and slightly purple. In contrast, after a dull day with a low light sum, the night temperature must be set accordingly lower, to prevent respiration burning up too much assimilate.

Vegetative/generative balance

The development rate (see above) determines the number of leaves and flowers or trusses in a plant. Assimilates are transported out of mature leaves towards the various plant parts: growing points, young leaves, stems, roots and generative organs (flowers, trusses, fruit). The warmest plant parts attract the most assimilates and grow the fastest. If there are many flowers, and if they attract a lot of assimilates, the plant becomes very generative and potentially very productive. But there must be enough mature leaves to produce the necessary sugars. If relatively more assimilates go to the leaves, the plants become more vegetative.

The vegetative/generative balance is very important, and should be kept stable. Temperature, in relation to light sum, plays an important role in this.

Fruit ripening

Higher temperatures strongly stimulate fruit growth and fruit ripening. If the fruit are warmer than the leaves (e.g. due to sunshine or heating pipes) they attract more assimilates than the leaves, so they grow faster. High temperature also makes them ripen faster. This shortens the fruit growth duration, and leads to faster picking, which reduces the 'fruit load' on the plants. In contrast, low temperature means that fruit hang on the plants longer. Cucumbers that hang on the plant for too long may have a shorter shelf life.

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Conclusion

Temperature has many effects on many levels, even more than described above. Research and practice have proven that the best strategy is to strive for a balance between average temperature (over 24 hours) in the greenhouse and average light level (or light sum, also referred to as radiation level or sum).

In the next article we will look at the Radiation–Temperature Ratio and give some clear guidelines for average temperature. Also, we will distinguish between day and night temperature, as they have quite different effects. After that we will look at temperature control in relation to energy use.