Controlling plant growth in greenhouses - introduction

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The production of greenhouse tomatoes is 10-20 times higher than the production of any field-grown crop. It has increased since the 1960s by about 3-5% per year every year. How is that possible? The answer lies in control. A greenhouse is a controlled environment, and a grower directly or indirectly controls nearly everything: climate, nutrition, growth rate, development, plant balance, fruit set, ripening, production. The production depends very much on how well the grower is in control. This article gives a brief introduction on controlling plant growth.

High output

The production of greenhouse crops is very high in comparison with other crops. Tomatoes can produce 60 kg/m2/year, which equals 600 tonnes per ha per year. Even higher is possible: up to 800 ton/ha/y at present. The average apple production in NZ is in the order of 40-50 ton/ha/y, and potatoes, onion, carrots produce 70-80 ton/ha/y. So greenhouse tomatoes produce 10 to nearly 20 times as much as field-grown crops. A greenhouse needs to produce so much, simply to pay for the huge investments.

Interestingly, the production of greenhouse crops seems to increase steadily and consistently. In 1960s the average tomatoes production was 10 kg/m2/y, in 1980 it was 30 kg/m2/y, and now in 2006 it is around 60 kg/m2/y. This is an increase of roughly 5% per year in early years, and 3% per year nowadays.

High input

The output (production) of a greenhouse is high, thanks to a high input of energy, water, fertilisers, labour and more. This makes greenhouse horticulture a very intensive industry. Moreover, everything has to be done flawlessly to get the required production. It starts with making the right choices for growing environment, growing media, plant variety, etc. Energy input has to be accurately controlled; plant nutrient input needs to be in accordance with plant uptake, etc.

By doing everything perfectly, the grower can control plant processes such as photosynthesis, transpiration, dry matter distribution, vegetative and generative growth, fruit set, ripening, etc. The grower has a range of 'instruments' available for steering the plants: temperature, 'dif' (difference between day and night temperature), CO2, irrigation frequency, CF, and many more, some very subtle. A grower who knows the tricks can better control the shape and performance of the plants, and hence the production.

Light & CO2

Plants grow due to the uptake of CO2 (carbon dioxide gas) by the leaves. Inside the leaves, the CO2 is converted to sugars (assimilates). This process, called photosynthesis, requires light. The more light, the faster the CO2 is taken up. Plants grow faster in summer than in winter thanks to the higher light level in summer. CO2 is taken up faster when there is more CO2 available in the air, which is the reason behind CO2 enrichment.

At night there is no CO2 uptake, simply because there is no light to drive the photosynthesis. So CO2 enrichment at night is useless. In contrast, at night the opposite of photosynthesis happens. The plants 'burn' a part of their assimilates and release some CO2. This break-down of sugars is called respiration. Some respiration is essential for plant maintenance and growth. Respiration goes faster at higher temperature.

Temperature
The optimal temperature for photosynthesis is 20 – 25 °C. This is therefore the ideal temperature range for the day time. At night, there is no photosynthesis, so the temperature is then irrelevant in that respect. However, higher temperature accelerates the respiration, which is a loss of assimilates. Hence it is good to set the night temperature quite a bit lower than the day time temperature.
Obviously plant growth is more than just photosynthesis and respiration, since there is also transpiration, distribution of sugars, development of new plant parts, vegetative and generative growth, fruit set, ripening, etc. Most of these processes are strongly influenced by the temperature as well. It is impossible to say which temperature is optimal, because there are so many different processes. By controlling the temperature in a subtle way, growers can influence ‘everything’ in the plant, including the production. This will be worked out further in later articles.

Example
A nice example of advanced temperature control is the ‘pre-night temperature drop’. This means that the temperature is lowered at the end of the day. At late afternoon, the leaves are full of sugars due to a whole day of photosynthesis. At that moment the air temperature can be dropped quickly by some degrees. This causes the leaf temperature to drop as well. The fruit, since they are plumper, don’t cool down very quickly. Hence the fruit are warmer than the leaves. The sugars (assimilates) have a tendency to travel to the warmer parts. In fact the sugars are transported in a flow of water to the warmer parts, in this case the fruit. So by this quick drop in air temperature, the grower can direct more sugars to where he wants them: in the fruit. This directly increases the production.

Distribution of sugars (assimilates)
The example above showed how temperature can influence the distribution of sugars in the plant. Most greenhouse fruit vegetable crops send about 2/3 of sugars (assimilates) to the fruit, while the other 1/3 goes to the roots, stem, leaves, and head. So about 2/3 of what the plant produces is harvestable. In lettuce the harvestable part makes more than 2/3 of the plant.
The distribution results in a certain balance between vegetative and generative growth. There are several factors, or several ‘tools’ that a grower can use, that influence the sugar distribution as well as the vegetative/generative balance in the plant. Some factors are: temperature, CO_2 level, humidity, water & nutrient supply, plant training, pruning, and more. Their role will also be discussed later in this series.

Fresh fruit
The aim is to get as much sugar as possible in the fruit. Once the sugars have arrived at their final destination, they are converted into other compounds, e.g. they form fruit tissue. The next step is that water and nutrients are incorporated. The water content of the fruit has a clear effect on the final production. The higher the fruit water content, the higher the production.
For example, cucumbers contain 97% water and only 3% dry matter. So the 3% assimilates are combined with 32 times their weight of water. This results in a huge fresh weight. Hence, cucumber can easily produce 90 kg per m2 per year. In contrast, capsicum fruit contain 91% water and 9% dry matter. The amount of water added is about 10 times the weight of assimilates. This makes a big difference in final production: capsicum produce in the order of 30 kg/m2/year. Tomato is in the middle: 4-5% dry matter. The amount of water added is about 19-24 times the weight of assimilates. The production is in the middle too: about 60 kg/m2/y. The water content is largely determined by genetics and is influenced a bit by the growing conditions. It is not the aim, though, to get as much water as possible in the fruit, because too high water content can have a negative effect on quality.

In summary

Plant production is the result of many processes, many of which can be controlled. It starts with photosynthesis in the leaves, which is uptake of CO2 and formation of sugars (called assimilates). A small part of the sugars is burned for plant maintenance. This assimilate burning, called respiration, is the reverse of photosynthesis. It releases CO2. At higher temperature, the respiration goes faster, or in other words more assimilates are burnt.
The assimilates that are not broken down are transported from the leaves to the various parts of the plants, including the fruit. When fruit are warmer they attract more assimilates. This is the reason behind a pre-night temperature drop. In the fruit, the assimilates are combined with an overdose of water to form the fresh fruit tissue. The more water is added, the higher the production. Therefore cucumber plants (with only 3% dry matter in the fruit) achieve a three times higher production rate than capsicum (with 9% dry matter in the fruit). Another important characteristic is the vegetative/generative balance of the plant, which is very dependant on external factors. Following articles will discuss the various ‘tools’ a grower can use for controlling plant growth, the vegetative/generative balance and production.