Plant balance
Greenhouse crops are grown in a very controlled and almost delicate way. Greenhouse operators can influence most plant processes, including plant balance. By 'reading' the plant, a grower can tell at an early stage whether the plants are either balanced or too vegetative or too generative. Too vegetative plants have large leaves, thick stems, strong head and little fruit production. The opposite, too generative plants, have small leaves, thin stems, weak head, small intense flowers, and possibly a large fruit load. The best indication of plant balance is the thickness of the plant head, and not the fruit load. Needless to say that a plant must be kept balanced to ensure a continuous production over the season. First we summarise three earlier articles about plant balance.

Influences on plant balance
Generally speaking, all mild growing conditions stimulate vigorous leaf growth, which means vegetative growth. In contrast, harsh conditions stimulate the production of seeds (as a way to survive), which means generative development. Mild spring weather makes most plants vegetative, while hot summer conditions make them generative. A wet growing medium and low EC makes plants vegetative, while lack of water and high EC hardens the plants and makes them generative. So the factors that influence plant balance include season, weather, greenhouse, variety, plant stage, growing medium, temperature, humidity, light, CO2, screening, and irrigation regime.

When conditions push plants in one direction, the grower has to steer them in the opposite direction in order to keep them in balance. The obvious tools are climate control [see Jan/Feb 2009] and irrigation control [see article in this issue]. If they can’t be used or don’t work, then it is time to take direct actions on the plants. The present article is the last one, and discusses how plant management actions can influence plant balance.
Plant and stem density
Plant density has a huge impact on plants, and would ideally be chosen in agreement with the average light level of the season. Under high average radiation in summer, plants are better off in a dense planting so they can shade each other a little. Poor light conditions in winter require a wider plant density. Unfortunately, plant density is decided at planting time and cannot be changed afterwards.

Cucumber is usually grown for a short period (e.g. 3 months) and therefore can be planted in the density that suits the season. But crops like tomatoes and capsicums are often grown for nearly a whole year. Fortunately, tomatoes offer the opportunity to create fewer or more stems on one plant. This is a way to adjust the stem density, which serves the same purpose as plant density.

In tomatoes, the technique is to let a lateral grow out in spring, which will be a full-grown extra stem in summer. This must be done in a very controlled way. For instance, one extra stem in every third plant results in 33% more stems per m². It can also be done in steps: first, one extra stem in every fourth plant (25% more stems per m²), and some weeks later an extra stem on the plant in the middle (giving 50% higher density than at planting). Remember that good timing is essential, and also that maintaining an extra stem requires extra work and skills.

Capsicum does not offer the possibility of adjusting the stem density to the seasonal light conditions, but there are other means to control plant balance, e.g. number of fruit per stem.

Stem density and source and sink
Stem density has a strong effect on plant balance. This can best be explained by ‘source’ and ‘sink’. Source stands for manufacturing of sugars in the leaves (leaves are then a source of energy). Sink stands for absorption of sugars in the young growing fruit. Under high radiation, the photosynthesis rate is very high, which means that the source is very high. A high source requires an equally high sink in order to keep the plants balanced. In simple words, when there is a lot of light, the leaves produce a lot of sugar, and therefore the plant needs a lot of fruit that can utilise all the sugars. This means we need more fruit on the plant in summer than in winter.
In tomatoes this does not happen naturally, because there are always three leaves for every one tomato truss, in summer and winter. The good effect of an extra stem is that it provides more fruit per m², thus more ‘sink’. If the number of stems is raised by winter. The good effect of an extra stem is that it provides more always three leaves for every one tomato truss, in summer and lower in the plants. This also affects plant balance.

A trained eye can see what happens to tomatoes in summer that don’t have an extra stem. Such tomato plants can become very meagre, with short curled leaves, but with a surprisingly high production. These are symptoms of oversupply of source and shortage of sink. Such a crop would produce much more if it had an extra lateral.

Pruning very young leaves
As mentioned above, tomato plants always make three leaves for every truss, in summer and winter. In a very young stage, the leaves are still sinks, because they need sugars for growth. At that stage the young leaves and young trusses are in competition with each other for sugars. By removing one of the three young leaves, the remaining leaves and the truss will get more assimilates. Research has found that removing a young leaf has more benefit for the truss than for the remaining two young leaves (see schematic drawing). This makes the young truss grow faster, which increases production. This action also restores the plant balance. This can only be done safely when the plant has enough leaf area. In fact, it is done in times when there is a surplus of source and a shortage of sink, as described earlier for tomatoes in summer. Only small leaves are removed, up to half their mature size.

Also, in cucumber some leaf pruning can be applied. For instance, large leaves in the top are removed to get more light lower in the plants. This also affects plant balance.

Fruit thinning and truss pruning
Fruit thinning (or in tomatoes truss pruning) can be used to control the load on the plant in various seasons. This also directly affects the ratio of ‘sink’ to ‘source’. Fruit thinning is an important tool in young cucumber and capsicum plants. These plants first need to build a strong plant body before they can start producing. If planted in winter or early spring, the light level is still relatively low, so source is fairly limited. Therefore, some of the earliest fruit have to be removed, to ensure that the sugars are invested in leaf growth.

Fruit thinning (or truss pruning) are also useful tools for plant balance control in late summer and autumn in tomatoes, capsicum, cucumbers and other crops. Although the light level can still be high in late summer, inevitably it will steadily decline in the following weeks. Since the new fruit (or trusses) have a life span of several weeks, they will later experience poorer light conditions. A good pro-active measure in late summer is to reduce the number of fruit (or in tomato to do some truss pruning). This avoids the problem of unbalance later in autumn, and keeps the plant in good shape until the end of the season.

Some tomato growers apply truss pruning in order to increase the size of individual fruit. If a larger grade receives a better price than a smaller grade, they choose to sacrifice some fruit. If this is in summer, it is important to keep an eye on the sink-to-source ratio. Removing fruit may increase the surplus of assimilates, and aggravate the unbalance in the plants.

Unloading
The last plant management action to mention here is plant control by ‘unloading’ the plants (i.e. to shed some fruit). If there are too many fruit on the plant for the average light conditions, the plants will suffer. In capsicum it is normal that plant growth comes to a complete halt when fruit are growing out. But if this lasts too long, it can be a worry. After all, capsicum plants need to grow further and produce new flowers for ongoing production. An effective method can be to get rid of some older fruit on the plant. Firstly, fruit ripening

Left: If too high fruit load slows the plant down, it can be ‘unloaded’ by picking green fruit. Alternatively, the temperature can be raised to speed up fruit ripening.
Right: Capsicum (pepper) plants stop growing completely when fruit grow out; a sheer example of plant balance effects.
can be accelerated by increasing the temperature. Secondly, some fruit can be harvested before they are completely ripe: harvesting green capsicums or partly-green tomatoes. The same principle applies to other crops too. Unloading will make more assimilates available for the plant. This will restore plant balance and benefit production in the long-term. This can be a good action in any season, including autumn.

**Diagnosis**

Whether plants are vegetative or generative is not always clear-cut. Actually, it is not a status but can be a trend: plants move gradually into generative or vegetative direction. The way to see trends is by looking at graphs that display plant measurements over time. For instance, the thickness of the top of the stem is measured every week (always on the same 10 plants in a test plot). The measurements are typed into a special computer programme or spreadsheet for crop-recording. This system then plots the measurements in a graph. A horizontal line in a graph indicates a stable condition, in other words a balance. A line in a graph that goes gradually up or down, indicates a generative or vegetative trend. The next step is to make graphs of the relevant growing conditions (light, temperature, water content, EC and more). This can provide clues to explain why plants responded as they did. A proper analysis requires a crop recording system.

**Choosing the tool for plant balance control**

Which tool can best be used for plant balance control: climate control, irrigation regime or plant management actions? This depends on the conditions. Generally, irrigation regime and climate control should be used in the first place. But control by irrigation requires a good-quality growing medium, a water content meter and good understanding of the processes.

Climate control too is a perfect tool for steering plant balance. But there are often limits to what can be done by climate control. For instance, low light level in winter has a major effect on plant balance, but nothing can be done about it (except when assimilation lighting is available). On hot summer days, the high temperature and low humidity often have an adverse effect on plant balance. But not a lot can be done to mitigate the stress on the plants (except when there is a shade screen, fogging or evaporative cooling). The CO₂ concentration can sometimes be lower than desirable, but little can be done about it when vents are wide open.

When climate control and irrigation regime can’t do enough for steering the plant balance, then plant management actions can still be used. It can be a drastic action that alters the ratio of leaves and fruit, and thus immediately tips the balance from vegetative to generative, or vice versa, as described earlier. Obviously, all sorts of plant management actions are commonly employed throughout the growing season.

**Short-term and long-term**

When choosing a control tool, it is good to be aware of some things: control can be short-term, long-term, or in between, or an immediate action. Some factors cannot be controlled but are ‘given’, for instance, season and weather. Some factors can be controlled by the grower but only in the long-term (e.g. greenhouse type). Other factors can be controlled in the medium-term, namely per season (e.g. growing medium, grafting, variety, plant density). Finally, there are instant control actions: climate control and irrigation regime. Some tools have both an immediate and a long-term effect, and can be applied at various times during the season. This includes crop management actions, such as keeping an extra stem, pruning, unloading. The result will be best when all actions steer the plants into the same direction, instead of giving ‘mixed messages’.

**Crop-recording**

It was mentioned earlier that crop-recording is a good way to determine whether plants are generative or vegetative. Crop-recording, or crop-registration, was developed in the 1980’s/1990’s in Europe. Nowadays it is common practice in most modern greenhouse operations. It involves collecting detailed measurements on at least 10 plants in a test plot. This in itself is very useful, because the grower then accurately reads the plants every week. Plant measurements and data on growing conditions are entered into a special crop-recording programme or spreadsheet (automatically or manually).

The crop-recording system then presents graphs. These assist to see whether the plant is balanced, vegetative or generative. They can also show production, plant growth rate, and development rate in relation to growing conditions. Such graphs may help to see trends and links that would not be detected otherwise. Crop-recording can also be a handy tool for looking back at what was done in previous years. Hence, such systems can help to make better decisions on climate control, irrigation control and plant management, and also on long-term decisions such as investments.

**About the authors**

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