



Improving Tomato Fruit Quality

Reducing or eliminating fruit physiological disorders with correct root zone management.

In the fifth of six articles for *Practical Hydroponics & Greenhouses*, Grodan® Crop Consultant ANDREW LEE describes the processes and reasons why at certain times of the year tomato crops are more susceptible to a number of fruit quality disorders.

When is fruit most susceptible to quality issues?

Fruit are most susceptible to quality disorders of various kinds when the 24-hour temperature is high (>23°C), when the weather conditions fluctuate day to day or in periods of dark, humid weather. During these times stresses on the crop and fruit development from environmental influences, temperature, humidity, differences in water uptake and light levels are at their highest.

For these reasons it is important to understand how the outside climate influences crop water use, a subject discussed in (*PH&G*, issue Jul-Aug 2009). It is also why it is important to understand the basics of substrate functionality and why Grodan substrates are designed to provide growers the opportunity to stabilise, refresh or change EC and WC levels according to the prevailing weather conditions (*PH&G*, issue Nov-Dec 2009). It is also the reason why it is important to have a plan, which meets both marketing (size and quality) and production (kg/m²) goals.

The plan, based on four key pillars, namely strategy, uniformity, strength and balance (*PH&G*, issue Jan-Feb 2010), should be robust enough to cope with extreme temperatures and facilitate strong and regular growth even in the darkest periods of the year. Finally, it is about getting the most out of systems such as the climate computer and measuring tools to provide you with the necessary management information in order to steer to the plan on a daily basis.

In the last article (*PH&G*, issue Mar-Apr 2010) I described how to optimise the start and stop times of irrigation, making reference to their impact on fruit quality in relation to changing weather conditions and how to stabilise and steer substrate EC.

I will now describe the benefits that this knowledge can provide and how it can be used to improve the financial returns to the company. Specifically, this article will address two of the most common fruit physiological disorders of tomato, namely blossom end rot (BER) and uneven colour (blotchy ripening). Furthermore, I will mention additional tips, which, used in combination with substrate management, can help alleviate these problems.

Knowledge is power

Travelling to different parts of the world, one of the most commonly spoken phrases I hear repeated by growers is, "it's different here, we're not the same as - so we can't do that, it's not like it is in...". This is surprising to me. I usually reply with the following remark: "We all grow using the same source of light, using the same composition of water and nutrients, which not surprisingly means that wherever you are the plants assimilate and dissimilate sugars in the same way. In most cases we use the same varieties from the same seed companies whether we are in The Netherlands, Mexico, Australia, Canada, France or Poland and usually in greenhouses constructed by the same manufactures. So how is it different here"?

What does differentiate growers is their knowledge of plant physiological processes (i.e. photosynthesis, respiration and transpiration) and how to translate this knowledge into making a plan and growing a crop in their specific climatic conditions (24-hour temperature, heat, vent and irrigation strategies). By taking this approach growers have the potential to optimise production for their specific location. However, what is the point in producing 65-70kg/m² if a large proportion of this is rubbish? It is the yield of top grade fruit sold in the market that provides the financial returns to the business. Focus should be placed on volumes leaving the pack house, not on volumes leaving the greenhouse. Acceptable levels of waste from a cluster variety producing 65-70kg/m² would be in the region 2-5%. How do you compare?

Any improvements to fruit quality you make will also improve the productivity of the business elsewhere. A huge cost to the business is labour, not least harvesting and packing costs. As a guide it should be possible to pick and quality grade cluster varieties directly in the greenhouse into 5kg marketing boxes at rates of 350-450kg/hr. These labour rates can reduce by 30-40% if fruit quality is poor (Table 1.). Likewise it should be possible to check weigh these boxes in the pack house, using automated machinery at rates of 1800-2000kg/hr. Quality problems can reduce this by 50% or more.

Table 1.
Harvesting, grading and packing rates for premium quality large truss tomatoes in The Netherlands.

*Harvesting & quality grading in greenhouse	Check weighing & stacking
350-450 kg/hr	1800-2000 kg/hr

*Rates are from a Dutch greenhouse and are influenced by weekly production /m² shown in Figure 1. These rates assume a weekly harvest of approximately 2.0kg/m².

Times of increased risk

To illustrate examples of how, when and why these fruit quality issues occur I have used the Grodan 6-phase model® (PH&G, issue Jan-Feb 2010).

Blossom end rot

BER is probably the most common of all fruit quality disorders. The external symptoms are characterised by blackening at the end of the fruit (Photo 1.). BER can occur suddenly and extensively, often with disastrous financial consequences. The symptoms are caused by local Ca²⁺ deficiency in the fruit tissue, which leads to a breakdown in the structure of the plant cell wall. Fruit are at greatest risk during the phase of fruit enlargement, 10 to 15 days after flowering (Picture 2.). Despite large advances in greenhouse crop production BER still remains a tiresome quality problem for tomato growers in all corners of the world.

The supply of Ca²⁺ in the drip solution in 99.9% of situations where BER is evident in the crop is more than adequate for plant and fruit growth, provided it has been prepared, mixed and is dosing correctly. Lack of Ca²⁺ in the feed is therefore unlikely to be the primary cause of BER. However, poor control of the aerial environment resulting in low water uptake, poor aeration or adverse temperature in the root zone resulting in root disease and poor substrate management leading to high EC can all reduce the uptake of Ca²⁺. This is because Ca²⁺ is transported primarily to the leaves within the water conducting xylem vessels by the process of transpiration (PH&G, issue Jul-Aug 2009). Fruit possess no stomata and only a small number of xylem vessels so have limited means of attracting and transporting Ca²⁺. To minimise the incidence of BER it is important to control the greenhouse environments, aerial and root zone, creating a balanced plant and balanced rate of fruit growth to ensure the demand from fruits for Ca²⁺ is matched by supply from the root zone. You must also understand the risks associated with certain planting strategies and growth phases.

Tip 1: Maintain balance in the crop. It is important to maintain the right balance in the crop. Fruit affected with BER will ripen at an earlier stage, reducing the fruit load and creating a vegetative crop. This further increases the risk of BER on subsequent clusters. It may look unsightly but to help create the right generative balance leave the fruit in place until it has turned red.

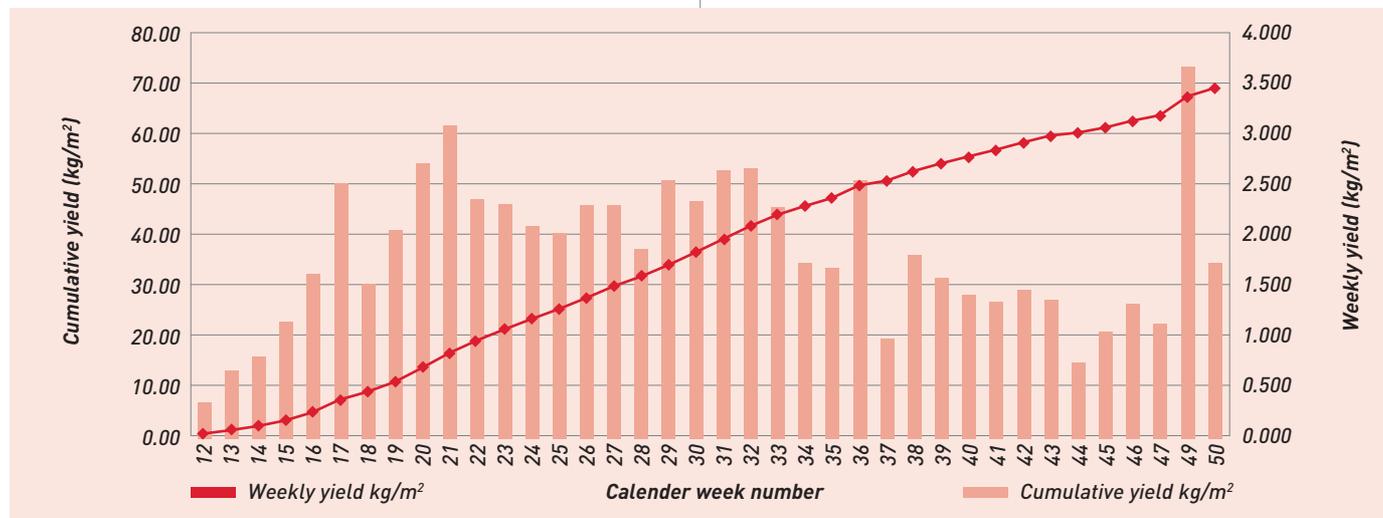


Figure 1.
Weekly and cumulative production cv Success grafted and pinched Emprador 2009 The Netherlands.

Phase 1: planting and rooting in

Obviously, there is no fruit load in this phase so there will be no visible signs of BER but the foundations for BER can be laid if rooting into the substrate is delayed, especially in hot conditions. When young plants are planted into the greenhouse under high light and temperature conditions, temperatures in the root zone can become too high. High root zone temperatures (>26°C) increase the risk of root disease such as *Pythium*, which if present will reduce root function and therefore Ca²⁺ uptake.

To minimise the risk in this situation the slabs should be initially saturated the night before the young plants are delivered to the greenhouse. This will prevent the substrate temperature from rising too high. The initial saturation of the substrate should be fast and uniform throughout the greenhouse, allowing the crop to be planted directly the following morning. It should then root quickly into the substrate, preferably within 24 hours. Fast rooting-in facilitates easy growth and rapid development of leaf area, which ultimately helps shade the slab. Once rooted in the plants are no longer reliant on the propagation block for water and nutrients and the irrigation strategy can be adjusted to avoid irrigating during the peak solar hours when slab temperatures are highest. Irrigation should be applied only to refresh the substrate solution in the morning and again if required in the evening.

Phase 2: rooting through and plant development

Under these same climatic situations as the plants are rooting through the substrate and setting, the initial clusters of plant and fruit growth will be very fast. This will increase the substrate pH (>6.2) resulting in low P-PO₄²⁻ availability – ideally, P-PO₄²⁻ levels in the substrate should be between 40ppm and 45ppm. With low P-PO₄²⁻ availability Ca²⁺ is not partitioned effectively to the ends of the fruit, and under these circumstances it is possible to induce BER on the initial (1-3) clusters. It is therefore important to have chosen a substrate as part of the overall strategy, where the nutrient solution is freely available and not buffered by organic material and is easy to balance and refresh with the minimal volumes of irrigation (*Table 2*). In this phase the addition of small quantities of NH₄⁺ (3-5ppm measured in the slab) will also help by lowering the pH and increasing P- PO₄²⁻ availability.



Photo 1. Characteristic symptoms of blossom end rot



Photo 2. Fruit are susceptible shortly after flowering when maximum cell division takes place.

	EC	pH	NH ₄	K	Na	Ca	Mg	NO ₃	Cl	S	HCO ₃	P	Si	Fe	Mn	Zn	B	Cu	Mo	K/Ca
Sample	mS/cm		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	
Drip solution used to saturate the slab	2.8	6.1	9.0	274.0	25.0	309.0	53.0	279.0	25.0	51.0	12.0	68.00	7.00	0.95	0.66	0.78	0.9	0.1	0	0.9
1 st drain stone wool	2.9	6.1	9.0	293.0	28.0	131.0	53.0	273.0	28.0	56.0	10.0	66.00	7.00	0.89	0.71	0.78	0.86	0.11	0	1.0
Slab stone wool	2.9	6.2	9.0	289.0	25.0	317.0	53.0	286.0	28.0	53.0	0	68.00	8.00	0.78	0.71	1.05	0.9	0.1	0	0.9
1 st drain coco	4.8	5.8	7.0	829.0	168.0	232.0	75.0	305.0	500.0	56.0	12.0	75.00	12.00	0.04	0.6	1.05	0.51	0.11	0	3.6
Slab coco	5.2	5.9	9.0	958.0	195.0	232.0	80.0	336.0	628.0	204.0	18.0	77.00	14.00	0.27	0.6	1.37	0.5	0.12	0	4.1

Table 2. Analysis of drip water used to initially saturate stone wool and coco slabs for bell peppers and the resultant analysis of the slab and drain solution.

Tip 2: Maintain the correct nutritional balance in the root zone for optimum fruit quality. Look to the analysis in the stone wool slab (Table 2.) - it is identical to that originally supplied. Then compare this to the analysis in the coco slab. Look in particular at the high K^+ levels and then the K^+/Ca^{2+} . Ideally, this should be 1/1, as it is in stone wool. This balance of elements is important and if not corrected can lead to BER. The reason is simple - K^+ is a monovalent ion whereas Ca^{2+} is a divalent ion. In essence this means that K^+ is more readily available to the plant. High levels can therefore compete and limit Ca^{2+} uptake. In this respect also take note of the high levels of Na^+ , another antagonist to Ca^{2+} uptake. Of course, over time this imbalance can be corrected by recalculation of the drip solution, in the short-term it increases the risk of physiological disorders and makes reuse of the initial drain solution difficult. In this case it would not be advisable to reuse this solution at an EC >1.0mS whereas the stone wool runoff can simply be reapplied.

Phase 4 production and balance

The risk of BER in the early phases of growth is not that great for winter planted crops due to the low development speed, low transpiration and low root activity of the crop. However, they can be at risk shortly after the first harvests are taken, expressing symptoms 14-21 days later. This is because following first harvests, the crop shows significant re-growth as the fruit load is released. The set speed of the flowering clusters also increases resulting in many more, smaller fruits of the same age and size and therefore, a higher demand for Ca^{2+} . This usually coincides with increases in light levels, changing outside temperatures and the requirement to ventilate the greenhouse faster and to a greater extent, all of

which lead to a sudden increase in the transpiration rate. For this reason the crop must be balanced during phase 3 and re-growth controlled in phase 4 (PH&G, issue Jan-Feb 2010). Too many leaves at this stage or a strong vegetative crop can result in BER.

Tip 3: alleviate the symptoms of BER on successive clusters.

High rates of transpiration will concentrate Ca^{2+} moving in the transpiration stream to the leaves and not the fruit. It is possible to manipulate the distribution of Ca^{2+} to the fruit by removing two or three additional leaves from the bottom of the plant during the weekly de-leaving process if successive clusters are affected. A pre-night temperature set point can also be used (if outside temperatures dictate) to create root pressure and 'pump' Ca^{2+} to the fruits.

Phase 5 maximum production

A high substrate EC in the summer is the most common cause of BER. This is because at high EC levels the xylem vessels in the fruit become more constricted limiting Ca^{2+} deposition. In the last article (PH&G, issue Mar-Apr, 2010) I reviewed the basic thought processes on how to manage substrate EC during this growth phase and how to keep EC stable from day to day (Figure 2.). The ideal substrate EC is of course influenced in some respects by the variety grown, for example, cherry types are usually grown at higher EC to attain certain minimum Brix values. For most cluster types the slab EC in this phase should be stabilised in the region 3.5-4.5mS, depending on the prevailing weather with a fluctuation in the slab during 24 hours of 0.5-0.8mS.

It is, however, important to have the EC stable and at its lowest during the hours of peak solar radiation. This is

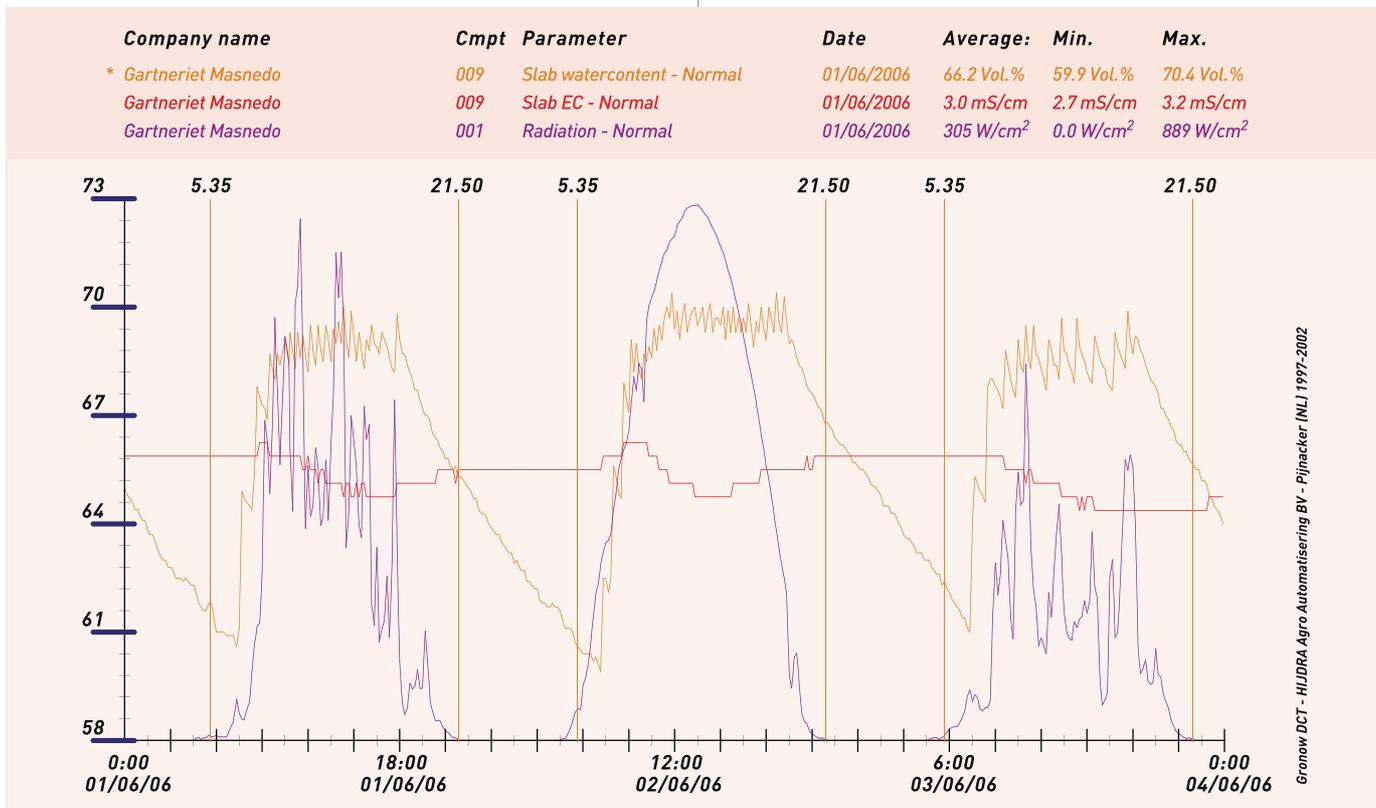


Figure 2. Optimised start and stop times and irrigation gift maintain a stable root zone EC despite large fluctuations in weather.

because the crop needs to transpire at its maximum to keep it and the greenhouse environment as cool as possible.

If the EC is deemed too high it should be lowered as soon as possible. Do not react by irrigating only fresh water - this will result in more BER, as no Ca^{2+} will be supplied. However, do decrease the dripping EC based on outside light levels (W/m^2) - that is, 3.0mS with a -0.5mS reduction in the range $500\text{-}900\text{W}/\text{m}^2$ and try to keep the ECslab - ECdrip between 1.0 and 1.5mS . In the morning check the time of first drain. This should occur at approximately $400\text{ J}/\text{cm}^2$ or $600\text{W}/\text{m}^2$. At midday, check the irrigation gift in relation to light - as a rule-of-thumb aim for $3.0\text{ml}/\text{J}$ (2.0ml for uptake and 1.0ml for drain). Also ensure that the minimum rest time setting is not restricting the maximum volume of water that can be applied, so check the start status on the climate computer. In the afternoon, check the drain percent, if it is too high use smaller more frequent irrigation sessions (ratio $3.0\text{ml}/\text{J}$) as this will make more water available to the plant - if it is too low, look to the irrigation gift (ratio $3.0\text{ml}/\text{J}$).

Tip 4: Maintain water uptake in extreme weather conditions. Ideally, the crop should be strong with a strong healthy root system in this phase of growth, a result of good planning and crop management through phases 1 to 4. Water uptake (applied - drain) as a minimum should be in the region $2.0\text{-}2.2\text{ml}/\text{J}$. Tools such as shading and fogging, if required for the climatic conditions, should not reduce this. They should be used to allow the plant to keep pace with higher levels of transpiration and therefore, prevent it from closing its stomata under pressure of water stress and inducing BER.

Uneven or 'blotchy' ripening

The symptoms are characterised by orange blotches on the surface of the ripening fruit (Photo 3.). Fruits are at greatest risk in hot or changeable, bright to dark, weather conditions.

The supply of K^+ in the drip solution in 99.9% of situations, where uneven ripening is evident, is more than adequate to allow the fruit to colour naturally. Indeed, evidence from trials conducted during the 1990s suggests that levels in the substrate must fall below 160ppm to induce symptoms in this way. Lack of K^+ in the feed or root zone is therefore unlikely to be the primary

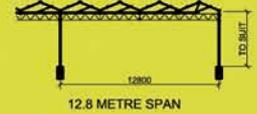
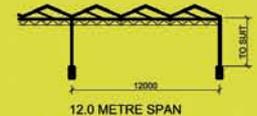
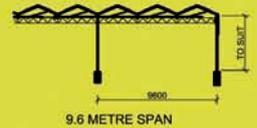
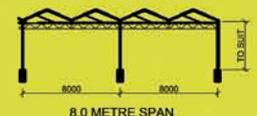


Photo 3. Uneven ripening of cluster tomatoes.



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Photo 4. Growth mottle spots are a result of too much water on dark humid days.

cause of uneven ripening. In this respect remember that the addition of extra K^+ to the feed solution as a knee-jerk reaction to alleviate uneven ripening on the lower clusters can actually induce BER in the developing clusters due to the K^+/Ca^{2+} (Tip 2).

Uneven ripening can be caused by a number of other factors such as high fruit temperatures ($>30^{\circ}C$). This is because lycopene, the red pigment in fruits, is actively synthesised between $15-32^{\circ}C$ and beta-carotene, the orange pigment, is actively synthesised at temperatures $>30^{\circ}C$. Fruit have no means of

cooling themselves so need protection from direct radiation. This is normally achieved naturally by maintenance of an adequate leaf area index and also by placing a shade screen over the central road-way and white-washing the side walls in summer.

By far the most common error is supplying too much water to the crop on dark days when transpiration is minimal due to poor adjustment of the start and stop times or growers trying to 'chase EC' in order to stabilise it by supplying high volumes of irrigation water. This creates too much root pressure (remember, transpiration then irrigation, *PH&G*, issue Jul-Aug 2009), which damages cell structure in the skin and the fruits do not colour properly during the ripening process. You may also see 'growth mottle spots' on the leaves and the crop exhibiting strong vegetative pale growth (Photo 4.) as another reaction to mismanagement in the root zone. To minimise the incidence of uneven ripening and radial skin cracking, which can also be induced in the same way, it is important to understand how to manage the root zone environment in response to changing weather conditions (*PH&G*, issue Mar-Apr 2010) and the risks associated in certain growth phases.

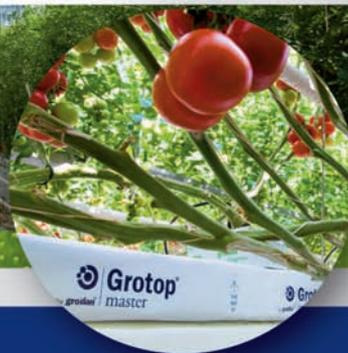
Tip 5: avoid situations, which can lead to increased root pressure. Optimise start and stop times of daily irrigation. Avoid low substrate EC, especially at the end of the day, maintain a constant fruit load and avoid high root zone temperatures.

Phase 3 growth and balance

The level of transpiration in this growth phase in spring for winter planted crops will vary widely. It is therefore important

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to manage the root zone accordingly. Please refer to *PH&G*, issue Mar-Apr 2010, on the thought processes that are involved to optimise the start and stop times of irrigation. You will know if you are giving too much water on the dark, mild days. The drain percent will increase and the substrate EC will decrease in comparison to a bright day. Remember, the design feature, 'nutrient refreshment efficiency' (*PH&G*, issue Nov-Dec 2009) and how easy it is to refresh and replace nutrient solution in Grodan® stonewool. This allows you to steer EC in the root zone on the dark days and when used in combination with late start and early stop times, you can protect fruit quality with minimal irrigation gift (*Figure 3.*). In fact, on these days it would not harm the crop if substrate EC increased a little in the range 0.2-0.3mS.

The combination of a late start and early stop time with large irrigation volumes has refreshed and stabilised the substrate EC on these two dark days with a total radiation sum 538J/cm² and 348 J/cm² respectively, preserving fruit quality.

Tip 6. optimise the number of irrigations per hour. As a general rule of thumb the number of irrigations you give per hour can be linked to global radiation (i.e. 200W/m² = 1 irrigation, 600W/m² = 4 irrigations, 800W/m² = 6 irrigations, 1000W/m² = 7-8 irrigations per hour). This guide can be used to adjust the maximum rest time setting, which of course, will govern the irrigation gift on dark days.

Phase 6 final production

Finally, when the heads are removed towards the end of the crop the demand for water is dramatically reduced. Uneven

ripening will occur in this phase if the irrigation strategy is not adjusted accordingly.

Future articles from Grodan

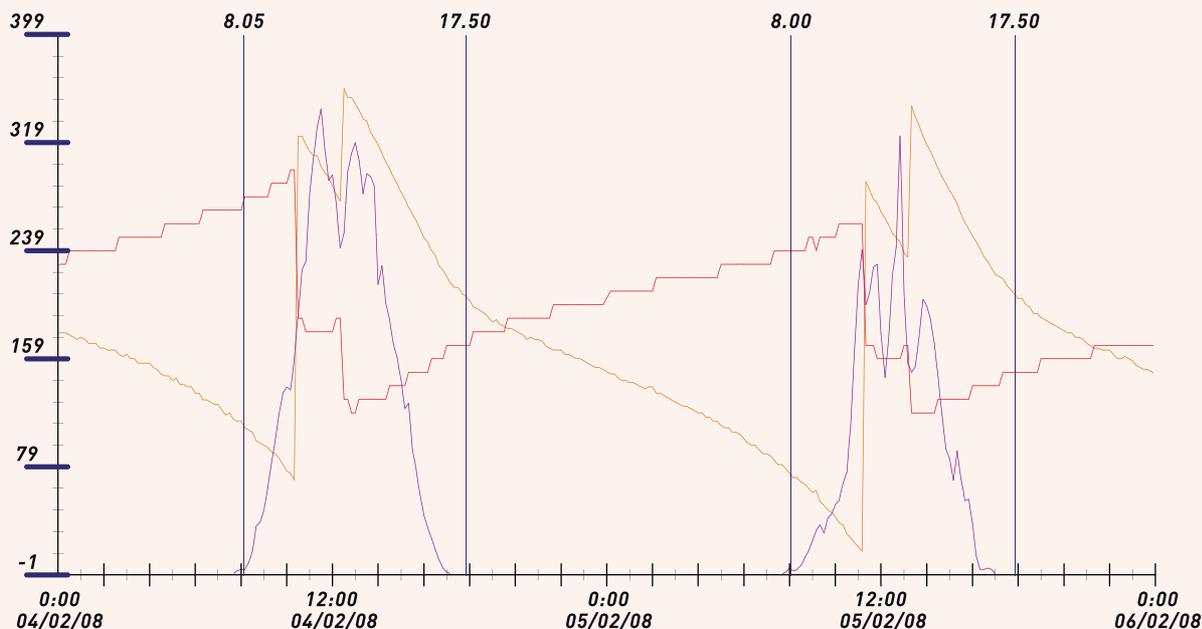
The root zone environment can be described as the engine room of the crop. A good quality root system will allow the crop to transpire and supply Ca²⁺ to the fruits, avoiding BER. However, the time that transpiration starts and the rate of transpiration during the day are governed by interaction with the aerial environment. The root zone climate needs to be managed accordingly in order to maintain optimum plant balance, production and fruit quality. Further, the intrinsic properties that the substrate has in respect to nutrient management and nutrient availability can go a long way in minimising the risk of fruit physiological disorders in extreme conditions.

It is also important to remember that maintaining regular production of high quality fruit will have significant impact on costs to the business elsewhere, not least harvesting and grading costs. In the next issue of *Practical Hydroponics & Greenhouses* I will define the additional benefits in terms of water and fertiliser savings that can be gained by correct root zone management.

About the author

Andrew Lee works for Grodan B.V. as Business Support Manager for North America and Export Markets. He is a PhD graduate from the University of London, England, and has been working for Grodan® over the past 9 years providing consultancy and technical support for its customer base worldwide. 

Company name	Cmpt	Parameter	Date	Average:	Min.	Max.
Gartneriet Masnedo	009	Slab watercontent - Normal	04/02/2008	60.2 Vol.%	50.1 Vol.%	71.5 Vol.%
Gartneriet Masnedo	009	Slab EC - Normal	04/02/2008	4.0 mS/cm	3.2 mS/cm	5.0 mS/cm
* Gartneriet Masnedo	001	Radiation - Normal	04/02/2008	132 W/cm ²	0.0 W/cm ²	344 W/cm ²



Gronov DCT - HIDRA Agro Automatisering BV - Pijnacker (NL) 1997-2002

Figure 3. Stabilised EC with minimal irrigation gift on dark days will help maintain fruit quality.