Water and EC Management

Picture 1. The WCM in the slab.

How to fine tune the irrigation strategy during spring and summer to avoid costly mistakes using tools such as the Grodan® Water Content Meter (WCM) and the graphics function of the climate computer.

In the fourth of six articles for *Practical Hydroponics & Greenhouses*, Grodan® Crop Consultant ANDREW LEE outlines how to set up an irrigation strategy using real life examples from his experience as a consultant.

Root zone management

The transpiration and how this process is influenced by the aerial climate have been described by me in the first article (*PH&G*, issue Jul-Aug 2009). In the second article I also defined key substrate functionalities and why these are important when it comes to substrate design and use in the greenhouse (*PH&G*, Issue Nov-Dec 2009). In the third article (*PH&G*, Issue Jan-Feb 2010) I introduced the Grodan 6-Phase model® and how this concept can be used to define medium and long-term growing strategies by setting clear objectives, targets and goals for climate and root zone management over the season.

In this article I will look more closely at the thought processes you should consider when setting up an irrigation strategy on a daily basis. Using examples for a mature crop growing in late spring/summer I will illustrate how measuring tools such as the Grodan® Water Content Meter (WCM) and the graphics generated by the climate computer can help you make informed decisions and avoid potentially costly mistakes.

What does a Water Content Meter measure?

The WCM measures directly the absolute WC, EC and temperature of the stone wool slab *(Figure 1)*. The sensor pins are placed directly in the slab about 10cm from the propagation block in the direction of the drain flow *(Picture 1)*. They measure the average WC and EC over the 7.5cm slab height. The information that the WCM provides is invaluable to the grower when it comes to fine tuning the irrigation strategy, in this way costly mistakes can be avoided.

The day dynamic of substrate WC & EC

Before going into too much detail on how to set up an irrigation strategy, it is prudent to describe the key features of the graphic that is generated by the WCM. During a 24-hour period there are three distinct phases, which occur in the root zone environment as a direct response to irrigation *(Figure 1)*.

Phase 1

The time at which the plants start to transpire can be seen by a change in slope of the WC line shortly after sunrise.

Phase 1 starts from first irrigation to the point of first drain. It is characterised by a step-like increase in substrate water content (WC). EC increases in this period as salts precipitated out of solution overnight are re-dissolved.

Phase 2

Phase 2 is characterised by a stable WC and decreasing substrate EC as the point of drain is realised. This period normally transcends the point of highest solar radiation.

Phase 3

Phase 3 from last irrigation in day 1 to first irrigation in day 2 is characterised by decreasing WC and increasing EC.

Through manipulation of start and stop times the volume and frequency of irrigation sessions growers have the opportunity to manipulate the day level WC and EC they wish to steer on depending on the growing phase of the crop (*PH&G*, Jan-Feb 2010) and therefore, development of the plant *(Table 1.)*.

Table 1.

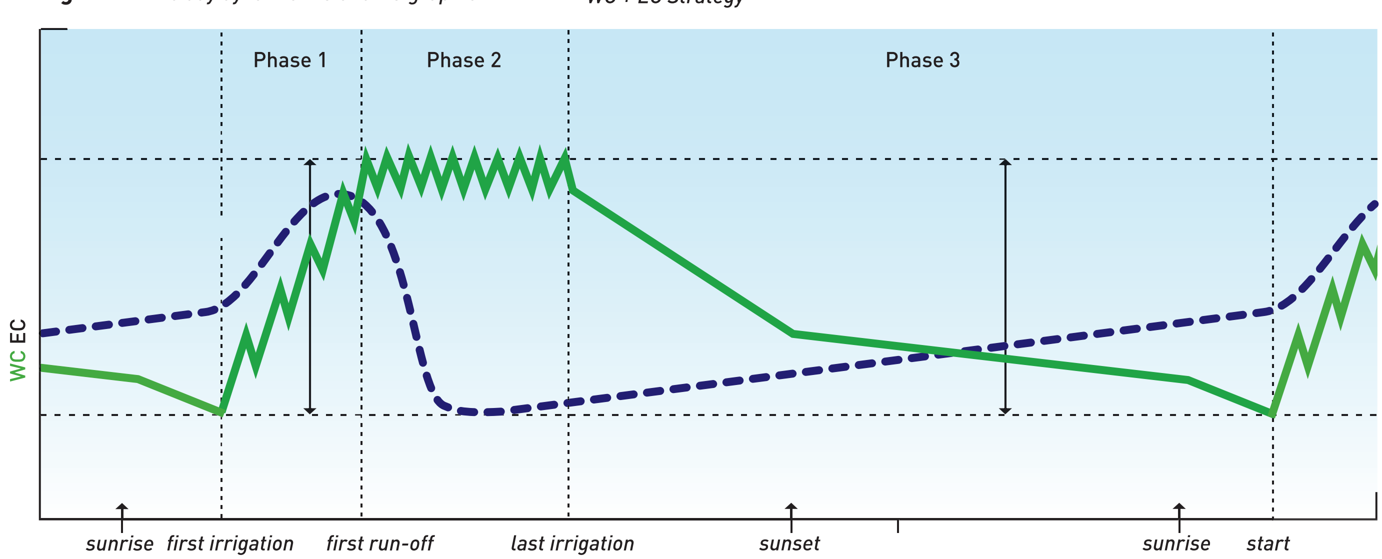
Effect of irrigation steering on plant development

	Generative effect on plant development	Vegetative effect on plant development
Start time	Later	Earlier
Stop time	Earlier	Later
Irrigation length	Larger	Smaller
Irrigation frequency	Lower	Higher

Setting up an irrigation strategy

For simplicity let us take typical strategies and thought processes that would be applicable for a developed crop in spring/summer conditions(i.e. one that is in growing phase 4 or 5 of the Grodan 6-Phase model). Remember, the objectives in these phases are to realise stable conditions (WC and EC) in the root zone environment to facilitate controlled and uniform re-growth of the crop following the first harvests and to maintain maximum production potential and fruit quality in the summer (*PH&G*, Jan-Feb 2010).

Figure 1. *The day dynamic WC and EC graphic.*



Start time

The golden rule is always transpiration then irrigation. This helps avoid all kinds of fruit quality issues such as uneven colour, radial cracking and split fruits. A simplistic approach would be to start the irrigation 1-2 hours after sunrise *(Table 2.).*

Table 2.

Irrigation start times in relation to sunrise.

Irrigation start time	Start time in relation to sunrise and increasing plant activity
0.0-1.0 hours + sunrise	Early
1.0-2.0 hours + sunrise	Standard
2.0-4.0 hours + sunrise	Late

Using solely 'time after sunrise' to start the irrigation day is normally fine if the outside weather conditions remain constant from day to day. However, with fluctuating weather conditions, especially in spring, it may be too late for a bright day and too soon on a dark day leading to instability in slab WC and EC. This can be demonstrated in *Figure 2*. The graphics are taken from a climate computer and depict the WC (dark blue), EC (red) and global radiation (green) over a 6-day period. The start time has been fixed at 08:30 hours, about 2 hours after sunrise. It can be seen that on the three days with 'low radiation' *(Figure 2a)*, slab EC remains stable at approximately 3.3mS. However, with three consecutive days of 'high radiation' EC rises up to 4.0mS as time 1st drain occurs too late *(Figure 2b)*. If the strategy (i.e. start time) is not adjusted for the bright days the end result would be that EC would continue to rise, potentially resulting in blossom-end-rot (BER) and loss of revenue to the grower.

In the example it is clear the start time should not be fixed at 08:30 hours but should be optimised to take account of the changeable weather. This is possible using the climate computer. How to do this will be illustrated using settings from the Priva Integro, a popular choice of computer worldwide, however, the thought process is the same for whichever climate computer you use. The Integro has six periods available *(Table 3.)*, which facilitate six different strategies over the duration of 24 hours. It is not required that you use all six periods but in this illustration I will do so.

Table 3.

Optimising the start time in relation to plant transpiration to account for changeable weather conditions in spring and summer.

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Start time	07:00 hrs	08:30 hrs	10:30 hrs			
Start Phase	320ml/m²	320ml/m²				
Minimum rest time	30 minutes	30 minutes				
Maximum rest time	---	40 minutes				
Rad. Sum		80J/cm²	80J/cm²			
Rad. Intensity	---	---				

Figure 2a.

	Company name	Cmpt	Parameter	Date	Average:	Min.	Max.
*	Gartneriet Masnedo	009	Slab watercontent - Normal	27/04/2006	64.8 Vol.%	57.6 Vol.%	70.3 Vol.%
	Gartneriet Masnedo	009	Slab EC - Normal	27/04/2006	3.2 mS/cm	3.0 mS/cm	3.7 mS/cm
	Gartneriet Masnedo	001	Radiation - Normal	27/04/2006	343 W/cm²	0.0 W/cm²	900 W/cm²

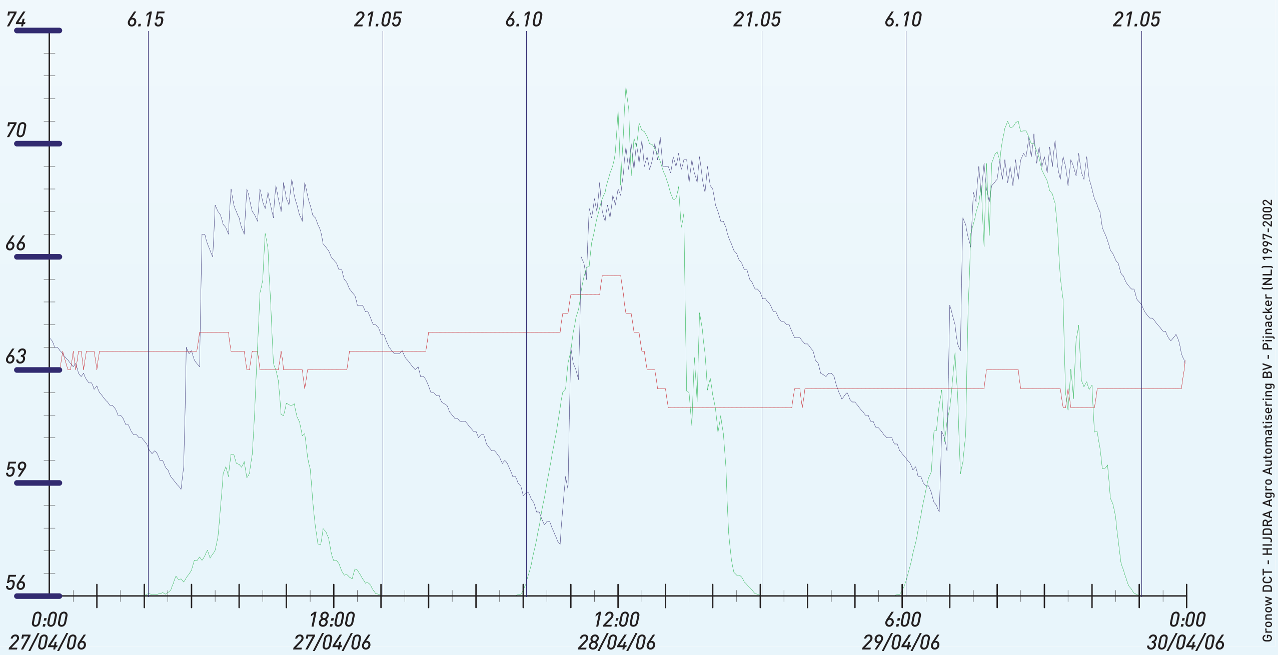
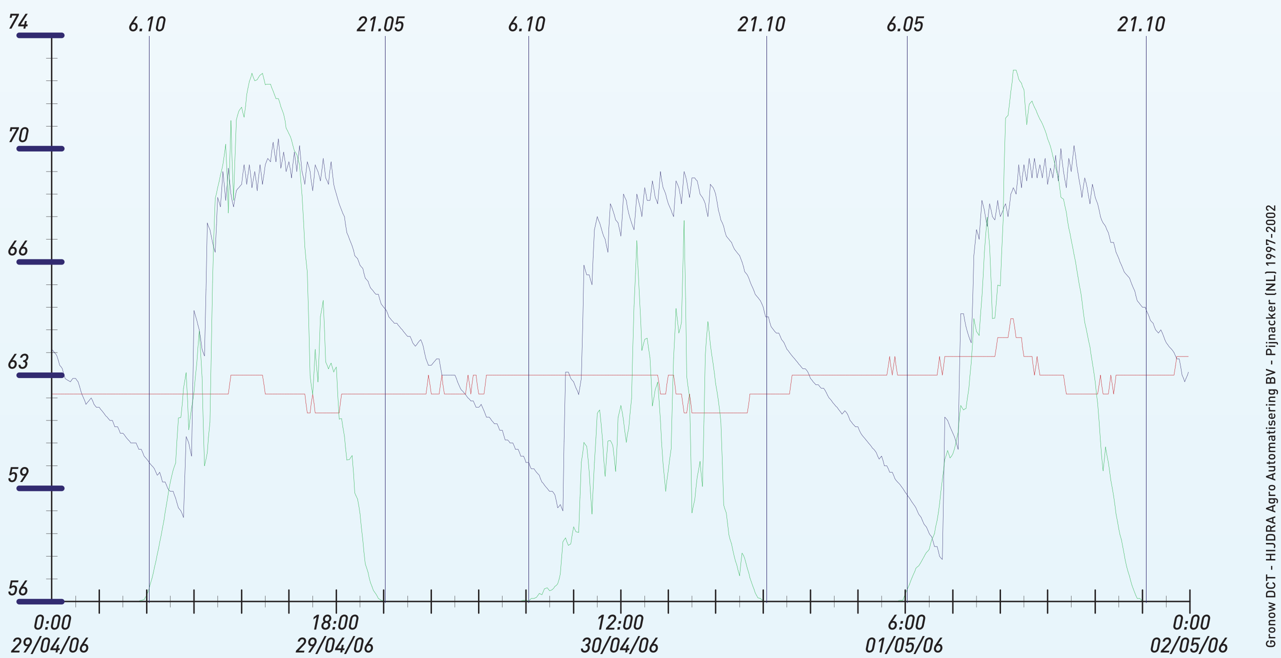


Figure 2b.

	Company name	Cmpt	Parameter	Date	Average:	Min.	Max.
*	Gartneriet Masnedo	009	Slab watercontent - Normal	29/04/2006	64.8 Vol.%	57.3 Vol.%	70.3 Vol.%
	Gartneriet Masnedo	009	Slab EC - Normal	29/04/2006	3.2 mS/cm	3.0 mS/cm	3.5 mS/cm
	Gartneriet Masnedo	001	Radiation - Normal	29/04/2006	339 W/cm²	0.0 W/cm²	844 W/cm²



Period 1

Based on the real life examples illustrated in *Figure 2a.* and *Figure 2b.* irrigation is now allowed to start 1 hour after sunrise *(Table 3)*, but only if it is sunny (i.e. it will deliver 320ml/m² per session when 80J/cm² light has accumulated). The minimum rest time is set to 30 minutes because the light intensity increases rapidly on bright days and I do not wish to give too much water in this period. In practice, this setting means that even if an additional 80J/cm² of light is accumulated after 25 minutes the irrigation will 'wait' until 30 minutes has elapsed.

There is no maximum rest time activated in this period. In practice, this prevents the computer from irrigating on maximum rest setting at 07:00 hours. So on a dark day we avoid potential fruit quality problems of uneven colour, radial cracking and split fruits.

Period 2

I selected 08:30 hours to start this period because based on the information in *Figure 2a* and *Figure 2b* this was 'on time' for a darker day. A maximum rest time for this period has been selected so the computer will irrigate on a 'maximum rest time' trigger at 08:30 hours and thereafter every 40 minutes if a light sum start is not given.

I have selected 320ml/m² irrigation volume in these periods to be applied every 80J/cm² (4.0ml/J). The thought process is simple. Assuming in this situation I have 8.0l/m² substrate volume in the greenhouse *(Table 4)*, a realised decrease WC of 10% overnight *(Figure 2a* and *Figure 2b)* equates to 800ml/m² loss in WC, due to the process of active water uptake by the plant. In this example let's also assume that by 10:30 hours 400J/cm² light has been accumulated, which is possible on bright days, check it on your computer. With water uptake from transpiration alone of 2.0ml/J this means that I should apply an additional 800ml/m² (400J/cm² x 2.0ml). So in order to bring the slab back to the same day level WC I need to apply 800ml/m² to account for the loss overnight plus an additional 800ml/m² to account for transpiration up to 10:30 hours(i.e. 1.6 l/m² by 400J/cm², the equivalent of 4.0ml/J). The maximum rest time of 40 minutes in this period prevents too much water being given on a dark day.

Table 4.
Calculation of substrate volume

Slab dimensions	100 (l) x 20 (w) x 7.5 (h) cm	Slab volume = 15.0 litres
Plants per slab	4.0	Substrate volume per plant = 3.75 litres
Plant density m²	2.2	Substrate volume per m² = 8.25 litres

Time of first drain

We can also set targets when we would like to see first drain. As standard this is normally 2-3 hours after the first irrigation is applied *(Table 5)*.

Table 5.
Time of first drain in relation to start of irrigation

Time of first drain following 1st irrigation	Start time in relation to sunrise and increasing transpiration
1.0-2.0 hrs	Early
2.0-3.0 hrs	Standard
3.0-4.0 hrs	Late

Period 3

Drain is required to stabilise and refresh EC to the required day level. It is important that in spring and summer this is achieved around 400J/cm² or 600W/m² *(Table 6)*. It is for this reason that I have timed *Period 3* to coincide with my expectation of first drain. From now into the afternoon it is important that EC remains under control when radiation is at its highest and stable between consecutive days.

Table 6.
Achieving drain on time and stabilising WC & EC in the afternoon

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Start time	07:00 hrs	08:30 hrs	10:30 hrs	15:30 hrs		
Start Phase	320ml/m²	320ml/m²	210ml/m²	210ml/m²		
Minimum rest time	30 minutes	30 minutes	20** minutes	20** minutes		
Maximum rest time	---	40 minutes	50** minutes	50** minutes		
Rad sum	80J/cm²	80J/cm²	70J/cm²	85J/cm²		
Rad In	---	---				

**This time should be reduced using -50% influence over the range 600-900 W/m² so that at high radiation you can apply up to six irrigations per hour (i.e. the minimum rest time should not restrict the maximum volume of water that you can apply on bright days).

What happens if drain occurs too late?

If drain occurs too late on a sunny day in this growing phase EC will continue to rise. In the example shown in *Figure 3.* it can be seen from the information provided by the computer that although the first irrigation is given around 08:00 hours (+2 hrs sunrise) EC is not reduced until 12:00 hrs. The result is that EC increases significantly over 24 hours. To correct this situation the grower should apply larger irrigation volumes in the morning.

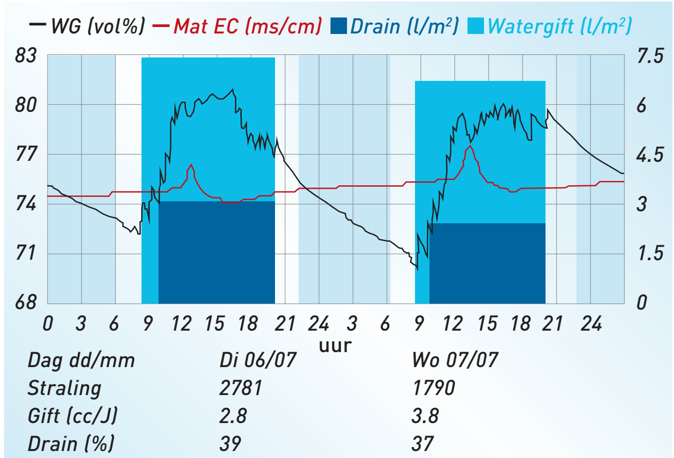


Figure 3. *Reaction of EC in the substrate when drain occurs too late on a sunny day. Black line = WC Red line = EC*
Light blue box = start and end of irrigation + total volume water applied
Dark blue box = start drain and total volume of drain applied

Figure 3. also illustrates a slight twist. It illustrates, most likely, that the grower was relying on the drain measuring tray too much in the decision-making process. Drain can be seen at 09:30 hrs (dark blue box) so with this information the grower probably thought the morning irrigation strategy was OK; he was forgetting to look for the reaction on EC. Remember, if everything is working correctly, time of drain and EC refreshment in the substrate should coincide.

From drain at 10:30 hours the goal now is to apply irrigation in line with transpiration. The general rule-of-thumb is 3.0ml/J, 2.0ml for transpiration and 1.0ml for drain, assuming 30% drain over 24 hrs. For this reason I have elected to supply 210ml/m^2 every 70J/cm^2 *(Table 6)*. However, with low outside humidity in combination with high temperatures this figure can be higher (3.5-4.0ml/J). Alternatively, if you use the shade screen or fog too much in this period it could be lower. In this respect remember that these tools, which you use to control the climate, should not reduce transpiration; they should merely help the plant keep pace with the higher demand, uptake should still be 2.0ml or above.

Generally, the irrigation volumes in this period of the day should be smaller but more frequent than in the morning. This prevents 'false drain', a phrase I use to describe the situation where slab WC falls and EC rises as a result of high drain percent per cycle. *Figure 4.* illustrates an example in practice.

Period 4

Period 4 (Table 6) starts at 15:30 hours; by now EC should be stable and the substrate nutrition refreshed. With outside radiation decreasing, I have elected to increase the joule sum to 95J/cm^2 applying the same volumes of water just to keep the 24-hour drain percent from being too high. Again, remember this is just another tool you can use, it is not absolutely necessary.

Stop time

A simplistic approach would be to stop the irrigation 1-2 hours before sunset *(Table 7)*. Using solely 'time before sunset' to stop the irrigation day is normally fine if the outside weather conditions remain constant from day to day. However, with fluctuating weather conditions, especially in spring, it may be too soon for a bright day leading to loss in fruit weight or too late on a dark day leading to a degradation of root quality. An optimised stop time using the climate computer is demonstrated in *Figure 4.* using the settings in *Period 5* and *6 (Table 8)*.

Table 7.
Irrigation start times in relation to sunrise

Irrigation start time	Start time in relation to sunrise & increasing plant activity
0.0-1.0 hours + sunrise	Early
1.0-2.0 hours + sunrise	Standard
2.0-4.0 hours + sunrise	Late

Table 8. *Optimising the stop time in relation to plant transpiration to account for changeable weather conditions in spring and summer.*

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Start time	07:00 hrs	08:30 hrs	10:30 hrs	15:30 hrs	17:30 hrs	21:00 hrs
Start Phase	320l/m^2	320ml/m^2	210ml/m^2	210ml/m^2	210ml/m^2	10ml/m^2
Minimum rest time	30 minutes	30 minutes	20** minutes	20** minutes	20** minutes	24:00 hours
Maximum rest time	---	40 minutes	50** minutes	50** minutes	---	24:00 hours
Rad sum	80J/cm^2	80J/cm^2	70J/cm^2	85J/cm^2	85J/cm^2	---
Rad In	---	---			200W/m^2	---

Figure 4. *Instability in WC and EC as a result of 'false drain' WC (blue line) decreases in the afternoon as a result of high drain percent per cycle and EC (red line) increases. If left undetected fruit quality issues caused by high substrate EC will be encountered. You can see in this example the grower has tried to correct for the falling WC using night irrigation, the wrong decision!*

Period 5

Period 5 starts at 17:30 hours *(Table 8)*. In the computer settings I have again de-selected the maximum rest time and told the computer that it should only irrigate if two start conditions are achieved (i.e. it must be over 200W/m² outside radiation and 75J/cm² must have been accumulated since the last irrigation for a start to be given). This avoids irrigating too late in the day. The outcome of this strategy can be seen in *Figure 5.* Radiation is very variable for each of 3 days but with the adjusted stop time in relation to plant activity the decrease in WC overnight remains constant. This helps maintain the generative/vegetative balance in the crop, fruit size and root quality.

Period 6

Period 6 starts at 21:00 hours. Maximum and minimum rest times have been selected for 24 hours - in practice this means that no irrigation will be given until *Period 1* or *Period 2* in the following day. Remember, night irrigation sessions are the exception rather than norm. Night sessions should only be given in respect to plant activity more then likely coinciding with the continued use of pad and fan or fogging systems to cool the greenhouse overnight.

Summary

This article has highlighted the thought process for optimum root zone steering over a 24-hour period in line with the Grodan 6-Phase model. It highlights the need for a substrate that can re-saturate quickly and at the same time offers good EC replacement and refreshment.

There are many ways to set up the ideal approach in the climate computer - the tables are only intended as examples. Whatever approach you take, make standardised graphics (WC, EC, global radiation) on the climate computer. These will provide you with the right management information on which you can base your decisions. Focus in over 1 or 2 days to see the detail, focus out over 7 or 10 days to see the trends. Look for the key triggers in the decision-making process should changes be required:

- Transpiration then irrigation
- Drain by 400J/cm² or 600W/m²
- First drain of the day in line with EC refreshment
- EC refreshed and stable in line with global radiation during peak solar hours
- Applied irrigation in line with radiation sum 3.0ml/J in the afternoon to ensure WC remains stable and EC under control
- Stop in relation to plant activity for a stable decrease WC over night.

About the author

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Figure 5. *Optimising the stop time based on changing weather conditions maintains a stable decrease WC overnight. Day 1 stop 17:45 hrs, Day 2 stop 19:05 hrs, Day 3 stop 18:05 hrs.*

	Company name	Cmpt	Parameter	Date	Average:	Min.	Max.
*	Gartneriet Masnedo	009	Slab watercontent - Normal	01/06/2006	66.2 Vol.%	59.9 Vol.%	70.4 Vol.%
	Gartneriet Masnedo	009	Slab EC - Normal	01/06/2006	3.0 mS/cm	2.7 mS/cm	3.2 mS/cm
	Gartneriet Masnedo	001	Radiation - Normal	01/06/2006	305 W/cm²	0.0 W/cm²	889 W/cm²