Making informed decisions in respect to water and EC management

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Introduction

How to fine tune the irrigation strategy during spring & summer to avoid costly mistakes using tools such as the Grodan GroSens system and the graphics function of the climate computer.

What does the GroSens system measure?

The GroSens systems measures directly the absolute WC, EC and temperature of the stone wool substrate (Figure 1.0). The sensor pins are placed directly in the slab about 10cm from the propagation block in the direction of the drain flow (Picture 1.0). They measure the average WC and EC over the substrate height, with different pin positions being used for 7.5 cm versus 10 cm high configurations. The information that the GroSens system provides is invaluable to the grower when it comes to fine tuning the irrigation strategy, in this way costly mistakes can be avoided.

Picture 1.0
The GroSens system inserted into a Grodan stone wool slab.

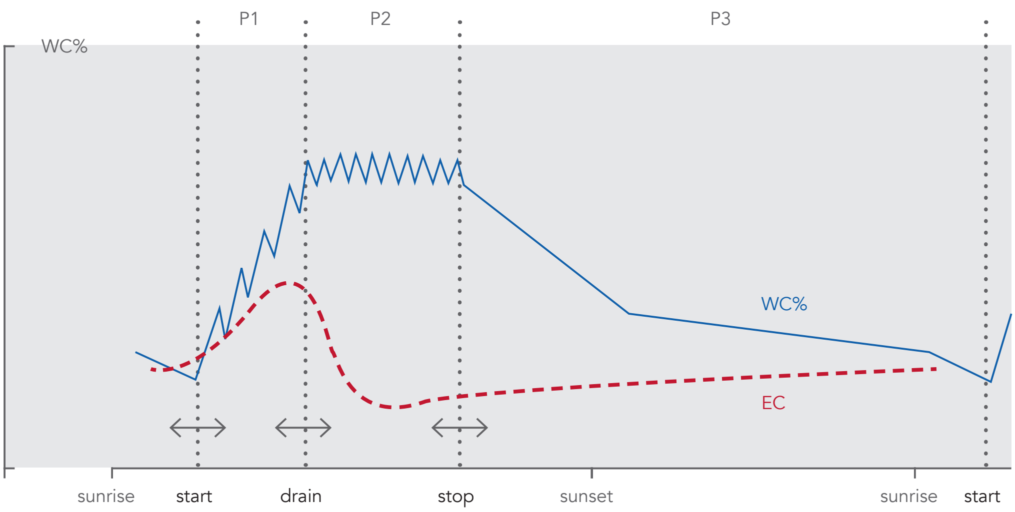
The day dynamic of substrate WC & EC

Before going into too much detail on how to set up an irrigation strategy, I think it prudent to describe the keys features of the graphic that is generated by the GroSens system. During a 24 hour period there are 3 distinct phases which occur in the root zone environment as a direct response to irrigation (Figure 1.0).

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. 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 and substrate EC is lowered. This period normally transcends the point of highest solar radiation.

Figure 1.0
Schematic representation of WC and EC development in the substrate over 24 hrs



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 and therefore development of the plant (Table 1.0).
Learn more about the 6 phase model

	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

Table 1.0
Effect of irrigation steering on plant development

Setting up an irrigation strategy

For simplicity let's 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. Remember the objectives in these Phases are to realise stable conditions (WC & 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.

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 1.0-2.0 hours after sunrise (Table 2.0).

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

Table 2.0
Irrigation start times in relation the sunrise.

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 2.0. The graphics are taken from a climate computer and depict the WC (dark blue), EC (red) and global radiation (orange) over a 6 day period. The start time has been fixed at 08:30 hours, about 2.0 hours after sunrise. It can be seen that on the 3 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. I will illustrate how to do this using settings from the Priva Connext, a popular choice of computer worldwide, however the thought process is the same for which ever climate computer you use.

Figure 2a

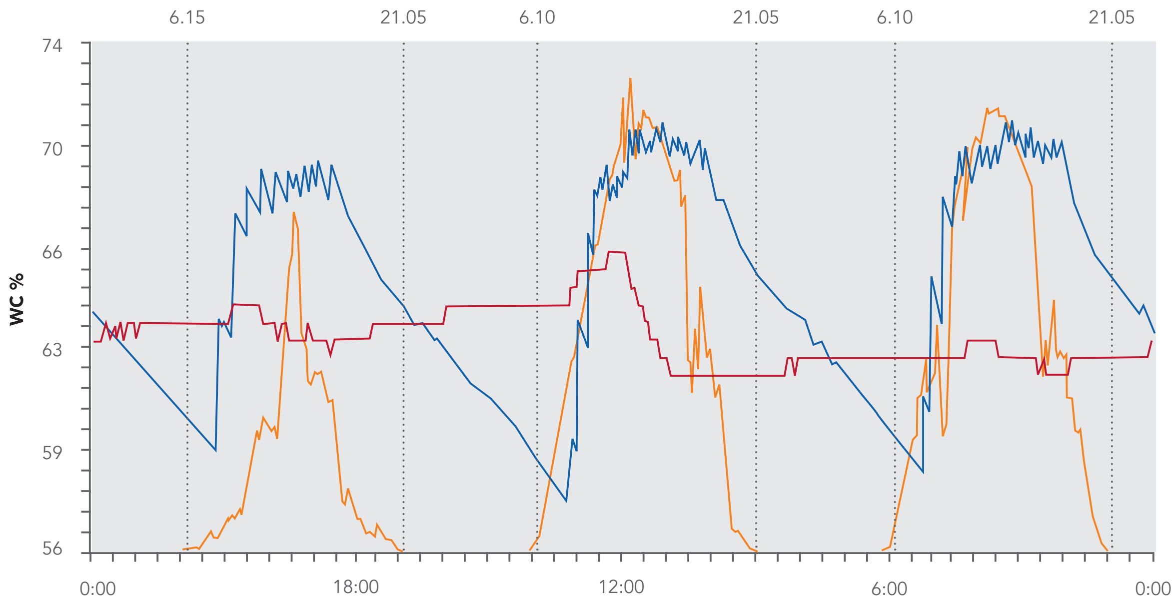
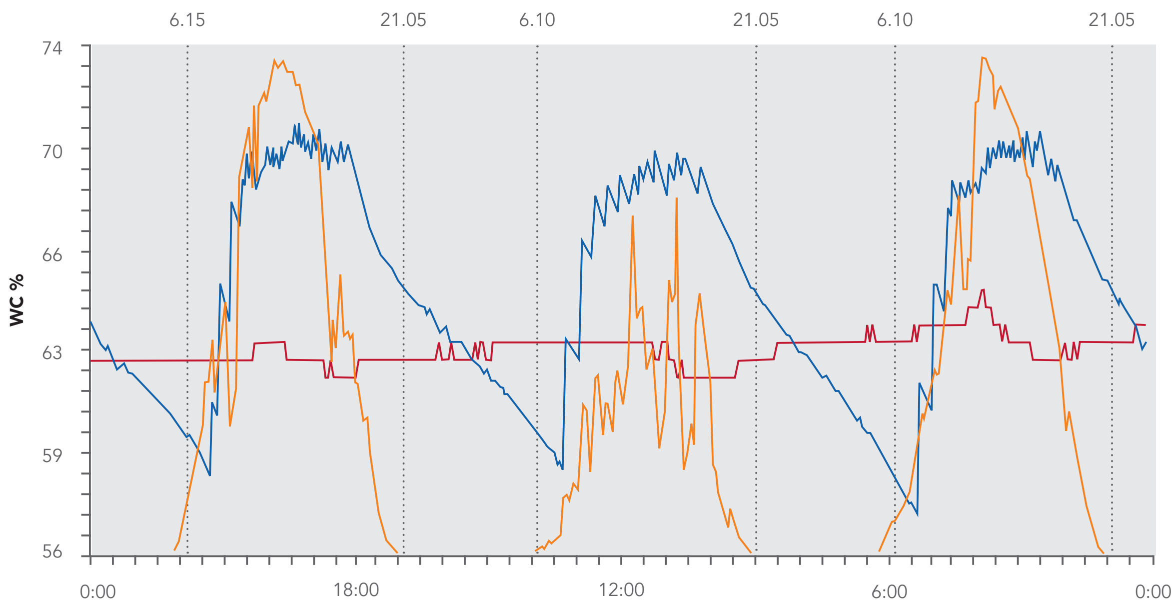


Figure 2b



The Connext has 6 periods available (Table 3.0) which facilitate 6 different strategies over the duration of 24 hours. It is important to link the time for reach period to the astronomical clock on the computer so that they adjust automatically with natural time changes in sunrise and sunset.

Period 1

Based on the real life examples illustrated in Figure 2a&b irrigation is now allowed to start if radiation sum ≥ 80 J/cm^2 (Table 3.0), i.e. it will deliver 320ml/m^2 per session when 80J/cm^2 light has accumulated. The minimum rest time is set to 20 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/cm^2 of light is accumulated after 19 minutes the irrigation will "wait" until 20 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 the start of this period. So on a dark day we avoid potential fruit quality problems of uneven colour, radial cracking & split fruits.

Period 2

I selected 08:30 hours to start this period because based on the information in Figure 2a&b this was "on time" for a darker day (you can see it's also 3.0 hrs after sunrise. In fact experience dictates that starting this period 3.0 hrs after sunrise is a 'good number to choose'. 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 (80 J/cm^2) is not given.

I have selected 320ml/m^2 irrigation volume in these periods to be applied every 80J/cm^2 (equivalent to 4.0ml/J). The thought here process is simple. Assuming in this situation I have 8.0 l/m^2 substrate volume in the greenhouse (Table 4.0) a realised decrease WC of 10% overnight measured by the GroSens system (Figure 2.0a&b) equates to 800ml/m^2 loss in WC. This is due to the process of active water uptake by the plant. In this example let's also assume that by 10:30 hours 400J/cm^2 light has been accumulated, which is not far from the mark 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/m^2 (400J/cm^2 x 2.0ml). So in order to bring the slab back to the same day level WC I need to apply 800ml/m^2 to account for the loss over night plus an additional 800ml/m^2 to account for transpiration up to 10:30 hours i.e. 1.6 l/m^2 by 400J/cm^2, 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. Noting that in practice the maximum rest time can be adjusted depending on the drain volume.

Table 3.0
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	05:30 hrs	08:30 hrs	10:30 hrs			
Start Phase	320ml/m^2	320ml/m^2				
Minimum rest time	20 minutes	20 minutes				
Maximum rest time	-	40 minutes				
Rad sum	80J/cm^2	80J/cm^2				
Rad In	-	-				

Table 4.0
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 m^2	2.2	Substrate volume per m^2 = 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 2.0-3.0 hours after the first irrigation is applied (Table 5.0).

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 6.0). 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 that EC remains stable between consecutive 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 3.0 it can be seen from the information provided by the computer that although the first irrigation is given around 08:00 hours (+2.0 hrs sunrise) EC is not

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

Table 5.0
Time of first drain in relation to start of irrigation

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Start time	05:30 hrs	08:30 hrs	10:30 hrs	16:50 hrs		
Start Phase	320 ml/m²	320 ml/m²	240ml/m²	240ml/m²		
Minimum rest time	20 minutes	20 minutes	20** minutes	20**		
Maximum rest time	-	40 minutes	60** minutes	-		
Rad sum	80J/cm²	80J/cm²	80J/cm²	80J/cm²		
Rad In	-	-				

Table 6.0
Achieving drain on time and stabilising WC & EC in the afternoon
***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 6 irrigations per hour i.e. the minimum rest time should not restrict the maximum volume of water that you can apply on bright days.*

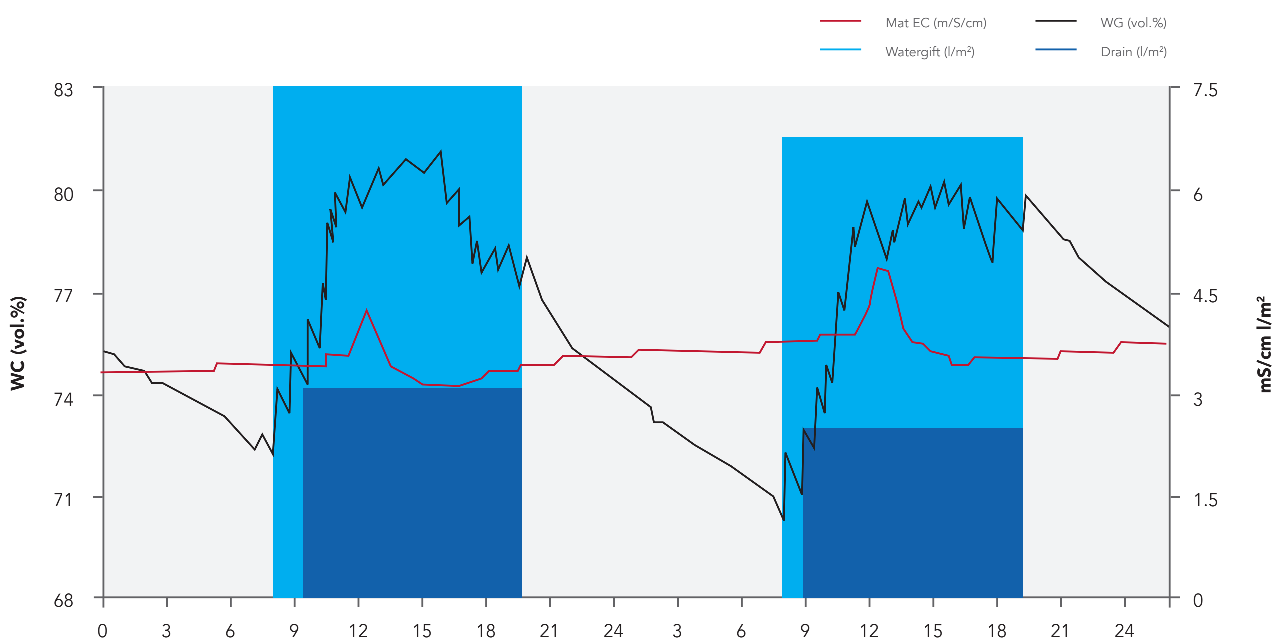


Figure 3.0
Reaction of EC in the substrate when drain occurs too late on a sunny day. Black line = WC; Red line = EC;
Light blue box = start and end of irrigation + total volume water applied; Dark blue box = start drain and total volume of drain applied.

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 3.0 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, on the principle that 2.0ml is required for transpiration and 1.0ml for drain (assuming 30% drain over 24 hrs). For this reason I have elected to supply 240ml/m^2 every 80J/cm^2 (Table 6.0). Crucially you can see that the frequency (irrigation on joules sum) remains unchanged. Keeping the frequency of irrigation constant means stability for the plant, instead I'm 'steering' on irrigation session length to manage substrate EC and drain volume. Remember with low outside humidity in combination with high temperatures this can figure can be higher (3.2-3.5ml/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 (transpiration) should still be >2.0ml/J.

Lowering the volume of irrigation in this period of the day 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 4.0 illustrates an example in practice.

Period 4

Period 4 (Table 6) starts at 16:50 hours, by now EC should be stable and the substrate nutrition refreshed, with outside radiation decreasing I have elected to remove the maximum rest time and set two conditions on which to trigger an irrigation 80 J/cm^2 combined with a light intensity threshold >150 W/m^2. This thinking helps control drain volume.

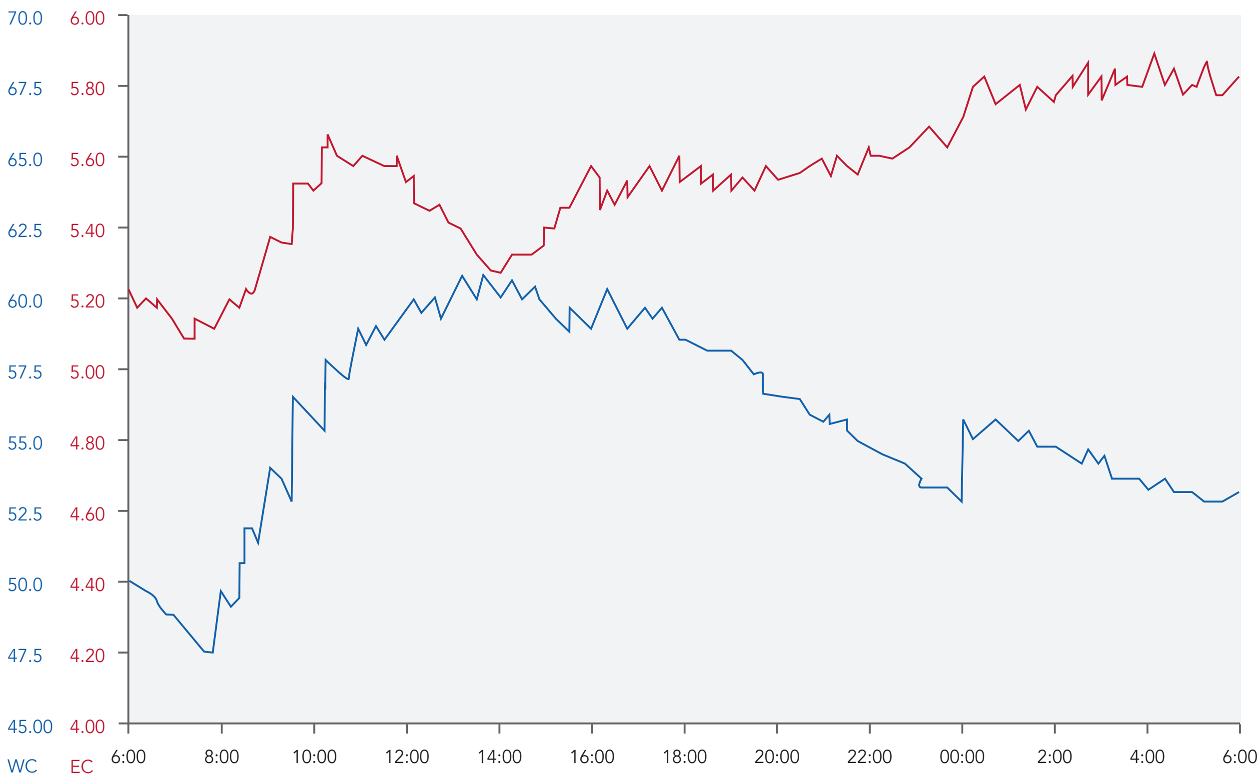


Figure 4.0
Instability in WC and EC as a result of "false drain" WC (blue line) decreases in the afternoon as a result of high drain percent per cycle and EC (red line) increases. If left undetected fruit quality issues caused by high substrate EC will be encountered. You can see in this example the grower has tried to correct for the falling WC using night irrigation, the wrong decision!

Stop time

A simplistic approach would be to stop the irrigation 1.0-2.0 hours before sunset (Table 7.0). 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 4.0 using the settings in Period 5 and 6 (Table 8.0).

Period 5

Period 5 starts at 18:50 hours (2.0hrs before sunset) (Table 8.0). I have reduced the irrigation session length to 200ml/m² to further reduce the drain volume. In the computer settings I have again de-selected the maximum rest time and told the computer that it should continue to use two start conditions i.e. it must be over 250W/m² outside radiation and 80J/cm² must have been accumulated since the last irrigation for a start to be given.

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

Table 7.0
Irrigation start times in relation the sunrise.

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Start time	05:30 hrs	08:30 hrs	10:30 hrs	16:50 hrs		21:00 hrs
Start Phase	320 ml/m²	320 ml/m²	240ml/m²	240ml/m²		
Minimum rest time	20 minutes	20 minutes	20** minutes	20**		24:00
Maximum rest time	-	40 minutes	60** minutes	-		24:00
Rad sum	80J/cm²	80J/cm²	80J/cm²	80J/cm²		
Rad In	-	-		150 W/m²	250 W/m²	

Table 8.0
Optimising the stop time in relation to plant transpiration to account for changeable weather conditions in spring and summer.

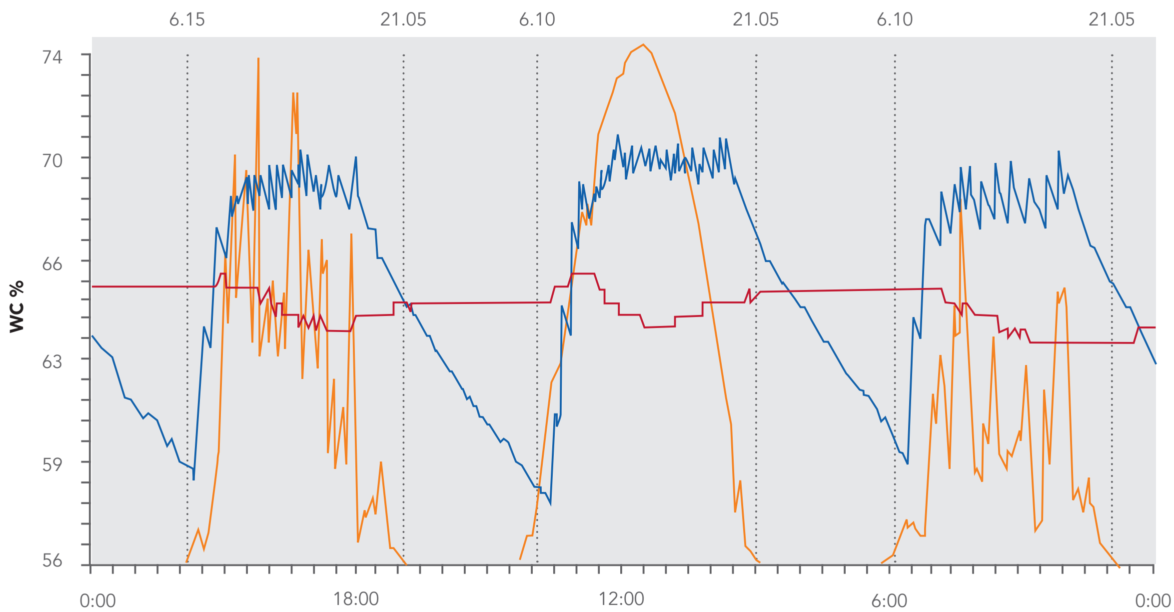


Figure 5.0
Optimising the stop time based on changing weather conditions maintains a stable decrease WC overnight. Day 1 stop 17:45 hrs, Day 2 stop 19:05 hrs, Day 3 stop 18:05 hrs

This allows irrigation to continue on sunny days but crucially avoids irrigating too late in the day on darker days. The outcome of this strategy can be seen in Figure 5.0. 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 sunset 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 than likely coinciding with the continued use of pad & 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 6 Phase model. It highlights the need for a substrate that can be steered on irrigation session length. There are many ways to set up the ideal approach in the climate computer the tables above are only intended as examples. Whatever approach you take make sure that you create standardised graphics from the GroSens system and climate computer WC and EC together with radiation intensity, radiation sum. It's important to scale the graphic correctly so that you can see the detail. This will provide you with the right management information on which you can base your decisions. Focus in on the graphic over 1 or 2 days to see the detail, focus out over 7 or 10 days to see the trends. When reading the graphic look for the key triggers in the decision making process should changes be required:

→ What was the light sum at irrigation start time?
→ At what light intensity was drain realised?
→ Was EC lowest when radiation intensity was highest?
→ What was the light intensity when the last irrigation was given?
→ How many joules remained until sunset?
→ What was the decrease in WC overnight?

About the author
Andrew Lee works for Grodan Technical Services. He is a PhD graduate from the University of London, England, and has been working for Grodan over the past 19 years providing consultancy and technical support for its customer base worldwide.

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