Understanding and steering the root zone environment

According to the Grodan 6 phase model

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Introduction

Goals and targets for crop and root zone management in response to changes in plant development, fruit load and light levels.

In this whitepaper Grodan specialist ANDREW LEE provides an insight into the 6 Phase model which describes plant growth and development and explains how using this knowledge grower's can form coherent strategies in respect to root zone management throughout the duration of the cropping cycle.

Root zone management

I have already described transpiration and how this process is influenced by the aerial climate in the whitepaper '*Movement of Water Through Plants'*. In the whitepaper '*Understanding Substrate Design'* I also defined key substrate functionalities and why these are important when it comes to substrate design and the fundamental thought processes behind an irrigation management strategy. Now I will introduce the Grodan 6 Phase model. The model describes each development stage of a crop (applicable to tomato, cucumber, pepper, aubergine) and defines 'targets' for crop and root zone management, in response to changing weather conditions and plant growth and development.

Growers worldwide have to react to developments in the market. Today's immediate challenge for hi-tech horticulture is *producing more for less.* This does not necessarily mean an ad-hoc approach to cost cutting. Producing more for less in this context means becoming more efficient at what you do in daily practice. We call this Precision Growing. The first thing you need is a growing plan, a strategy that provides a structured approach to the way of growing. In essence the structure should have 4 key pillars;

1. Strategy
2. Uniformity
3. Strength
4. Balance

A **strategy** is simply taking a global overview of the production cycle and your market. It is invariably a paper exercise conducted between grower and consultant that will consist of choosing the right variety for the right retail outlet which planted at the right time and density, will achieve the right fruit size, yield and quality. **Uniformity** in both climate and root zone environments is also an important consideration because without uniformity in you will be unable to grow to the defined strategy. This ultimately comes down to infrastructure and tools at your disposal i.e. the quality of greenhouse construction, vent calibration, heat / fog distribution, substrate quality, evenness of the irrigation delivery system etc. You must also consider the quality and uniformity of the young plants you receive from propagation, if these plants are of uneven size and development it will result in many compromises to your strategy. On a seasonal basis maintaining **strength** in the crop throughout the production cycle is also important because without strength it is impossible to achieve the right crop **balance** on a daily basis, for example a weak crop cannot be steered generatively and production will be compromised.

6 Phase model

As cultivation systems become more hi-tech and greenhouse businesses get larger the requirements for structured growing plans are more important than ever. These global blueprints are the basis for ensuring optimal crop performance. Growers are able to become more focussed at producing high quality produce for minimal cost. The Grodan 6 Phase model takes account of all 4 pillars described above and is now accepted worldwide by growers, consultants and seed companies. The model describes specifics changes in crop development and consequently defines targets and objectives for each Phase of growth (Table 1.0). It therefore provides a structured plan to follow over the course of the year, because if you have objectives and targets over the long term, decisions on a daily basis become easier and more informed. Moreover the model is applicable worldwide, wherever you are the objectives and targets will be the same, only the week numbers related to the start and end of each growing Phase will change.

	Cultivation Phase	Objective	Target crop	Target root zone
Phase 1: Planting & rooting in	Week 48 - 02	Continue the uniform development of a strong generative plant with good formation of the first and second clusters. Fast and uniform rooting into the substrate.	Plants should continue to exhibit uniform growth after delivery from the propagator. Uniform growth should continue and the leaf area should increase to enable the plant to intercept as much radiation as possible. Truss development should remain strong and generative with good flower and pollen formation.	A successful start for the plant is determined by good root development which should remain confined to the block. Attention should be given to developing as many pin roots as possible to enable fast rooting in as soon as slab contact is required. The pin roots should grow easily out of the block and uniformly into the substrate. It is important to supply enough water and nutrition to the blocks until the plant can rely on the available water in the slab.
Phase 2: Rooting through & plant development	Week 02-08	Continuation of uniform controlled plant development and the realisation of a root system that fills the entire substrate volume.	Work on plant development and increasing the leaf area to capture the available radiation and keep vegetative – generative balance in the plant.	Establish complete root penetration of the entire substrate volume. This will enable the plant to take up all the water and nutrition it will need for maximum summer production and quality.
Phase 3: Growth & balance	Week 08-14	Retain the right balance in the crop during first harvest (as the fruit load increases) and assimilate supply is variable and strongly depending on the weather.	Growth should remain constant and uniform while the fruit load is increasing. The 24 hrs temperature should be adjusted to the light levels to ensure optimum partitioning of available assimilates for plant and fruit growth.	Root quality should be retained to ensure controlled and uniform re-growth of the crop as first harvest approaches.
Phase 4: Production & balance	Week 14-22	Realise controlled and uniform re-growth of the crop following the first harvests.	Focus on keeping the crop in balance as the plant load and production continue to increase.	To control the balance in the crop the root zone environment should remain stable and uniform throughout the greenhouse. The recommended WC and EC levels for spring and summer should now be realised.
Phase 5: Maximum production	Week 22-35	Maintain maximum production potential by keeping plant and root quality in excellent health.	Vegetative or generative steering will depend on the condition of the crop. The crop should remain strong to cope with large and extreme fluctuations in weather conditions. The set speed should match the harvest speed to maintain constant fruit load.	Water uptake should match the needs of the crop for maximum cooling potential to create good climate and plant conditions inside the greenhouse. Good root penetration throughout the entire substrate volume realised in Phase 2-4 will help the crop to cope with extreme weather conditions.
Phase 6: Final production	Week 35-45	Keep the crop in a healthy condition to ensure production and quality is maintained right through to the last planned harvest date.	Maintain strength and growing power of the plant and limit the ingress of disease in the crop as the light levels diminish towards final harvest.	Maintain a healthy and active root system and to keep the correct nutrient balance.

Table 1.0
A description of the Grodan 6 Phase model: In this case a tomato crop grown without assimilation lights planted in North West Europe is used as the example. Week numbers refer to calendar weeks.

I will now focus specifically on the root zone environment within each growing Phase and expand on the objectives taking the example for tomatoes described in Table 1.0 further.

Phase 1a/b

If you opt to stand the plants on the side of the slab (Phase 1a) you should understand that during propagation the block was steered to a WC 30-40% before it was re-saturated back to WC 80% and this strategy should be continued with the objective of developing more pin roots within the block (Picture 1.0 illustrating Pin roots tomato in propagation block) and allowing you to find the right balance between generative and vegetative growth. This will ensure the plants continue to grow in a controlled, uniform way. Remember that uniformity of WC and EC over the height of the propagation block increases the period of steerability whilst the plant is standing next to the plant hole. So if you opt for this strategy it is an important feature of block quality. A typical strategy during this Phase is summarized in Table 2.0. Start times can be determined by block weight (g) or water content (WC%).

When slab contact is made, usually when the 1st or second cluster is flowering, (Phase 1b) your objective is to get the roots quickly established into the substrate. In this Phase it is important to maintain good block / slab contact by minimising the difference in WC% between the two components (Table 3.0). This practice will ensure increased DM% in the growing crop and improve the resilience to disease, particularly *Botrytis* in later growing Phases.

Picture 1.0
Development of pin roots in Grodan block.

	Bright day - Vegetative steering	Dark day - Generative steering
Start time	+2.0 hrs after sunrise <300g 10 x 10 cm <350g 10 x 15 cm	+3.0 hrs after sunrise <270g 10 x 10 cm <300g 10 x 15 cm
Stop time	-2.0 hrs before sunset	-3.0 - 4.0 hrs before sunset
Target minimum WC% before re-saturation	Delay irrigation until block WC 40 - 45%	Delay irrigation until block WC 35 - 40%
Target decrease WC overnight	Maximum 20%	Maximum 20%
Moment 1st drain	Not applicable	Not applicable
EC drip	3.5 - 4.0 mS/cm	3.5 - 4.5 mS/cm
EC block	5.0 - 8.0 mS/cm	5.0 - 11.0 mS/cm
24 hr Drain	10 - 40%	0 - 20%
Irrigation volume & frequency	2-4 sessions 75 - 100 ml per 10 x 10 cm 100 - 150 ml per 10 x 15 cm	1-2 sessions 100 - 200 ml per 10 x 10 cm 150 - 250 ml per 10 x 15 cm
ml/joule	Not applicable	Not applicable
Night irrigation	If decrease >20%	If decrease >20%

Table 2.0:
Typical strategy for steering tomato plant development during Phase 1a.

This Phase comes to an end when the roots have penetrated into the substrate by several centimetres and water uptake no longer depends on the moisture content in the propagation block.

Your choice of substrate, made as part of your overall strategy will now influence dramatically what you can and cannot do in terms of root zone management, hence I will use typical strategies employed when using GT Master in this and subsequent growing Phases. But remember what ever your choice of substrate the goals and objectives (Table 1.0) will remain exactly the same.

Phase 2
It is essential to form a large volume of roots in this growing Phase as this forms the basis for crop growth and quality. Irrigation in relation to crop activity will encourage the roots to "look" for water and nutrition in the substrate. Steering in the root zone on a daily basis should also be adjusted to the required direction of crop development (vegetative or generative) in order to keep the crop in balance. For maximum generative steering your objective should be to gradually lower day level WC% of the substrate from 85-90% to 50-60%* by the time the 5th cluster is flowering (Table 4.0). However please remember the control range WC% for GT Master can be steered toward a lower level (45-50%) if greater generative actions are required.

Phase 3
As the fruit load increases the quantity of assimilates available for the development of shoots and roots will decrease. It is important that you distribute the available assimilates evenly between fruit, shoot and roots. Good crop registration will supply the required data as to how to keep strength in the crop with adjustments to the 24 hour temperature in accordance to the daily light sum. The growth of new roots and root tips should be encouraged by adjusting the start and stop times of irrigation especially on darker days. On bright days the WC% can be steered upwards (Table

	Bright day - Vegetative steering	Dark day - Generative steering
Start time	+2.0 hrs after sunrise	+3.0 hrs after sunrise
Stop time	-2.0 - 3.0 hrs before sunset	-3.0 - 4.0 hrs before sunset
Target day level WC	Slab >75% Block >50%	Slab >75% Block >50%
Target decrease WC overnight	Not applicable	Not applicable
Moment 1st drain	Not applicable	Not applicable
EC drip	3.5 - 4.0 mS/cm	3.5 - 4.0 mS/cm
EC block / slab*	Block: 5.0 - 8.0 mS/cm Slab: 3.5 - 4.0 mS/cm	Block: 5.0 - 11.0 mS/cm Slab: 3.5 - 4.0 mS/cm
24 hr Drain	Not applicable	Not applicable
Irrigation volume	200 - 250 ml/m²	250 - 400 ml/m²
ml/joule	Not applicable	Not applicable
Night irrigation	If used in line with techniques of 'the new way of growing' (HNT). these should cease by second flowering cluster	If used in line with techniques of 'the new way of growing' (HNT). these should cease by second flowering cluster

Table 3.0:
Typical strategy for steering tomato plant development in Phase 1b.
**EC drip also indicates slab EC at initial saturation of the slab.*

	Bright day - Vegetative steering	Dark day - Generative steering
Start time	+2.0 hrs after sunrise	+3.0 hrs after sunrise
Stop time	-2.0 hrs before sunset	-3.0 - 4.0 hrs before sunset
Target day level WC	50 - 55%	45 - 50%
Target decrease WC overnight	6 - 8%	8 - 10%
Moment 1st drain	Before 12.00 hrs	After 12.00 hrs
EC drip	3.5 - 4.0 mS/cm	3.8 - 4.2 mS/cm
EC slab	5.0 - 7.0 mS/cm	6.0 - 9.0 mS/cm
24 hr Drain	15 - 25%	0 - 15%
Irrigation volume	Week 4: 300 - 350 ml/m² Week 8: 350 - 400 ml/m²	Week 4: 350 - 450 ml/m² Week 8: 450 - 500 ml/m²
ml/joule	Not applicable	Not applicable
Night irrigation	No	No

Table 4.0:
Typical strategy for steering tomato plant development in Phase 2.
Note data values are indicative for GT Master. Slab EC rises due to limited or no drain volumes in this phase.

5.0). In combination with a targeted irrigation strategy this will facilitate maximum growth and development of the crop. The drip EC is an important steering tool to maintain balance and fruit quality in this Phase. Ideally this should be maintained sufficiently high which in combination with large dripping sessions especially on dark days, provides maximum generative development for a strong crop.

Picture 2.0

Phase 4

After the first harvest the fruit load should be in balance with crop growth (Picture 2 illustrating lots of good quality tomato fruit on the plant). The crop will assimilate all radiation into re-growth and weekly production will start to increase. However re-growth should not be *'explosive or jerky'*. Targeted start and stop times between bright and dark days (Table 6.0) will ensure a good balance between vegetative and generative growth and will prevent fruit quality issues such as Blossom end rot (BER), soft fruit and uneven colour. I will deal with these fruit physiological quality issues in a subsequent whitepaper.

The GroSens system is a good tool to use in this respect. I like to see at least 1.5-2.0% decrease in WC% between sunrise and the start of irrigation on dark days (Table 6.0).

Picture 3.0

	Bright day - Vegetative steering	Dark day - Generative steering
Start time	+1.0 - 2.0 hrs after sunrise 60 - 100 J/cm² or 150 W/m²	+3.0 - 4.0 hrs after sunrise When WC falls 1.5 - 2.0% from sunrise
Stop time	-1.0 - 2.0 hrs before sunset Ideally leaving 150 -200 J/cm² and a light intensity threshold 200 - 300 W/m² to sunset	-3.0 - 4.0 hrs before sunset
Target day level WC	55 - 60%	45 - 50%
Target decrease WC overnight	8 - 10%	10 - 15%
Moment 1st drain	400 J/cm² or 600 W/m²	Less than 4 irrigation's
EC drip	3.0 - 3.3 mS/cm	3.5 - 3.8 mS/cm
EC slab	4.0 - 5.0 mS/cm	4.5 - 5.5 mS/cm
24 hr Drain	20 - 30%	10 - 20%
Irrigation volume	300 - 350 ml/m²	400 - 500 ml/m²
ml/joule	Not applicable	Not applicable
Night irrigation	Only if additional vegetative steering is required	No

Table 5.0:
Typical strategy for steering tomato plant development in Phase 3.
Note data values are specific to GT Master.

	Bright day - Vegetative steering	Dark day - Generative steering
Start time	+1.0 - 2.0 hrs after sunrise 80 - 100 J/cm² or 150 W/m²	+2.0-3.0 hrs after sunrise When WC falls 1.5-2.0% from sunrise
Stop time	-1.0 - 2.0 hrs before sunset Ideally leaving 150 - 200 J/cm² and light intensity threshold 200 - 300 W/m² to sunset	-3.0 - 5.0 hrs before sunset
Target day level WC	70 - 75% increasing 75 - 80% week 22	70% increasing 75% week 22
Target decrease WC overnight	6 - 8%	10 - 12%
Moment 1st drain	400 J/cm² or 600 W/m² or 4-6 irrigation's	Less than 4 irrigation's
EC drip	2.8 - 3.3 mS/cm	3.0 - 3.5 mS/cm
EC slab	3.8 - 4.5 mS/cm	4.5 - 5.2 mS/cm
24 hr Drain	25 - 30%	10 - 20%
Irrigation volume	Morning: 350 - 500 ml/m² Afternoon: 300 - 400 ml/m²	350 - 500 ml/m²
ml/joule	3.0 ml/J	Not applicable
Night irrigation	No	No

Table 6.0:
Typical strategy for steering tomato plant development in Phase 4.
Note data values are specific to GT Master.

Phase 5
During this Phase the crop will have the highest production capacity, however it is also when most fruit quality problems related to lack of water and nutrient uptake occur i.e. BER. It is during this Phase that the root system you created and maintained by having a good root zone management strategy through Phases 2-4 really pays dividends (Picture 3.0 illustrating excellent tomato root system inside GT Master slab). Vegetative steering will encourage the crop to grow optimally for maximum production (Table 7.0). The start time of irrigation should now be related to light sum (J/cm²) or intensity (W/m²). It is also important to keep the decrease in WC% overnight to 8-12%. A larger decrease will impact negatively on production as the fruits will become "dry" at the end of the day. This normally occurs if the stop time is targeted too early. I therefore like to stop irrigation when the outside light intensity is around 200-300 W/m².

	Bright day - Vegetative steering	Dark day - Generative steering
Start time	+1.0 - 2.0 hrs after sunrise 60-100 J/cm² or 150 W/m²	+2.0 - 3.0 hrs after sunrise When WC falls 1.5-2.0% from sunrise
Stop time	-1.0 - 2.0 hrs before sunset Ideally leaving 150 - 200 J/cm² and light intensity threshold 200 - 300 W/m² to sunset	-3.0 - 4.0 hrs before sunset
Target day level WC	75 - 80 %	70 - 80% (3 - 5% lower than a bright day)
Target decrease WC overnight	6 - 8%	10 - 12%
Moment 1st drain	400 J/cm² or 600 W/m² or 4-6 irrigation's	Less than 4 irrigation's
EC drip	2.8 - 3.3 mS/cm	3.0 - 3.5 mS/cm
EC slab	3.5 - 4.5 mS/cm	4.0 - 5.0 mS/cm
24 hr Drain	30 - 35%	10 - 20%
Irrigation volume	Morning: 350 - 400 ml/m² Afternoon: 250 - 300 ml/m²	350 - 450 ml/m²
ml/joule	2.8 - 3.5 ml/J	Not applicable
Night irrigation	Only if corrective actions are required delta WC >10%	No

Table 7.0:
Typical strategy for steering tomato plant development in Phase 5.
Note data values are specific to GT Master.

Phase 6
This Phase starts when the growing heads are taken out, leaving 7-8 trusses on the plant. However the objective is still to continue producing high yield of high quality produce (Table 1.0). Fruit quality will be assured by adjustments to the irrigation strategy which is aimed at preventing root necrosis and at maintaining the correct nutritional balance in the root zone by ensuring adequate drain over 24 hrs (Table 8.0). This is especially important if you wish to extend the growing season (harvesting period) by reducing 24 hr temperatures.

	Bright day - Vegetative steering	Dark day - Generative steering
Start time	+1.5 - 2.5 hrs after sunrise 80 - 100 J/cm² or 200 W/m²	+3.0 - 4.0 hrs after sunrise When WC falls 1.5 - 2.0% from sunrise
Stop time	-2.0 - 3.0 hrs before sunset Ideally leaving 150 - 200 J/cm² and light intensity threshold 200 - 300 W/m² to sunset	-3.0 - 5.0 hrs before sunset
Target day level WC	70-75% decreasing to 60-65%	70% decreasing to 60%
Target decrease WC overnight	8 - 10%	10 - 15%
Moment 1st drain	400 J/cm² or 600 W/m² or 4-6 irrigation's	Less than 4 irrigation's
EC drip	3.0 - 3.3 mS/cm	3.3 - 3.5 mS/cm
EC slab	3.5 - 4.5 mS/cm	4.5 - 6.0 mS/cm
24 hr Drain	20 - 30%	10 - 20%
Irrigation volume	Morning: 350 - 450 ml/m² Afternoon: 300 - 400 ml/m²	400 - 500 ml/m²
ml/joule	2.8 - 3.2 ml/J	2.5 - 3.0 ml/J
Night irrigation	No	No

Table 8.0:
Typical strategy for steering tomato plant development in Phase 6.
Note data values are specific to GT Master.

Summary

The 6 Phase model is accepted worldwide as a method of describing crop development. Using this framework growers and consultants can plan strategies in climate and root zone over the duration of the cropping cycle. Having long term objectives facilitates better decision making in short term when reacting to daily changes in weather conditions.

In the next article I will describe how to interpret information from the GroSens system (substrate WC / EC) and using specific examples how this can be used to implement a sound irrigation management strategy with the aid of a climate computer to achieve short term objectives within the root zone.

About the author
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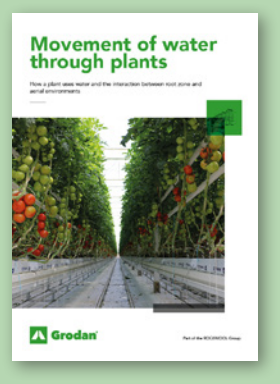

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