Crop Steering Irrigation

with GrowControl™ Cultivation Control Systems

REV 11/23

Introduction

Crop Steering is the practice of controlling the agricultural growing conditions in a specific way to induce either a “vegetative” or a “generative” response from a crop. Growing conditions include environmental factors such as temperature, humidity, lighting and CO_2 concentration, in addition to root zone factors such as soil temperature, moisture levels and nutrient concentrations in the water supply and media.

Vegetative periods are designed to promote root and foliar growth while generative periods are designed to promote fruiting and flowering growth. By implementing a pattern of vegetative and generative periods through a crop cycle, the crop can be “steered” to seek the desired responses from the crop.

Correctly implementing the set points, patterns, and timing of these periods can lead to significant benefits in crop yield and quality as well as reduced costs through improved irrigation efficiency. Agrowtek’s control systems manage all aspects of crop steering including environmental, lighting and irrigation parameters.

Contents

Glossary of Terms

Terms in this manual that are specific to Crop Steering Irrigation and GrowControl™ systems.
These terms are explained in more detail through out the application note.

Dry Back: A reduction in VWC typically referenced from the highest VWC achieved as a result of an irrigation event. For example if VWC has risen to 50%, a dry back of 3% VWC would be achieved at 47% VWC.

Percent Dry Back: Typically referred to as "overnight dry back," this is a percentage of change in the VWC from the start of the P3 phase to the end of the P3 phase. For example, a 10% Dry Back from a 50% VWC would be a change of 5% VWC.

P0, P1, P2, P3: Phases of irrigation through a 24-hour period starting with Phase 0 (P0) at lights-on.

Shot Size: Amount of water that is dispensed during a single irrigation event. Shot size is typically expressed in units of %VWC and references a "1% shot time" which tells the system how much time to irrigate for in order to dispense the equivalent of 1%VWC.

VWC: Volumetric Water Content (VWC, %) is the ratio of water volume in a growing media to the total volume of the growing media. For example, a 1 gallon pot of soil containing 1/2 gallon of water would have a VWC of 50%.

Field Capacity: The maximum %VWC that a media can hold without after being saturated and run-off allowed to drain.

Run-off: The excess amount of water (%VWC) that drains out of the media and is not taken up by the plant.

Vegetative Steering: A set of environment conditions that are designed to promote root and foliar growth.

Generative Steering: A set of environment conditions that are designed to promote fruiting and flowering growth.

Hydrophobic: The tendency of a material to repel water rather than hold or absorb it. Rockwool material is at risk of becoming hydrophobic if allowed to dry out excessively.

EC: Electrical conductivity (EC) is the measure of electricity's ability to flow through a material. This measurement provides an indication of the nutrient or salt and mineral content within a liquid or media. The higher the conductivity, the more salts that are present in solution.

Function: Controls (control functions) tell the control system what to do. The user adds the desired control functions to the controls workspaces and then configures rules within the functions.

Output: A physical output (relay contact, dosing pump, etc.) that the system can operate from a control function.

Rule: A rule exists within a function. Many rules can be created within a single function in order to provide different set points through out the day or through out the growth cycle.

Equipment for Irrigation Control

Controlling irrigation with modern steering techniques requires precision sensors and programmable valve controls to synchronize irrigation events according to recipes and schedules.

Soil moisture sensors are required to read the crop media conditions such as volumetric water content (VWC) and electrical conductivity (EC.) The sensor readings and recipe parameters are used by the system to automatically operate the irrigation valves. Recipes and schedules can change on demand or as programmed according to crop cycle requirements.

Typical equipment for crop steering includes a control system such as the GrowControl™GCX, sensors such as the Teros 12, and irrigation valve controllers such as the VX8i Valve Controller.

A minimum of one (1) moisture sensor is required for each irrigation zone valve that will be controlled.
Up to three (3) sensors can be averaged together per valve.

Moisture Sensors
A high quality moisture sensor is key to succesful crop steering; the Teros 12 sensor by Aroya® is well known as an accurate and reliable sensor that provides VWC, EC and temperature data. Moisture sensors are connected into the GCX system with the "HXT" Teros Sensor Hub. The HXT hub is plug and play allowing up to 8 sensors to be connected through a single RJ-45/Cat5 cable connection.

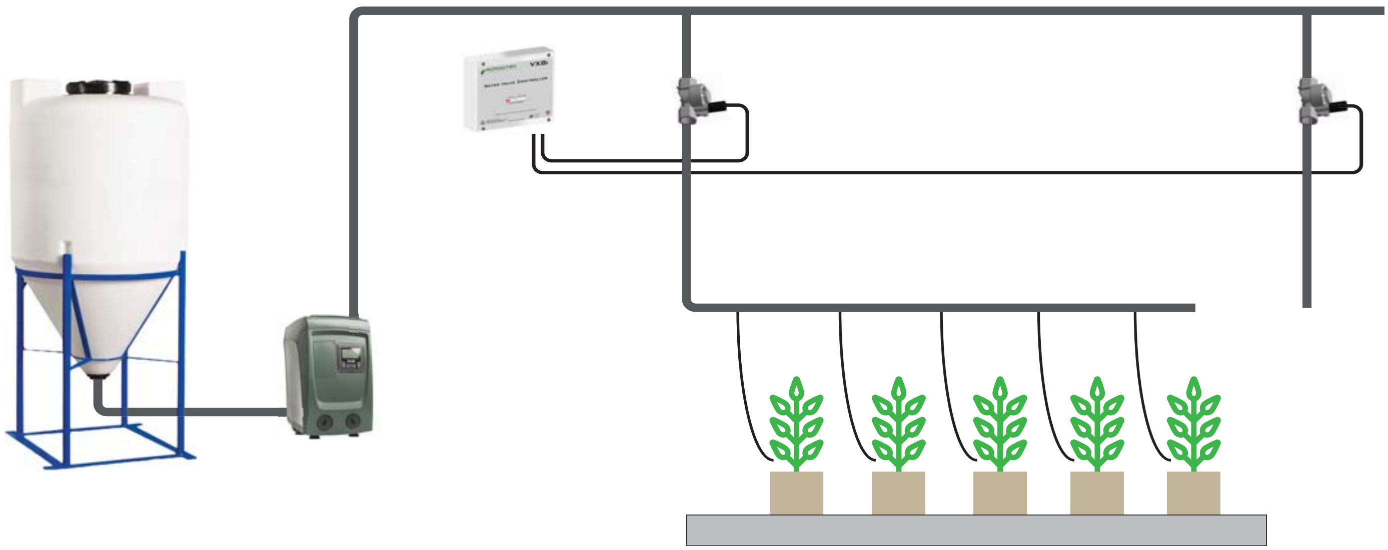
HXT Teros Sensor Hub

Teros 12 Sensor

Irrigation Valve Control

In most applications water is supplied to irrigation zones from a stock tank of mixed water using a transfer pump and irrigation valves. A pressure controlled pump (such as DAB or Grundfoss, for example) can be plumbed to one or more irrigation valves such that the pump will activate automatically when any of the valves open.

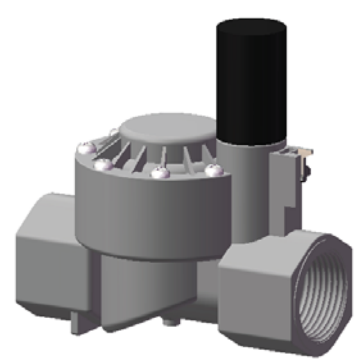
Pumps can also be manually controlled with a relay contact if the model is not pressure sensing.



Operating the irrigation valves requires available outputs on the control system. Any type of discrete (on/off type) of output can be used to operate a valve. The most common models for irrigation valve control include the VX8i valve controller or dry contacts in a RD8i relay.

VX8i Irrigation Valve Controller

WX Series Irrigation Valves



VX8i valve controllers can operate up to eight (8) irrigation valves from the GrowControl™ GCX controller. VX series controllers can operate any standard 24VAC irrigation valve or two-wire (auto closing) ball valve. VX valve controllers include a power supply to operate the valves.

Sensor Placement

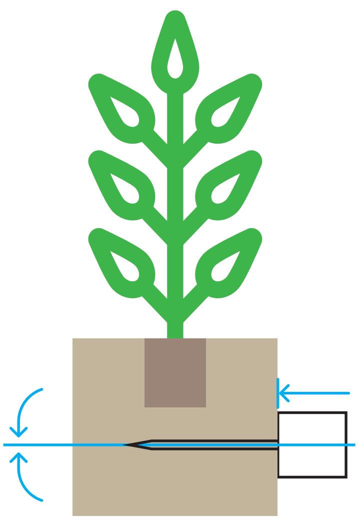
Proper sensor installation is critical to achieve accurate readings. A sensor alignment tool is recommended for consistent location and level installation of the sensor.

1. Place the alignment tool against the side of the media block or container.
2. Push the sensor straight into the media ensuring the spikes are entering level.

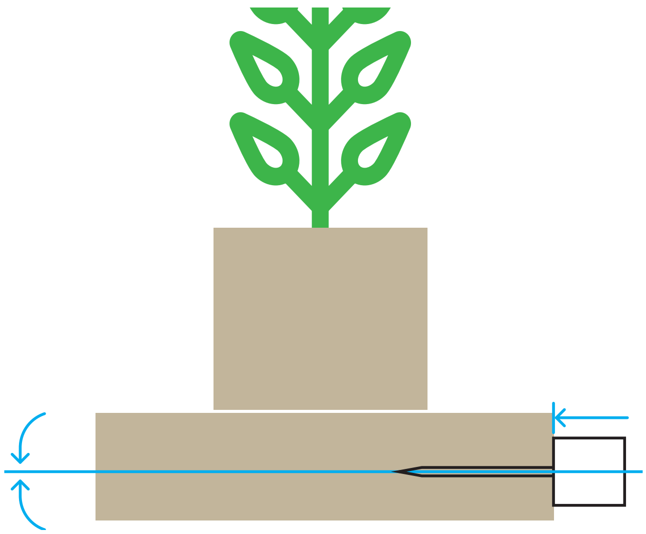
Note: Avoid wiggling the spikes during installation as this creates air gaps between the media and spikes resulting in inaccurate sensor readings.

3. Remove the guide tool and push the sensor flush against the media container.

Avoid moving the plant and sensor to keep the contact between the sensor needles and media consistent. Avoid penetrating the plug hole with the sensor spikes.



Single Cube or Soft Pot



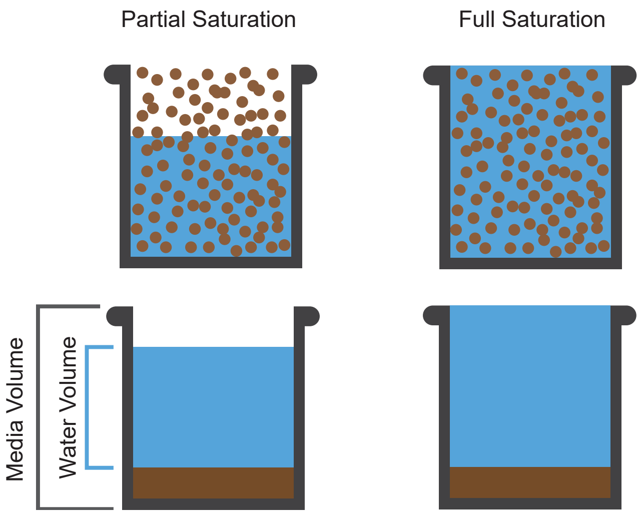
Cube on Slab

Crop Steering Theory

The Crop Steering irrigation method is a popular technique that drives plant activity in part by carefully controlling the moisture levels (volumetric water content, or VWC) of the growing media through various phases of the day and night. This is done using irrigation drippers with a known flow rate, and feedback from media moisture sensors. The sensors allow the system to monitor for "dry back" of the media providing the ideal times to irrigate.

Volumetric Water Content

It is important to understand how volumetric water content (VWC) is measured and what the value is describing. VWC is the ratio of the volume of water in a container to the total volume of the container. VWC is expressed as a percentage.



VWC % = (Water Volume / Media Volume) x 100

The volume of the growing media is based on the dimensions of the media (cube size) or pot volume.

The diagram to the right depicts a container in partial and full saturation visualized to show the ratio concept.

Why doesn't VWC read 100% when wet?
Consider a 1 gallon pot full of soil as depicted in the diagrams above. Water can be added to the soil until all of the air space in the soil is replaced with water, but the soil is still there. Because there is soil in the pot, there can never be 100% water in the pot.

Irrigation Shots

Irrigation "shots" are sized to provide a specific increase in VWC. Shot sizes are specified in percent of the media volume. An irrigation shot of a specific percentage should result in an increase in the VWC reading by an approximately equal amount.

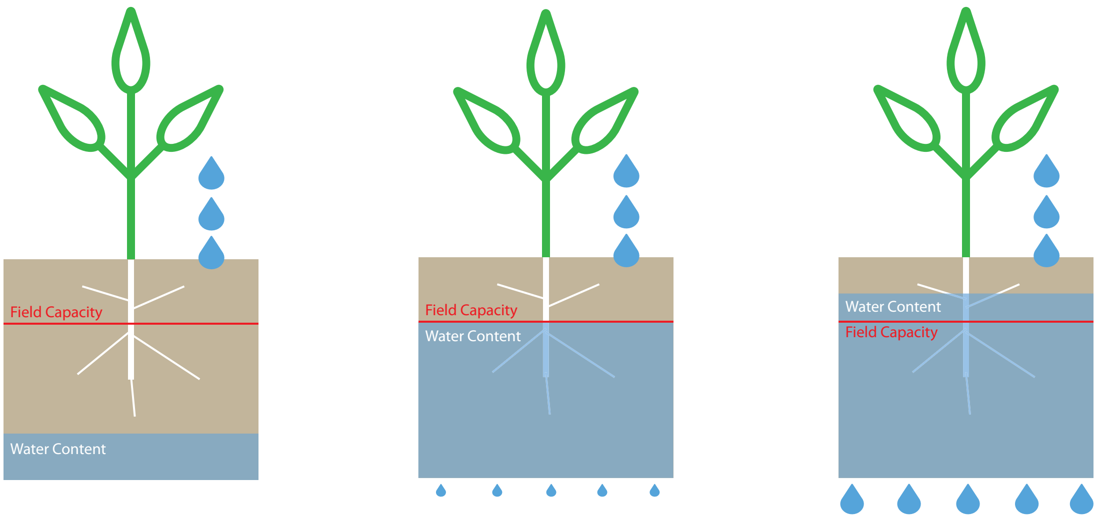
In order for the control system to be able to irrigate shots according to a percentage value, it must be told how much time a 1% shot is equal to. This is referred to as the "1% Shot Time." Using this value, the controller will be able to operate the irrigation valves for the necessary durations according to the shot sizes in the crop steering recipe.

Determining the "1% Shot Time" requires knowing the media volume and the flow rate of irrigation water to the media. Irrigation drippers are sized for a specific flow rate and pressure range. Pressure compensating emitters are recommended to ensure even water distribution across the crop.

Leachate (Run-Off)

Leachate, commonly referred to as "run-off," is excess irrigation water that is not retained by the growing media. When a media reaches field capacity it can not store any additional water without "overflowing." Excess water will pass through the media and drain as "run-off."

Run-off should typically not occur until media reaches field capacity. Run-off prior to reaching field capacity can indicate channeling through the media. Channeling can occur from irrigation events occurring too frequently during ramp-up or from damaged, hydrophobic media.



Testing Leachate

Monitoring run-off volumes can ensure that target run off levels are being achieved. Adding sensors to monitor pH and EC of the run-off can provide additional insight. EC sensors can assist with validating moisture sensor EC readings or analyzing nutrient losses in run-off water. Monitoring changes in pH between input and run-off can indicate either over or under feeding of the crop.

Agrowtek has options for sensors to monitor the run-off water for pH, EC, temperature and volumes. The standard SXH hydroponics sensor (right) monitors and logs all of these parameters. Probes can be mounted inline in piping or in a drain-line sample pot.

Calculating % Run-off

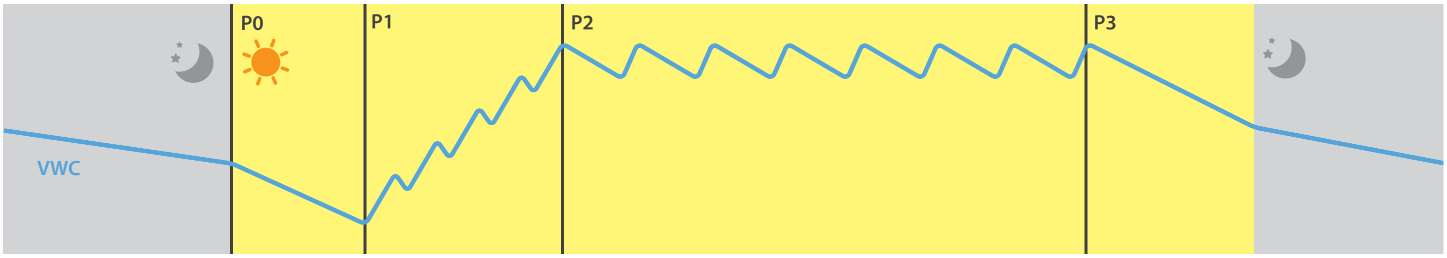
If run-off volumes are monitored, the percent run-off can be calculated using the total irrigation volume and run-off volume.

$\% \text{ Run-off} = (V_{\text{run-off}} / V_{\text{irrig}}) \times 100$

For Example: Irrigation Volume = 10 gal, Run-off = 1.5 gal
% Run-off = (1.5 / 10) x 100 = 15%

Irrigation Phases

Irrigation recipes define parameters for four distinct **"phases"** through a 24-hour period; these phases are referred to as P0 (P zero) through P3. Each phase has specific objectives and, consequently, different settings within irrigation recipes for each phase.



P0 - Activation
The P0 phase begins at lights-on. No irrigation events take place in the P0 phase which typically lasts 1-3 hours. The goal is to observe an "additional dry back" in the media as the plant activity increases. The plants should begin transpiring before initiating irrigation events; a more aggressive drop in VWC suggests that the plants are taking up moisture from the media.

P1 - Ramp Up
The P1 phase is a transition phase between minimum VWC and the target saturation level for the media. Ramp up is achieved by applying specified shot volumes to the media and allowing for a specified 'dry-back' amount between irrigation shots. The cycle is repeated until the target is reached (or time limit is exceeded.) The goal is to reach saturation and achieve run-off within 1-3 hours of P1 start.

P2 - Maintenance
Once the target VWC is reached (or P1 times out) the maintenance phase is entered. In the maintenance phase the media is "maintained" in a more level irrigation pattern. In generative recipes the shot size typically equals the dry-back setting, while vegetative recipes often feature a shot size larger than the dry-back setting to promote higher levels of run-off.

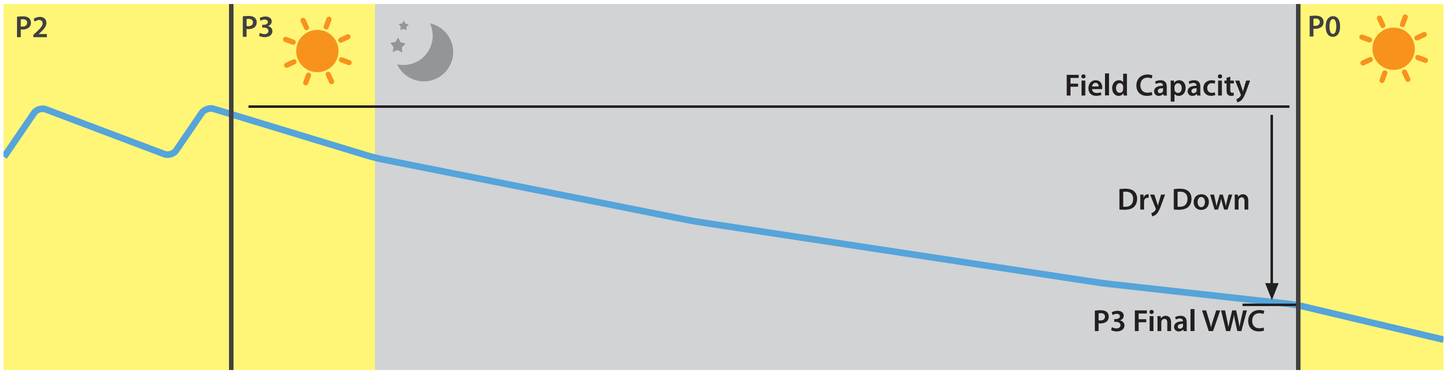
The goal of the maintenance phase is to maintain the moisture level at or near field capacity until 1-2 hours before lights-off. Timing the end of the P2 phase correctly plays a significant role in achieving the desired dry down in P3.

P3 - Dry Down (Overnight Dry Back)
The P3 phase typically begins 1-2 hours before lights-off and continues overnight until the start of the P0 phase the following day. The goal of the P3 phase is to achieve a specific "overnight dry-back," or dry-down of the media. Ideally, no irrigation is necessary during the P3 phase, however, small shots may sometimes be necessary to ensure minimum moisture levels are maintained or maximum EC levels are not exceeded.

Overnight Dry Back

The P3 phase is referred to as the "dry down" phase in GCX systems; otherwise known as the "overnight dry back" period. During this period of time irrigation has been paused and the media is drying down.

The P3 phase typically begins 1 - 2 hours before the end of the day period. Timing of the end of the P2 phase and subsequent transition to the P3 phase is a key factor in achieving the desired overnight dry back.



It is important to understand that the irrigation system does not directly control the P3 dry-back. This value must be observed and recipe parameters adjusted.

The most common adjustment made to the irrigation parameters is when irrigation ends for the day. End irrigation sooner if dry-back targets are not reached and the media remains too moist at the end of the P3 phase. Conversely, if minimum irrigation shots are required during the P3 phase due to minimum moisture levels in the media, extend the irrigation duration to end closer to the beginning the P3 phase.

Parameters that affect the P3 overnight dry-back include:
- Phase of crop growth
- Media type and volume
- Irrigation timing, frequency
- Duration of daily irrigation window (when irrigation stops)
- Room conditions including temperature and humidity

Calculating the P3 Final VWC

If P3 dry-back is specified in terms of a percentage of the media's field capacity, the final P3 VWC target can be caluclated using the formula:

P3 FinalVWC = FieldCapacity x (1 - DryBack%)

For Example: If the maximum field capacity of the growing media is 70% VWC and a P3 dry back of 15% of field capacity is desired, the final VWC in P3 would be calculated as follows:

P3 FinalVWC = 70 %VWC x (1 - 0.15) = 60 %VWC

Vegetative vs. Generative

Vegetative recipes are designed to promote root and foliar growth while generative recipes are designed to promote fruiting and flowering growth. By implementing a pattern of vegetative and generative periods through a crop cycle, the crop can be "steered" to seek the desired responses from the crop. These responses can include changes in internodal spacing and foliar density.

The chart below is a general guide for parameter ranges in vegetative vs. generative recipes. The exact values used in your recipes will vary based on conditions and experience or trial and error.

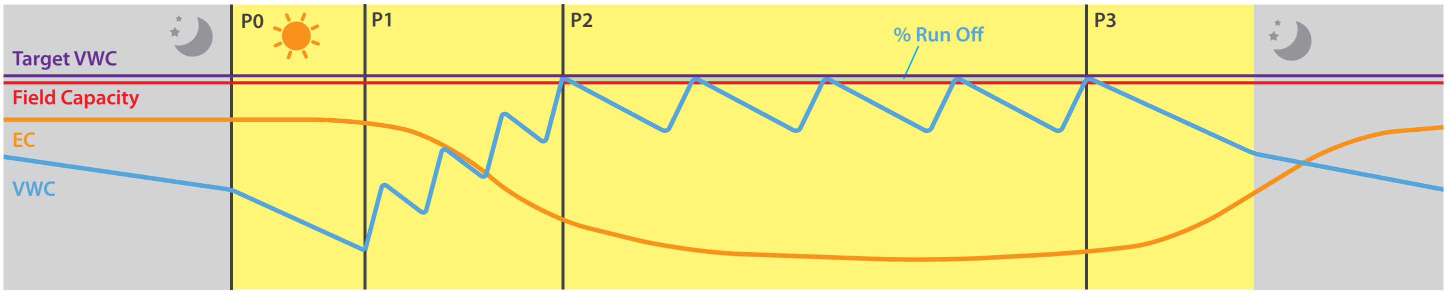
	Vegetative	Generative
P0 Dry Back	2 - 4 %VWC	4 - 6 %VWC
P1 Shot Size	3 %	4 - 8 %
P1 Dry Back	1 %	2 - 3 %
P1 Shot Frequency	Less than 30 minutes	Greater than 30 minutes
P2 Target VWC	55 - 70 %VWC	25 - 75 %VWC
P2 Shot Size	1 - 3 %	4 - 8 %
P2 Dry Back	1 - 3 %	4 - 8 %
P2 Last Shot	1 - 2 Hours before lights off	1 - 2 Hours before lights off
P3 Dry Back	10 - **15** % of Field Capcity	20 - **30** % of Field Capacity
Media Temperature	Warmer	Cooler
EC	Lower	Higher

Conductivity (EC) response will vary depending on the irrigation phase and recipe type. In general, generative recipes will result in less run-off and higher EC build up in the media while vegetative recipes will be result in more run-off and a lower EC due to flushing.

ℹ Caution must be used when transplanting or rooting. Excess moisture levels can inhibit root growth.

Generative Recipes

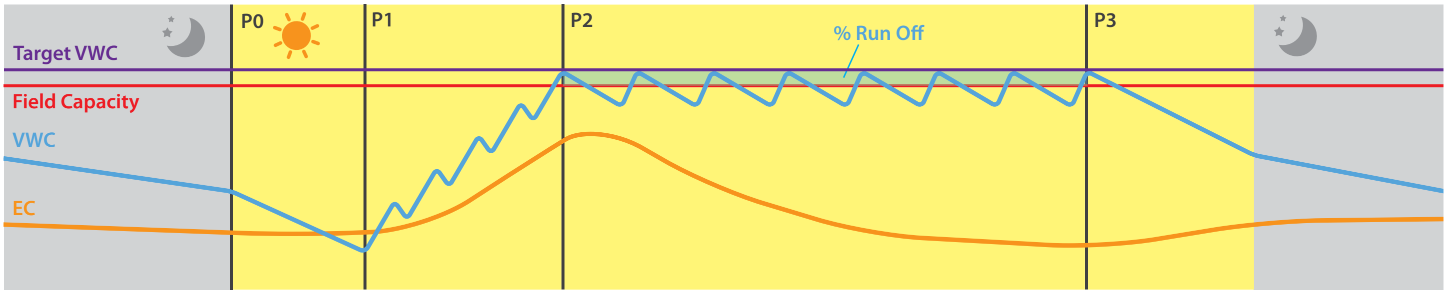
Generative recipes maintain lower VWC levels and higher typical EC levels to induce stressors and promote a strong flowering/fruiting response. Consequently, generative recipes will have minimal run-off with the VWC target typically at or below the field capacity of the media. P1 shot sizes are larger and less frequent with a larger dry back.



P2 shot sizes are typically equal to the P2 dry back setting in generative recipes. Equal shot size and dry-back coupled with a VWC target at or below field capacity results in low run-off and higher EC.

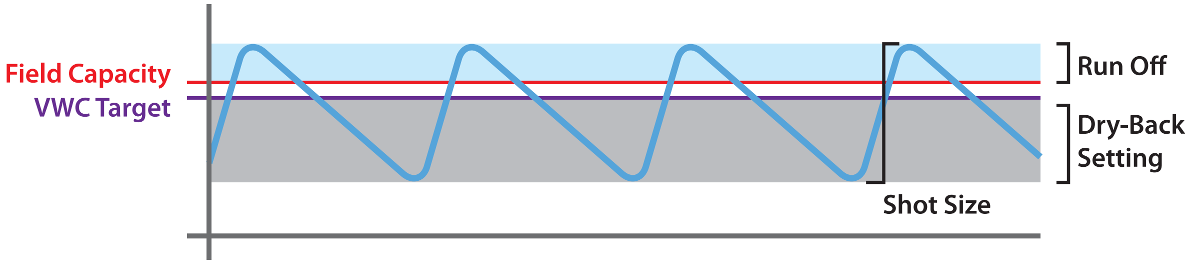
Vegetative Recipes

Vegetative recipes maintain higher VWC levels and lower EC levels to reduce plant stressors and promote vigorous foliar growth. As a result, vegetative recipes will typically have a VWC target at or above field capacity for higher run-off. P1 shot sizes are smaller and more frequent with a smaller dry back. P2 shot sizes are typically equal to or greater than the P2 dry back setting.



P2 Super Saturation

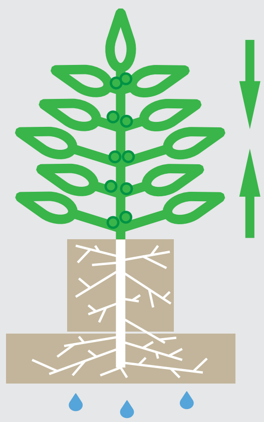
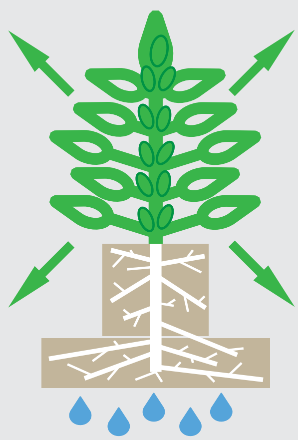
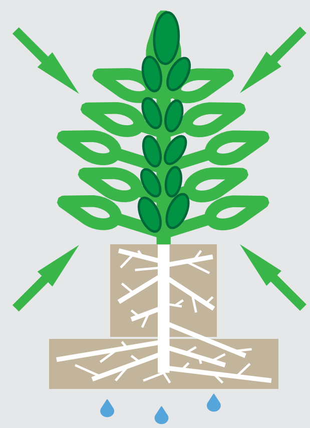
A P2 shot size greater than the P2 dry-back allows (or guarantees) a specific run-off. In cases where media has trouble reaching field capacity, target VWC can be set below the field capacity allowing reliable transition from P1 to P2 before reaching field capacity while still providing desired run-off rates in P2.



ⓘ *The system calculates the P2 dry back from the VWC target even if the VWC exceeds the target.*

Scheduling Recipes

It is suggested to create four standard irrigation recipes which are scheduled through the crop cycle. The chart below describes the recommended stages of irrigation steering for a flowering crop. The recipes may be named Vegetative 1, Generative 1, Vegetative 2, Generative 2, or any other convention.

Week		1 - 3	4 - 6	7 - 9
Lights	18 / 6	12 / 12	12 / 12	12 / 12
Recipe	Vegetative	Generative	Vegetative	Generative
Objective	"Stretching"	"Stacking"	"Bulking"	"Densing"
				
Run-off	Higher	Lower	Higher	Lower

Stretching
In the "stretching" phase the crop is growing vegetatively in a longer light cycle with higher access to water and warm, humid conditions. The crop should grow vigorously and stretch out with large internodal spacing. In early stages

Stacking
The "stacking" phase switches to a generative recipe in the first three weeks of flower production to increase foliar density and build a 'foundation' for the crop to build on. Inducing stress in the plant at this stage can result in production of more flower bud sites and tighter node spacing.

Bulking
Returning to a vegetative recipe mid-flowering promotes a "bulking" response allowing the crop to rapidly produce mass. Lower EC and and higher moisture allows crops take up water and transpire more easily.

Densing
The final weeks again return to a generative recipe to promote increased density and ripening of the crop.

Media Tips

Media Type & Dry Back

Substrates with higher field capacities will require less frequent irrigation events for a similar volume resulting in a more generative pattern. Media with a lower capacity will require more frequent irrigation cycles resulting a more vegatative pattern. Similarly, a larger volume of substrate will require less frequent irrigation while smaller volumes will require more frequent irrigation cycles.

Determining Field Capacity

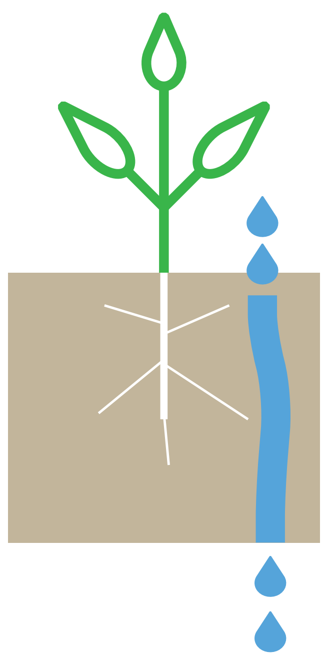
If field capacity is not provided by the manufacturer or is not known, it can be determined with a moisture sensor and basic saturation test. Install the sensor and fully saturate the media either by soaking or manually irrigating to the point of heavy run-off. When run-off ceases, the media is at field capacity and the sensor VWC reading can be recorded.

Media Minimum VWC

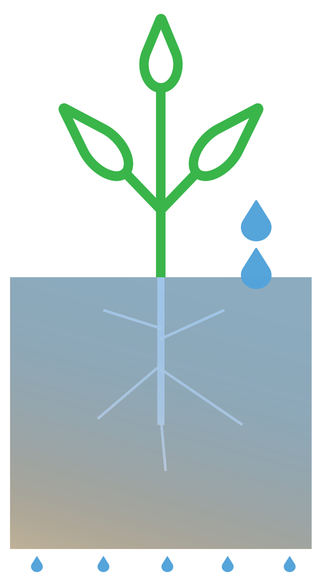
Some media must be always be maintained within a minimum and maximum VWC or the media can be damaged and the field capacity reduced. Rockwool material is particularly vulnerable to over drying which can result in the media becoming "hydrophobic," or water repellant. Instead of the media absorbing the irrigation water, it channels and passes mostly through the media resulting in high levels of run-off and failure to properly raise the VWC of the media. Ensure rockwool material is never dehydrated beyond the manufacturer's use recommendations. *See common problems for more information.*

Media Saturation & Channeling

Irrigation shots must be sized and supplied in a controlled manner to allow the water to absorb and saturate the media without forming "channels" in the media. Channeling casues water to flow in a "river" through the material rather than being absobed; this results in excess run off and failure to increase VWC as expected.



Irrigation water channeling through media; excess run-off and low VWC.



Irrigation water saturating media evenly; proper run-off and VWC.

Common Problems

Crop steering irrigation techniques require some trial and fine tuning when setting up any new facility, new media, or other change in farm variables.

Overdrying, Hydrophobic Media

The most common mistake is allowing the media to dry out below the recommended minimum moisture content according to the media manufacturer. This leads to inability to reach field capacity and leads to channeling of water through the media. If media has become hydrophobic try to re-saturate it either by soaking, or with excessive irrigation. If the field capacity is unable to be attained, a wetting agent may be required to restore the field capacity of the media.

Media Quality

Not all media are created equal and some will have a higher field capacity than others. Refer to the manufacturer's specifications.

Sensor Placement

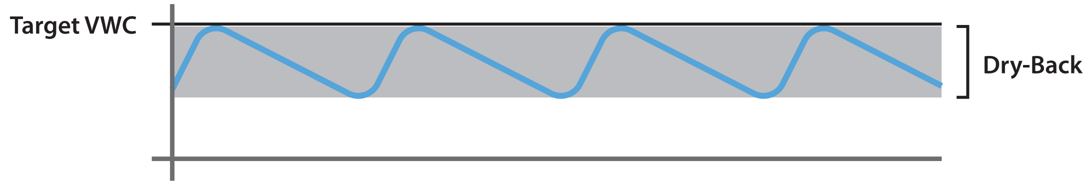
Ensure the sensor installation instructions are followed and the sensor alignment tool is used to install the sensor correctly. Ensure the sensor spikes do not penetrate a void or opening in the cube. Poor sensor placement will result in inconsistent sensor readings.

Irrigation Consistency

Quality drippers and correct irrigation system design are critical to ensuring consistent irrigation to a crop. Pressure compensating emitters and pressure equalization loops are recommended. Consult with an irrigation specialist or contact Agrowtek for help finding irrigation assistance.

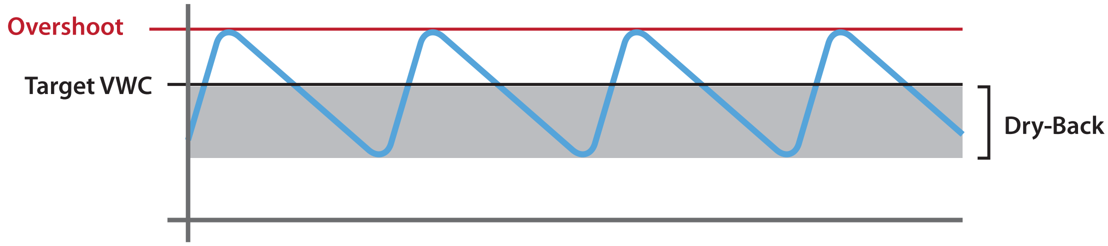
P2 Troubleshooting

The P2 "maintenance" phase is designed to maintain the VWC between the P1 target value and the dry-back amount. Correct maintenance cycles depend on the settings being applied correctly. The 1% shot time is set correctly when an irrigation shot results in 1% VWC change. During maintenance, it is suggested to size shots equal to the dry-back amount and should result in cycles that return the VWC to the target value after dry-back.



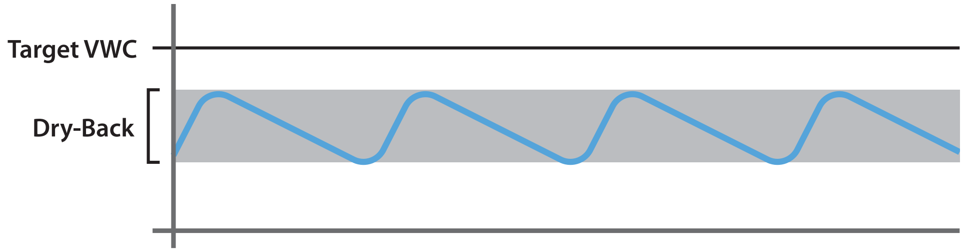
Undesired VWC Overshoot

If P2 maintenance cycles are overshooting the target value significantly, then the 1% shot time may be too long. Errors in the shot time can be due to incorrect dripper flow rates or media volume measurement. Correct the shot time or reduce the shot size in the P2 phase.



Saturated Media

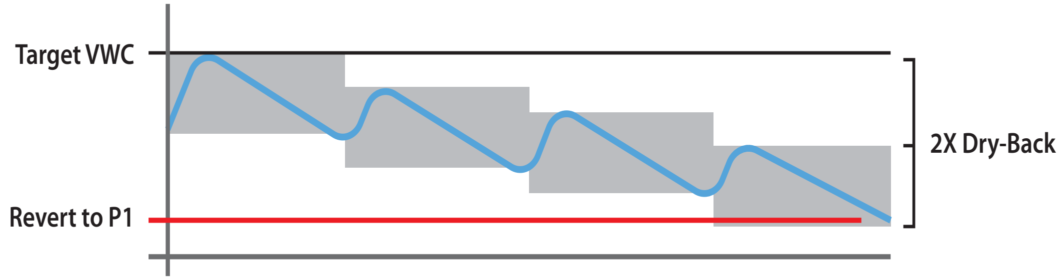
If P2 maintenance cycles are not able to achieve the desired target value, the media may already be fully saturated and unable to take on additional water content. The result is excess run-off which may be desirable in some circumstances but in most cases wastes water. Excess run-off or failure to reach field capacity may also be due to media (rockwool) being allowed to dry out excessively causing it to become hydrophobic.



Insufficient Feeding

If the 1% shot time is too short then the irrigation cycles will not be able to rehydrate the media after a dry back. If P2 maintenance cycles are not able to restore the VWC after a dry-back period and the VWC continues to fall due to lack of water, the function can revert to P1 phase in an attempt to restore the VWC level.

Allow Fallback to P1: Function reverts from P2 to P1 when VWC has fallen below the target by double the dry-back setting if "allow fallback to P1" is enabled in the recipe.



Calculating the 1% Shot Time

The 1% shot time can be calculated manually using the formula and steps below.

$$T = (3600 \times V_{1\%}) / (Q \times 231)$$

T = 1% Shot Time (seconds)
$V_{1\%}$ = Media Volume, $in^3 \times 0.01$
Q = Emitter Flow Rate (gal per hour)

1. Calculate the Volume (V = L x W x H)
   4 x 4 x 3 in cube = 48 in^3

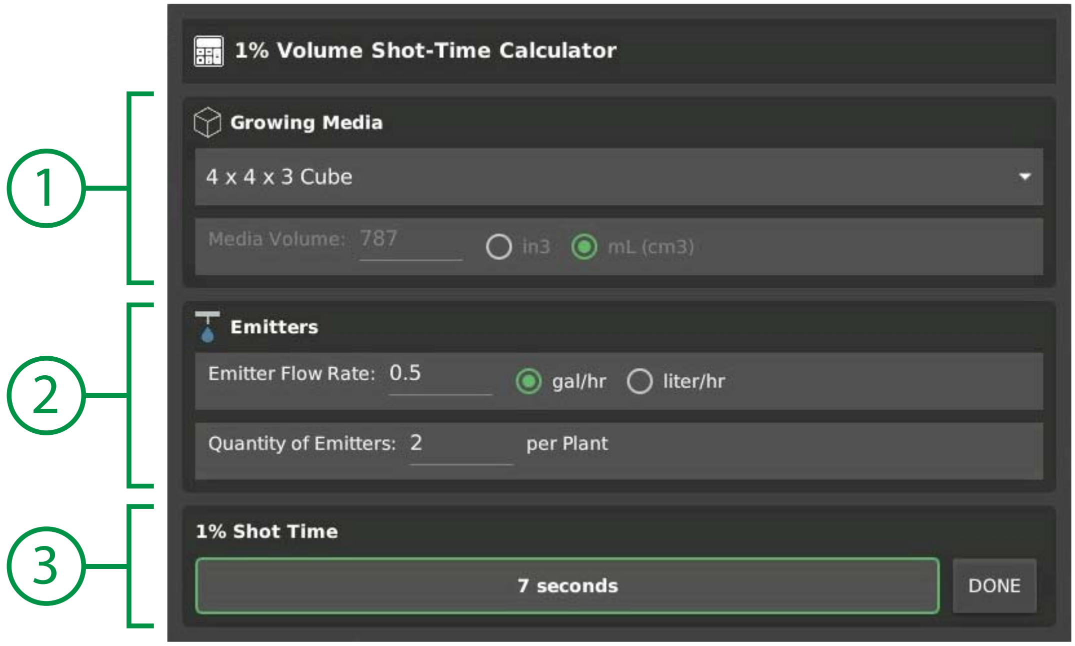
2. Calculate 1% Volume ($V_{1\%}$ = V / 100)
   48 in^3 / 100 = 0.48 in^3

3. Calculate the 1% Shot Time (example: Q = 0.5 gph emitter)
   T = (3600 x 0.48 in^3) / (0.5 gph x 231)
   T = 15 seconds

4. Divide by the number of emitters: (example = 2 emitters)
   T = 15 / 2
   T = 7 seconds

1% Shot Time Calculator

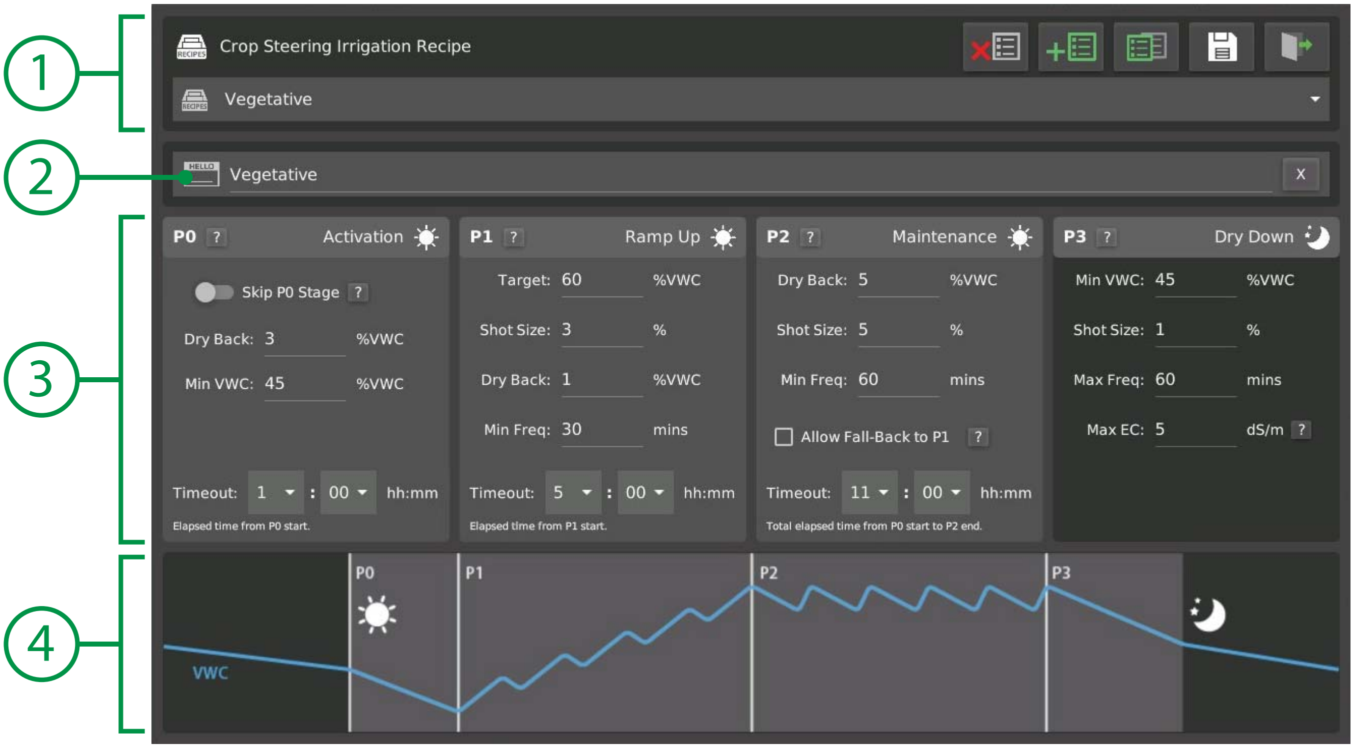
GrowControl™ GCX control systems feature an 1% shot time calculator to assist with this calculation. The calculator has a number of pre-configured common media selections, or a custom media size can be specified.



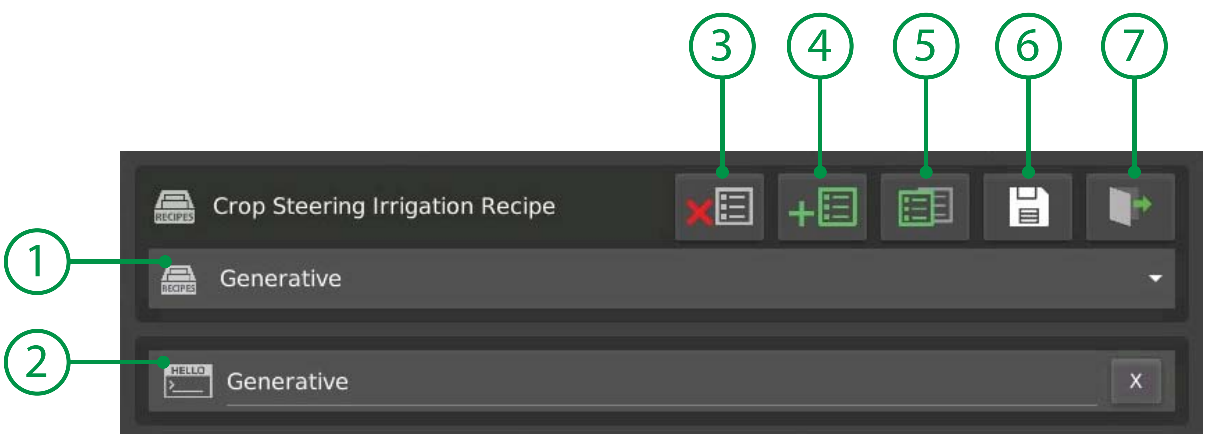
1. Media Selector	Use the drop-down to select a standard media type or enter a custom value.
2. Drippers/Emitters	Enter the flow rate and number of drippers per plant.
3. Result	The shot time is automatically calculated based on your inputs. *Press the DONE button to exit and set the value in your function.*

GCX Irrigation Recipes

Open the irrigation recipe editor dialog by pressing the “Recipe Editor” button in the Crop Steering function. Recipes that are created and edited in this dialog can be used in any crop steering function on the controller.



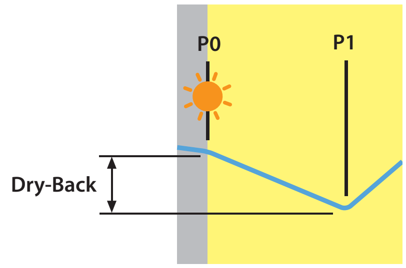
1. Editor Heading	Contains a drop-down menu to select a recipe and various button commands. *Delete, New, Copy, Save, Exit*
2. Recipe Name	Edit the recipe name by touching on the text field. *Use the X button to erase the text field.*
3. Phase Settings	Settings for the various P phases in the recipe.
4. Example Graphic	Depicts a generic graphic of the media moisture through the various phases.



1. Recipe Selection	Drop-down menu to select a recipe.
2. Recipe Name	Edit the recipe name by touching on the text field.
3. Delete Recipe	Deletes the current recipe.
4. New Recipe	Creates a new recipe from scratch.
5. Copy Recipe	Copies the current recipe to a new one.
6. Save Recipe	Save the changes to the current recipe.
7. Exit	Close the editor dialog.

The recipe editor provides four grouped areas to configure the settings for each of the irrigation phases. Each area has a heading describing the phase. Phases P0, P1 and P2 each have a "timeout" area at the bottom of the phase settings. Timeout settings ensure that irrigation phases do not get stuck if a set point can not be achieved or if there is some sort of sensor reading problem. P0 and P1 time outs can be set to zero to ignore the time out, however, the P2 timeout is required to time the "irrigation window" and end irrigation events at the appropriate time.

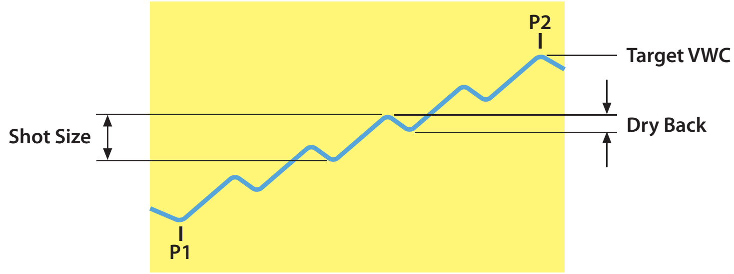
P0 - Activation



During the P0 phase no irrigation occurs. The function looks for an "additional dry-back" to indicate that the plants have begun the transpiration process before switching to the P1 phase to begin irrigation. A time-out is provided to switch to P1 in the event dry-back is not achieved in the allotted time.

A minimum VWC can be configured to end the P0 phase if the VWC is at or below the minimum setting. This prevents the possibility of dry-back below a minimum desired value in the P0 phase.

P1 - Saturation



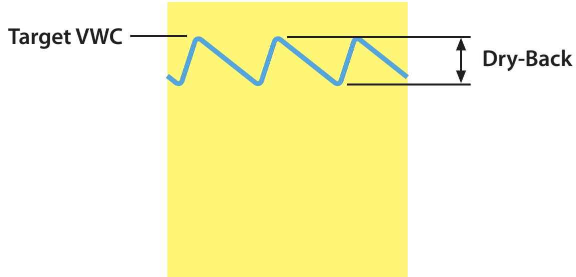
During the P1 phase the function irrigates in shots to raise the VWC of the media to a target value. Between each shot the media is allowed to "dry back" by a specified VWC before peforming another shot.

A minimum shot frequency can be configured to ensure irrigation in the event of a sensor malfunction.

TIP: To prevent shots at minimum intervals, set the minimum frequency time to zero.

A phase time out allows the function to automatically switch to P2 after a specified time out. The P1 phase timeout counts from the start of the P1 phase.

P2 - Maintenance



During the P2 phase the function irrigates in shots to maintain the target VWC after a dry-back period. In the maintenance phase the shot size is typically set equal to the dry-back amount, but may be set differently.

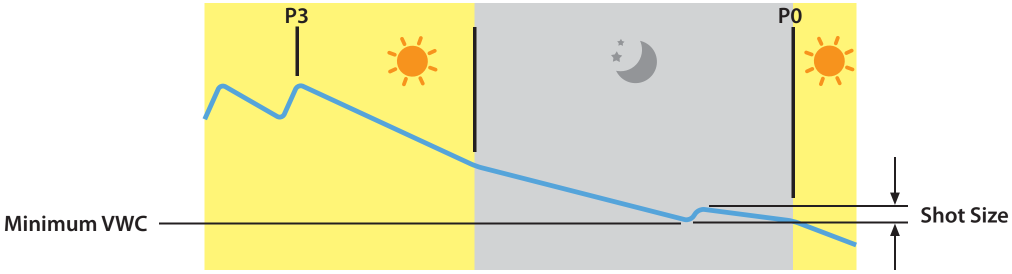
A minimum shot time can be configured to ensure adequate irrigation in the event of a sensor malfunction.

TIP: To prevent shots at minimum intervals, set the minimum frequency time to zero.

A time out is required to switch the function into the P3 phase.
P2 timeout begins counting at the start of P0 (or P1 if P0 is skipped.) This allows the function to enter the P3 phase at a set time from when P0 begins. P3 should typically begin 1 to 2 hours before lights turn off.
For example: a 12 hour light cycle would have a P2 timeout of 10 to 11 hours.

For additional details on the P2 phase please see the section "P2 Phase Troubleshooting."

P3 - Dry Down



The goal of the P3 phase is to achieve a "percent dry back" from field capacity. (See glossary.) Ideally no irrigation is required during P3, however, a minimum VWC can be set to trigger small shots to prevent excess dry back.

Irrigation can also be triggered in P3 by a high EC condition using the "Max EC" setting.
A maximum shot time can be configured to prevent excessive irrigation in the P3 phase.

NOTE: Percent dry-back, often referred to as "overnight dry back," is typically specified as a percentage of change in the VWC from field capacity to the end of the P3 phase.
For example: a 10% dry-back from a 50% VWC would be a change of -5% VWC.

TIP: Setting the shot size or maximum frequency to zero will prevent any shots during P3.

Rule Configuration

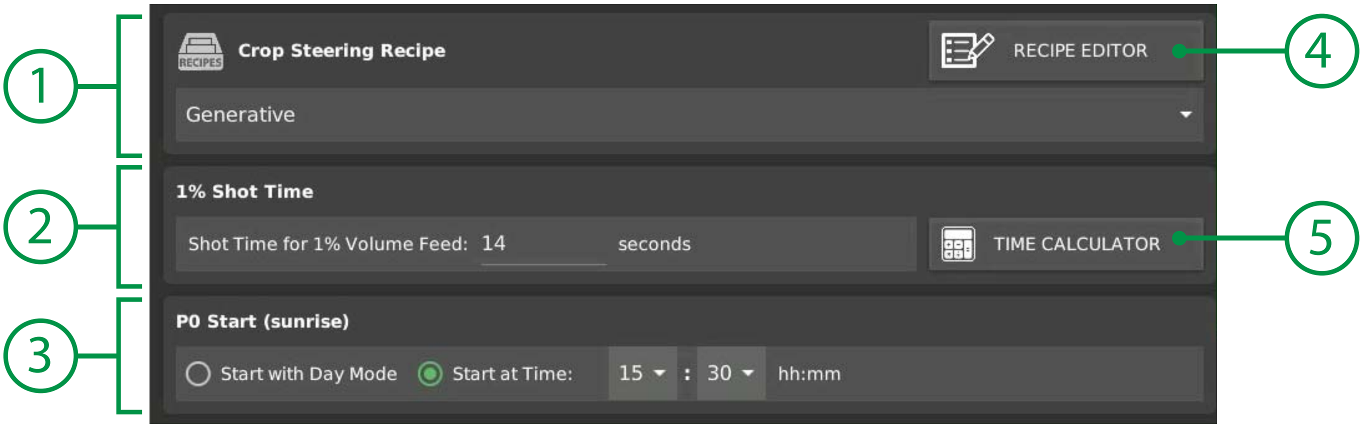
In the crop steering irrigation function, rules specify:

• Which recipe to use.
• What the 1% shot time is.
• When to start P0.

1% Shot Time
This is the amount of time it takes your drippers to provide a shot in the amount of 1% of the media volume. *If your cube is 4x4x4in (64 cu. in.) then it is the time it takes to deliver 0.64 cu. in. of water.*

TIP: Different recipes may require different 1% shot times depending on changes in media volume (repotting or adding slabs) during the growth cycle.

NOTE: If you are not sure what the 1% shot time is for your media and dripper combination, or you are not sure how to calculate it, use the Time Calculator to figure the shot time.



1. Recipe Selector	Use the drop-down box to select the recipe for the rule to use. *If you do not have a recipe available or to create and edit recipes, press the Recipe Editor button (4) to open the editor dialog.*
2. 1% Shot Time	Time required to dispense water equivalent to 1% of the media volume. *If you do not know the 1% time, use the Time Calculator (5) dialog.*
3. P0 Start Mode	Select if the P0 phase should begin with the workspace Day mode time, or with a custom set time of day (hh:mm).
4. Recipe Editor	Press to open the recipe editor dialog.
5. Time Calculator	Press to open the 1% shot time calculator dialog.

Equipment Configuration

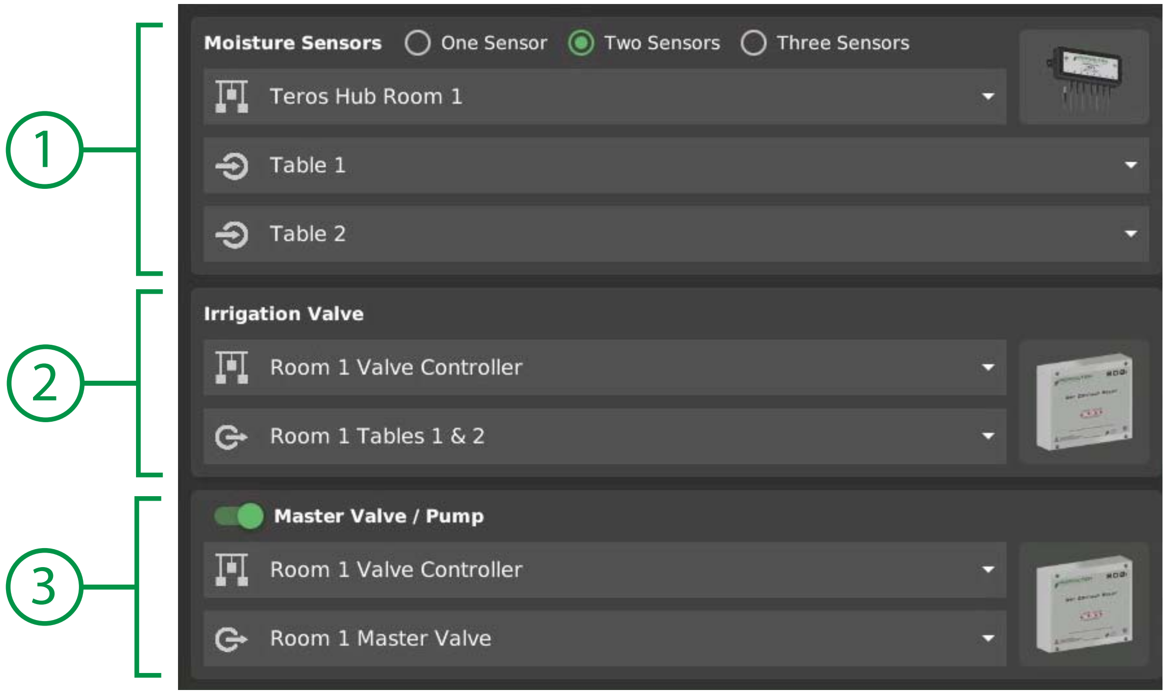
The equipment tab is where the sensors are specified and the valves are assigned for the irrigation shots. The assignments on the equipment tab apply to all of the rules created within the function.

Moisture Sensors

Up to three sensors from a single sensor hub can be averaged. Select the number of sensors to average, then select the hub device and sensor channels to monitor.

Valves

A zone valve and a master valve/pump output can be specified. Both output selections will operate simultaneously when an irrigation shot is required.



1. Moisture Sensors	Select one, two or three sensor inputs for the function to monitor, then select a sensor input device and the desired sensor input channels. *At least one moisture sensor is required to use this function.*
2. Irrigation Valve	Assign the primary irrigation controller and output channel that will operate irrigation zone valve for this function.
3. Master Valve/Pump	If a master valve or irrigation pump output must be operated in tandem with the irrigation zone valve, enable the option and select the valve controller and output channel to operate.

GrowControl™ Overview

GrowControl™ GCX Cultivation Control Systems can manage nearly every aspect of a facility's environment and water management with extensive and intuitive programming capabilities. Automated crop steering irrigation with moisture sensor feedback, HVAC, CO2, lighting control and more are all included in the GCX.

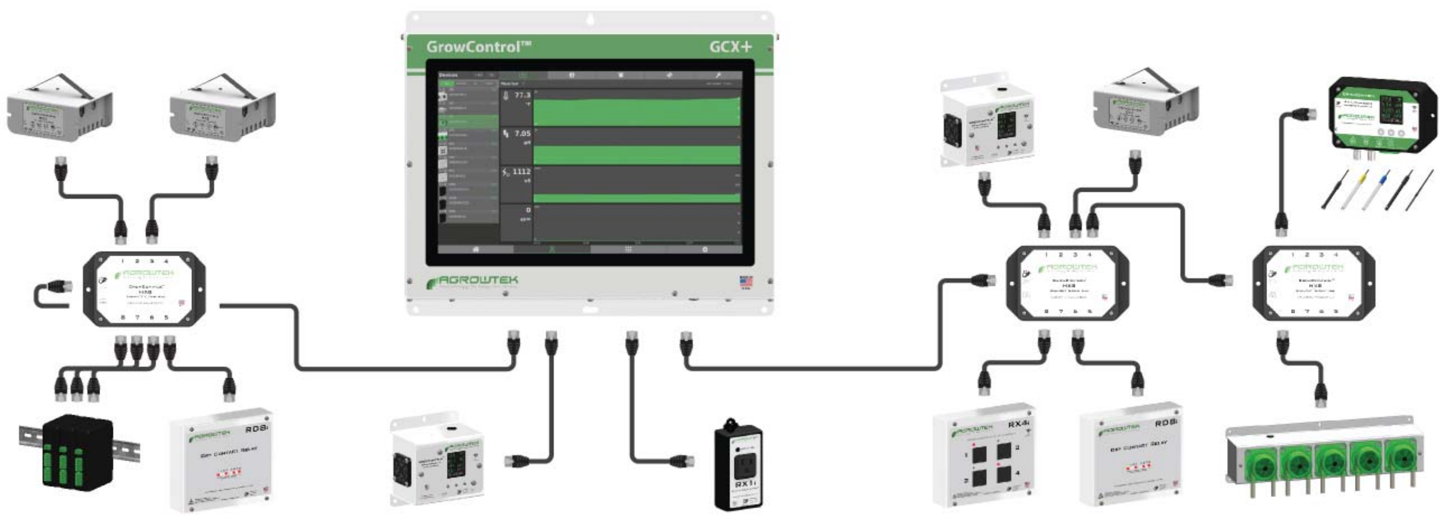
- High Reliability Industrial Technology
- Free Remote Monitoring & Control
- Free Email/SMS Alerts & Internet Updates
- On Board Data Logging & Graphing
- USB Import / Export
- Easily Expandable, Just Add Devices

GrowNET™ Devices

A large variety of 'GrowNET™' plug-and-play peripherals are available to sense and control the environment including:

- Environment Sensors (temperature, humidity, light, co2, etc.)
- Hydroponics Sensors (pH, conductivity, ORP, etc.)
- Peristaltic Dosing Pumps
- Control Relays
- DIN Rail I/O Modules

GrowNET™ devices connect using standard CAT5/6 Ethernet cable and RJ-45 connections. HX8 GrowNET™ Hubs expand one GrowNET™ port into eight more ports. HX8 hubs provide power to the devices from the hub ports, further simplifying installation. *Recommended maximum cable length is 1000ft.*

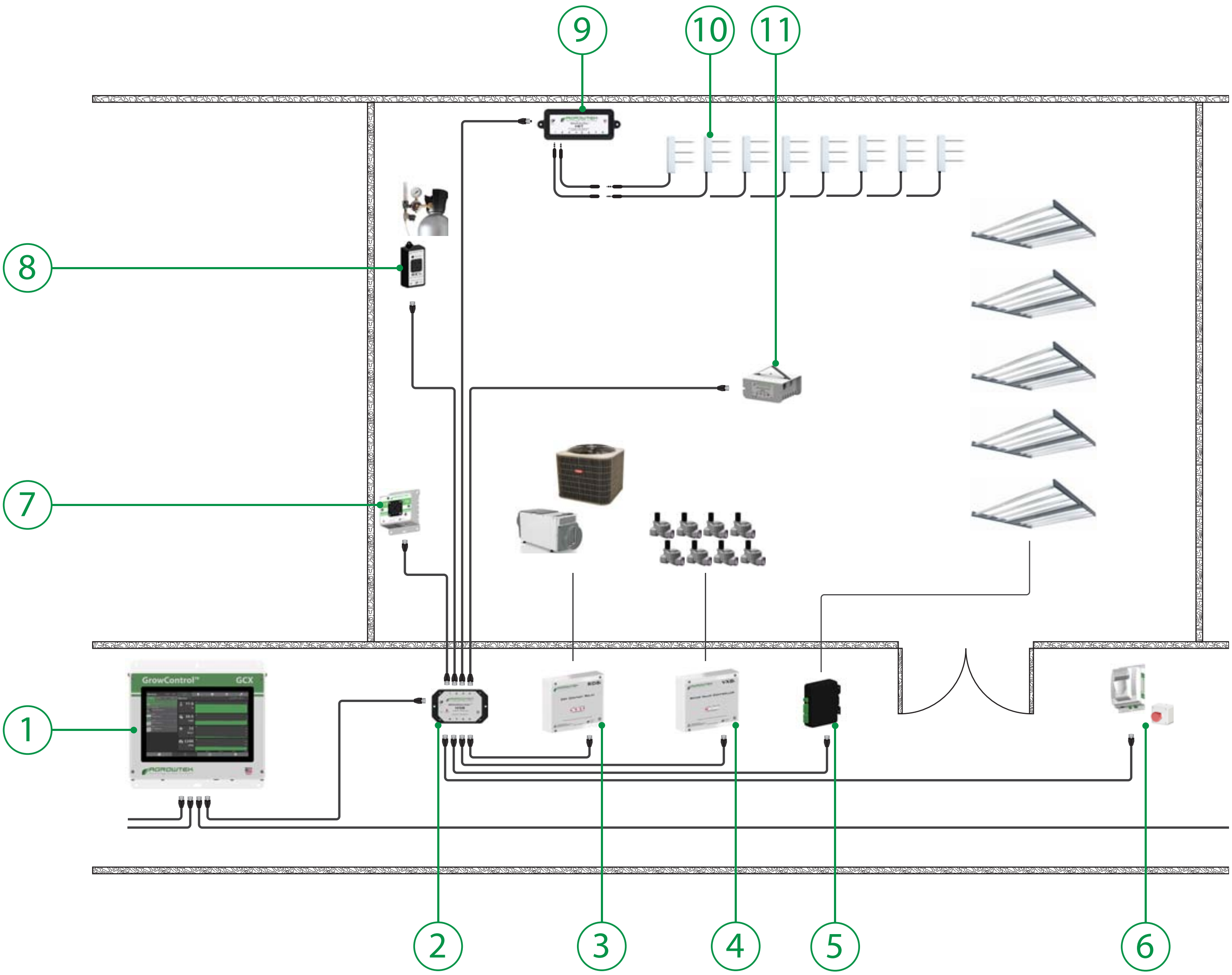


Standard Control Functions

- Clock Timers
- On/Off Delay Timers
- Cycle Timers
- Thermostats / HVAC Control
- Humidistats / Dehu Control
- Light Dimming & Spectrum Controls
- CO2 Injection, Exhaust & Alarms
- Motor Position Controls (Vents/Shades/Curtains)
- Irrigation Stage Timers & Automated Crop Steering
- Tank Level (Refill) Control
- Nutrient & pH Dosing
- Sensor Averaging
- Alarms
- Logic & More

Typical Room Equipment

A typical growing environment features sensors to bring information about the environment into the controller. User configured rules act on the sensor data to control equipment in the environment through output devices. A standard growing environment with climate control, CO2 injection and alarming, irrigation valve control with media moisure content sensors and dimmable lighting control is depicted below.

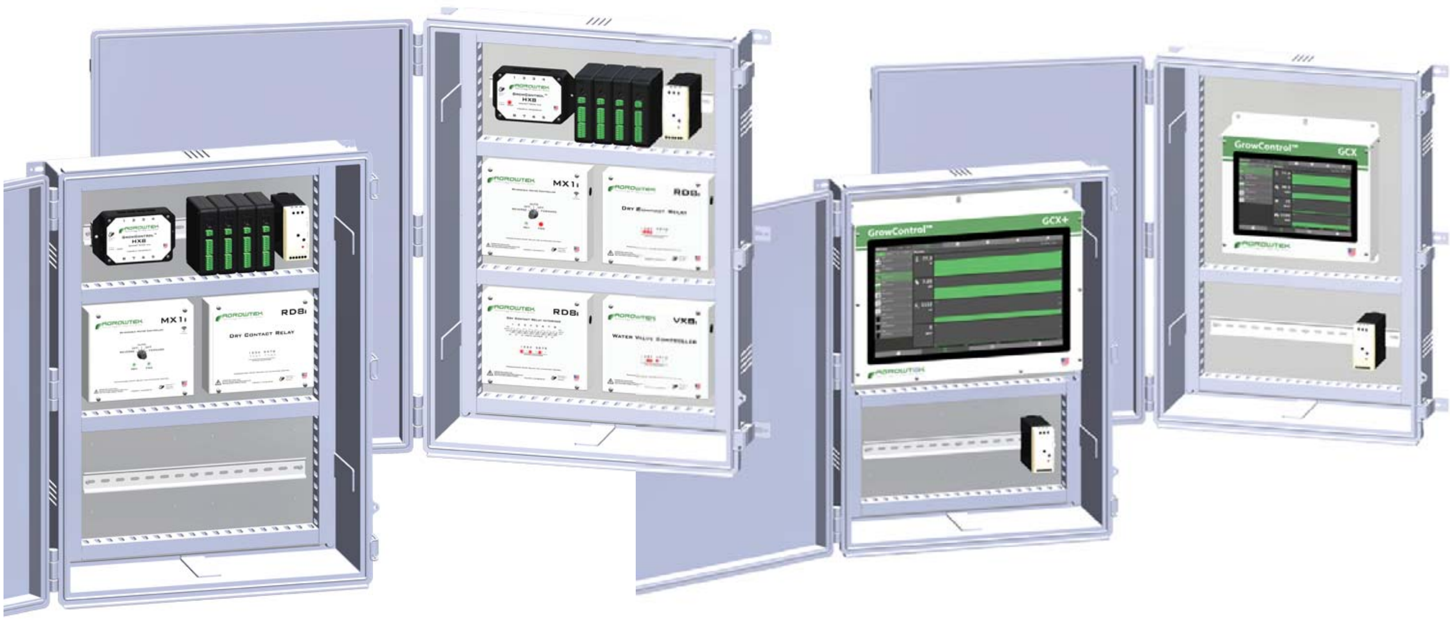


1. GCX Controller	One controller operates the entire facility in most cases.
2. HX8 Hub	HX8 hubs split the RJ-45 GrowNET connections from the controller to devices. One HX8 is usually located outside of each growing environment.
3. RD8i Dry Contacts	Dry contacts control HVAC, Humidifiers, Dehumidifiers and other equipment.
4. VX8i Valve Controller	Operates up to 8 irrigation valves with included power supply.
5. DXV4 or LXD	Lighting interface for 0-10V dimmable lights or digital lighting protocols.
6. AXG Alarm	Horn Strobe module with purge button for CO2 gas alarming and room purge.
7. SXG Gas Sensor	CO2 Gas sensor for wall mounting near ground levels for CO2 alarming.
8. RX1i Outlet	Single outlet relay used for CO2 valves, fans and other misc. 120V equipment.
9. HXT Hub	Teros 12 moisture sensor hub for eight (8) T12 sensors.
10. Teros 12	Soil moisture and conductivity sensors for crop steering.
11. SXC Climate Sensor	Integrated precision sensor for temperature, humidity, light, CO2 and IR.

GPanel Enclosures

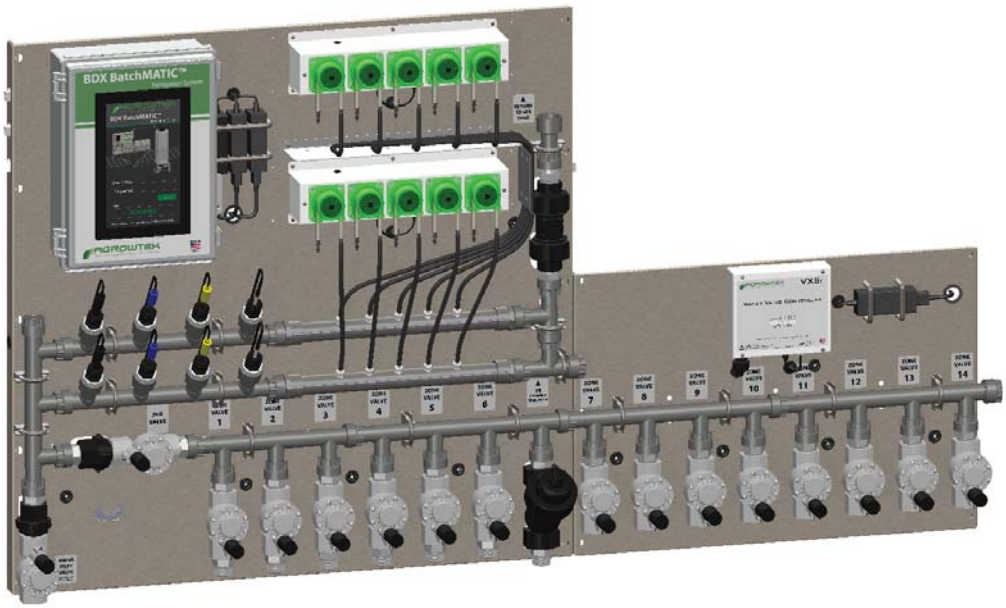
GrowControl™ Panel Service by Agrowtek offers several standard configurations for pre-mounted and pre-connected components from the factory. Components are mounted on a custom stainless steel back panel with DIN rail and wire trough for a clean, professional installation in a weather-proof enclosure from the factory. Reduce time spent on the job site during installation with a pre-tested and pre-configured panel from Agrowtek.

G Panel Service Includes:
• Polymer weather-proof enclosure.
• Stainless steel back panel.
• Mounting of all components.
• Connection of all components to the HX8 hub.
• Connection of all components to DC power supply.

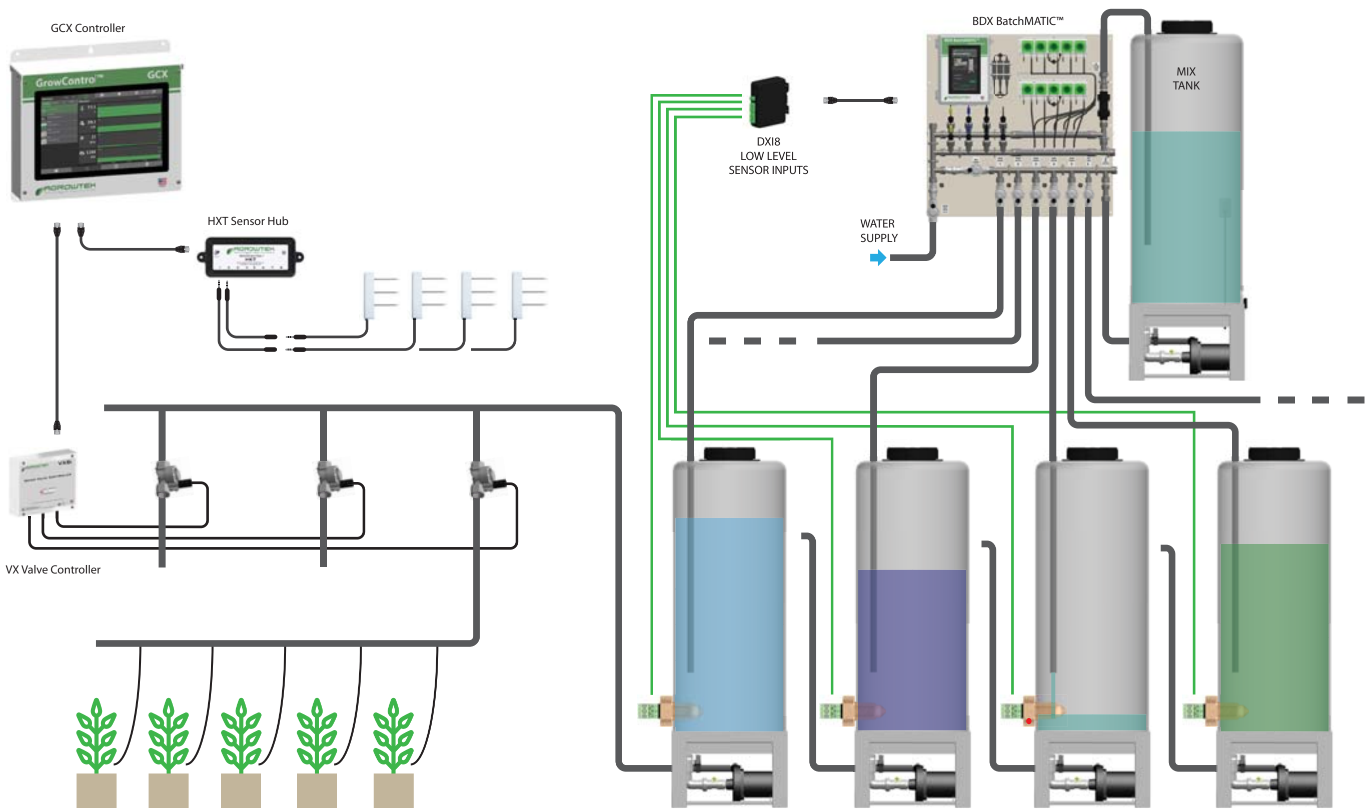


BDX BatchMATIC™ Fertigation

BDX BatchMATIC™ Dosing & Fertigation System is a batch nutrient mixing and irrigation system. Control up to14 zone valves to feed batch tanks or crop zones. Available with up to 12 peristaltic dosing pumps for mixing multi-part fertilizer solutions according to recipes and sensor targets. Alarms and automatic shut down functions standard. Free remote monitoring and control, email alerts and updates. Compact system is easy to use and maintain. Pre-fabricated assembly on stainless steel back panel for simple installation.



BDX BatchMATIC™ Fertigation Systems are typically used in tandem with a GrowControl™ GCX Cultivation Controller for complete facility control. BDX systems automatically refill batch tanks for each room when a sensor detects a low water level in a tank. The GCX system controls irrigation events from the batch tanks based on recipe programming and moisture sensor data.



About Agrowtek

Technology to Help You Grow™ since 2007

Agrowtek Inc. is a premier automation controls and fertigation systems manufacturer for a variety of agricultural and industrial sectors around the world. Our products include environment sensors and controls, liquid sensors and fertigation systems, soil sensors and irrigation controls, chemical pumps, relay modules and other devices for intelligent automation.

Our extensive product offerings have been developed and evolved based on direct feedback from customer needs and experiences in the field. With nearly two decades in electronic controls, our team of experts is dedicated to delivering innovative and cost effective technologies that are keys to a "growing" organization's success.

Precision
High quality digital sensor technology delivers accurate data to the control system about the environment, water and soil conditions for intelligent feedback based control and data logging.

Reliability
Systems and components are designed for high reliability in demanding environments. Automated assembly, optical inspection systems, robotic conformal coating and multiple stages of testing during manufacturing are in place to ensure product quality.

Scalability
Our fully scalable product range is designed to manage nearly every aspect of a modern growing facility's climate, lighting and fertigation requirements. Systems easily scale as a business grows and facilities expand simply by connecting more components.

Forward Design
Our systems feature free, easy firmware and software updates over the internet with new features and capabilities as we continue to innovate with feedback from customers and new industry trends.

Made in USA
We manufacture our high-tech products in the U.S.A. at our factory in Brookfield, Wisconsin. Our facility features two high-speed precision SMT assembly lines for electronics assembly, automated optical inspection systems, robotic conformal coating and in house engineering and support staff. We take pride in the quality of manufacturing and engineering that we put into every one of our products and services and we stand behind them with full warranties and helpful support.

AGROWTEK
Technology to Help You Grow