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Using Sensor Technology for Irrigation of Substrate Berries

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Worldwide Expertise for Food & Flowers

Irrigation Scheduling Methods in Substrate Berries?

A wide variety of technologies are used to control (schedule) drip irrigation in substrate-grown berries.

1. <u>Clock Timer</u>. (Low tech option)

- Needs good knowledge of crop ET demand (water use) at different growth stages.
- Requires frequent alteration to timer schedule, to cope with changes in weather.
- Least Accurate method. (Very labour intensive in changeable weather).

2. Weather Station Data. (Medium Tech Option).

- Can use accumulated Solar Radiation (Radsum) to track crop ET demand.
- (Due to relatively close correlation for unheated crops grown under protection).
- Some growers use Vapour Pressure Deficit (VPD) – estimates ET potential from temp & humidity.
- Both methods take no account of wind or initial substrate moisture content. (Extra cycles may be required).

3. Root Zone Sensors. (High tech option).

- Use 1-5 fixed sensors, measuring either volumetric moisture content (% VMC), or soil moisture tension.
- More expensive option. % VMC sensors need calibration, to identify substrate full-point (Container Capacity).
- V accurate once properly set up. But 1-2 sensors may not accurately represent a whole field situation?

4. Weighing of Crop (e.g. Priva Gro-Scale). Medium/High tech option.

- Selected area of crop is set up on weighing scale & irrigated according to change in weight (water uptake).
- (Priva system = expensive). Best suited to hanging crops, where there is no ground level support.
- Set up is often too sensitive to wind-rock/disturbance to be sufficiently robust in a field tunnel situation.

In the early days of substrate growing, clock starts were generally popular for irrigation scheduling.

- Many growers then moved to Radiation starts for better synchrony between plant water use & ET Demand.
- In heated Glasshouses (with lower synchrony & less wind-rock), Weigh scales became more popular.

With the evolution of affordable Root-Zone sensors, global adoption of this technology is now taking place.

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Basic Substrate Physics - Air/Water Relations

To understand how root zone sensors work, we need to understand a little about substrate Physics!

Horticultural Substrate consists of individual particles of different sizes, loosely mixed together.

In the spaces (pores) between individual particles: Either water or air can be stored.

From a plant perspective: we talk about 3 critical states in the air/water balance:

1. The Optimal Zone (At or just below Container Capacity).

- This is a narrow band - with easily available water for good root uptake.
- But also sufficient air content for good root health.
- **Container Capacity** occurs once excess water has drained - by gravity.
- (Following rainfall, or an irrigation event).
- The optimal air/water balance is maintained as the substrate dries back a little.
- For substrate crops, this generally equates to a Moisture Tension between -1 & -4 kPa.

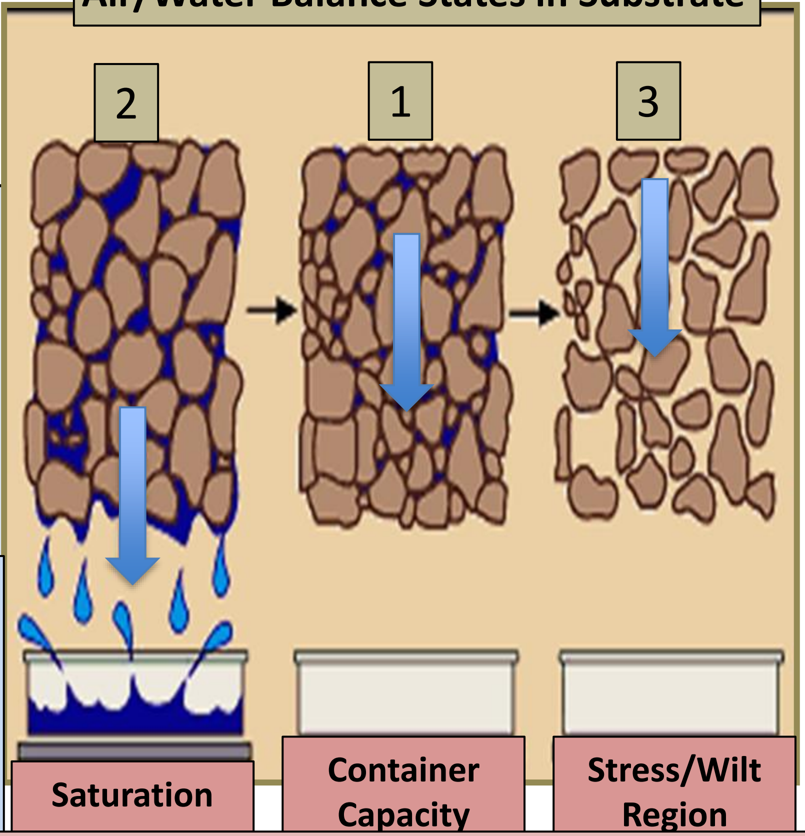
2. Substrate Saturation.

- This occurs when too much water has been applied.
- (And the water has not had sufficient time to drain away between irrigation rounds).
- There is too little air (oxygen), leading to root damage by asphyxiation.
- This can easily occur when a crop is over-irrigated, or when drainage is poor.
- This generally equates to a Moisture Tension between 0 & -1 kPa.

3. Plant Stress/Wilt region.

- This occurs when the substrate has dried back too much.
- Resulting in too much air and not enough easily available water.
- This can restrict crop growth – resulting in lower yields & reduced fruit size.
- Visible wilting can occur at ≥-10 kPa. Plant death can occur at ≥-20 kPa.

Air/Water Balance States in Substrate



Optimal Moisture Tension Requirement for Soil-Grown Crops

- **Raspberry:** -15 to -20 kPa (depends on root depth).
- This is 5x higher tension than for substrate Raspberry.

Soil Grown Crops have a much larger surface area of roots.

- So can extract water more efficiently at higher tension.
- **They have much greater <u>suction power</u>!**

Due to root miniaturisation: Substrate grown plants need much lower moisture tension than soil-grown crops.

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Assessing Moisture Tension in Substrate Grown Crops

A simple way to assess Substrate Moisture Tension is to carry out a squeeze test.

Take a handful of moist substrate:

- Squeeze it in your palm, to assess how easily moisture droplets appear.
- **A Hard Squeeze** with little or no moisture = Too dry (**<u>Plant Stress</u>**).
- **A Medium Squeeze** to give moisture = Little bit dry (**<u>Ready for Irrigation</u>**).
- **A Gentle Squeeze** to give moisture = Close to Container Capacity (**<u>Optimal</u>**).
- **No need to squeeze** (Water already visible) = Too wet (**<u>Saturation</u>**).

Static Electronic Micro-Tensiometer in Raspberry pot (Tip = 10 cm height)

Medium/Hard Squeeze Bit dry – Needs refilling

By using a statically deployed electronic Micro-tensiometer:

It is possible to accurately measure & record substrate Moisture Tension.

This gives the most accurate assessment of plant water availability:

- In different substrates (with different pore size distribution).
- Also, as any individual substrate ages (Reduced Average Pore size).

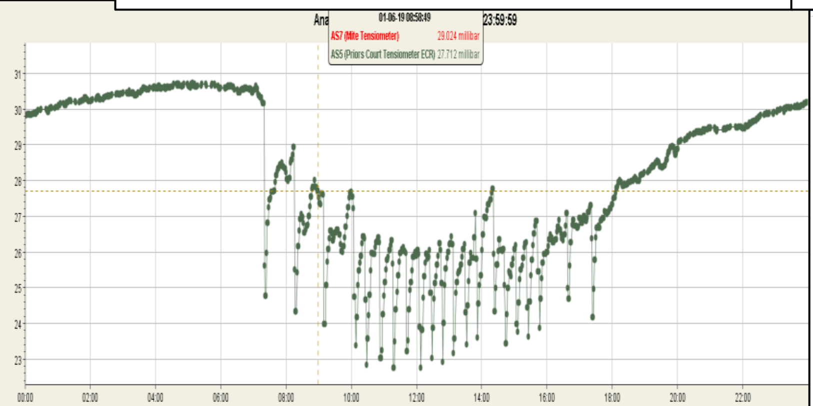
Allows precise irrigation scheduling in different substrate conditions.

However, Tensiometers are not widely utilized for substrate growing.

- It is increasingly more common to use devices measuring % VMC.
- But, % VMC does not necessarily reflect plant-water availability.
- **The same % VMC in different substrates can be different tension?**

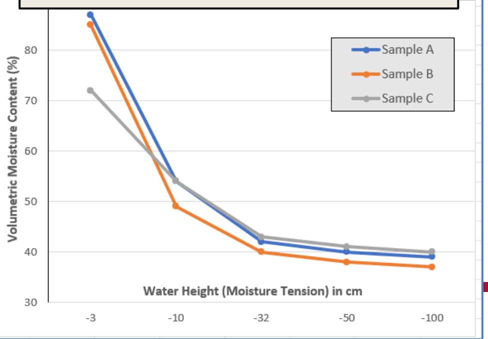
For any substrate, % VMC & Tension need to be correlated by:

- Referring to a laboratory pF curve (Only useful for unused substrate).
- Or by conducting a manual calibration exercise. (For in-use substrate).



Micro-Tensiometer Irrigation Record

Coir substrate pF Curves



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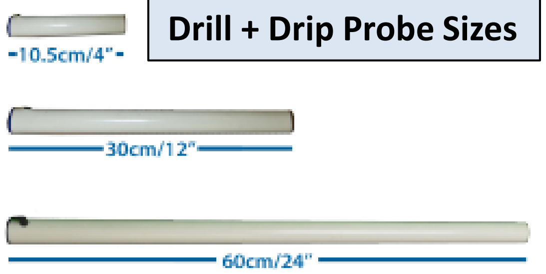
Electronic Measurement of Root Zone Moisture (% VMC) in Substrate

There are 2 common methods of electronically measuring % VMC (Substrate Volumetric Moisture Content):



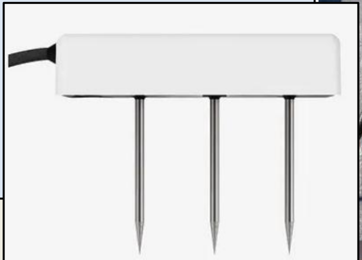
Drill + Drip Probe Sizes

1. Capacitance Probes (e.g. Sentek Drill & Drop, Enviro-Pro).

- These measure volumetric moisture content (%VMC) every 10 cm along the length of the probe.
- Various probe lengths available, the most common in substrate being 30 & 60 cm.
- Single Point (10 cm) probes are also available & are less obtrusive in smaller containers.
- Capacitance probes can only be statically employed.
- They are also expensive, which limits the number of probes employed.
- Their precision in substrate is also debatable. (Don't have substrate calibrations).

60 cm Drill & Drop In 4.7l Rasp Pot

Enviro-Pro probe in 25l Blueberry pot



Teros 12 probe

2. Reflectometry Probes (TDR/FDR).

- **TDR = Delta-T WET Sensor, Acclima; FDR = Teros 12, Bluelab Pulse.**
- These are devices that generally have 2 or 3 steel rods.
- The rods can be manually inserted into the substrate to take a % VMC reading.
- Reflectometry probes give an average reading over the length of the rods.
- So, awareness of the moisture profile and/or the depth of probe insertion is required.
- Reflectometry Probes are said to be more precise & flexible than Capacitance Sensors.
- Some devices (e.g. WET Sensor) have substrate specific Calibrations, so are v precise.
- FDR Probes are cheaper but more prone to EC induced error than TDR devices.
- Both types can be employed either as a roving device, or in a static location.

Bluelab Pulse

Delta-T WET Sensor

Acclima Sensor
- (longer rods)

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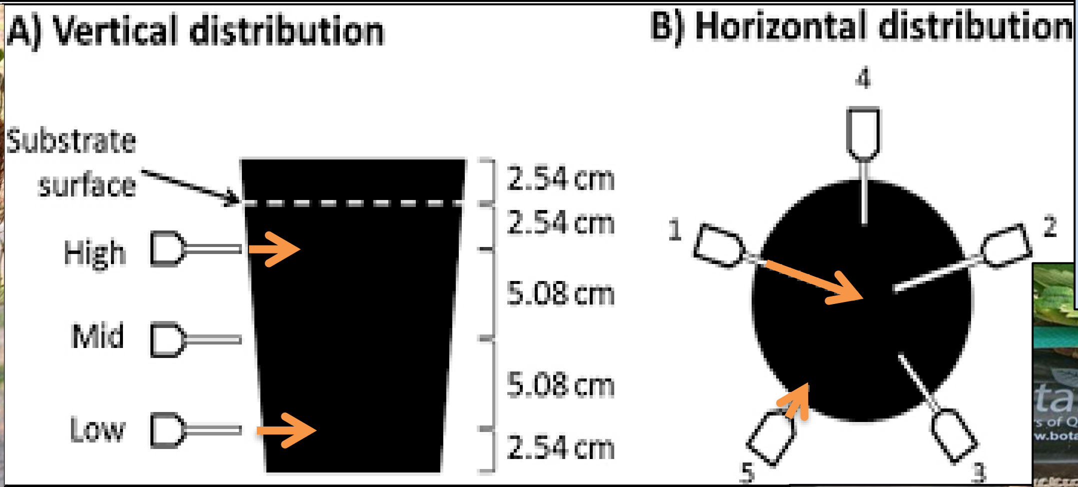
Correct Use of Sensors in Pot/Bag Grown Crops

Substrate Moisture content (& Tension) varies according to height of pot & distance from dripper(s).

- By measuring %VMC at different heights, we can approximate the readings to tension.

Variation in Pot Moisture Content

1. **Vertical Gradient** (Gravitational).
   - Surface is driest. Basal layers are wettest.
2. **Horizontal Gradient** (Capillarity).
   - Immediately around/below emitter is wettest.
   - Between drippers/furthest point from emitter is driest.

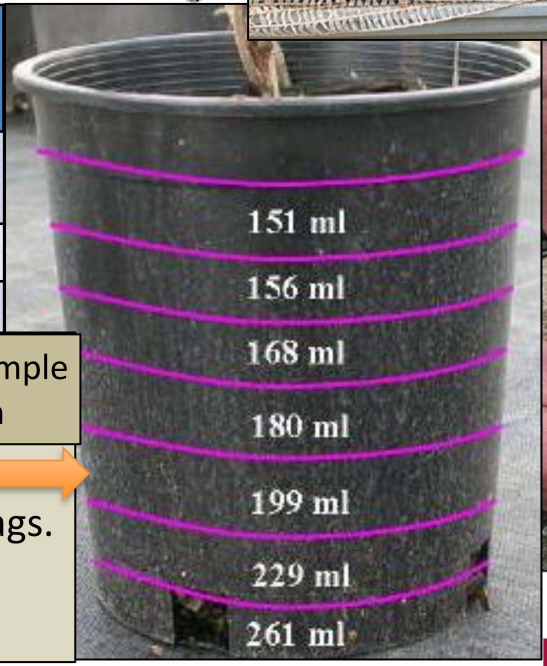


Sample height	Tension at Container Capacity	Tension at Refill point
0 cm (Pot Base) (Saturated zone)	0 kPa	-1 kPa
10 cm from base	-1 kPa	-2.2 kPa
22 cm from base	-2.2 kPa	-3.4 kPa

Best height to take a single reading:

- 10 cm from pot base in larger
- (7-10 litre) pots.
- Around ⅓ height from base in small (5l) pots & bags.
- Keep TDR Forks oriented **horizontally**.
- (To keep in same horizontal layer).

Best Sample Position



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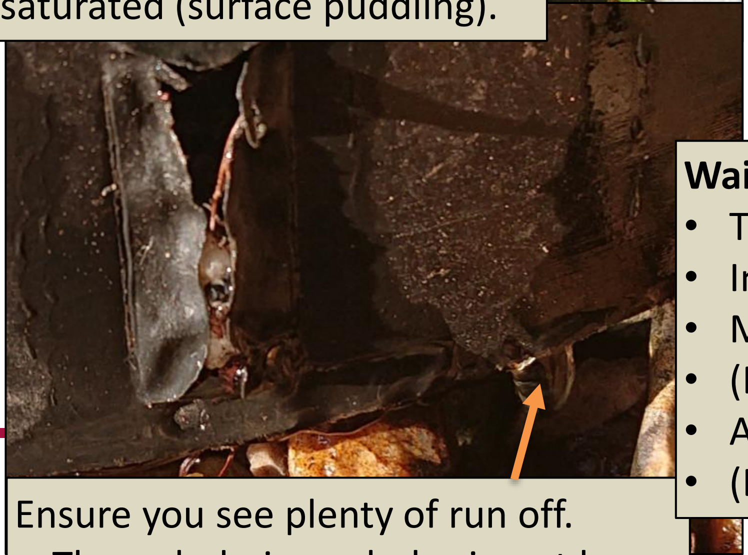
Manual Calibration of Container Capacity & Refill Point in 25l Blueberry Pot - Using TDR Device

As peat/coir substrate ages, pore size declines & it becomes more water retentive (due to root ingress, compaction & particle decomposition).

To understand how this affects tension: Calibration of % VMC at Full point (-1 kPa) & Refill point (-2.2 kPa) in a fully irrigated pot is done (2-3x/yr).

Ideally, use a watering can, to evenly wet up substrate throughout profile.

Ensure surface layers are fully saturated (surface puddling).



Ensure you see plenty of run off.
- Through drainage holes in pot base.

Wait for surface & drain water to disappear:
- Then, remove Plant from container.
- Insert TDR Probe & measure % VMC.
- Measure at 10 cm from pot base.
- (Equates to %VMC at -1 kPa).
- Also, measure %VMC at 22 cm from base.
- (Equates to Refill point at -2.2 kPa).

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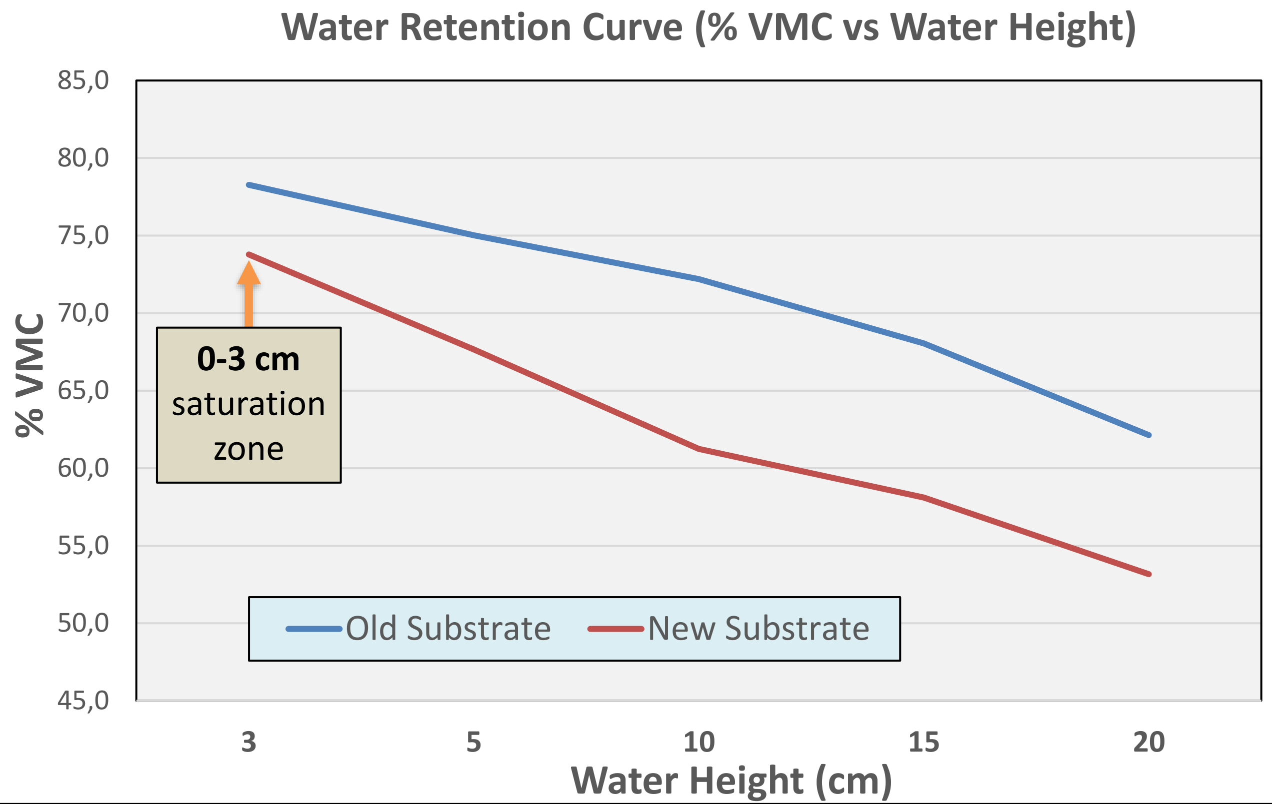
Calibration of %VMC vs Tension in Raspberry Substrate (3-5 Yr Old Substrate vs New Substrate)

Results from Watering Can Calibration Procedure on 16 Pots of New Substrate & 18 pots of Older Substrate.

Pot sizes:
Old substrate = 10l pots (planted 2019/21); **New** = 7l pot (planted 2024).



Older substrate
- Holds around 10% more moisture at each water height.
- Except at very base of pot (0-3 cm height).
- (Due to perched water table & migration of fine particles).

The extra water in older substrate is held at higher tension.
- Due to reduction in average pore size in older substrate.
- Arising from root colonisation & substrate ageing.
- (Compaction & microbial decomposition of coir particles).

10 cm water height = 1 kPa Tension

At 10 cm Water height (-1 kPa)
- New Coir = 61% VMC
- Old Coir = 72% VMC

At 20 cm Water Height (-2 kPa)
- New Coir = 53% VMC
- Old Coir = 62% VMC

Can use these %VMC values as a basis:
- To trigger irrigation rounds

Irrigation settings for %VMC Reading with WET Sensor (on Coir Setting)
- Aim to keep 10 cm reading (from base of pot) at:
- **50-60% in New Coir** (-1.2 kPa to -2.2 kPa). Will be -2.2 to -3.2 kPa @ 20 cm
- **60-70% in Old Coir** (-1.2 to -2.2 kPa). Will be -2.2 to -3.2 kPa @ 20 cm.

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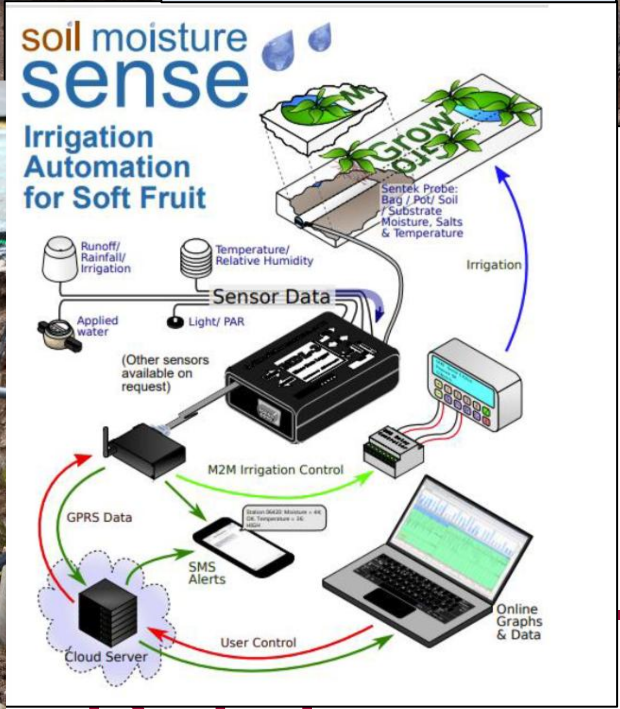
Gathering/Recording Electronic Sensor Data in Field Crops

Raspberry 3 Pot Drain Station with Sensor & Drip Spoon

Climate Sensors & Control Box

WET 150 TDR Sensor in Pot

Close-Up - Drip Spoon



Soil moisture Sensors – some examples:

- **Delta WET 150** (similar to WET Sensor)
- **Sentek Drill & Drop** – Single Point Probe
- **Teros 12** (FDR) From Meter Group)
- **Micro-Tensiometer** (Teros 31, Talgil, Famidan)

Other Useful Sensors

- Water meter (Drip water volume)
- Drip Spoon (For drain volume)
- pH & EC (Drip & Drain Recording)
- Light (PAR or Global Radiation)
- Climate (Temp, RH & VPD)

Data is sent to suppliers website

- via Modem telemetry (from control box).
- Graphical interface gives climate and irrigation reports.

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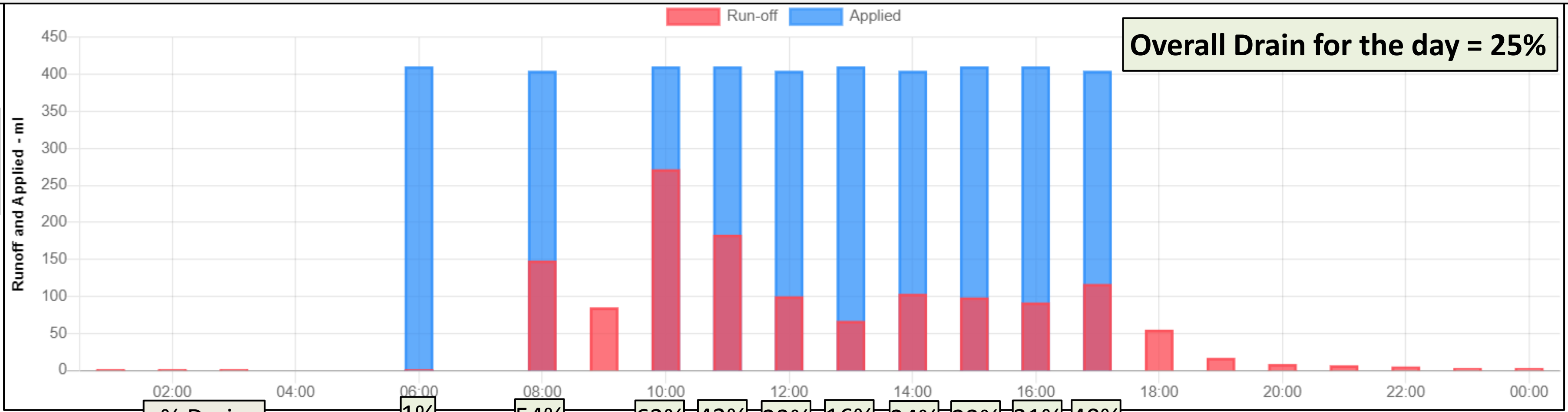
Graphical Output - Drip & Drain Station Data

03-08-22 (Normal Day) Peak tunnel temperature = 27.3C; RH = 51.3; Peak VPD = 1.8 kPa. Radiation Sum = 2100 J cm^{-2}
Drip cycle = 4 mins 1x per hour (433 ml m^{-1} per drip cycle). Applied 10 cycles (4.33 litres m^{-1}) between 6.00 & 17.00.



% Drain	1%	54%	62%	42%	23%	16%	24%	23%	21%	40%

Grower Comment:

Overall Drain Reading = Black & White TV

Hourly Drain Readings = HD TV!!

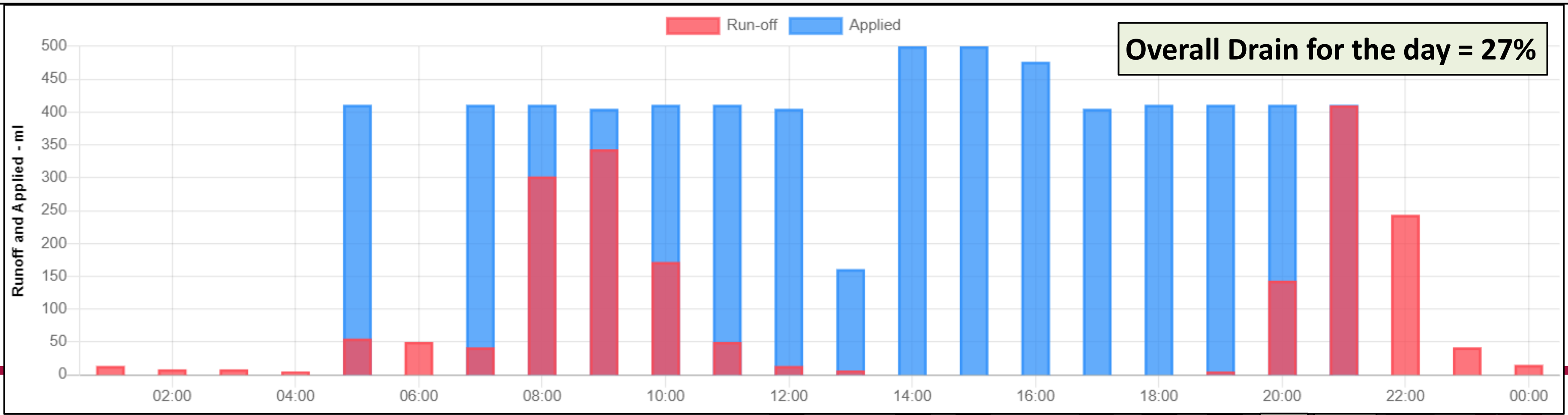
Take-home points:

Grower needs to irrigate more frequently in hot weather.

Over irrigating at the beginning of the day is ineffective.

As not enough water can be stored in pots To last through the hot period.

18-07-22 (Hot Day): Peak tunnel temperature = 36.4C; RH = 25.8; Peak VPD = 4.5 kPa. Radiation Sum = 2700 J cm^{-2}).
Drip cycle = 4 mins, 1x per hour (433 ml m^{-1} per drip cycle). Applied 16 cycles (6.93 litres m^{-1}) between 5.00 & 22.00.



% Drain	24%	9%	69%	78%	39%	12%	5%	1%	0%	0%	0%	0%	0%	1%	33%	100%	65%

Same overall drain %: Plants overwatered early/late. Water-stressed in middle of day!

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Thanks for Your Attention

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