Case Study

Tracing Water Consumption for Guaranteed Cannabis Growth Outcomes

hydra UNLIMITED

Shift to RDWC provides plants with precision feeds and minimal waste

ABSTRACT

Despite overwhelming prevalence and acceptance of substrate farming in the cannabis industry, Hydra Unlimited sought to evaluate recirculating deep water culture (RDWC) systems to test success or failure of grow outcomes in parallel with a traditional grow.

Over the course of 16 weeks in 2022, what intentions had been set for partnering with a cannabis grow operation to seek bud outcomes as proof of success, pivoted instead to an unrealized outcome that RDWC is a breakaway leader of water and nutrient resource management - minimizing wasteful runoffs prevalent in other grow methods and offering predictive capabilities of grow process.

This case demonstrates not only a cultural shift in mindset required to take on RDWC as a grow method, but also the unrealized potential of sustainable grow outcomes, drawing down resource demands from staffing to water and nutrient needs.

BACKGROUND

The following groups entered into agreement to a test growth of cannabis in spring 2022 to prove viability of recirculating deep water culture cultivation as compared with a standard substrate grow operation. Hydra Unlimited provided equipment and initiated the relationship with a West Michigan cannabis grower (henceforth referred to as “CANNABIS COMPANY”). Lake Superior State University entered the partnership for water and nutrient quality and consumption testing. Nuravine provided cloud-based technologies to continuously monitor the growth over the total grow period.

KEY PARTNERS

Hydra Unlimited

Hydra Unlimited is owned by Flow-Rite Controls, a 40+ year-old company that has built its reputation on high-quality innovation. As premiere fluidics experts, the Flow-Rite team was ideally poised to venture into the Hydroponics space where their knowledge and intuition engineered the Gold Standard in Hydroponics Systems: HydraMax. With hundreds of global patents and over one billion fluidics products sold and serviced, no one is better suited to partner with to take your grow to the next level.

Hank Bonnah, BS/MS	Chief Scientist & Principal Engineer
Chris Gioia	Sr Business Development Manager
Sean Burnetter	Business Development Manager
Garrett Harris	Product Engineer

CANNABIS COMPANY

With claims of “Michigan’s premiere craft cannabis cultivator, producer, and supplier,” CANNABIS COMPANY is a commercial grower with over 7,000 marijuana plants, grown in coco coir substrate indoors. They offer over 30 types of cannabis products for both medical and legal adult-use in the state of Michigan. The business has been in operation for 7 years and cultivating for 5 at the time of this study.

Redacted	Head Grower
Redacted	Managing Partner
Redacted	Staff

Lake Superior State University

Lake Superior State University in Michigan’s upper peninsula is a state university focused on liberal and technical studies. And with a Cannabis Chemistry degree program focused on the quantitative analysis of cannabis related compounds and contaminants, LSSU was the perfect partner for assessing water quality and nutrient consumption—as well as other data above and beyond what was realized at the onset of partnership.

Steven Johnson, PhD	Associate Professor	Dean of College of Science and Environment
Derek Wright, PhD	Associate Professor	Analytical Chemistry and Environmental Science
Benjamin Southwell, BS/MS	Assistant Professor	LSSU Chemistry Analysis Laboratory

Nuravine

Nuravine automated nutrient delivery is a cloud-based solution for growers and farmers to dose crops with precision and monitor and adjust feeds from anywhere on earth. Coupled with recirculating cultivation in RDWC (recirculated deep water culture cultivation), Nuravine machine learning allows water reservoirs to remain exactly where they need to be, dosed with exactly the nutrients a grow demands.

Alex Babich	CEO and Founder

METHODS + TECHNOLOGY

Hydra Unlimited engaged with CANNABIS COMPANY on behalf of their standing grow operation and understanding of cannabis farming. The grow was assigned a 12 week to 16 week period in separate grow rooms (RDWC; 12 week grow, Substrate: 16 week grow) within the campus of CANNABIS COMPANY. CANNABIS COMPANY would be responsible for cultivation, feeding, water management and general oversight of both grows happening in parallel over spring 2022.

<u>Grow Medium</u>

CANNABIS COMPANY adheres to the industry standard substrate farming practice. With substrate farming, an organism lives, grows and obtains nourishment from the material in which it thrives. Substrates can range from peat to soil, clay to loam. CANNABIS COMPANY grows in coco coir – a compressed brick form that is user-friendly, economical and ensures superior water retention and aeration. CANNABIS COMPANY practices typical industry fertigation methods for substrate including 10 – 30% runoff for every fertigation cycle.

Partnering with Hydra Unlimited meant testing a different grow format. Recirculating deep water culture (RDWC) allows a plant to be submerged in water within a bucket system that circulates the nutrients an oxygen directly to the root of the plant. Advantages include sterility and savings to nutrients and water consumption due to the nature of direct-to-root application.

<u>Grow Equipment</u>

Four of Hydra Unlimited’s complete 20 HydraMax bucket systems were supplied to CANNABIS COMPANY. This number was decided upon between the two parties, Hydra Unlimited and CANNABIS COMPANY, in hopes of producing a certain leaf canopy and a pre-determined number of flowers.

Each HydraMax system includes the following:

- 20 8-Gallon Buckets
- 20 Lids w/ inspection port & cover
- 20 HydraFlex Circulators
- Qwik-Lok Plumbing (a patented Flow-Rite fluid handling product)
- 1 Pump – 2.2A, 2600 gal/hr
- 1 Dosing Funnel and manual mixing tanks
- 1 Refill Valve with float
- 20 5.5″ Netpots
- 24 Liters of TetraBase (fully inert and reusable grow media - Pictured)
- ½ Hp Water Chiller Refrigeration Unit

Grow Room Specifications:

In order to accurately compare a parallel grow operation of coco coir to RDWC, it was imperative that the grow spaces were prepared in alignment (from racking to climate control and layout). These are those agreed specifications.

- **Room Layout and Spec, as estimated based on Hydra Unlimited systems within the space** (note: grow room size was quite small as compared to CANNABIS COMPANY standard grow rooms. The specs noted below are estimated):
    - Room Width (ft): 20
    - Room Length (ft): 35
    - Square Footage (ft^2): 700

Figure 1: HydraMax systems during setup within grow room at CANNABIS COMPANY

- **Plant Layout:**
    - The following key and plant grid diagram visualizes the system placement and plant layout within the grow room. Green squares depict location of evaluated (via growth expression) cultivars. The grey boxes depict location of cultivars not evaluated.

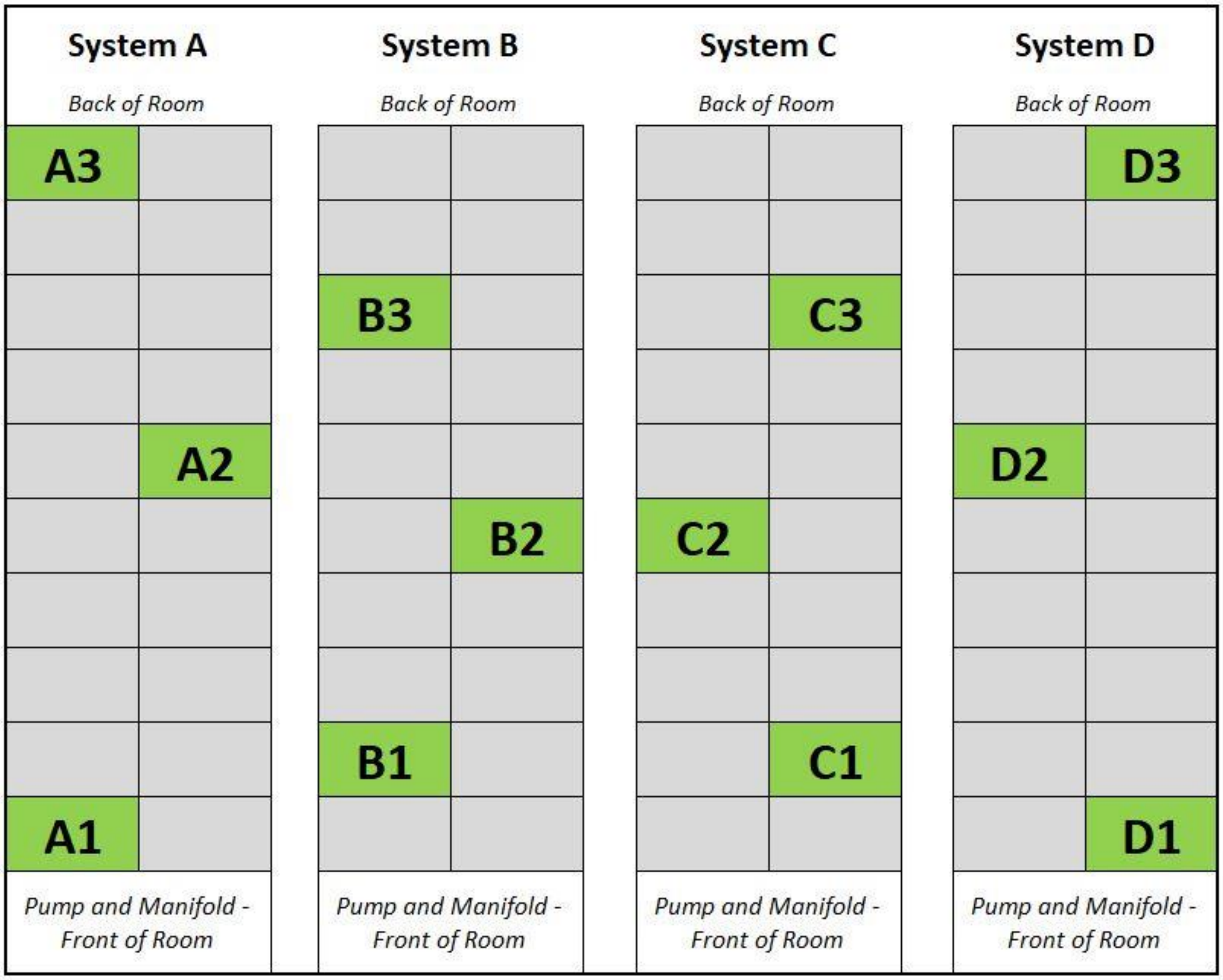
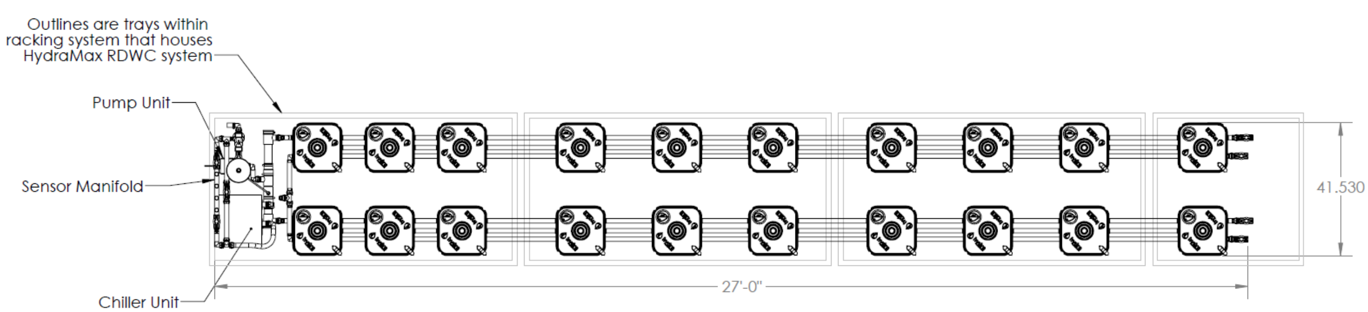


Figure 2: Schematic of HydraMax bucket system in row layout

- **PIPP Racking & Trays:**
  PIPP Horticulture Mobile Racking was utilized in the grow trial through upright racking, modified tray sections, and PIPP's mobile carriages. (Layout shown)



- **Climate Control:**
    - Climate control is critical in a cultivation environment. CANNABIS COMPANY utilized an in-room climate control unit that was a known risk to not maintain environmental parameters. Thus, supplemental dehumidification units were added to the grow room.
    - Supplemental dehumidification units were the following:
        - Make: Anden
        - Model: A320V1
        - Quantity: 5

Figure 3: Sample Anden Dehumidification Unit utilized during grow for climate control due to known unstable environmental parameters. (Used with permission Anden Products)

Mother Plant

Mother plant was selected by CANNABIS COMPANY. Mother was “Dead Head” and prepared hydroponically with 10% bleach/surfactant dip/rinse for microbial control, then into reverse osmosis (RO) water for a soak to prepare roots for the cloner.

Feed + Water

CANNABIS COMPANY had complete control to feed the plants as the grower decided. A premier liquid fertilizer program was chosen for the RDWC cultivation. A recommended feeding schedule was provided by Hydra Unlimited to assist growth success.

Many intervening factors can and will affect ultimate plant success over the course of any given grow, particularly as related to light, temperature, % humidity, nutrient & oxygen concentration, room CO_2 and human error.

Hydra Unlimited performed lab-grade titrations of the chosen premier liquid fertilizer and constructed a dosing calculator based upon these titrations. This dosing calculator was provided to CANNABIS COMPANY. Knowing the need to train the grower in a new way of thinking (RDWC instead of substrate farming), the dosing calculator offered three solutions to overcoming known risks in the grow. They are:

1. A solution to training the CANNABIS COMPANY in RDWC feeding techniques
2. Closely align CANNABIS COMPANY activity realities with the suggested feeding plan designed by Hydra Unlimited, based on Hydra Unlimited system knowledge
3. Offer ongoing guidance throughout the RDWC grow to tune (up and down) grower actions with a point of reference for this new (to them) grow method in combination with data derived from Nuravine provided data and trends

Water was provided by CANNABIS COMPANY for the grow through reverse osmosis. The water fills were manually initiated by CANNABIS COMPANY with automatic shutoff once proper water levels were reached. All nutrient additions were manually performed by CANNABIS COMPANY staff.

All water and nutrient volume additions were carefully recorded.

<u>Timing</u>

The start date of the grow is April 21, 2022 for RDWC and minus-two (-2) weeks for substrate grow.

GOALS + TRACKING MEASUREMENT

Original goal and tracking agreements included the total-per-square-foot (or per light) quantity of flower (in pounds of dried flower) evaluated against a similar canopy (square foot) of substrate-farmed cannabis. Parallel growth and comparison could offer insights to defined success or failure of RDWC versus the current industry standard of substrate farming.

Measurement included four inputs: Hydra Unlimited, CANNABIS COMPANY staffing, continuous cloud-based monitoring through Nuravine technology of the buckets and, Pulse Grow for room atmospherics.

At the onset of this partnership, the following Key Performance Indicators were considered for their importance of final salability of final flower in the cannabis marketplace:

- Microbial testing, Plate and QPCR
- Crop yield
- THC content [Total Delta-9 THC] per plant; MU (Measurement Uncertainty 0.06%)
- Grow time
- Terpene comparison
- Taste
- Labor hours per plant
- Power consumed (in kW-Hr)
- Total water and nutrient consumption

Plant Progress was monitored continuously, daily and weekly in the following ways:

<u>Continuous</u>

Timing	Continuous automatic
Performed By	Edge Devices & Cloud-based Data Acquisition
Logged to	Nuravine and Pulse Grow

The following continuous measurements were gathered, by device:

1. Nuravine
   a. System pH
   b. System Electrical Conductivity - EC (in µS)
   c. System Dissolved Oxygen
   d. System Reduction Oxidation Potential
   e. System Water Temperature

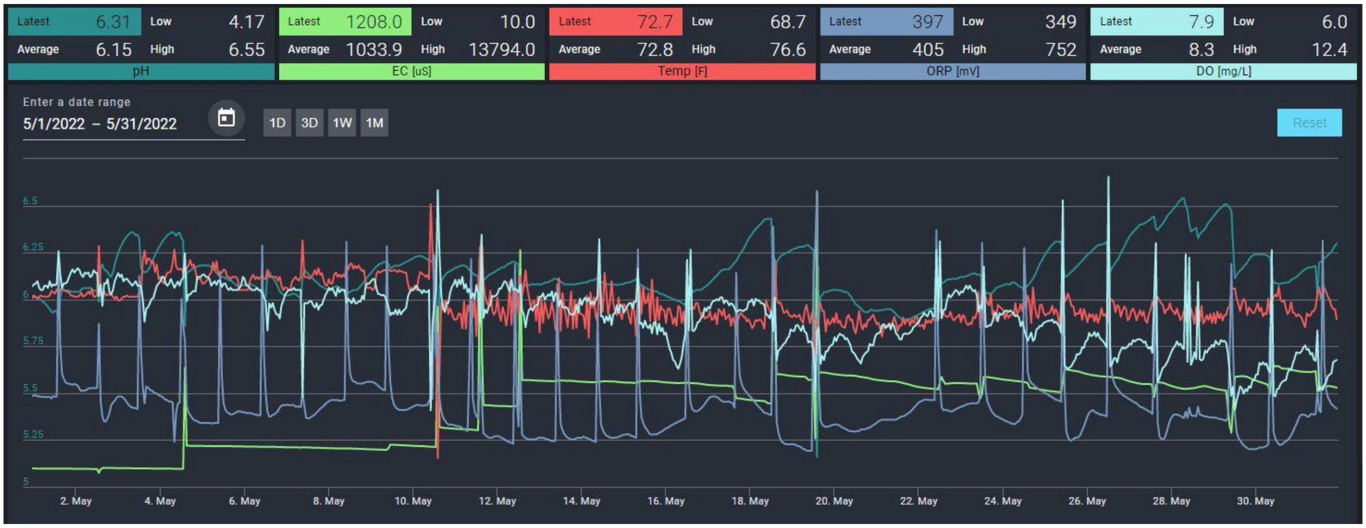


Figure 4: A sample Nuravine continuous tracking screenshot

2. Pulse Grow
   a. Room Temp and Humidity profile
   b. Room dew point
   c. Room vapor pressure deficit [VPD]
   d. Hours of light per day and intensity (in relative % intensity)

Figure 5: Screenshot of Pulse Grow monitoring system

Daily

Timing	Daily, morning by 9AM
Performed By	CANNABIS GROWER
Logged to	Excel spreadsheet

The following daily measurements were gathered:

- Incoming DI water pH/EC
- Incoming water quantity
- Nutrient usage (how much and how often)
  - Spreadsheet based on EC/pH from Nuravine system and applied through the use of the Dosing Calculator by CANNABIS COMPANY staff.

Weekly

Timing	Weekly Tuesday mornings around 9:00 AM
Performed By	Hydra Unlimited personnel
Logged to	Excel spreadsheet

The following weekly measurements were gathered:

- Weekly photos of plants
  - System wide, overview shot
  - Timelapse camera
- Individual plant height, with tape measure
- Leaf size with a ruler and leaf color with Munsell color standards
- Canopy diameter, with yardstick/tape measure
- Stem diameter, using digital calipers. Image shown of stem measurement on site.


Figures 6 & 7: Physical measurements to calculate growth index.

- Leaf color utilizing Munsell Color Charting (Munsell Plant Tissue Color Book). Image shown of leaf color mapping. Color evaluation occurred at the highest node offering a fully developed leaf in the individual plant canopy of assessed cultivars.

Figures 8 & 9: Physical measurements to evaluate leaf color

- Samples of nutrient solution to be collected and sent to LSSU lab for analysis. Lake Superior State University nutrient/water assessed the following chemical constituents:

Alkalinity (CaCO3)	Calcium	Mercury	Sodium
Aluminum	Chloride	Molybdenum	Sulfate
Ammonia	Chromium	Nickle	Sum Nitrogen (mg/l)
Antimony	Cobalt	Nitrate	Thallium
Arsenic	Copper	Nitrite	Thorium
Barium	Fluoride	pH	Uranium
Beryllium	Iron	Phosphate	Vanadium
Boron	Lead	Potassium	Zinc
Bromide	Magnesium	Selenium	
Cadmium	Manganese	Silica	

As previously suggested, in addition and as part of the tracking methodology, Hydra Unlimited invested in a secondary tracking layer through the development of a dosing calculator to monitor feed profiles. The dosing calculator is a math-model based calculator utilizing the %w/V information and Hydra Unlimited titrations for each nutrient/additive used during the grow.

The following is a list of the typical Macro and Micro-nutrients that were ultimately controlled by the dosing calculator.

Alkalinity ($CaCO_3$)	Iron (Fe)	Phosphate (P_2O_5)
Ammonia (NH_4)	Magnesium (Mg)	Potash (K_2O)
Boron (B)	Molybdenum (Mo)	Silica (K_2SiO_3)
Calcium (Ca)	Nitrate (NO_3-)	Sulfate (SO_4)
Copper (Cu)	Nitrite (NO_2–)	Zinc (Zn)

Through use of the dosing calculator, the feed schedule targets could be reached and maintained should the grower opt to reach Hydra Unlimited recommended ECs for each week and phase of the grow.

Nutrient Component A

	Bloom A %w/V	PPM Full Concentration	ml/Gallon	Gal/Liter	PPM
Total Nitrogen	4.0000	40000	1.07	3.78541	11.307
Nitrate Nitrogen	3.8000	38000	1.07	3.78541	10.741
Ammoniacal Nitrogen	0.2000	2000	1.07	3.78541	0.565
Soluable Potash	5.0000	50000	1.07	3.78541	14.133
Calcium	3.2000	32000	1.07	3.78541	9.045
Magnesium	0.1700	1700	1.07	3.78541	0.481
Boron	0.0100	100	1.07	3.78541	0.028
Iron	0.0600	600	1.07	3.78541	0.170
Manganese	0.0130	130	1.07	3.78541	0.037
Molybdenum	0.0007	7	1.07	3.78541	0.002
Zinc	0.0045	45	1.07	3.78541	0.013
Other solubles (est.)	8.5000	85000	1.07	3.78541	24.026
Total PPM TDS(500)					**59.241**
Total EC in µS					**118.483**
Titration Expectations in µS					**147.239**

Nutrient Component B

	Bloom B %w/V	PPM Full Concentration	ml/Gallon	Gal/Liter	PPM
Total Nitrogen	0.7000	7000	1.07	3.78541	1.979
Nitrate Nitrogen	0.5000	5000	1.07	3.78541	1.413
Ammoniacal Nitrogen	0.2000	2000	1.07	3.78541	0.565
Available Phosphate	6.0000	60000	1.07	3.78541	16.960
Soluable Potash	5.0000	50000	1.07	3.78541	14.133
Magnesium	0.9400	9400	1.07	3.78541	2.657
Sulfur	1.3000	13000	1.07	3.78541	3.675
Copper	0.0050	50	1.07	3.78541	0.014
		0	1.07	3.78541	0.000
		0	1.07	3.78541	0.000
		0	1.07	3.78541	0.000
Other solubles (est.)	0.0000	0	1.07	3.78541	0.000
Total PPM TDS(500)					**39.418**
Total EC in µS					**78.835**
Titration Expectations in µS					**94.381**

Calcium and Magnesium

	CaMg %w/V	PPM Full Concentration	ml/Gallon	Gal/Liter	PPM
Total Nitrogen	2.0000	20000	0.535	3.78541	2.827
Calcium	2.1000	21000	0.535	3.78541	2.968
Magnesium	1.1000	11000	0.535	3.78541	1.555
Iron	0.0600	600	0.535	3.78541	0.085
		0	0.535	3.78541	0.000
		0	0.535	3.78541	0.000
		0	0.535	3.78541	0.000
		0	0.535	3.78541	0.000
		0	0.535	3.78541	0.000
		0	0.535	3.78541	0.000
		0	0.535	3.78541	0.000
Other solubles (est.)	7.5000	75000	0.535	3.78541	10.600
Total PPM TDS(500)					**18.034**
Total EC in µS					**36.068**
Titration Expectations in µS					**44.157**

Titratration Math at 25C

Use the **"input"** cells for calculations

System Size in Gallons	168	gal	635.9 Liters
Current System EC	1000	µS EC	
Target System EC	1500	µS EC	500 = Gap to close

***Use Feed Program to Populate These Values - Feed Program May Modulate the Dose**

Bloom A ml/Gal Ratio Specified*	4	147.24 µS EC Expected (A)	**Bloom B ml/Gal Ratio Specified***	4	94.38 µS EC Expected (B)	**CaMg ml/Gal Ratio Specified***	2	44.16 µS EC Expected (CaMg)
Desired Bloom A ml/Gal	1.07	<- How to drive the system	**Recommended Bloom B ml/Gal**	1.07		**Recommended CaMg ml/Gal**	0.535	

System Total EC Expected	**1500.206**	**µS EC**

Figure 10: Dosing Calculator – partial view

Said differently, the grower chooses the target EC, the calculator simply reports the dose needed to achieve that EC based upon the nutrients recommended for that stage of growth. By way of example, if the current EC is 1000 µS and the grower wishes to increase the EC to 1500 µS, the calculator will offer the quantity of each chemistry add to achieve the grower's desired new EC. In short, the grower decides where to drive the crop, the dosing calculator simply aids the grower in achieving the grower-decided EC level.

It is to be noted that this is a known risk to the study of cultural shift, training and human error. This was a topic of ongoing concern and discussion during the grow.

RISKS + UNKNOWNS

Through partnership, assumptions were made that additional grow loops would be necessary to dial-in process and consistent data to prove correlation and causation. The following unknowns were outstanding barring outcome of the grow:

- How was the yield to be measured?
- How was taste to be measured?
- How to compare terpene outputs compared to other cultivation methods?
- Does soil prep differ from RDWC needs?
- Comparisons of room atmospherics/humidity from RDWC vs. soil grow
- Use or disuse of the provided dosing calculator by Grower, for RDWC crop
- Human error and selection. Choices made during a grow greatly impact the ability to fully capture a success target.

Risks and Outliers

At the onset of the partnership, it was disclosed that CANNABIS COMPANY experiences powdery mildew in their grow facilities. An established treatment protocol involves spraying Oxidizer Acetic Acid and H_2O_2 and Regalia in rooms.

A secondary risk to the grow operation is CANNABIS COMPANY having control over clone selection at the onset of grow. This became a primary risk factor in that plant vitality from the onset was an issue. However, having this disparity in plant heath as well as how the plants were arranged in the four systems offered insight into plant success and water consumption. In short, the unplanned plant variability offered a unique opportunity to understand water consumption with a resolution we did not anticipate. That being noted, the Hydra Unlimited team was fully prepared to exploit the opportunity presented by the unexpected data resolution.

Lastly, it is a known and understood risk of human error through the internal management of CANNABIS COMPANY to staff, feed and water the grow across the facility. There was an agreed and understood need for training from Hydra Unlimited. The overall understanding (or lack thereof) in the shift to RDWC and its necessary training for every staff member can and will severely impact the outcome of the grow.

RESULTS

The room was mapped to track plant progress across the various metrics and KPI's being evaluated daily, weekly and continuously. These are the primary results of those metrics.

Figure 11: Note that data outputs are suggested by row. Those rows are outlined by letter. Refer to Figure 2 for the room schematic that is photographically depicted here.

Growth Expression

Growth expression data are measurements of stalk diameter as well as a calculated Growth Index (GI). The growth index can be calculated several ways. In this study, growth index is a result of three measurements: overall plant height (h), maximum canopy diameter ($Ø_{max}$), canopy diameter 90° from maximum canopy width ($Ø_{90}$). $GI = h \times (Ø_{ave}/2)^2 \times \pi$

Data Collection Input Sheet (Growth Expression)

Week	Plant Variable	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3
1	*Growth Index*	10.1	23.2	9.0	15.7	22.6	14.9	25.8	36.2	88.4	39.7	60.5	5.4
	Avg Stalk Ø	4.8	4.4	3.2	4.3	4.1	4.5	4.4	4.9	6.4	5.5	7.0	5.1
2	*Growth Index*	24.1	25.4	11.5	22.1	29.3	28.4	51.8	80.6	131.5	56.6	40.0	33.9
	Avg Stalk Ø	4.9	4.5	3.4	4.8	4.9	5.1	4.9	5.1	7.4	6.8	7.8	4.2
3	*Growth Index*	90.2	94.6	61.1	84.0	208.8	124.0	170.5	385.0	482.4	365.6	339.2	187.1
	Avg Stalk Ø	6.2	5.6	4.5	6.9	7.6	6.8	6.6	9.2	10.5	8.9	9.9	5.9
4	*Growth Index*	470.2	526.9	347.7	526.9	1133.9	785.4	894.6	1291.4	1793.5	1270.3	1162.8	724.2
	Avg Stalk Ø	10.2	11.0	8.1	11.8	14.7	13.5	11.9	15.5	16.7	14.9	15.5	10.7
5	*Growth Index*	1541.3	2058.0	1045.8	1716.8	3285.3	2159.5	2364.1	2513.7	2893.3	2497.8	2592.6	1714.0
	Avg Stalk Ø	15.5	17.6	13.1	17.0	19.9	19.5	18.4	21.0	21.7	19.9	21.0	15.6
6	*Growth Index*	4395.6	4115.8	3453.8	3065.9	4319.7	4014.7	4177.3	4831.1	4931.4	3979.6	5833.4	3923.3
	Avg Stalk Ø	17.5	21.2	15.6	19.4	21.2	21.9	19.4	23.8	22.9	21.8	23.3	18.4
7	*Growth Index*	4249.1	4274.2	4302.8	4612.0	5022.1	4798.1	5415.6	5814.9	6005.9	5779.2	6294.2	5194.4
	Avg Stalk Ø	18.4	21.6	16.4	19.8	22.6	23.5	20.8	24.9	24.1	22.8	24.8	19.3
8	*Growth Index*	4444.8	5423.0	4579.1	5352.9	4376.0	4270.3	4680.3	6669.5	4984.0	6204.9	4969.6	5680.9
	Avg Stalk Ø	18.6	22.0	17.1	20.0	22.2	22.5	21.4	24.8	24.6	22.5	25.3	20.0
9	*Growth Index*	4554.0	5155.3	4303.0	4636.8	5091.8	4969.6	4376.6	5140.8	5716.5	6155.7	5571.4	5953.2
	Avg Stalk Ø	18.5	21.8	16.9	19.9	22.0	22.1	21.2	25.1	24.4	22.6	25.1	21.0
10	*Growth Index*	4722.7	4947.3	3517.1	4573.2	5950.8	3372.9	5148.0	5398.1	6002.7	5407.7	5725.4	7941.3
	Avg Stalk Ø	18.3	21.7	17.1	19.6	22.4	21.1	19.3	25.1	23.4	22.7	24.4	18.7

Figure 12: Plant expression table

Figure 12 details plant expression over ten weeks for systems A through D. Both growth index and average stalk diameter at the base of the plant were measured and tracked week over week throughout the grow.

Across the top of the table are the locations of the plants evaluated (per schematic Figure 2). The top row is week 1 with subsequent weeks progressing down the table. It is noted that the Growth Expression table labeled in green and red does not necessarily reflect extremes of success or failure, but rather relative size and vibrancy from highest to lowest for that particular week of measurements. Cells shown in white represent average measurements for that week. Red cells annotate lower than the week’s average, while green cells annotate greater than average. Darker colors depict greater excursion from average.

Through Nuravine continuous nutrient water monitoring, as well as the daily and weekly checks of plant expression, it was found that the plants began to fail to express themselves fully and vibrantly during the third week of the grow. Using active monitoring, it was found and proven that the plants were chronically underfed during each phase of the grow. The rationale for this being that the staff was under the mindset of substrate grow process and failed to accept guidance from Hydra Unlimited staff by adopting and adapting to RDWC methods and thinking.

Feed / Nutrient Consumption

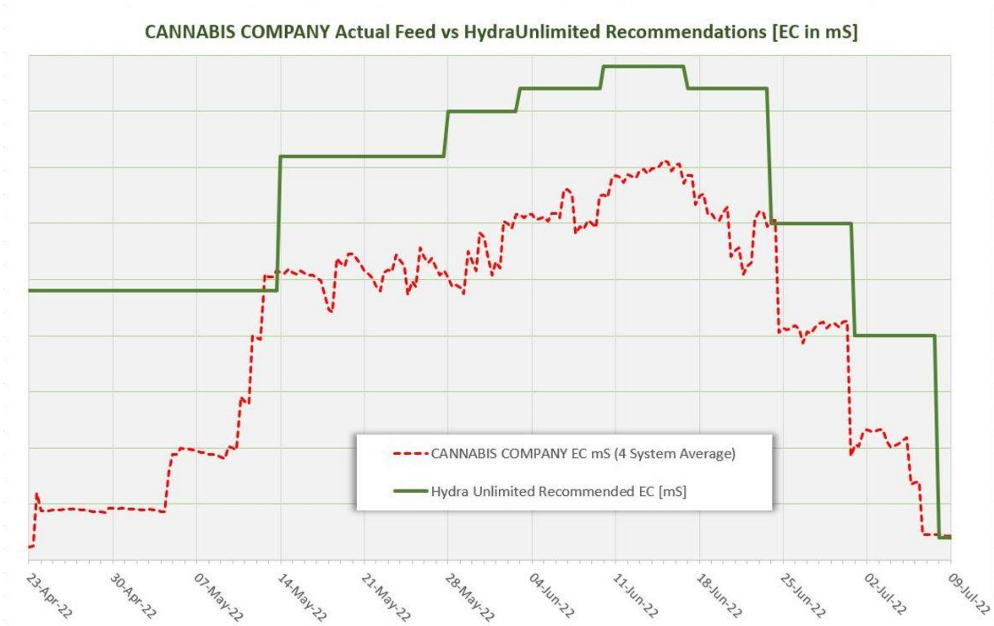


Figure 13: Recommended EC feed schedule vs the actual performed feed

Figure 13 (above) reflects underfeeding of plants for the entirety of the grow (red) against the recommendations of Hydra Unlimited staff (green). It is important to note that final metrics reflect suppressed nutrient costs due to the chronic underfeeding throughout the grow.

To the original intent of this study, the failure of the plants to thrive was seen as a setback to yield. However, the data accumulated has proven invaluable with respect to the strengths of Hydra Unlimited RDWC, and we were in a position to exploit the situation as a benefit.

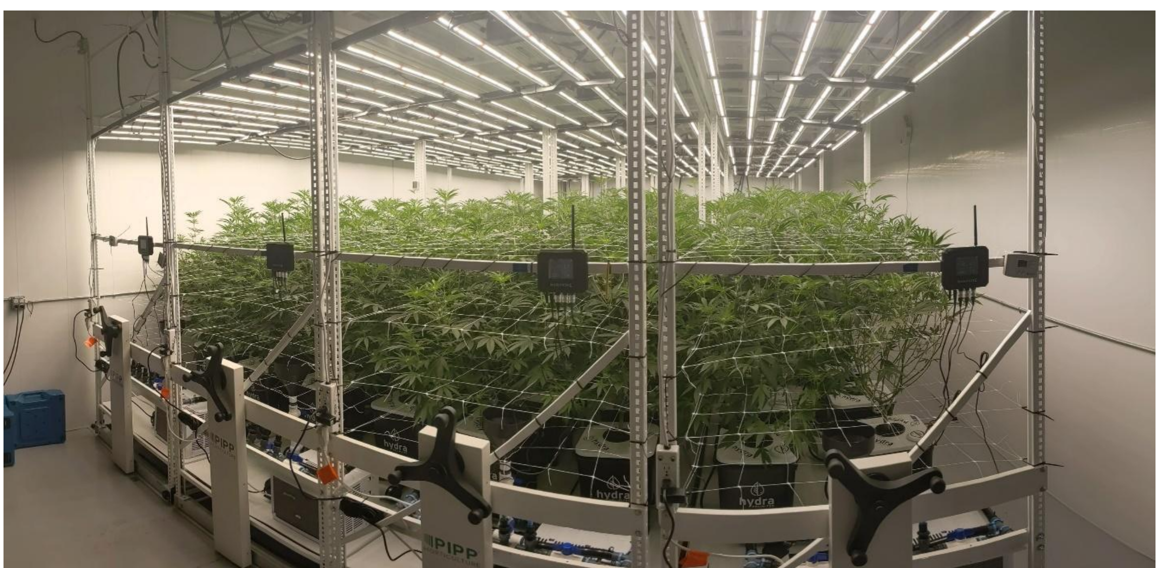


Figure 14: At week 5, these plants are healthy, but well-behind where Hydra Unlimited expectations would be for this grow.

Water Consumption

The first major takeaway realized through the reflection of water consumed, a known risk factor was found to have impacted the outcome of the grow. The data set collected during the grow revealed that the clones provided by CANNABIS GROWER were from a mother plant that was end of useful life. This, in turn, resulted in cultivars starting out in trouble. Across the 8 rows (two rows per system, it is seen that many of the provided plants were failing to thrive as compared to expected healthy cultivars employed in other grow operations.

Poor, underfed clones proved to be less vibrant than expected and from this, smaller plants resulted. It is also an important note that smaller plants with smaller canopy will take up less water through evapotranspiration.

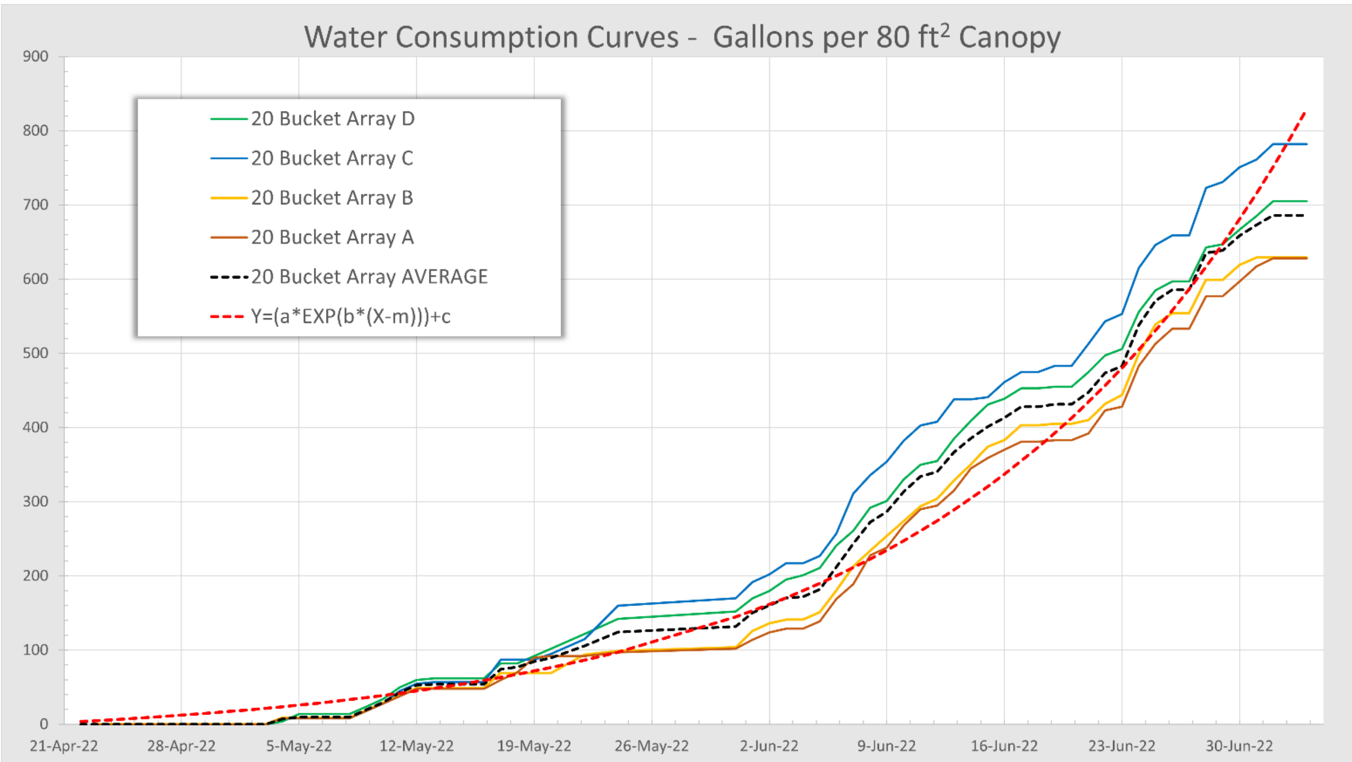


Figure 15: Water consumption across April 21 to June 30, by bucket system

In figure 15 we see generalized water consumption curves for each of the four systems (A through D). The black dotted line is the arithmetic average where the red dotted line shows the best fit exponential curve for generalized water consumption. It can be noted systems A and B (below the average line) are consuming water at a consistently lower rate than systems C and D (above the line). Comparing plant expression as shown in figure 12, we can clearly see plant expression being directly related to water consumption. Generally, below average water consumption is proportional to below average plant expression, while above average water consumption is proportional to above average plant expression.

Secondarily, and a surprise outcome to the original intent of the study, even with the combination of sub-standard clones being underfed, we can see relative success and failure within 14 days, and clearly within 21 days based solely upon the amount of water consumed by the plant.

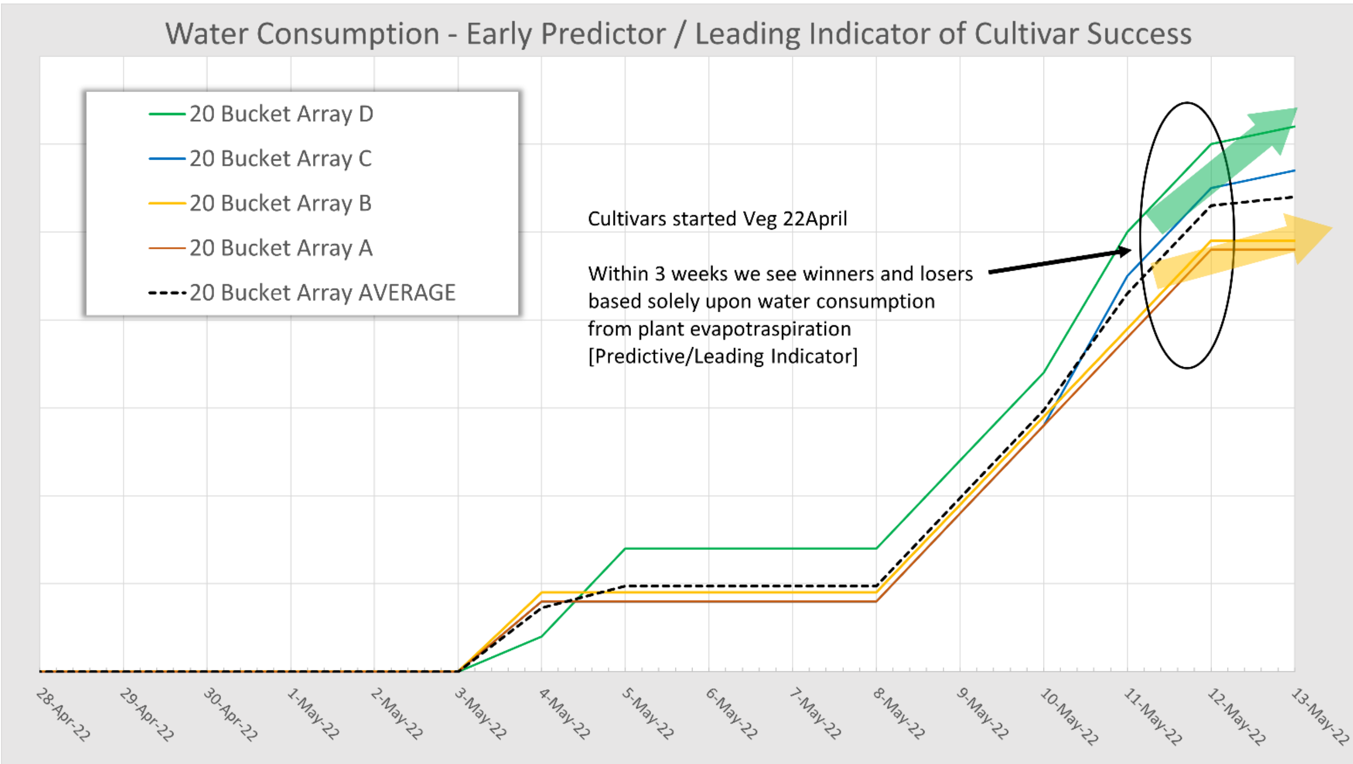


Figure 16: Division of plant success curve beginning at week three, by bucket system

Key in describing and tracking plant success is that RDWC is a closed loop system – meaning 99% of water consumed is consumed solely from plant evapotranspiration. (only %1 loss from system evaporation: a result of the unique Hydra Unlimited RDWC design). Growers can now, in advance and based upon cultivation history, graphically predict expected outcomes for any cultivar. Any future grow departing from the water consumption forecast predicts trouble and begins the trouble shooting-correction process. Being "on plan" assures the grower of better, more predictable outcomes. Through the gathered data set, it is proven that Hydra Unlimited allows growers to rely upon data, not opinion, with respect to the progress of a grow – a substantial takeaway to the future of cannabis salability forecasts at the onset of a grow.

Third, with a closed loop system from Hydra Unlimited, water consumption is a proxy for plant progress and no other measurements are necessary for the grower to comprehend plant progress for a given strain. Leaf canopy volume is directly, physically linked to water consumption. This realization, only available in a closed loop system, allows the cultivator to change the structure of their thinking. Cultivators can rediscover what they already know: of course, more leaf area means more water consumed, this is not new. What is very new and extraordinarily exciting is cultivators can discover what is being done right and what needs correction based solely on water consumption. Cultivators now have the ability to objectively and simply measure progress and forecast success. This, in turn help plants become their best selves with a minimum of resources consumed.

Fourth, through the metrics gathered, a crucial finding is that of predictive performance and leading indicators for cultivation process control. It can be stated that for any given room and cultivar, the Hydra Unlimited RDWC system coupled with Tetra-Base grow media will transfer 99% of water consumed from the buckets to the room solely through plant evapotranspiration. This knowledge has direct effect on room atmospheric control. Plant/canopy size for any specific Vapor Pressure Deficit will transpire a set amount of water during the growth of the plant, given other factors are well controlled. This means that a lack of VPD control can be traced by water consumption and is a predictor of grow success. Success can be measured directly and tracked historically. Other grow factors (nutrients, CO_2, light, etc.) can thusly be evaluated as proxies for photosynthetic rate.

Further, armed with the knowledge of exactly how many gallons or liters of water through evapotranspiration have been introduced into the room, plant-produced HVAC load is directly known and can be anticipated as the grow progresses.

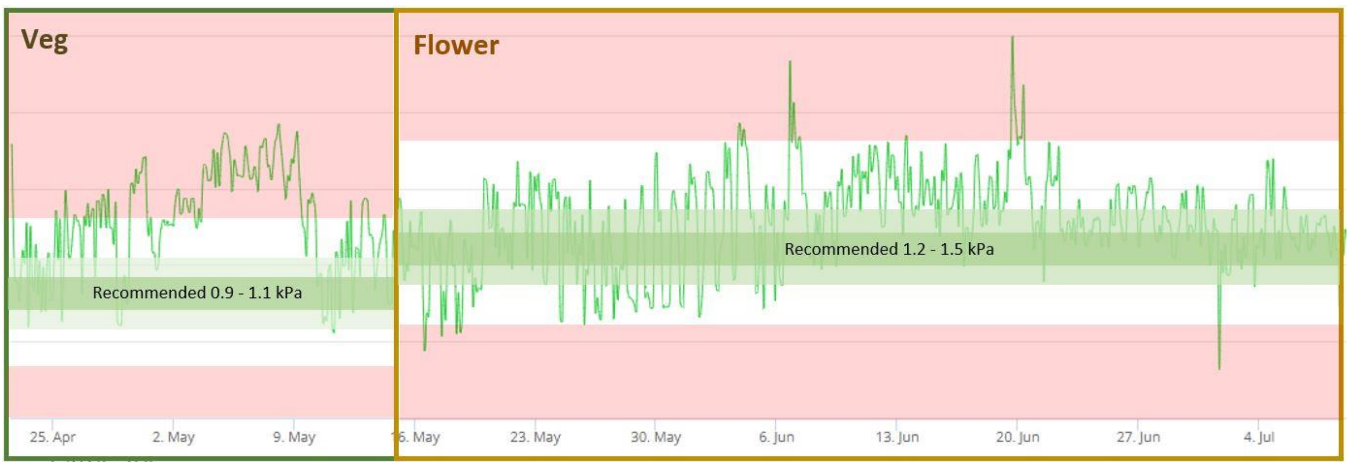


Figure 17: Actual VPD graph from the room during the entirety of this grow. Data reflects unwieldy room atmospherics through the entirety of the study – a known risk that was further proven as a factor in outcomes.

Lastly, and perhaps most important, it is proven that Hydra Unlimited RDWC systems utilize less water than any conventional substrate cultivation method and correspondingly, less wasted nutrients. Hydra Unlimited RDWC system users practice "Conservation Agriculture." Conservation agriculture is all about reducing water consumption and -in turn- reduction of total cost.

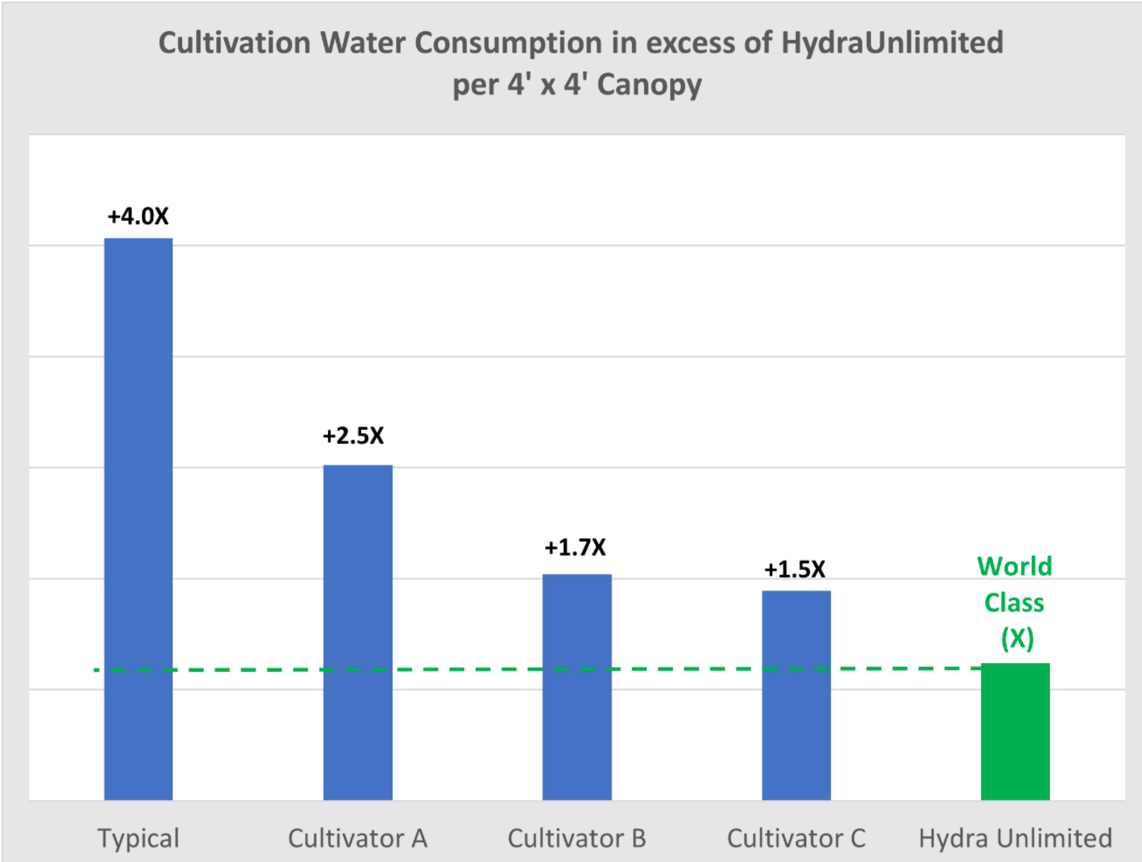


Figure 18: Hydra Unlimited water consumption as compared with other cultivation methods

In summary, while the study originally set out to prove the final state of the plant marketability to be the Key Performance Indicator, the data proved a different takeaway altogether as water consumption became the most vital indicator of success for the following reasons:

1. Control of healthy mother plant is vital. In this case, the variation in clone health revealed the importance of the measurement of water consumption to plant success
2. Chronic underfeeding severely impacted plant success. The crop eventually starved and succumbed to pathogen due to inability fight infection (refer to point #6, below)
3. Water consumption trends by 21 days into a grow can forecast likely final outcome of a 12 week grow. Countermeasures can be employed in response to the data for improved outcomes should the grower choose to do so
4. RDWC methods prove a direct predictable correlation between plant water consumption and plant success
5. An example of the ancillary benefits of water consumption data: Demonstratable data to align evapotranspiration to HVAC systems demands
6. Adoption and adaptation of RDWC systems like that offered by Hydra Unlimited RDWC requires a new way of thinking. With it, growers can enjoy world-class use of nutrient and water savings from both cost and sustainability measures, as compared to any other cultivation method

CONCLUSION

The trajectory of this study changed from early goals to final outcomes. And despite the origin of the project, the data set collected over the course of this grow has proven invaluable for reasons previously unrealized.

First, through this first of its kind study, it has been found that Hydra Unlimited RDWC is a very different way to cultivate, and therefore requires acceptance of a different mentality and training. Grow staff cannot maintain substrate practices with any intention of a thriving, successful RDWC grow. What does that mean? Training and open mindset to a new way of thinking is critical to the future of RDWC.

Secondarily, this study proved success of micromanagement of nutrient dosage through the use of the dosing calculator and high-resolution water consumption tracking. While the original intent of the grow may have been “try a different grow method” and “see what cannabis results,” the reality is the massive amount of data gathered through the continuous monitoring systems allows for different interpretations altogether. The dosing calculator set the feeds for successful growth, while Nuravine proved the feed was being consumed by the plants successfully right up until the point they weren’t. For these two facts, the grow outcome wasn’t a failure due to a lack of flower bud achieved, but rather allowed the study to realize the importance of these tools as one overall system for grow success.

And lastly, and perhaps most importantly, this grow irrefutably proves RDWC and Hydra Unlimited equipment as a world-class leader for plant nutrient and water management - allowing water resource savings never seen in the hydroponic space. Through the systems management leveraged during this grow, a groundbreaking takeaway is the direct reflection of plant health to water consumption. Through recirculating water systems and the precision of Nuravine nutrient management, Hydra Unlimited can forecast a grow trajectory within just two weeks – saving resources ranging from staffing, water runoff, wasted nutrients, and time.

Congruent with the micromanagement of water and nutrient consumption as it directly relates to plant ingestion, it can be stated that any facility opting for a Hydra Unlimited RDWC system with Nuravine can not only forecast the success of their grow within weeks, one can also for the first time acutely manage HVAC and duty cycle demands on their facilities as it correlates to water intake and outputs.

In summary, it can be said that with proper training and a culture shift to RDWC, the use of Hydra Unlimited RDWC bucket systems coupled with Nuravine nutrient management software and dosing calculator titrations set for a proposed grow can guarantee success or failure of a grow within two weeks’ time.