Guidelines for Developing an Irrigation Strategy
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When a cultivator moves from the hobby sector into the professional commercial sector, there are always many new things to learn. An irrigation strategy is typically the largest most important thing to learn when looking at high-end crop production. An irrigation strategy should be designed to achieve the maximum potential of your cultivation space; the key is knowing how to steer crop growth to a point where plant stresses are expected and then maintain that state through to harvest without causing damage or stress acceleration. In reality, this is a balancing act which is often difficult to achieve - particularly when lacking experience and having so many variables. Consider top-tier growing an art form. When a professional cultivator is planning his/her facility there should be an overall cultivation strategy developed as well as an irrigation strategy. The overall cultivation strategy begins at production and doesn't end until storage of the final product well after harvest. The irrigation strategy is much less encompassing; for the irrigation strategy, propagation doesn't matter as it has little-to-no effect on flowering stages; in reality, it is another topic in itself. A true irrigation strategy starts at the point where the plant health and growth-rates have an impact on the final outcome of the plant. For purposes of commercial crop cultivation, the irrigation strategy starts well into vegetative growth and continues until harvest.

Medium (substrate) choice is definitely the most interactive and reactive part of an irrigation strategy. The substrate itself has so many variables to account for that many growers overlook or fail to realize. On top of all the variables within the substrate choice, there is also the volume of substrate accounted for each plant. The ideal volume of substrate is that which will allow for the highest growth rates but make the plant root bound just prior to or in accordance with time of harvest; this means you have to know the crop well enough to judge rhizosphere volume needs as well as growing time to harvest.
To calculate the needed volume of substrate we will need to account for the number of desired irrigations per day as well as the drying capacity and the plant consumption. Once you have these factors in mind, it's then time to consider your desired final plant size. You can assume that the root zone volume will be equal-to or slightly larger-than the volume of the canopy itself. As a very broad example, assume your final plant canopy (per plant) needs to be 1 ft wide by 1 foot in length and 1 foot in height (just canopy not main stem/s leading up to canopy); this means the plant canopy will be 1 cu ft. Under this assumption, 1 cu ft of root zone is equal to a 7.5 gallon container.

You should also take into account the type of substrate. This example calculation reflects soil (peat mix) needs. If using coco, the roots actually have more space so the volume of substrate will be slightly less, about 5-10%. If stonewool is used for the substrate, there is substantially more root space for the same volume of media; in that case, you would assume a required substrate volume of 30% less compared to a soil (peat mix).

When you get involved in commercial production there are typically two routes to choose from with respect to the growing medium. Rockwool (stonewool) and Coco are the two most widely used greenhouse substrates for production of crops. Peat mixes are another option but are typically used in conjunction with organic growing. In reality, organic cultural practices are not practical on a large scale.

Rockwool and Coco have similar, but different, irrigation strategies. Several things have to be taken into account: CEC, water content, cleanliness, uniformity, and crop species.

Managing root zone water content is the single most difficult piece for growers to master. Those that can judge moisture content without meters often make the best growers as they read the plant and its environment as well as look at the growth rate. In today’s technological world, we don’t all have to be plant whisperers - we can use water content meters to judge the root zone moisture. By continuous knowledge of root zone moisture, we can use the irrigation systems to deliver precise amounts of water and fertilizer at exact intervals to drive growth well beyond what was previously possible.

Caution exchange capacity is definitely something that has to be taken into account when developing the irrigation strategy - it’s knowing how high you can push the EC levels and how rapidly the salts will accumulate within the root zone; lack of this knowledge and its negative potential has led to failure for many cultivators. Constant awareness of the CEC also helps judge how long the final flush phase will need to be to completely clean the nitrates stored within the plant.

Environmental parameters can be easily tracked in this day and age but will make a large impact on how the irrigation strategy is executed. As a general rule, high light situations (greenhouse) will use a lower EC for the same size plant because there is a greater need for water uptake and transpiration to cool the plant. Indoor growing with the best lights is still considered a low light situation and therefore requires a higher EC.

Relative humidity of the air, both indoors and in the greenhouses, is one of the most important and challenging factors to consider for cultivators. Certain varieties of your favorite plants prefer low humidity levels (below 50%), and this is often difficult to achieve when growing plants on a large scale. Greenhouses

often deal with this issue much easier by using ridge vents and exhaust fans – a factor limited to certain geo locations however. Fortunate growers at high altitude in colder climates have extremely dry air and very few problems - especially considering high altitudes typically have more intense sunlight. Temperature is typically a major concern for growers but in reality many popular plants can deal with high temperatures if the radiation isn't too high.
CO_2 levels inside a warehouse, or greenhouse, make a large contribution to the growth rate of the plants and therefore has to be considered in the irrigation plan. As a general rule, if CO_2 is supplemented then the plants run at a higher metabolism regardless of the temperature. If the plants have a higher metabolism, they can process higher concentrations of fertilizer. Many growers run CO_2 programs using large fluctuations to stress the plant; this is not something I advise as you are stressing the plant. If you can increase the metabolism with CO_2, why not keep it high the whole time? The plant is still working as hard as possible to process the light and nutrients so there is no need to add stress; stress slows growth rates and that causes lower secondary metabolite levels as well as lower yields. My advice is to supplement CO_2 at the beginning of flowering and keep it high (light hours only) until harvest.

One concept most indoor growers haven't heard of is dryback (also known as drydown). Dryback means the amount of drying that occurs between cycles (typically overnight). The reasons this is important is root growth and development. Every scientific study will tell you that roots grow when dryness occurs; If roots are sitting in water all the time, they won't grow.
The substrate has to have enough drying capacity to keep root growth stimulated throughout the flowering cycle. Dryback is typically measured as a percentage - by measuring the water content at the end of the day cycle then measuring again at the beginning of the next day cycle; subtracting what you end up with leaves a change in water content. This change is the dryback. As a general rule, the more dryback you can achieve, the higher your growth rates.
When we look at irrigation strategies we also have to look at drainage. There are two parameters associated that can be measured. Time of first drain is just that - the time after the beginning of the day cycle where our irrigation causes runoff from the plants. This time of first drain gives us an idea of how accurate our dryback numbers are as well as how accurate our session length is. If session length is too long, we see drain quite early in the day versus if session length is to short, we won't see drain until late in the day - if at all. Drain percentage is also important; by measuring the amount of drain we can have an idea of how much of the nutrient solution inside the root zone has been refreshed. If we see a large amount of drain-through then we can assume the entire root zone has fresh solution. If there is little or no drain, we can assume the solution is not completely refreshed in the root zone. Ideally the solution will always stay balanced; it is the plants job however, to absorb the nutrients and water which is continually throwing the root zone solution out of balance. The reason we don't always want a large amount of drain through is because the dryback is more important than the solution being fresh all the time - and all the while we keep in

mind crop steering for number of irrigations per day to drive the growth toward flowering (or vegetative) growth. It is truly a balancing act and as biological creatures, plants create the changes causing imbalance.

Monitoring the EC and pH of the drain is not as important as many growers think. While we can learn things from this drain, we can learn more by measuring the solutions going into the root zone and by taking samples of the water within the root zone. As a general rule, healthy plants will cause pH to rise over time within the root zone. This is due to caution/anion exchange reactions. EC levels can fluctuate up or down depending on the CEC of the substrate and the feeding rates vs what the assimilation rates of the plant. As a generalization, the number one mistake in horticulture is overwatering; however, under fertilization (the second most common mistake) will exhibit the same symptoms. Over fertilization is much more easily corrected compared to overwatering.

Session length, the length of each irrigation, can be measured or monitored in volume or time (duration) – an extremely important piece of the puzzle because the session length helps to control the root zone water content. Being able to keep the water content level in line with your desired growth steering can be an art. The ideal session length will provide the amount of nutrient solution needed to put the water content levels in line to match up with the dryback and number of irrigations per day. With each irrigation, you should go past the desired water content level and allow to dryback to desired amount (likely below desired water content levels) prior to the next irrigation; this is a very complex variable structure that dynamically changes with plant development and environmental conditions. Growth steering means that the grower makes changes and manipulates the crop to do what is desired. In most cases, this means keeping the growth rate high and either forcing vegetative growth or generative growth (flowering). The main strategies we use with irrigation are number of irrigations per day. More frequent irrigations and lower volume drives growth vegetative effects where less frequent irrigations at higher volumes push growth generatively. To truly steer plant growth, a grower must balance water content, session length, dryback, drain, and irrigation frequency.

Root development is our key observational judge on plant health. If roots continue to develop through flowering at an aggressive rate then we are right on track for our irrigation strategy. If root development slows or starts to show discoloration however, that is our first indicator that something needs to be adjusted in the irrigation strategy. Most often, you can assume your first mistake is overwatering and in that instance irrigation session length should be decreased. Session length should always be measured; even if it is calculated through the amount of time and the flow rate of the system. First and foremost, growers should not irrigate during the dark cycle. When looking at irrigation timing, it should occur after daylight cycle begins and final irrigation should be completed well before day cycle ends. The number of irrigations that should occur throughout the day cycle should be based on environmental parameters, plant size, growth rate, growth steering and developmental phase also keeping in mind the desired amount of overnight dryback.

Plant developmental stage is a key part of knowing how to develop an irrigation strategy. Many plant species we have classified can have up to 5 phases of developmental growth for production staging. An argument could be made for additional preliminary phases but the plants are so juvenile that the irrigation strategy isn't as crucial.

Planting and rooting in will define phase 1. This is a transition phase where the vegetative plants are in place in the flowering zones but still in the vegetative photoperiod of 18hrs. It provides a settling period before the plants go into rapid growth rates.

Rooting through and crop development (at flower initiation) is classified as phase 2. This will be the point where the photoperiod is switched to 12 hours per day to induce flowering. Nitrogen levels will remain high but increases in phosphorous and potassium will begin. The plants will begin to show high rates of internodes expansion, "stretching."

Balanced Growth (formation of flowers) defines phase 3. This development is structured around first flower set. During this time, high water usage occurs and nutrition is crucial as flower cells are experiencing rapid division. The plant is laying the building blocks of structure and growing rapidly. Nitrogen feeding levels will begin to decline while phosphorous and potassium levels will continue to be increased. Calcium, magnesium, and iron supplementation will level off as plant water consumption slows. During this time we may begin a basic liquid carbohydrate supplementation. While scientific evidence shows plants exhibiting little to no exogenous carbohydrate uptake, the indoor gardening industry has - to some extent - proven the potential. As carbohydrates are organic we supplement in low concentrations; these carbohydrates will also provide food for microbial activity within the root zone - which may assist in mineral uptake.
Flower and growth balance classifies phase 4. This period will show rapid expansion of flower cells showing daily gains in mass. Nitrogen fertilization will be decreased to near zero while phosphorous and potassium levels will peak drastically. Calcium and magnesium levels will remain high to correlate a sensible calcium to potassium ratio. Carbohydrate supplementation will progress and plants will begin to exhibit visible signs of essential plant oil production. Terpenoid levels will begin to drastically increase, particularly during daily dark cycles.

Phase 5 is the pre-harvest flush and ripening of flowers in preparation for harvest. In this final developmental stage, we force the plants to ripen rapidly by delivering pure water (0 EC, no fertilizer) for the last two weeks of the plants development. The plant will be forced to feed off the stored nutrients and carbohydrates within the large leaves. The plants will begin to yellow slightly as nitrogen within the plant becomes scarce - a good sign. The clean, final ripening stage will ensure the flavor and bouquet of the final product; this will finalize the fragrance profile and harden the flower structure which allows the plant to senesce (cure).

Feeding EC levels are probably the most misunderstood piece of plant production. The most common mistake is fertilizer levels that are too low. As a general rule, fertilizer works off of a sufficiency level (nitrogen is an exception); if a plant is deficient there are symptoms. The relationship changes once the fertilizers reach adequate levels. Adequate does not mean optimal. The level of fertilizer can be increased beyond what is adequate to show better plant performance.

There is a point of damage from over fertilizing. As fertilizer levels are increased gradually throughout development, there's a point each crop should not be pushed to for slight over fertilization - this slight overage can easily be corrected and once corrected, we would consider that level optimal for that particular breed in that environment. We cannot find the optimal level for each progeny without pushing it to slight over fertilization. The level that each variety finds optimal will also change with changes in the environment.

Most growers and consumers alike will tell you that a major factor of quality is flower density. The flowers that are airy and spongy could have gone through any number of stressful situations. High temperature, low EC, overwatering and lack of light intensity can all cause these symptoms. The high-end production on a large scale requires attention to detail and lots of knowledge. Every environmental parameter and cultural practice will have an impact on the final product. The best way to manage the balancing act of the facility is to monitor every single parameter you can. Monitoring requires technology and many technologies are available so it is all about finding the best piece of equipment for your facility.

Controlling plant growth takes an expert, which is why most indoor gardeners have never heard of an irrigation strategy. While all the concepts discussed here will make you a more advanced grower, they will not make you an expert. The ability to control and observe all parameters of growth is a rarity which can only be mastered over time in one space - meaning that a space whether a greenhouse or warehouse, is different in every location; even if it is set up exactly the same. Besides location variances, there will also be seasonal variances and annual variances for the same time of year. A true production situation should be an ever-evolving being of its own and the growers progress with the facility or get left behind. The best growers are the ones causing these progressions! If your grower isn't the one to facilitate the progression you want, your best option is to find a consultant to implement the progress. In the end, if your facility isn't moving forward you are being left behind because your competitor is learning while getting more efficient and increasing productivity.