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Nutrient Solution Management and Longevity

for small recycling systems

There are many ways in which people determine the longevity, or useful life, of their hydroponic nutrient solutions. These range from the "replace it every week or two to be safe" method, to not replacing it at all except between crops. The latter, meant primarily for commercial operations, requires costly plant tissue and nutrient solution lab analyses to be performed. This becomes more attractive as an operation grows larger, for example, when a point is reached where costs to replace an 8,000 gallon solution start to approach the lab and personnel costs required to maintain it. For the home gardener who hasn't the resources nor the financial incentive to have lab tests performed, other management methods are used. As home gardeners not using lab tests, in this article we will not consider maintaining the elemental makeup of the solution. Attempting to do so without such tests would have no basis in fact and would be based solely on guesswork.

Useful Life

Useful life can mean many things to many people depending on their definition of *useful*. Two factors can be used to define useful where it relates to nutrient solutions; plant health and economics.

Plant Health

A solution is no longer useful when it has potential to negatively impact growth or the health of plants, and ultimately yield. The nutritive quality of a solution is determined by the gardener at the time he mixes a new solution. Over time, water and nutrients will be used by plants and will slowly change the elemental composition (or balance) of the original mix, leaving some elements in short supply while others become proportionately over-abundant. There are two facets involved with elemental availability. One is the *existence* of an element, the other is the effect the chemistry of an imbalanced solution has on the *availability* of that element. An aged solution's imbalance can be such that it either has an insufficient quantity of an element existing in the mix, or that the imbalance has changed other properties of the solution to cause the element to become unavailable to the plants. For example, a solution may have had all but a trace of its nitrogen depleted, or it may still contain adequate nitrogen but it will be unavailable because of the pH shift resulting from the imbalance. Either condition is unfavorable to plant health. The difference being that the former points to a spent solution that has no more useful life and needs to be replaced, and the latter points to a solution which may still be useful but is starting to require more maintenance than desired.

It should go without saying that using the plants themselves as a means of measuring the useful life of a solution is counterproductive. The purpose of nutrient solution management is to avoid any unhealthy solution condition, waiting for plants to show signs of nutrient stress defeats that goal. Instead of using the plants as guinea pigs, we use indicators in the solution that will alert us to *approaching potential problems* so that we can avoid those problems thus insuring uninterrupted plant health for the life of the solution.

Economics

A useful solution will not be discarded before its time. If economy is defined as...... *Careful, thrifty management of resources, such as money, materials, or labor*, then replacing a solution before it's time is less economical on all three counts. When a solution with a life of 20 days is replaced after 10 days because the stage of growth is now demanding a different NPK formulation, it could be said that was not thrifty management. So in some cases a solution can have *too long a life* to be economical. On the other hand, when a solution with a life of 10 days is used for a crop requiring only 2 growth stage formula changes, each 30 days apart, it could be said that was not thrifty management of labor resources, because replacing six solutions takes more work than replacing 2. So in other cases a solution can have *too brief a life* to be economical. The value people place on their time can be much different from that they place on their money or materials. Many would gladly spend a dime to save an hour while others would gladly spend an hour to save a dime. Perhaps the best practice is to seek opportunities to save an hour or a dime whenever the *payback can be seen on a repeat basis*, where the gains could be enjoyed over and over again.

Solution Maintenance Required to Insure Plant Health

Although a solution may pose no potential threat to plant health, most gardeners consider a solution no longer useful when it causes the gardener to spend more time maintaining it than is desired. Needless to say, what is and what isn't a desired amount of time can produce a hundred different answers from a hundred different gardeners, but it can be assumed that less time is more desirable than more time when results are the same. Solution maintenance can be said to consist of two activities; maintaining the solution volume and maintaining its pH/TDS (TDS and EC can be considered the same in this article).

Maintaining the solution volume

Water volume maintenance is a matter of adding plain water to the reservoir as its level drops, generally replenishing the reservoir level to its full line. Add backs (another term for water volume adjustments) are made at predetermined intervals usually complimenting a gardeners schedule, or randomly at the gardener's convenience. In some cases, in lieu of manually performing and scheduling any repeated add backs, a gardener may instead opt to maintain a float valve connected to a secondary water source such as another reservoir or a tapped water line, to keep levels constant, and maintain that device only once each time a new solution is mixed and water replaced. Water volume adjustments are easily predicted after only one or two crops, if one keeps track of water use during those crops.

Because of the plants' relatively higher absorption of water than of salts in the water, maintaining the solution volume is *essential* in a recycling system in order to prevent salts from over-accumulating in the solution, and with systems such as ebb/flow a full volume of water is a requirement to insure that growing beds can fill to the proper level. Since add backs are an *unavoidable* fact of life, and because any additional pH/TDS maintenance and adjustments *are avoidable*, a maintenance program that limits itself to only add backs will be easier, less time consuming to maintain, and less of a drain on your resources. Furthermore, in the interest of economy, pH/TDS measurements can be performed at the time add backs are made while access to the reservoir solution is already convenient.

Maintaining the volume pH and TDS

pH/TDS maintenance requires measurements, and keeping their parameters within an acceptable range. For example, a pH range of 5.5 to 6.3. TDS ranges could be defined two ways, as a static ppm range (750 to 1250), or as a +/- percentage of the TDS for the original mix (+/-25% of 1000). Adjustments for pH/TDS are much more difficult to predict than water usage because the quantity and quality of the add back water itself has a profound affect on their outcome. Solution maintenance doesn't need to include interim pH/TDS adjustments (between add back sessions) when a gardener is deliberately using add backs to affect the pH/TDS ranges to his advantage. In other words, maintaining pH/TDS can become part of a deliberate volume adjustment program, thus allowing a gardener to kill two birds with one stone. See the Control Track article for more on predicting pH/TDS.

pH

One of the most common reasons people replace their nutrient solution is because controlling its pH to stay within its range keeps them running in circles. As a solution ages and nutrients are removed, the ability for the solution to buffer against future pH shifts becomes less. A fresh solution has a pH behavior that's generally predictable, it will fluctuate but will do so within the acceptable range, thus requiring no adjustments or maintenance other than add backs. An older solution finds the pH wanting to run out of range (usually in the direction of the source water pH), this runaway pH drift constantly needs attention. At this point pH can start to become more trouble to maintain than the trouble it takes to replace the solution and return to the lower maintenance of a balanced and well buffered fresh solution. The problem here is that by the time a gardener realizes he's been going in circles chasing a pH ghost, the solution can have already passed its useful life in other respects.

TDS

Using TDS as a yardstick by which to gauge a solutions' useful life can be tricky. That TDS drops 25%, or 250ppm, isn't of itself an indicator for possible nutrient deficiencies, or that plant yields will suffer because of it. The assumption often made here is that the starting solution was at or near the **nominal threshold** of the plants' ability to sustain healthy growth, thus concluding the reduced TDS to be well *below* the threshold, and possibly deficient in one or more elements. Since it's relative to the starting TDS of a solution, if the starting solution was originally mixed 25% stronger than the nominal threshold, then when the solution TDS had dropped 25% it would be *at the threshold* instead of below it. Plant nutrient requirements are not something that can be nailed down to *the* ppm, for that reason thresholds for many crops are given as a range of recommended minimum and maximum *elemental* ppm values (not to be confused with TDS ppm values). For example, a flowering recommendation might be given as N 40-100 ppm, P 70-100, K 100-200, Mg 30-60. To know your crop's limits is to be able to use it to your advantage. As you can see from the above example, a gardener has a good deal of latitude in how he can configure his nutrient solution mix. *A safety margin for TDS measurements can be built-in to the original mix* by mixing the solution nearer to the high end of a crops' recommended range, doing so will also provide more buffering power thus extending the solution's life to a degree where it relates to pH stability. In other words, TDS can have an affect on pH changes, but pH has no effect on TDS changes, so TDS also plays a role in controlling pH.

Reservoir Sizing

A common rule-of-thumb estimate of water usage in a greenhouse is about 1 liter/sq ft/day for vine crops such as tomatoes. For a mature indoor garden under strong artificial HID lighting it would be about 25% less, or 0.75 liter/sq ft/day (0.20 US Gallons). An indoor home gardener wanting a starting point for determining his reservoir size can use approximately 3 US gallons (11.36 liters) of reservoir water volume for each square foot of mature crop canopy space. This water volume to space ratio has been found to produce both low maintenance and solution life expectancies that can easily coincide with growth stage nutrient formula changes. Waste not, want not:-)

Management Strategies

Time Based Management Strategy

The "replace it every week or two" idea is *usually* safe regarding plant health, however, it doesn't distinguish between those using small reservoirs with large crops and those using large reservoirs with small crops. What really determines solution life is the plants' ability to transpire, which is a function of its leaves. This means that if you have one more leaf today than you did yesterday, that today you would need a little more water than you did yesterday because of the new growth that was born since yesterday. As you can see, *water uptake is a constantly moving target,* and while it does have an element of time associated with it, it's really controlled by the mass of leaves in a garden at any given time.

To adopt a static time frame for when solutions should be replaced, doesn't account for the scant water uptake from the few leaves found on small seedlings at the start of a crop, compared to the demanding water uptake of what those seedlings will become after 60 days once they possess the thousands of leaves typical of some matured crops. Nor does it account for those gardens using a reservoir size that is undersized for the amount of growth it supports, while other gardens might be using oversized reservoirs. Someone using the "replace it every week or two" method with an undersized reservoir might be safe when a crop is new but not be as safe as he thought once the crop has matured, while someone using an oversized reservoir may be needlessly performing six or more solution changes over a twelve week crop when he could get the same results doing only three changes.

Clearly, time alone doesn't answer to all the variables taking place between different gardens or the growth stages those gardens are in at any given time. In other words, this method is tied to the calendar, not to the plants. I suppose it should be mentioned that I have seen some fertilizer labels suggesting very strong mixes to be replaced at unusually frequent intervals for the strength of the mix. While it's unlikely that crop damage would result from following such instructions, one can only wonder if such labeling suggestions are an honest effort to simplify use of the product or to bolster sales for it, or both.

Water Uptake Based Management Strategy

Water uptake based management determines the useful life to end at a point where the original volume has been completely replaced by *plain water add backs*. For example, when a 25 gallon reservoir has had 25 gallons of water added back to it. This is sometimes also referred to as the 100% add back point. As you add back plain water, simply make note of the quantity and replace the solution when the total quantity of all add backs equals the reservoir capacity.

In case you haven't noticed, the determining factors behind a reservoir's useful life can all be traced back to the *rate of water uptake*, which is directly tied to the current demands of the crop. These demands will constantly increase as plants slowly fill their allotted space, often taking sixty or more days and spanning multiple growth stages before *peak* water uptake is eventually seen by the reservoir for the first time. As more water is being used by the plants, more nutrients are being removed from the nutrient solution, this naturally affects the nutrient balance in the remaining solution. In essence, the nutrient balance is also being controlled by the rate of water uptake. Simply put, a fuller garden space uses more nutrients because it uses more water. So what we have here is a direct relationship between solution volume maintenance (add backs) and pH/TDS maintenance.

When that relationship between volume and pH/TDS maintenance is recognized, a grower can take advantage of repeat labor savings if he adopts a *proactive* approach to managing his nutrient solution rather than *reacting* to its changes. The idea being to eliminate the work of several mid-stream pH/TDS correction adjustments by accounting for future corrections at the same time the solution mix is being prepared - and while tools and products are already in use. Although this requires advanced knowledge or experience needed to predict how a working solution will change over time, the long term labor & time savings from obtaining such knowledge is significant. Not only is the proactive payback repeated with each solution mix, but crop after crop as well.

Proactive Approach (see Control Track for predicting changes)

Formulating a starting solution mix in concert with the unique properties of *your source water*, while at the same time anticipating changes in the solution, can allow you to run a nutrient solution without making any secondary pH/TDS correction adjustments during the entire life of that solution, thus limiting your maintenance to only the unavoidable plain water add backs. For example, an alkaline source water will tend to produce an alkaline solution as more and more of it is added back to the reservoir over time. You can avoid correcting unacceptably high pH levels that occur later during a solutions' life by adjusting its starting pH a bit lower to compensate. Similarly, to keep the ending TDS of a solution from falling below the nominal threshold for a given crop, you can adjust the starting TDS a bit higher to compensate. The advantages of making all corrections at one sitting are obvious, and speaks strongly to the gardeners' economy of labor. It's not all that different from making the kids pee *before* they get in the car for that long drive!

Some things to consider about a water uptake based strategy and proactive management.....

- Water uptake based management self-adjusts to the stage of growth and environmental variables affecting water use.
- At a reservoir size of 3 gallons/sq ft....

  - solution life at *peak* crop water demand (when plants are largest) lasts appx 15-20 days
  - solution life at *new* crop water demand (when plants are smallest) lasts appx 35-50 days
  - 90 day crops seldom require more than 3 reservoir changes

- Reservoir life ends with a TDS of approximately 75% that of the starting TDS (depending on source water)

  - minus 25% TDS tends to coincide with the point at which buffering power is about to be lost and pH begins to become unstable

- When proactively adding back plain water....

  - time spent mixing nutrients or making pH/TDS adjustments is limited to only the original mixing session.
  - anyone who can pour water to a full line can maintain a crop in your absence.

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