MANAGING GREENHOUSE SOILS THROUGH SPLIT APPLICATIONS OF NITROGEN

A summary of Perennia's winter webinar series, brought to you through the On-Farm Climate Action Fund. More details available at **ofcaf.perennia.ca**

Navigating soil health is a complex topic, especially in protected spaces where all precipitation has been excluded. The lack of rain and snow moving through the soils results in a build-up of nutrients in the rootzone, which can impact the ability of the crop to extract key nutrients for growth. This 'irrigated desert' requires careful and strategic applications of fertilizers, bulk amendments, and cover crops to prevent salt accumulation, maximize plant performance and reduce the loss of greenhouse gases to the environment.

Figure 1. An example of a tunnel soil where salt accumulation has reached the point of forming a visible crust on the surface. This is an indication that salt levels are very high in the soils, which can impact water and nutrient uptake by the crop.

Judson Reid is an extension specialist from Cornell University specializing in high tunnel production of soil-based vegetables. He is well versed in the complexities of managing soil health in protected spaces and participated in three webinars in 2023: two sessions discussing nitrogen management, and one discussing the use of cover crops to improve and maintain soil health. Below is a summary of what was discussed during the nitrogen management sessions:

One of the most common ways to supplement nitrogen to the crop is through bulk applications of soil amendments such as compost and manure. In order to meet the nutrient needs of your crop, large volumes of these products need to be applied. These bulk amendments, however, are also sources of phosphorus (P), magnesium (Mg^{2+}), and calcium (Ca^{2+}), which typically exist in equal to greater percentages compared to the amount of nitrogen. This results in the application of excessive quantities of 'other' nutrients on a regular basis, far exceeding the needs of the target crop, and creating problems that can be difficult to resolve within the constraints of a growing season

TOO MUCH OF A GOOD THING, IS NOT A GOOD THING!

As nutrients accumulate in protected soils, there is tendency to see an increase in pH as well. Plant nutrient uptake is highly impacted by pH, as well as the ratio of key developmental nutrients to one another. Take potassium (K^+) for example – this can be present in high quantities in the soil but will be displaced from soil exchange surfaces when excessive magnesium and calcium ions are also present. This displacement interferes with plant uptake, and results in the plant operating in a state of potassium deficiency (impaired nutrient and water movement throughout the plant as well as delayed/inhibited ripening in key cash crops). In addition, crops grown in salty soils tend to experience additional abiotic stresses (i.e., water stress despite readily available water), and biotic stresses (i.e., root disease), ultimately decreasing the yield of high quality, marketable vegetables.

Let's use a fairly standard compost test analysis as an example. If the compost test analysis read that it was:

- 1.08% nitrogen,
- 0.52% P_2O_5, and
- 0.53% K_2O
- With a bulk density of 872 kg/m^3

If a farmer applied 2.5 cm of compost, that would be 218 metric tonnes/ha and

- 2,350 kg N/ha
- 1,134 kg P_2O_5/ha
- 1,155 kg K_2O/ha

Which would far exceed any crop uptake.

For more details on compost analysis interpretation, check out Perennia's factsheet: How to Interpret a Compost Analysis Report.

Figure 2 shows an example of how the nutrient composition of a protected soil can change over time when it is not being monitored on a regular basis. Where there is a noticeable improvement in the amount of organic matter over time, these improvements were done at the expense of the nutrient, or chemical, health of the soil. The levels of P, K^+, Ca^{2+} and Mg^{2+} following regular amendment applications are extremely high. Where the image is useful to put into context the various levels of these nutrients in relation to each other, this is only valuable to a degree - past a certain point the image is unable to fully capture the full scope of abundance that the nutrients exist in.

SOIL TEST RESULTS FROM EARLY PRODUCTION DAYS

Element	lbs/acre*	Very Low	Low	Optimum	High	Very High
Phosphorus (P)	2					
Potassium (K)	160					
Calcium (Ca)	4,553					
Magnesium (Mg)	584					

Element	Value	Element	Value	Element	Value
Soil pH	6.5	Manganese (Mn), lbs/acre	16	% OM	4.9
Buffer pH	6.3	Zinc (Zn), lbs/acre	0		
Iron (Fe), lbs/acre	4	Aluminmum (Al), lbs/acre	35		

SOIL TEST RESULTS FROM PRESENT DAY

Element	lbs/acre*	Very Low	Low	Optimum	High	Very High
Phosphorus (P)	669					
Potassium (K)	2,616					
Calcium (Ca)	16,142					
Magnesium (Mg)	1,971					

Element	Value	Element	Value	Element	Value
Soil pH	7.8	Manganese (Mn), lbs/acre	56	Aluminum (Al), lbs/acre	4
Iron (Fe), lbs/acre	6	Zinc (Zn), lbs/acre	6	% OM	11.9

Figure 2. A side-by-side of a soil test taken from a vegetable high tunnel. The top image represents the soil early on in the production process. The bottom image represents a soil test taken after a few years of continuous amendment.

Tools for Prevention:

With the exclusion of overhead precipitation that would typically help remove salts and other nutrients, nutrient management becomes extremely important for long-term health and resiliency in the protected space. There are many tools available in our testing toolbox that should be used to manage our amendments, reduce unnecessary input costs and support productive crops for many years to come.

1. **Soil test**- this is essential and should be done at least once a year in protected settings. Early fall is the best time to sample, where the soil is still warm and biologically active, which should translate to plant-available nutrients. This also allows for plenty of time to come up with a fertility plan going into the following year as well allow for any pH adjustment agents (ex. lime to raise pH, elemental sulfur to drop pH) to work their magic.

2. **Water test**- water is the biggest input used in greenhouses by volume, so knowing the chemical breakdown of it is extremely important. Soil acts as a massive reservoir for any amendment added to it, and without overhead precipitation, there are no natural flushes of the reservoir.

   What key features are we focusing on here?

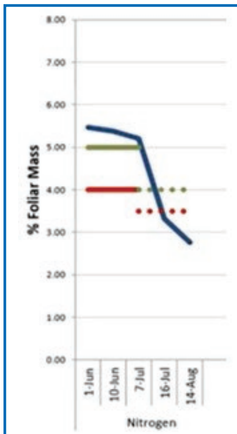
   - pH (affects nutrient availability)
     - Less N is taken up by the plant at higher pH values
   - Alkalinity, or 'hardness' measured in mg/L
   - EC (measure of salt concentration; affects water availability to the plant)
     - We want to see this value as low as possible in our irrigation water. The upper limit here is around 2 mmhos
   - Mineral content (i.e. calcium, magnesium, etc.)

3. **Tissue test**- an evaluation of how well your crops are taking up the applied nutrients. Regular sampling throughout the season can be used to spot trends over time, provide context on necessary adjustments to remaining in-season split nutrient applications, as well as help in nutrient decision making for the following year (ex. Initial N incorporated was too low/high). It is recommended to do these tissue tests on a biweekly basis to allow time for fertility adjustments before deficiencies/toxicities occur.

4. **Bulk Amendment Analysis**- If you don't know what you are adding to your soil, you don't know if you are meeting your crop's needs or if you are over-fertilizing to the detriment of your crop and soil health.

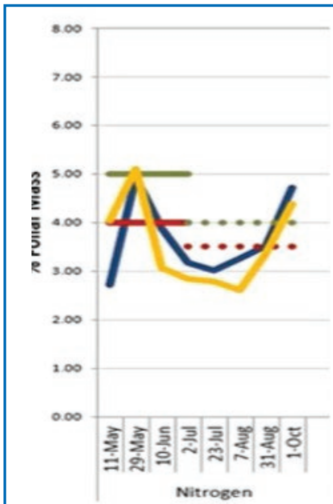
BY THE TIME YOU CAN VISUALLY IDENTIFY A DEFICIENCY IN YOUR PLANT, YOU HAVE ALREADY LOST YIELD.

Below are some examples of different nutrient management strategies and their corresponding tissue tests throughout the summer. The solid lines represent the target nitrogen values during the vegetative stage of production and the dotted lines are the targets for the fruiting stage of production. Green is used to indicate the upper limit of the recommended range, and red is used to recommend the lower limit.



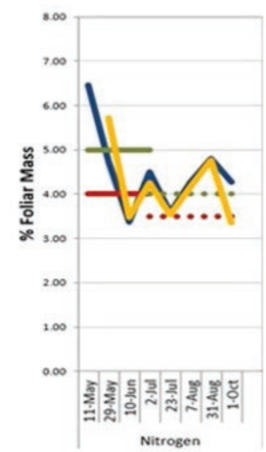
In this scenario, 100% of slow-release N was applied at pre-plant. There was no additional supplementation in response to falling N levels shown through foliar testing, resulting in N falling below optimum levels. These levels did not recover throughout the growing season and would impact overall production.

Figure 3. The graphed results from a series of tissue tests taken over the course of a season. This scenario illustrates a strategy that relies on 100% N incorporation at pre-plant.



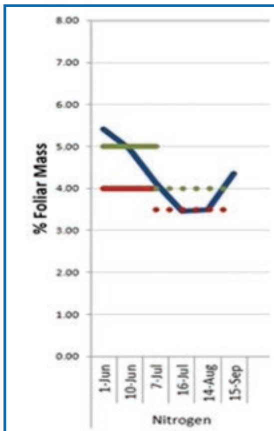
In this scenario, 100% of the in-season N was applied in a soluble form through the drip. There was no adjustment to the rate of N despite less than sufficient levels being reported through tissue testing. These levels did not recover throughout fruiting, and only bounce back after the main harvest is complete.

Figure 4. The graphed results from a series of tissue analysis, illustrating a strategy of N management where the pre-determined application rate for soluble N through the drip is not adjusted based on information gathered from tissue tests.



Based on the trends observed in %N over time, there is a grower response directly related to the foliar sample result. While effective for preventing N from dropping below critical levels, the grower spends the season playing catch-up.

Figure 5. The graphed results from a series of tissue test analysis over the course of a growing season. Soluble nitrogen was applied through drip lines at a variable rate.



Soluble N was applied through the drip based on the results of foliar tests. This prevents the %N from dropping below critical levels during the vegetative and generative stages of production.

Figure 6. The graphed results from a series of tissue test analysis over the course of a growing season. In this scenario, organic N was applied pre-plant, followed by soluble N applied through the drip.

All of the above tests can be done at the Nova Scotia Department of Agriculture Analytical Lab (**https://novascotia.ca/agri/programs-and-services/lab-services/animal-plant-lab/**). Farmers with a valid farm registration number are eligible for a discount on select tests. While some farms might feel that testing is a financial burden, the burden isn't nearly as great as losing a crop due to mismanagement. The use of the listed tests will reveal all potential sources of 'salt contamination' finding its way into protected spaces and provide the opportunity for management that will not contribute to excessive nutrient accumulation.

Managing Nutrient Build-Up

One of the best ways to manage the influx of nutrients is to consider single-source inputs that are applied during pre-plant, and/or alongside in-season split applications. The nutrients that are typically applied in-season are nitrogen and potassium. This can be challenging for organic farmers as there are not many single-source inputs, so careful planning is necessary.

Nitrogen is a highly mobile nutrient. If it is applied too heavily at any point in the season, it will move down through the ground into the water table, or it will volatilize and become an undesirable greenhouse gas. From a plant perspective, excess nitrogen in the spring applied to cold soils leads to issues with calcium deficiency in the crop, presenting as internal blossom end rot (Figure 7). This over-application of nitrogen sends the signal to the plant to focus energy and resources on building shoots, which diverts calcium away from fruits and into the vegetative growth.

If nitrogen levels are too high during the fruiting/harvest period, there will be a delay in fruit maturity, as well as a decrease in the total number of flowers that the crop is going to set.

If nitrogen is too low during the harvest period, there is a higher incidence of flower drop and poor-quality fruit, resulting in lower yields.

Figure 7. Internal blossom end rot on an immature tomato fruit.

To protect the quality of the crop and reduce the opportunities for release of greenhouse gases, it is necessary to take a more precise approach to nutrient application. Targeted, split in-season applications of nitrogen will meet the crop demand when calculated properly, reduce the potential for losses to the environment, reduce overall input costs, and result in higher quality yield. The price for nitrogen fertilizer has significantly increased over the last few years, so close management is beneficial from multiple standpoints.

Implementing Split In-Season Applications of Nitrogen

In order to split up the applications of nitrogen to meet the target values (crop dependent), some level of dosing equipment is needed. These small injectors (Figure 8) will pull from a stock solution and mix into the greenhouse water before being fed out to the crop through the drip irrigation. The use of a soluble N source will ensure immediate availability to the crop, allowing for scheduled nutrient amendments throughout the season. In conventional agriculture, some commonly used soluble N products are urea, potassium nitrate, and calcium nitrate. In organic agriculture, some fish or seaweed extracts are in liquid form, but often have other nutrients beyond what the crop needs (i.e. a test analysis of 2-4-1, so 2% nitrogen, 4% P_2O_5, and 1% K_2O) which can result in nutrient build up. An organically certified single-source nitrogen option used with success on some Nova Scotia farms is EZ-Gro, which is 18-0-0 (18% nitrogen).

Figure 8. An image of a dosatron, used for injecting set amounts of concentrated nutrient solution into the irrigation water.

Many extension (i.e. Cornell Cooperative Extension, UMass Extension, etc.) and provincial departments of agriculture (i.e. OMAFRA from Ontario, CRAAQ from Quebec) will have published nutrient recommendations depending on the crop in question. The recommended level of nitrogen for a tomato crop lies somewhere between 150-200lbs N/acre (or 1.56 – 2.08 g of actual N/ft^2).

- For producers who plan to incorporate a bulk amendment before the growing season starts, the target should be 50% total N for the crop in question. In this case, that translates to 75-100lbs N/acre. The remaining N budget should then be divided by the number of weeks in production (starting from transplant until the anticipated final harvest). For example, if you transplant the first week of May, and plan to push production until the second week of October, you are expecting 22 weeks of growth. This will guide you in how much needs to be applied on a weekly basis. Weekly foliar tests can help determine the best time to start regular in-season applications.

- For those who are relying strictly on the application of a soluble N source throughout the season, this target value can be broken up by the number of weeks in production (starting from transplant until the anticipated final harvest) to know how much needs to be applied on a weekly basis. The use of foliar tests will help fine-tune the amendment schedule – if N is too high, increase the amount of time between applications or decrease the amount of N being applied.

There are 43,560 ft^2 per acre. To convert from lbs/acre to lbs/ft^2, divide by 43,560.

i.e. 200 lbs N/acre = 0.00459 lbs N/ft^2

There are 454 g in a pound. To convert from lbs to grams, multiply by 454.

i.e. 0.00459 lbs N/ft^2 = 2.08 grams N/ft^2.

It is highly recommend to get an accurate scale (in grams to 0.1 decimal places) for in-season amendments used in a high tunnel. You can buy a kitchen scale for ~$30 at a kitchen store or online.

Once the value of N/week has been determined, this should be further subdivided into 3-4 applications across that week. In deciding the area of greenhouse to apply amendments to, it can be decided on a case by case basis. Typically, in spaces where production takes place in raised soil beds, and that soil is all subject to the incorporation and tillage of a bulk amendment (ex. compost spread using a larger tractor), the entirety of the greenhouse square footage is used when calculating amendment volumes to be applied. For producers with raised wooden boxes or those dealing with amendments that can be applied on a smaller scale (ex. applying soluble N through the drip, spreading handfuls of alfalfa meal across the beds), then bed feet might be a more suitable choice for the 'tunnel space' portion of the calculation below.

Sample Calculation:
Tunnel space= 1/10th of an acre

Bulk amendment = feather meal (supplier reported 12% N)

N plan = 50% incorporated pre-plant, with the remainder split over the growing season

Target crop = Tomato

Target N for the season = 200lbs N/acre

Determining the amount of feather meal to apply preplant:
½ target N for the season ÷ % N in amendment = Preplant volume

100lbs N/acre ÷ 0.12 = preplant volume

625 lbs feather meal/acre = preplant volume

Adjusted for tunnel space:

625 lbs feather meal/acre x .1 acres = 62.5 lbs feather meal in 1/10th of an acre

Interested in learning more about managing soil health in protected spaces? Check out the following resources or reach out to Perennia's Protected Crop Specialist.

'Greenhouse Playlist' on Perennia's YouTube Channel

'Protected Crops' Commodity Information located on perennia.ca

Perennia's Protected Crop Specialist

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