Developing a Nitrogen Balance Sheet for a Container Nursery[1]

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Abstract. -- Laboratory results for seedling, media and fertilizer solution samples are often expressed in meaningless values, but these values can be used to calculated nitrogen inputs and outputs for a container nursery system. Equations necessary for developing a nitrogen balance sheet are provided, and examples using these equations are given.

INTRODUCTION

As discussed earlier (Dumroese and others 1991), impending legislation, public scrutiny and possible litigation make it imperative nursery managers developing sound water management plans for their operations. To develop a waste management plan for your nursery, it is necessary to determine the quantity and quality of your waste water. A nitrogen balance sheet will help you identify your N inputs and outputs, and perhaps give some insight into where in your operation the most waste occurs. Further, good documentation showing where all your nitrogen comes from and where it goes would be invaluable when facing potential legislation or litigation. This paper will show you how to use laboratory data to estimate the nitrogen inputs and outputs from you container nursery system.

Nitrogen Inputs

There are three possible nitrogen (N) sources in forest nurseries: irrigation water, fertilizer, and the growing medium. Generally, irrigation water contains very low amounts of N. Conversely, fertilizer solutions carry the bulk of N in our operations. The growing medium often has some nutrients, including N, added to it in small quantities during processing.

Nitrogen Outputs

Once entered into the nursery production system, almost all N will end up in three locations: in seedlings, the medium, or in discharge solutions. Our aim as nursery managers is to have the bulk of applied N eventually reside in the seedlings. Preliminary data from the University of Idaho indicate about 10% of the applied N remains in the medium and about *50%* is discharged in waste water (see Dumroese and others 1991).

INFORMATION REQUIRED FOR THE BALANCE SHEET

Nitrogen Added By Irrigation Water

The calculations to determine the amount of N input into the nursery production system are relatively easy. The two things you need to know are the amount of irrigation water applied and the average ppm N of the water.

$$\frac{\text{Average ppm N of solution}}{1000} \times \text{total liters applied} = \text{grams of N applied}$$

$$\text{liters} = 3.785 \text{ gallons} \qquad \text{pounds} = \frac{\text{grams}}{453.6}$$

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Nitrogen In Growing Medium Prior to Irrigation

Reputable suppliers of growing medium should be able to give you the concentration of NO_3^- and NH_4^+ and bulk density of the mix. These NO_3^- and NH_4^+ values are usually obtained using a saturated extract, are corrected for dilution factor and moisture content, and are expressed in ppm N. Bulk density is expressed as weight per volume, usually in pounds per cubic foot or grams per cubic centimeter. Both ppm N and bulk density are essential for calculating the amount of N held in your mix prior to the first irrigation.

The first calculation necessary uses the bulk density value to determine the weight of medium per cell. It is most convenient to calculate this in grams per cell, so if bulk density is expressed in grams per cm^3, multiply the value by volume of an individual cell in cm^3. (Divide cubic inches by 16.39 to obtain cubic cm). Bulk densities expressed in pounds per cubic foot can be converted using the following equation:

$$\frac{\text{pounds}}{\text{ft}^3} \times \frac{\text{ft}^3}{1728\ \text{in}^3} \times \frac{\text{in}^3\ \text{of cell}}{\text{cell}} \times \frac{16\ \text{ounces}}{1\ \text{pound}} \times \frac{28.35\ \text{grams}}{1\ \text{ounce}} = \frac{\text{grams}}{\text{cell}}$$

Once grams per cell is known, the following equation will yield grams of N in medium:

$$\frac{\text{grams}}{\text{cell}} \times \text{number of cells} \times \frac{\text{kg}}{1000\ \text{grams}} \times \frac{\text{mg}}{\text{Kg}} \times \frac{\text{grams}}{1000\ \text{mg}} = \text{grams of N in medium}$$

$$\text{Where ppm N} = \frac{\text{mg}}{\text{kg}} \qquad \text{i.e. } 100\ \text{ppm N} = \frac{100\ \text{mg}}{\text{kg}}$$

Nitrogen in Growing Medium During the Growing Season

This can be calculated using the same equations as above.

Nitrogen Applied

The simplest way to calculate how much N is applied to the crop is to record the pounds of fertilizer applied in a crop history. Multiplying pounds by the percentage N in the fertilizer will yield pounds of N applied. This value is as accurate as your scale and weighing procedures. If samples of the fertilizer solution are analyzed for ppm N, and the amount of fertigation solution applied is known, pounds of N applied can also be calculated quite easily. This can be done for one fertigation event, or for a whole season if average applied ppm N is known, by using the following equation:

$$\frac{\text{Average ppm of solution}}{1000} \times \frac{\text{average liters}}{\text{application}} \times \text{number of applications} = \text{grams of N applied}$$

Nitrogen in Seedlings

The critical step involved in determining the N in seedlings is converting the concentration of N per seedling into the N content per seedling. Most analytical laboratories determine seedling nutrient concentration by analyzing the needles and sometimes a mixture of needles and succulent stems, and express these results on a percent basis. If your laboratory analyzes for nutrient content this way, it is important you determine the average, oven-dry weight (ODW) of the seedlings using just the portion of the seedling tested for nutrients. In other words, if the lab only uses needles for nutrient concentration, determine the ODW of just the needles. Otherwise, the amount of N in the seedlings may be overestimated. The best results would be obtained by analyzing the entire seedling for nutrient concentration and determining the average ODW on a whole seedling basis. The following equation will yield the amount of N held in seedlings (or in the foliage) in either ounces or grams, depending on what units were used to measure the average ODW of a seedling (or just the needles if the lab is only analyzing needles):

$$\text{Number of seedlings} \times \text{Average seedling ODW} \times \text{N concentration} = \text{Amount of N in seedlings}$$

Nitrogen Discharged From the System

This is very similar to the calculation for determining the amount of N applied via fertilization. The average ppm N of the discharge solution, along with the volume of the discharge, must be measured. Similarly, this can be done for one discharge event, or for a whole season if average discharged ppm N is known, by using the following equation:

$$\frac{\text{Average ppm of solution}}{1000} \times \frac{\text{average liters}}{\text{discharge}} \times \text{number of discharges} = \text{grams of N discharged}$$

AN EXAMPLE NITROGEN BALANCE SHEET

Calculating the Inputs:

Nitrogen Added By Irrigation Water

Once each month during the growing cycle, we sent plain irrigation water samples off to an analytical lab. The average values reported back to us are 0.75 ppm $N0_3^-$ and 3 ppm NH_4^+. For our crop of 300,000 ponderosa pine, we made 60 irrigations, and each irrigation consists of 1200 gallons of water.

$$60 \text{ irrigations} \times \frac{1200 \text{ gallons}}{\text{irrigation}} \times \frac{3.785 \text{ liters}}{\text{gallons}} = 272{,}520 \text{ liters applied}$$

$$\frac{3.75 \text{ ppm N}}{1000} \times 272{,}520 \text{ liters applied} = 1031.49 \text{ grams of N applied}$$

$$\frac{1031.49 \text{ grams}}{453.6} = 2.27 \text{ pounds of N applied via plain irrigation water}$$

Nitrogen In Growing Medium Prior to Irrigation

The supplier of our growing medium reports a bulk density of 9 pounds per cubic foot, and an average ppm N of 70, determined using saturated extract. We are using pine cells that have a volume of nearly 4 cubic inches, and there are 300,000 cells sown.

$$\frac{9 \text{ pounds}}{\text{ft}^3} \times \frac{\text{ft}^3}{1728 \text{ in3}} \times \frac{4 \text{ in}^3}{\text{cell}} \times \frac{16 \text{ ounces}}{1 \text{ pound}} \times \frac{28.35 \text{ grams}}{1 \text{ ounce}} = \frac{9.45 \text{ grams}}{\text{cell}}$$

Once grams per cell is known, the following equation will yield grams of N in medium.

$$\frac{9.45 \text{ grams}}{\text{cell}} \times 300{,}000 \text{ cells} \times \frac{\text{Kg}}{1000 \text{ grams}} \times \frac{70 \text{ mg}}{\text{kg}} \times \frac{\text{grams}}{1000 \text{ mg}} = 198.45 \text{ grams of N in medium}$$

$$\frac{198.45 \text{ grams}}{453.6} = 0.44 \text{ pounds of N in growing medium}$$

Nitrogen Applied

From our crop history, we know we applied

6 applications of 7-40-17 fertilizer at *5* pounds per 1000 gallons

12 applications of 20-19-17 fertilizer at *2.5* pounds per 1000 gallons

18 applications of 4-25-35 at 5 pounds per 1000 gallons
18 applications of liquid calcium nitrate (17% N) at an equivalent rate of 2.5 pounds per 1000 gallons.

Each application of fertilizer was carried in 1000 gallons of water.

Using this basic equation for the 7-40-17 fertilizer:

$$6 \text{ applications} \times \frac{5 \text{ pounds}}{\text{application}} \times 7\% \text{ N} = 2.1 \text{ pounds of N}$$

and continuing for the other 3 types of fertilizer, we calculate *19.35* pounds of N were applied via fertilizer solution according to crop history.

As a double check, we sent three samples of each fertilizer type to the laboratory for analysis. The results (both nitrate and ammonium) were:

7-40-17 --- 52 ppm N
20-19-17 --- 73 ppm N
4-25-35 --- 30 ppm N
Liquid calcium nitrate --- 62 ppm N

Remembering that each fertigation was 1000 gallons (3785 liters), the calculation for the 7-40-17 fertilizer was:

$$\frac{52 \text{ ppm N}}{1000} \times \frac{3785 \text{ liters}}{\text{application}} \times 6 \text{ applications} = 1180.92 \text{ grams of N applied} = 2.6 \text{ pounds of N}$$

Notice the pounds of N applied for this fertilizer is about 0.5 pounds more using this method. Errors in weighing fertilizer, inaccuracies of the scale, and deficiencies with the injector will all contribute to this difference. Continuing for the other fertilizers, we calculate 23.7 pounds of N applied.

SUMMARY OF NITROGEN INPUTS

Nitrogen Additions	Pounds	Pounds
Via irrigation water	2.27	2.27
Held in medium prior to irrigation	0.44	0.44
Applied according to crop history	19.35	--
Applied according to lab analysis	--	23.70
Total N Input	22.06	26.41

Calculating the Outputs:

Nitrogen In Growing Medium

Essentially, this is the same calculation used for determining the amount of nitrogen in the growing medium prior to irrigation. You will need to use the grams per cell value arrived at earlier. We removed medium from seedling root systems and sent it to an analytical lab; the lab reported the medium had 282 ppm N.

$$\frac{9.45 \text{ grams}}{\text{cell}} \times 300{,}000 \text{ cells} \times \frac{\text{kg}}{1000 \text{ grams}} \times \frac{282 \text{ mg}}{\text{kg}} \times \frac{\text{grams}}{1000 \text{ mg}} = 799.47 \text{ grams of N in medium}$$

$$\underline{799.47 \text{ grams}} = 1.76 \text{ pounds of N in growing medium}$$

453.6

Nitrogen in Seedlings

The analytical laboratory reported our ponderosa pine seedlings had 1.8% nitrogen in the *total* seedling. The average oven-dry weight of a sample seedling is 1.35 grams. Although we sowed 300,000 cells, our inventory indicates we have only 94.3% occupancy.

$$282{,}900 \text{ seedlings} \times 1.35 \text{ grams} \times 1.8\ \%\ \text{N} = 6874.47 \text{ grams of N in seedlings}$$

$$\frac{6874.47 \text{ grams}}{453.6} = \mathit{15.15} \text{ pounds of N in seedlings}$$

Nitrogen Discharged From the System

Every other week for the entire growing season, samples of waste water were collected in gutters beneath the benches and sent to an analytical laboratory. Using the volume of waste water collected from each gutter and the area of each gutter, we calculated the total volume of water wasted per fertilizer application. The total area irrigated is 3500 square feet. The average area of the gutters is 6.05 square feet. The average volume collected was 1.05 gallons.

$$\frac{1.05 \text{ gallons}}{6.05 \text{ ft}^2} \times 3500 \text{ ft}^2 = 607 \text{ gallons of waste water per application}$$

Averaging all the reports from the lab, the average ppm N in the waste water solution is 30.5 and we made 54 fertilizer applications to the crop.

$$\frac{30.5 \text{ ppm N}}{1000} \times \frac{2297.495 \text{ liters}}{\text{discharge}} \times 54 \text{ discharges} = 3784 \text{ grams of N discharged}$$

$$\frac{3784 \text{ grams}}{453.6} = 8.34 \text{ pounds of N wasted}$$

SUMMARY OF NITROGEN OUTPUTS

Nitrogen Outputs	Pounds
Held in medium	1.76
Contained in seedlings	16.28
Discharged from the site	8.34
Total N Output	26.38

In this example, total outputs exceed total inputs when the inputs are calculated using crop history. As stated earlier, this could be because of errors in the scales, weighing, or recording in crop history. However, the input and output values are very close when sample solutions are used to calculate the amounts of N. Naturally, determining these values is much more difficult in a production nursery, especially when working with multiple species and multiple fertilizer regimes between and within species.

MANAGEMENT IMPLICATIONS

These equations and examples should help nursery managers build a nitrogen balance sheet for their container nursery, and thereby have essential information for developing a water management plan that will stand against public scrutiny. These equations could be used for any nutrient applied to the crop, as well as for pesticides.

LITERATURE CITED

Dumroese, R.K., D.S. Page-Dumroese and D.L. Wenny. 1991. Managing pesticide and fertilizer leaching and runoff in a container nursery. In these proceedings.