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CONIFERS: A Computer Program for Liquid Fertilization in Container Nurseries

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Most nurseries that produce conifer species in controlled environments use liquid-based fertility programs. Many of these nurseries rely on commercially available fertilizer formulations. The microcomputer program CONIFERS calculates mixing rates and run times for liquid-based fertilizer incorporation into irrigation systems, using commercially available fertilizer formulations. The program, based on setting target nitrogen levels for a commercial fertilizer formulation, calculates the amount of nitrogen, phosphorus, and potassium applied and provides mixing instructions for stock solutions. The CONIFERS software program provides a rapid and accurate means of adjusting fertilizer applications to the container nursery grower using liquid- based fertilizer solutions. Tree Planters' Notes 47(4):120–125; 1996.

Injecting liquid fertilizer solutions (solutions of granular fertilizers) into an irrigation system—often called "fertigation"—is the most common means of fertilizing conifer species grown in controlled environments in container nurseries (Landis and others 1989). Fertigation offers many advantages over other fertilization systems, including the ability to adjust nutrient levels and ratios to match the growth stages of a nursery crop. Many nurseries and greenhouses use commercial, premixed, water-soluble fertilizers for fertigation. Commercial fertilizers are available in a wide range of formulations and ratios of nitrogen (N), phosphorus (P), and potassium (K).

Several steps are required to determine mixing rates for these fertilizers. First, a target nitrogen level is set for the applied solution. The amount of fertilizer required to achieve the targeted nitrogen application rate is then calculated. This value is then adjusted for the injection ratio of the fertigation system. To determine phosphorus and potassium levels in the applied solution, a series of calculations are completed. CONIFERS, a microcomputer program requiring an IBM-compatible computer with DOS 2.1 or higher, simplifies this process and can reduce computational time associated with these steps to less than 1 minute. The program can also provide a rapid means of determining the duration of fertilizer application necessary to achieve target amounts of fertilizer on a per-seedling basis by using irrigation and container system characteristics. The application time feature assists nursery managers in reducing fertilizer costs and runoff by reducing over- and under-fertilization. The application time portion of the program is adaptable to both fixed and traveling boom irrigation systems.

Running CONIFERS

Fertilizer mixing. The fertilizer mixing portion of the program, which the user needs to enter as prompted by the program, requires the following information:

- Target level of N in parts per million (ppm)
- Ratio of N, P, and K from the fertilizer label
- Injection ratio of the irrigation system

CONIFERS was written for commercial fertilizers with phosphoric oxide (P_2O_5) being the only source of P and potassium oxide (K_2O) the only source of K. CONIFERS automatically converts P_2O_5 to P and K_2O to K by using the following 2 equations:

$$\text{"A" ppm } P_2O_5 \times 0.4364 = \text{"B" ppm P}$$
$$\text{"C" ppm } K_2O \times 0.8301 = \text{"D" ppm K}$$

If no injection system is used, the value 1 is entered as the injection ratio.

For example, a targeted applied solution with 150 ppm N, using a 20:20:20 (N-P_2O_5-K_2O) fertilizer with an injection ratio of 1:100 requires that 75.0 g (2.65 oz) of fertilizer be mixed in 1 L of water (0.6 lbs/gal). This solution will contain 150 ppm N, 65 ppm P, and 125 ppm K (figure 1). This output can be printed if necessary. At this point, CONIFERS offers the user the option to run a different fertilizer scenario, proceed with the application time calculation, or end the session.

Determining run time. The second portion of the CONIFERS program determines the run time required to saturate the water-holding capacity of the growing medium. This portion of CONIFERS was written using a combination of both English and SI units. This was done because measuring devices commonly used in container nurseries differ in their respective units of measure (that is, flow meters in gallons per minute and graduated cylinders in milliliters). The user will be prompted by the program to enter the following information:

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What is the desired concentration level of Nitrogen (N) in ppm
for the applied solution? 150 <Enter>
What is the percentage of elemental Nitrogen (N)
in the fertilizer? 20 <Enter>
What is the percentage of elemental Phosphorous oxide (P2O5)
in the fertilizer? 20 <Enter>
What is the percentage of elemental Potassium (K2O)
in the fertilizer? 20 <Enter>
What is the injector ratio or siphon rate 1:###? 100 <Enter>

Mix 75.00 grams of fertilizer per liter, 283.90 grams of fertilizer per
gallon, or 0.63 pounds of fertilizer per gallon in the stock solution to
obtain 150 ppm of Nitrogen (N) in the applied solution.

There is 150 ppm of P2O5 and 65 ppm of P applied.
There is 150 ppm of K2O and 125 ppm of K applied.

Would you like a printed copy of this setup y/n?

Do you want to 1) Calculate a different scenario, 2) proceed with
application time calculations or 3) End this session 1/2/3? 2
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Figure 1—*An example of the fertilizer mixing instructions generated by CONIFERS.*

- target amount of fertilizer solution (in milliliters) or N (in milligrams) to be applied to each container
- flow rate of the irrigation system in gallons per minute
- irrigation system efficiency
- container system efficiency
- area of crop to be irrigated

Determining the target amount of fertilizer to be applied to each container can be determined several ways. The upper limit of the target amount would be to saturate the entire water-holding porosity of the medium in the container. Landis and others (1990) provide detailed instructions for determining this value. An abbreviated version of this procedure is also described in the CONIFERS User's Manual. In most cases, however, the water-holding porosity is not allowed to be completely depleted between irrigations or fertigations. Therefore, only in a few instances, such as leaching salt build-ups in the medium, would the water-holding porosity amount be used. Currently, measuring container weight is the most common approach in container forest nurseries to determine irrigation rate—see Landis and others (1989) for a description of this technique.

Irrigation system efficiency (percentage of irrigation water landing on the crop) is never 100% because irrigation water lands on non-crop surfaces such as walkways and walls. Several detailed techniques exist to calculate irrigation system efficiency, but nursery managers familiar with their own systems can provide close approximations of this value. Container system efficiency (percentage of crop space occupied by container openings) is less than 100% because of gaps or voids on surface areas between container openings due to the arrangement of containers or their support structures. A simple method to determine container system efficiency is provided in table 1 and in the CONIFERS User's Manual.

For fixed irrigation systems, the program requires the surface area of 1 bench in square feet and the number of benches being irrigated or fertilized simultaneously. The program uses this information to calculate the total area being irrigated or fertilized. When using traveling boom systems, the width of seedling bed, that is, the boom width (in feet), the length of the boom run (in feet), and the boom speed (in feet/minute) are necessary. Many traveling boom irrigation systems are available today. CONIFERS was programmed to consider 1 pass in 1 direction as a single pass. If a traveling boom irrigation system irrigates in both directions, the length the boom travels must need to be adjusted accordingly. To achieve target fertilization

Table 1—*Calculating container system efficiency*

Step 1—Calculate the area of the container opening for 1 container. Most containers are either round or rectangular:

area of a circle = πr^2 = 3.14 × (radius)^2

area of rectangle = length × width

Step 2—Count the number of containers per tray or flat.

Step 3—Calculate the total area of container opening per tray. Multiply the area of the container opening for 1 container (step 1) by the number of containers per tray (step 2).

Step 4—Calculate the total surface area of a tray or flat. Most trays or flats are rectangular.

Step 5—Calculate the container system efficiency. Divide the total area of container opening per tray [step 3] by the total surface area per tray [step 4] and multiply by 100.

levels when using a traveling boom irrigation system, adjustments to the irrigation system (travel speed or flow rate) may need to be made. CONIFERS automatically computes these adjustments if the actual application rates differ from target rates. To correct this discrepancy, other simple adjustments can be made, including changing fertilizer concentration in the applied solution, or changing the injection ratio. Running CONIFERS several times and adjusting these attributes usually achieves an acceptable solution.

For example, using the fertilizer formulation calculated above (150 ppm N, 65 ppm P, 125 ppm K), CONIFERS can calculate the volume of stock solution and application time necessary to apply 350 ml (0.09 gal) of applied fertilizer solution to a crop growing in 3.7-L (1-gal) pots using a fixed irrigation. The pots are 15.14 cm (6 in) in diameter arranged in a square grid (79% of the area is occupied by container openings) with 4 seedlings/ft^2. The fixed irrigation system has the following attributes: flow rate = 15 gal/min, and an over spray = 10% (a 90% efficiency for the irrigation system). Seven 128-ft^2 (11.9-m^2) benches are to be fertilized. According to the program, this application would require 31.07 min to apply 350 ml (0.09 gal) of the applied fertilizer solution using a stock solution with 1,323.21 g (2.91 lbs) of fertilizer dissolved in 17.64 L of water (2.91 lbs/4.66 gal) (figure 2).

Using the same target application rate of 350 ml (0.09 gal) of fertilizer/seedling and the same container system (3.7-L pots) and a traveling boom irrigation system with the following characteristics bed width = 12 ft, travel length = 200 ft, flow rate = 15 gal/min; overspray = 10%, and boom speed = 6 ft/min CONIFERS generates the output in figure 3. Using the stated irrigation system and fertilizer attributes would result in 140 ml (0.04 gal) of fertilizer applied per boom pass to each container. This quantity is close to 40% of the desired application rate of 350 ml/container. Three solutions to this discrepancy are provided. These include reducing boom speed to 2.4 ft/min, increasing flow rate to 37.5 gal/min, or changing flow rate to 18.2 gal/min and reducing boom speed to 2.8 ft/min (figure 3).

The application time portion of CONIFERS may become inaccurate over the production time of a crop, depending on container size and species. Two explanations exist for this reduction in accuracy. First, as a seedling matures, the water-holding porosity of the growing medium in the container is reduced due to compaction and to roots growing into portions of this space. This loss in water-holding porosity results in the CONIFERS program overestimating the volume required to saturate the water-holding porosity of the growing medium. Secondly, as crops mature, plant canopy over the containers increases, and the proportion of the irrigation water or fertilizer falling outside the container increases. Loss due to this runoff can be significant in long needled conifer species such as ponderosa pine or in broad leaved species. At the New Mexico State University—Mora Research Nursery, we found that CONIFERS underestimates fertigation time after 8 to 12 weeks following germination for long-needled pines and broad-leaved plants, depending on species and growth rate. For spruces, true firs, and Douglas-fir, fertigation time is underestimated later in the crop cycle. The decline of application time accuracy may be due to a trade-off in reduced water-holding porosity and reduced infiltration due to canopy runoff. When underestimation is suspected, we recommend using the container weighing system or by monitoring the leachate volume passing through the container to determine irrigation and fertigation duration.

Obtaining CONIFERS

CONIFERS is a public domain program available free of charge. The program can be downloaded from the New Mexico State University Mora Research Center's home page on the World Wide Web:

http://taipan.nmsu.edu/aght/mora/mora.html

At this site, go to the nursery research hyperlink. The nursery research page contains the information required to download the software and the corresponding manual. A second option for obtaining the CONIFERS program and manual is to send a stamped, self-addressed disk mailer and 3 ½-inch formatted (IBM) diskette to Mora Research Center, PO Box 359, Mora, NM 87732.

A

Is the application system a fixed spray or a traveling boom
enter an F or a T? **F** <Enter>
Is the Nitrogen (N) application figured in milligrams/seedling or
in milliliters/seedling enter a G or an L? **L** <Enter>
How many milliliters of solution are applied to each seedling? **350** <Enter>
What is the flow rate for the system in gallons/minute? **15** <Enter>
What is the application area in square feet for one bench? **128** <Enter>
How many benches are being fertilized simultaneously? **7** <Enter>
Enter a number from 0 to 100 that indicates the percent of overspray
that does not fall on the seedling bed? **10** <Enter>

B

There is an inherent inefficiency in most containerized production operations. This inefficiency is due to the arrangement of containers within their support structures. The following example is of a common container and expresses its efficiency in a ratio of container opening surface area to total surface area.

Container	Diameter	Number of Containers/ Square Foot	Container Surface Area/ Square Foot	Efficiency
1 gallon	6.00 in.	4	113.10 sq. in.	79%

What is the efficiency of the container system being utilized? **79** <Enter>
How many seedlings exist per square foot? **4** <Enter>

C

These application rates are on a per seedling basis.

Time required to apply 350 milliliters of solution is 31.07 minutes.
1,323.21 grams or 2.91 pounds of fertilizer and 4.66 gallons
or 17.64 liters of water are required for the stock solution.

Would you like a printed copy of the results y/n?

Figure 2—*Examples of the irrigation system input screen for the application time portion of CONIFERS (A); container efficiency input screen (B); and output screen generated by CONIFERS using the* ***fixed irrigation system*** *described in the text (C).*

The CONIFERS program's quick and accurate ability to calculate mixing rates removes many obstacles associated with using liquid-based fertilizer solutions in nurseries. The user-friendly design of CONIFERS and training on reading fertilizer labels allows all levels of nursery employees to mix fertilizer stock solutions correctly. Changes in fertility programs due to changes in the irrigation system, fertilizer supply, or crop needs can be readily assimilated without the need for tedious hand calculations.

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Literature Cited

Landis TD, Tinus RW, McDonald SE, Barnett JP. 1989. The container tree nursery manual: Volume 4, Seedling nutrition and irrigation. Agric. Handbk. 674. Washington DC: USDA Forest Service: 119 pp.

Landis TD,Tinus RW, McDonald SE, Barnett JP. 1990. The container nursery manual: Volume 2, Containers and growing media. Agric. Handbk. 674. Washington DC: USDA Forest Service: 87 pp.