Managing Pesticide and Fertilizer Leaching and Runoff in a Container Nursery[1]

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Abstract. -- During the first 15 weeks of the growing cycle in a container nursery with travelling-boom irrigation, nearly 60% of the water and 50% of the nitrogen were discharged from the facility. Chemical pesticide use was kept to a minimum using integrated pest management. Waste water was effectively treated with a constructed wetland. Using best management practices in nursery operations can mitigate waste water problems.

INTRODUCTION

The production of container-grown seedlings requires large volumes of water because of our industry's cultural methods: nearly all fertilizers and pesticides are applied with water as the carrier. Nursery managers waste a lot of water during irrigations. Water is sprayed onto the walls and floors, drips through the containers, leaches from cells, and eventually flows from the nursery. This flow is increased by additions of fertilizer and pesticide solutions from post-application purging of water lines.

New legislation in Oregon mandates growers of container stock eliminate waste water discharge from their operations by 1993 (Grey 1991). Whether or not this is an actual problem, or one perceived by the public, concerns over groundwater quality will without doubt force this issue on the industry in other states in the coming years. Obviously, nursery managers need to be aware of their water consumption and waste in order to develop management plans that will stand against public scrutiny (Wilkerson 1991). Landis and others (1991) provide more background on this issue.

At the University of Idaho Forest Research Nursery, we decided to evaluate our water usage and the quality of water discharged to ascertain environmental impacts.

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Our objective was to determine the quality of water entering the nursery, the efficiency of applications, and the quality of water being discharged. Our study, begun in April 1991, was designed to evaluate an entire growing season, but only the results of the first 15 weeks are reported here.

METHODS AND MATERIALS

The Nursery

The University of Idaho Forest Research Nursery grows about 850,000 conifer seedlings annually in Ray Leach Pine Cells filled with a 1:1 peat: vermiculite growing medium (Grace/Sierra, Portland, OR). Seed is sown during the first week in April. Seedlings are grown on rolling benches and 86% of the greenhouse area is in production. Water is supplied by an on-site well. Crops are watered and fertilized with an overhead, travelling-boom irrigation system. Fertilizer is applied via a 1:100 Smith injector.

Four species were evaluated for nitrogen (N) and water use efficiency: western larch *(Larix occidentalis)*, Douglas-fir *(Pseudotsuga menziesii)*, ponderosa pine *(Pines ponderosa)* and western white pine *(Pines monticola)*. Growing regimes for each species during the first 15 weeks are provided in Table 1.

Weekly Measurements of Water Quality

Water was collected weekly from five sources within our nursery each week: (1) well water, (2) applied fertilizer solution, (3) leachate from individual containers, (4) a combination of water dripping through the trays, leachate from containers and water being sprayed directly onto the floor (hereafter called errant spray), and (5) from our waste water pond.

Well water samples were collected from the tap once each Monday morning after allowing the tap to run for about five minutes. ***Fertilizer samples*** were collected

Table 1. Growing regimes for western larch, Douglas-fir, ponderosa pine and western white pine during the first 15 weeks of the growing cycle.

Weeks	0 1 2	3 4 5 6	7 8	9	10 11 12 13 14 15
Western larch	Germination	Irrigated twice weekly 42 ppm N		Irrigated as needed -- alternated micronutrient solution with 50 ppm N	
Douglas-fir	Germination	Irrigated twice weekly 42 ppm N		Irrigated twice weekly 120 ppm N	
Ponderosa pine	Germination	Irrigated twice weekly 42 ppm N	Irrigated twice weekly 50 m N		Irrigated as needed 50 ppm N
White pine	Germination	Irrigated twice weekly 42 ppm N	Irrigated twice weekly 190 ppm N		

See Wenny and Dumroese 1991, 1987a, 1987b, 1987c.

directly from the boom system three times during fertigation. ***Leachate samples*** were collected from 15 seedlings within each species by connecting a balloon over the egress holes on each pine cell. Leachate was allowed to collect for about an hour after irrigation was complete. To determine the quality and quantity of ***errant spray*** entering the drains, we placed a series of gutters beneath the tables. Two 10-foot sections of plastic gutter were connected with wing-nuts and the entire assembly held beneath the benches with bungie cords. Gutters were positioned under the tables to intercept all errant spray, including that sprayed directly onto the floor. The gutter assembly drained into a plastic bucket. Three assemblies were used per species for each sample collection. The buckets were emptied about 1.5 h after irrigation ceased. These sampled all water sources entering the drain: leachate, water spraying through and between trays, and water applied directly to the floor. Surface area of the gutters was determined so the volume of water per square foot being wasted could be calculated. ***Waste water pond samples*** were taken each Monday morning from three different areas of the pond.

All samples were immediately frozen until analyzed. In addition, the volume of leachate from individual containers was measured.

Other Measurements

The growing medium was analyzed for potential mineralizable N at both optimum (40° C for 7 days) and greenhouse (20° C for 7 days) conditions. Potential mineralizable N was estimated using the anaerobic incubation technique on undried samples (Powers 1980). Fifteen weeks after sowing, three replications of ten seedlings from each of the four species were oven dried (60° C for 24 h) for dry weight measurements, analyzed for nutrient concentration (total seedling), and nutrient content was determined. Also at week 15, the growing medium under each species was evaluated for nitrate ($N0_3^-$) and ammonia (NH_4^+) concentration.

Nitrogen Analysis

$N0_3^-$ and NH_4^+ were determined using an Alpkem Rapid Flow Analyzer, but soil $N0_3^-$ and NH_4^+ were first extracted using 1N KC1. Appropriate blanks, reference samples and duplicates were used for quality control. Seedling nutrient content was determined by Grace/Sierra Testing Laboratories (Allentown, PA).

Equations for calculating N inputs and outputs are given in Dumroese and Wenny (1991). ,

Determining Water Volume Applied

To determine the amount of water applied per irrigation event, we measured the individual output delivered for one minute by nozzle on each boom system to calculate an average volume per nozzle per minute. We also timed the system as it made one pass over the greenhouse. By recording the time the system was irrigating the crop, we could then calculate gallons of water applied per irrigation.

For comparison, we decided to make a few measurements at another northern Idaho nursery which used fixed overhead irrigation. This nursery had a flow meter to chart total gallons applied per irrigation. By comparing before and after irrigation block weights, we were able to determine the gallons of water absorbed by the growing medium and thereby calculate the amount of water that went down the drain.

Pesticide Applications

For each pesticide application, the chemical, amount of active ingredient, and volume of water used as the carrier were recorded. Because of the low amounts of chemical pesticide used, no analysis of waste water for residual chemical was done.

CHEMICAL INPUTS AND OUTPUTS

Water

During the first 15 weeks of the growing season (week 0 was sowing), our well water had NO_3^- and NH_4^+ levels below the reference standards we used with the analyzing equipment ($NO_3^- < 0.2$ ppm and $NH_4^+ < 2.0$ ppm).

The amount of water wasted in crop production varies with the application objective. For ponderosa pine, low volume, specialty applications like misting and foliar fertilization resulted in efficient use of applied water (Table 2). Most waste from these applications is water sprayed directly onto surfaces other than seedlings. Conversely, high volume applications like fertilization and leaching result in higher waste.

Water use efficiency varied by species (Table 3). Ponderosa pine had the highest efficiency, which can be partially attributed to the growing regime used. This species was at target height by week eleven. Subsequently, seedlings were watered after the medium was allowed to dry down, rather than on the twice per week irrigation schedule. Obviously, the drier plugs were able to absorb more of the applied water so less was wasted, especially during weeks 12 through 15.

Estimates of leachate were made using balloons as collectors. However, the balloons had several drawbacks. First, balloons with inflated diameters of Less than 7 inches (18 cm) tended to restrict air displacement between the uninflated balloon and the pine cell, resulting in low leachate volumes. Second, several brands of balloons contained high amounts of NO_3^- which

Table 2. Breakdown of water applied to 306,000 cells of ponderosa pine and the gallons subsequently wasted.

	Water applied (gals)	Water wasted (gals)	Water wasted (%)
First soak [1]	2000	800	40.0
Germination misting [2]	2400	300	12.5
Fertilization [3]	30640	15600	50.9
Leaching [4]	5200	4600	88.5
Foliar fertilization [5]	400	50	12.5
Total	40640	21350	52.5

[1] Water applied initially to bring the medium to field capacity.
[2] Mists applied during the heat of the day to keep the seed zone moist.
[3] All water applied during fertilization, including plain water used to pre-moisten the foliage and rinse the foliage after fertilizer application.
[4] One long application of plain water to leach salts and excess fertilizer from the medium.
[5] Low volume applications of foliar fertilizer -- applied until runoff from the foliage.

Table 3. Water applied and wasted during the first 15 weeks of the growing cycle.

	Percent of total crop	Water applied (gals)	Water wasted (gals)	Water wasted (%)
Western larch	10	8925	5750	64.4
Douglas-fir	10	9825	5830	59.3
Ponderosa pine	36	40640	21350	52.5
Western white pine	28	41820	26310	62.9
Eleven mist. species	16	18750[1]	10910[2]	58.2
Total crop	100	119960	70150	58.6

[1] Based on crop history records.
[2] Estimated from weighted averages of other species.

had to be corrected for during data analysis. Between 40 and 80% of the total water discharged from the nursery leaches through the medium (data not shown).

About 60% of the water applied at our nursery was discharged from the site (Table 3). Samples collected at the other nursery which uses fixed, overhead nozzles indicated the amount of water wasted approached 80%. This seems likely since the design of fixed systems usually delivers appreciable water to the walls and aisles.

Analysis of water from our waste water pond indicated average level for both NO_3^- and NH_4^+ were below the reference standards we used with the analyzing equipment (NO_3^- < 0.2 ppm and NH_4^+ < 2.0 ppm). A few samples taken during the accelerated growth phase were above a detectable limit, but NH_4^+ values were less than 7 p m and NO_3^- values were less than 2 ppm.

Nitrogen

Specifications from Grace/Sierra (Portland, OR) on the growing medium indicate it has about 80 ppm extractable N, or about 1.43 lbs in 850,000 4 in^3 containers. Because half of the growing medium is organic matter, N could be mineralized through the decomposition of the peat by microorganisms. We estimated the medium in our greenhouse had the potential to release about 2.35 lbs of N in 7 days at greenhouse temperatures (20° C -- 70° F). Mineral nation values were about the same at optimum temperatures (40° C).

For our particular crops and growing regimes, about 37% of the nitrogen applied was used by the seedlings (Table 4). Nearly 51 % of the applied N was discharged, while 10% remained in the medium.

N use efficiency varied by species (Table 4), and as one might expect, the faster growing species used N more efficiently than slower growing species. Both ponderosa pine and western larch, which at our nursery have rapid initial growth and are generally fertilized at lower rates of N, showed the best use of applied N. Over 70% of the N applied to ponderosa pine was absorbed by seedlings, while larch used 65 % of the applied nitrogen. Douglas-fir, which often grows slowly during the initial phase, had the poorest uptake of N, using less than 20% of the applied N. Western white pine, a slow growing species throughout the growing cycle, also exhibited low N uptake.

Pesticides

At our nursery, we made only eight pesticide applications, four each of fungicides and insecticides. These applications were made only to seedlots with a problem or to particular areas with a pest, resulting in the low amounts of pesticides used (Table 5). Our insect pests were Lepidoptera larvae and fungus gnats. All. insecticide applications were made using *Bacillus thuringiensis* varieties specifically formulated for these pests. These microbial products are used because re-entry restrictions are unnecessary and the chemical is ineffective against predatory insects that also inhabit our greenhouses.

Table 4. Nitrogen applied, absorbed by the seedlings, held by the medium and discharged from the nursery during the first 15 weeks of the growing cycle.

	Seedling Number[1] (M)	Seedling dry Weight[2] (gms)	Base level N in medium[3] (lbs)	N applied (lbs)	Seedling N concentration[4] (%)	N used by Seedlings[5] (lbs)	N held in medium (lbs)	N wasted (lbs)	N Wasted[6] (%)
Western larch	77.8	0.57	0.14	1.84	1.57	1.53	0.04	0.64	34.8
Douglas-fir	76.3	0.48	0.14	2.22	1.53	1.23	0.26	1.84	82.9
Ponderosa pine	292.5	0.94	0.51	10.91	1.33	7.80	1.48	3.04	27.9
Western white pine	229.9	0.89	0.40	36.44	2.23	10.09	3.16	21.29	58.4
Eleven mist; species	133.1		0.24	4.55[7]		3.21[7]	0.54[7]	1.68[7]	36.9
Total crop	809.6		1.43	55.96		23.86	5.48	28.49	50.9

1 Based *on* occupancy inventories.

2 At week, 15 (15 weeks after sowing).

3 Nitrogen present in the growing medium prior to sowing. Differences between values in this column are due to differences in the total number of cells sown for each species.

4 Based oh analysis of the entire seedling, not just needles.

5 Calculated by multiplying the seedling number by dry weight by N concentration.

6 Percentage of N wasted to N applied.

7 Estimated using weighted averages of western larch, Douglas-fir and ponderosa pine.

Table 5. Pesticide applications made to a crop of 850,000 seedlings during the first 15 weeks of the growing cycle

	Total solution applied (gals)	Total chemical applied (oz)	Total active ingredient applied (oz)
Banrot	100	8	3.2
Benlate	300	24	12.0
Dipel	300	24	1.5
Gnatrol	50	64	0.4

MANAGING WASTE WATER

Best management practices (BMP's) are voluntary measures taken to reduce the potential for agricultural contamination of surface or ground water. BMP's include source controls and practices designed to reduce inputs into the nursery production system. BMP's also include practices designed to mitigate any potential harm from waste generated within the nursery production system. For container nurseries, this means a structural control, either containing and treating waste water prior to release, or containing and recycling water within the nursery.

BMP's -- Source Controls

In the nursery production system, we have essentially three source controls: fertilizers, pesticides, and the volume of water used to carry them.

Water Source Controls -- There are several ways to reduce the amount of water wasted in seedling production. Obviously, maximizing the amount of greenhouse area in production allows more applied water to be intercepted by seedlings. Rolling benches can minimize aisle space while still allowing access to all seedlings.

For proper seedling growth, it is important nursery managers irrigate sufficiently to completely saturate the root plug for proper root growth and to flush excess salts from the container. Landis and others (1989) recommend irrigating 10% more water than is necessary to saturate the plug to complete this objective. This sounds good in theory but is difficult to achieve operationally. As mentioned earlier, between 40 and 80 % of water wasted in our operation was leachate. During irrigation, we checked medium saturation by extracting sample seedlings and feeling the moisture content of the plug. Of course, finding a dry sample seedling dictates the need for continued irrigation until dry plugs are no longer found. This means, however, those seedlings whose medium saturated early in the irrigation yield larger leachate volumes. Further, many nursery managers probably fail to monitor individual irrigations closely enough and inevitably over-water after all plugs have been saturated. Developing a container weight scale to determine growing medium saturation and checking container weights during irrigation, would greatly reduce this over-watering. Landis and others (1989) explain how to develop container weight scales.

Fertilizer Source Controls - *We* fertilized twice each week during the initial and accelerated growth phases. These habitual applications are probably unnecessary, especially when the seedlings are very small. It is quite likely we could reduce the total amount of N applied by cutting back to fertilize only when watering is necessary during the initial and accelerated growth phases. This would also reduce the leachate volume which comprised a major portion of waste water from the nursery.

In addition, when most growers apply fertilizer during these growth phases, it is usually at a standard rate, or at least a rate consistent through that particular phase. Ingestad and Lund (1986) developed a method to control relative growth rates by controlling nutrient supplies. Essentially, they found the amount of nutrient supplied over time is more important to seedling growth than the nutrient concentration in the growing medium. The optimum nutrient supply rate varies by species (Burgess 1990, 1991; Ingestad and Kahr 1985). In a study on red pine *(Pines resinosa),* a species that grows very slowly like western white pine, researchers using this concept of relative addition rates successfully grew a crop with 75 % less fertilizer than typically used to grow the seedlings to a similar size (Timmer and Armstrong 1987). Obviously, growers could reduce their N discharges if they apply nutrient rates to seedlings that allow only optimum, not luxury, uptake.

Finally, as nursery managers, it is important to know how much N you are applying, not what you *think* you are applying. Make sure scales weigh accurately and the injector is operating properly. Send some samples of your fertilizer solution to an analytical laboratory to see if the actual ppm N is close to your target application rates.

Pesticide Source Controls -- By eliminating habitual applications based on seedling phenology or the calendar, and only applying pesticides once the pests exceed our threshold levels, we have been able to decrease our pesticide application frequency by about 80 percent at the Forest Research Nursery. Further, by applying chemical only to the affected seedlots or portions of the greenhouse, we have been able to reduce total chemical applied by about 90 percent (see Dumroese and others 1990).

Proper pest identification is critical to ensure efficacy of applied chemicals. Make sure the chemical you select will indeed control the pest. Use the lowest rate given on the label to prevent unnecessary amounts of chemical from being applied and to reduce the chance the organism will become tolerant to the chemical. Follow the label directions for proper disposal of empty containers.

Develop an integrated pest management plan for your nursery. IPM is more than using predatory insects instead of chemicals. Modifying your cultural practices and growing regimes to create less favorable conditions for pests are part of IPM. An IPM program for

Fusarium has been described by James and others (1990), and the basics of this program also apply to most other nursery diseases. Proper cleaning of your greenhouse, containers, and seed between crops, and rogueing dead seedlings and keeping the facility tidy during the growing cycle will help reduce pest incidence (see Shrimpton 1991).

BMP's -- Structural

Waste water can be managed in several ways, but it basically involves either catching discharge and recycling it for another purpose, or catching discharge and treating it prior to release. Oregon legislation allows each nursery to formulate a site-specific water management plan. Ways of treating waste water are as numerous as there are nurseries.

Contain and Recycle -- Recycling waste water in the nursery is one possibility for eliminating discharge, and is especially attractive in situations where water supplies are limited or costly. To successfully recycle water, a containment structure is necessary, small amounts of chlorine mint be added to kill pathogens, and the water must be evaluated for residual nutrients. Monrovia Nursery Company recycles all water from their operations, resulting in 50% water conservation as well as a 50% savings of most nutrients (Wells 1990). Further, Wells (1990) found better plant growth using recycled water than with fresh fortified water.

Contain and Treat -- Potlatch Corporation in Lewiston, Idaho, pumps their nursery waste water into pulp effluent treatment ponds. For nurseries without that luxury, it may be possible to hook up to municipal sewer lines and have the water treated at the sewage treatment plant. Another relatively inexpensive method is pumping the waste water onto other agricultural products like alfalfa, as is the practice of Plum Creek Timber Company in Pablo, Montana.

Another possibility, and one we use at the Forest Research Nursery, is a constructed wetland. Wetlands are natural water purifiers. We had the Soil Conservation Service design a pond to handle our waste water plus additions from groundwater and precipitation. They recommended a 300,000-gallon pond, covering about one-half acre with a 6-foot maximum depth. Through the Idaho Department of Fish and Game (IDFG) Habitat Improvement Program, cost share dollars for projects that create or enhance habitat for upland game birds and/or waterfowl are available. Our pond qualified for waterfowl habitat, and $1000 of the $2500 construction fee was paid by IDFG. The pond took less than 3 days to excavate, and because the nursery site is located on very deep clay soils, no liner was necessary. We stabilized the pond banks and planted the shallow end with emergent vegetation, anticipating these plants would help remove excess nutrients from the water. In the pond we planted cattails *(Typha angustifolia* and T. *latifolia),* bulrush (*Scirpus acutus),* wapato duck potato or arrowhead *(Sagataria latifolia),* pondweed *(Potamogeton pectinatus)* and water iris *(Iris versicolor).* The banks were also planted with clovers and near the water we planted Juncos and *Carex.* Water analyses indicated low amounts of N, probably due to both dilution in the pond and use by the plants. An excellent reference for designing a wetland for water purification is Hammer (1989).

MANAGEMENT IMPLICATIONS

The 1990's are a decade of renewed environmental concern. Growers of trees and other conservation seedlings fit well into this trend and are respected in the public eye. We should be promoting our efforts to increase sales, government appropriations, and/or research grants. Unfortunately, our respect can be easily lost if we are also seen as operations that harm ground and surface water quality with excess nutrients, or waste precious water sources through poor management.

As members of the "green industry," we need to be pro-active and develop sound water management plans to ensure our continued favor by the public. Whether or not our nurseries indeed degrade the environment, a good water management plan will eliminate the potential for water quality degradation while protecting our operations from litigation and legislation (see Wilkerson 1991).

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