DEVELOPMENT OF FERTILIZER AND IRRIGATION PRACTICES FOR COMMERCIAL NURSERIES

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Introduction

Container-grown woody plants are an important agricultural commodity in California, accounting for most of the $1.99 billion farm gate for nursery products in 1999. California nurseries contribute over 20% of the nursery crops produced in the U.S. Production is intensive, usually involving daily application of water and high concentrations of fertilizers, especially nitrogen. Because of their high demand for nitrogen, the potential for nitrogen pollution from runoff and leaching losses in nurseries is great. Commercial nurseries have addressed this problem by improving methods of applying nitrogen and water. A practice of long standing has been to apply soluble nitrogen in irrigation water (liquid feeding), either by overhead irrigation using impact sprinklers or through emitters placed in each container. Liquid feeding offers the advantage of management over nutrient supply, since the grower can control fertilizer concentration, form of nutrients applied, and the composition of nutrients in the liquid feed. However, it suffers from the disadvantage of fertilizer waste because of the combined effects of a limited soil volume in containers and the need for frequent irrigation and fertilization. Application through overhead irrigation is particularly inefficient, since as much as 75% of the applied water is not intercepted by the containers.

Nurseries have responded to this problem with three major changes in fertilizing and irrigating. 1) Many nurseries have installed drainage systems that allow for capture and reuse of runoff. This has the advantage of permitting continued use of overhead irrigation, but the installation cost is high and retrofitting established nurseries is problematic. 2) Liquid feeding through drip irrigation systems has replaced use of impact sprinklers in many nurseries. This is more efficient and can reduce N losses substantially, provided appropriate amounts of N and water are applied. Unfortunately, the water requirements of individual nursery crops can vary greatly, and the water and nutrient requirements of most nursery species are not well known. As a result, it is likely that excessive application of water and fertilizer occurs, leading to leaching and runoff of nitrogen. Another drawback to drip systems is that installation is labor intensive and not usually cost effective for small container sizes. 3) The third method in common use is application of encapsulated, controlled-release fertilizers and irrigation with clear water rather than a liquid feed. This approach can be effective, but there is still the potential for leaching losses due to overfertilization and overirrigation. In addition, crops in large containers (5 gallons or larger) typically require multiple applications of fertilizer, which can result in a substantial labor expense.

A hybrid method of fertilizing has been proposed, in which a slow-release form of N is applied in a liquid feed. Some workers have argued that this method results in low leaching losses of N, while avoiding the need for labor-intensive multiple applications of fertilizer. This project was undertaken to test this proposed method, and to document the fertilizer and irrigation needs of large nursery stock.

Objectives

1. Determine water use of seven tree species grown in 5-gallon containers. The species, chosen to include both deciduous and evergreen species that are widely used in California, were *Magnolia grandiflora, Pistacia chinensis, Platanus racemosa, Prunus ilicifolia, Quercus agrifolia, Quercus lobata,* and *Sequoia sempervirens*.

2. Determine nitrogen uptake and leaching losses for these trees and compare nitrogen use efficiency of three methods of fertilizer application (liquid feeding with nitrate and ammonium, liquid feeding with polymethylene urea, and surface application of controlled release fertilizer).

3. Determine dry weight gain of trees.

Description

Two-inch liners of *Magnolia grandiflora, Pistacia chinensis, Platanus racemosa, Prunus ilicifolia, Quercus agrifolia, Quercus lobata,* and *Sequoia sempervirens* were obtained from commercial nurseries in Spring 2000, and 15 replicates of each species were planted into 5-gallon containers on June 1. The container medium contained equal amounts by volume of sphagnum peatmoss:redwood sawdust:medium sand. It was chemically amended with dolomite (5 lb yd^{-3}), superphosphate (2 lb yd^{-3}) and Micromax (1 lb yd^{-3}).

The containers were arranged on raised benches in the Environmental Horticulture experimental nursery. Each fertilizer group was irrigated through a separate drip irrigation system controlled by a solenoid valve and a timer. One supplied tap water to plants fertilized with controlled release fertilizer (designated as CRF treatment), and the other two used a Smith injector to introduce one of two fertilizer solutions into tap water and deliver a final N and K concentration of 100 mg L^{-1}. One of the fertilizer solutions contained polymethyleneurea (Growth Products' Nitro-30) and potassium sulfate (designated as MU treatment); the other solution contained a standard liquid feed solution of calcium nitrate, potassium nitrate, and ammonium nitrate, with 25% of the N supplied as ammonium (designated as SLF). Controlled release fertilizer (Osmocote 24-4-9) was applied to the surface in the appropriate treatment at the recommended rate (100 g/container). Irrigation water was applied through adjustable emitters to provide the different species with the volume of water necessary to produce a 0.25 leaching fraction.

Volumes leached were measured gravimetrically every 6 to 10 days. Plant water use was calculated as the difference between applied and leached volumes. Values of water use were compared to ET_0, reference evapotranspiration obtained from the Davis CIMIS site. Leachate samples were collected for measurement of different forms of N.

Trees were harvested at the end of October, when defoliation of deciduous trees started. All plants were separated into leaves, wood, and roots. Final fresh and dry weights of leaves, wood and roots were measured, and their N content was determined.

Results and Conclusions

Plant dry weight differed among species and was affected by fertilizer treatment (Table 1), but there was no interaction between species and fertilizer. The total dry weight of plants from the SLF and the CRF treatments was greater than that of plants in the MU treatment. The SLF treatment resulted in a higher leaf dry weight than in the other two treatments, and roots made up a larger portion of dry weight among plants fertilized with the controlled-release fertilizer.

Leaf N varied with species and fertilizer treatment, with a significant interaction (Table 2). The SLF resulted in a higher leaf N concentration than in plants fertilized with MU or CRF. This difference was most pronounced in *Platanus* and *Q. lobata*. The fast-growing *Platanus* plants had a significantly lower leaf N concentration if they were fertilized with CRF. In other species the differences among the three fertilizer treatments were not large. Total N uptake by plants during the experiment was affected mostly by species, but there was also a significant effect of fertilizer treatment (Table 3). *Platanus* plants took up far more N than any other species, and the SLF treatment resulted in greater N uptake than either other fertilization method. The benefit of SLF treatment on N uptake was most pronounced on *Magnolia, Platanus, Q. lobata,* and *Sequoia*.

Leaching losses of N were greatest among species that received the SLF treatment, and the CRF treatment resulted in significantly lower N leaching losses than the other treatments did (Table 4). Nearly all of the leachate N in the SLF and CRF treatments was in the form of nitrate-N. In the MU treatment, over 40% of the leachate N was polymethyleneurea. Nearly one-third of the N applied in the SLF treatment was lost to leaching, whereas only 2% of N applied as CRF was lost to leaching (Table 5). A large portion of the applied N was present in a soluble form in the soil at harvest, especially among plants that received CRF. N use efficiency in this experiment was expressed as the ratio N uptake/ N leached (Table 6). The N efficiency of the CRF treatment was significantly greater than that of the SLF and MU treatments. Leachate N concentration after the first few days was less than 100 ppm for all fertilizer treatments (Figure 1). Concentrations were highest in the SLF and MU treatments (averaging 82 and 53 ppm, respectively), and only 6 ppm for the CRF treatment.

Cumulative water use varied widely among species, from 9.5 gal (36 L) for *Prunus* to 35.4 gal (134 L) for *Platanus*. The cumulative water use of most of the species was between 9.5-13 gal. There was a substantial amount of variability in water use within species. As expected, daily water use was greater in summer months than in spring (Figure 2).

Fertilization of 5-gallon trees with controlled-release fertilizer was much more efficient than fertilizing by liquid feeding with either a traditional soluble N source or a slow-release source, such as polymethyleneurea. Nitrogen demand and fertilizer release rate appeared to be well matched in the case of CRF, so that even containers that received a high leaching fraction did not have high losses of N. Liquid feeding with either the traditional soluble N or polymethyleneurea resulted in substantial leaching losses of N. The leaching fraction is not easily controlled under typical commercial nursery conditions because micro-sprinkler emitters may not maintain a uniform rate of delivery and because water use within and between species can vary widely.

After analysis of N in plants, leachate, and soil, we were able to account for 92% of the N applied as CRF, but only 62% of the N applied in the polymethyleneurea liquid feed. N recovery in the traditional liquid feed treatment was 78%. Although we did not measure directly the N volatilization in the experiment, we assume that most of the unrecovered N was lost to the atmosphere.

Average daily water use during the summer ranged from 200-1200 mL. Even the highest values of water use are less than half the volume that we estimate is typically delivered to plants of this size in commercial nurseries. The problem of leaching losses in a liquid feed system could be alleviated greatly by applying the appropriate amount of N and water. By dividing total N uptake, in mg, by cumulative water use, in L, we can estimate the ideal concentration of applied N in ppm. For the slow-growing species in this study, a concentration of 30-50 ppm would meet this ideal (Table 7). Only the fastest-growing species should need a liquid feed N concentration in excess of 100 ppm.

Table 1. Tree dry weight, in grams, as a function of fertilizer treatment.

Fertilizer	Leaves	Wood	Roots	Total
SLF	36.8a	45.8a	48.4ab	131.0a
MU	26.2b	32.6b	36.5b	94.5b
CRF	30.2b	40.1ab	56.4a	126.8a

Table 2. Effect of species and fertilizer treatment on leaf N concentration, expressed as a percentage of dry weight. Values followed by different letters are significantly different at P=0.05.

Species	Leaf N
Magnolia	1.77a
Pistacia	2.10b
Platanus	2.12b
Prunus	2.42c
Q. agrifolia	1.96d
Q. lobata	2.55e
Sequoia	1.56f

Fertilizer	Leaf N
SLF	2.26a
MU	1.97b
CRF	1.98b

Table 3. Effect of species and fertilizer treatment on total N uptake, expressed in grams. Values followed by different letters are significantly different at P=0.05.

Species	Tissue N
Magnolia	1.24a
Pistacia	1.85b
Platanus	4.40c
Prunus	0.32d
Q. agrifolia	0.42d
Q. lobata	0.65e
Sequoia	1.83b

Fertilizer	Tissue N
SLF	2.95a
MU	1.27b
CRF	1.27b

Table 4. Cumulative N leached, in grams, from application of three fertilizer treatments to seven tree species. Values followed by different letters are significantly different at P=0.05.

Species	N leached
Magnolia	1.95a
Pistacia	2.62b
Platanus	2.79b
Prunus	1.77a
Q. agrifolia	2.11a
Q. lobata	1.94a
Sequoia	1.95a

Fertilizer	N leached
SLF	3.50a
MU	2.49b
CRF	0.50c

Table 5. Percentage of applied N that was leached from application of three fertilizer treatments to seven tree species. Values followed by different letters are significantly different at P=0.05.

Fertilizer	%N leached
SLF	32.2a
MU	24.3b
CRF	2.1c

Table 6. N use efficiency of three fertilizer treatments, expressed as the ratio N uptake:N leached. Values followed by different letters are significantly different at P=0.05.

Fertilizer	N uptake/N leached
SLF	0.70a
MU	0.66a
CRF	3.74b

Table 7. Ratio of N uptake to water use (in ppm) for seven tree species growing in 5-gallon containers.

Species	N uptake/water uptake
Magnolia	89
Pistacia	71
Platanus	135
Prunus	29
Q. agrifolia	32
Q. lobata	47
Sequoia	127

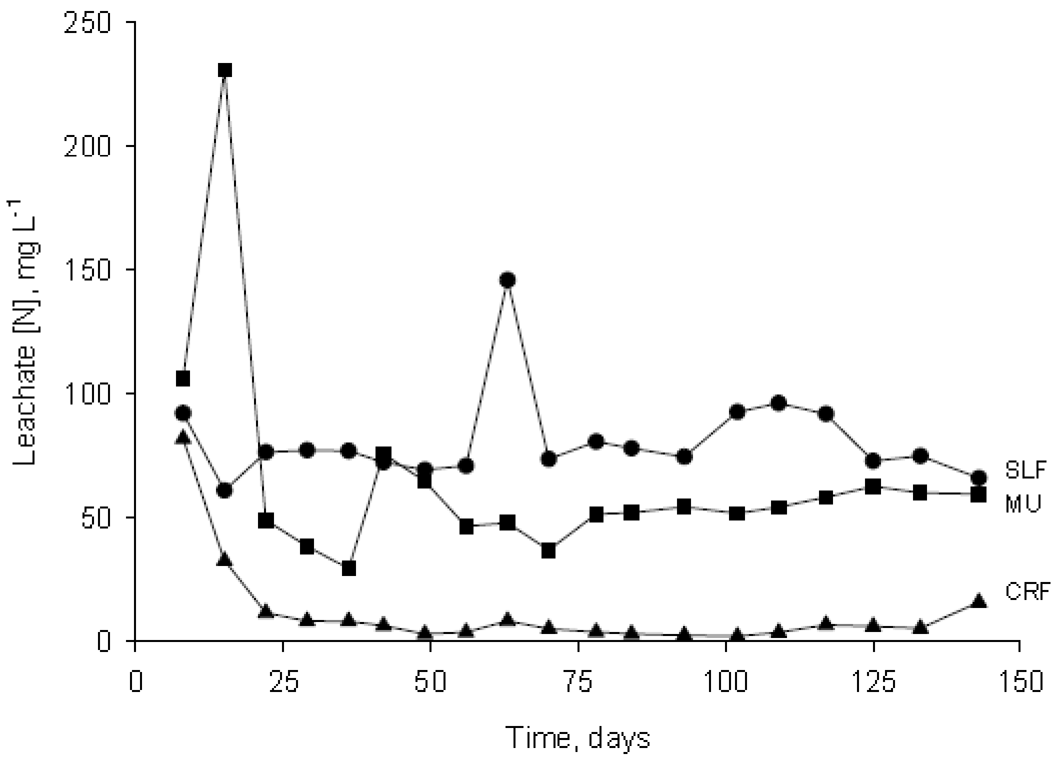

Figure 1. Leachate N concentrations among fertilizer treatments.

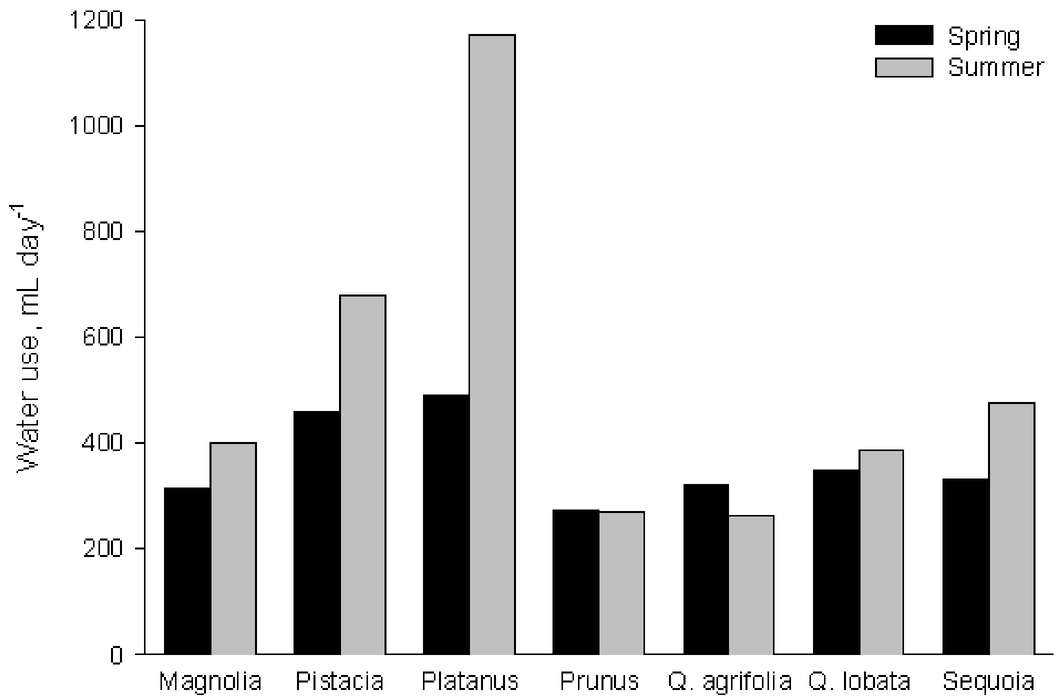

Figure 2. Average daily water use in spring and summer months for seven tree species growing in 5 gallon containers.