SLOW-RELEASE FERTILIZERS IN BAREROOT NURSERIES

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Abstract

Maintaining sufficient soil fertility in tree nurseries for good tree growth can be implemented by annually performing soil analyses and following a fertility maintenance program. Percentage recovery by trees of fertilizer applied indicates efficiency of fertilizer use. There is a wide variation in the recovery among the various fertilizer elements. Our research has shown that, of the primary nutrients, nitrogen recovery is much more variable, spanning from deficits to almost complete recovery. Low efficiency of nitrogen recovery is the usual rather than the exceptional occurrence. Soil characteristics, climatic conditions, cultural practices, fertilizer source, and fertilizer application method influence nutrient recovery. Most applied nitrogen is either recovered rather soon after application or lost from the soil-plant system. An approach to resolving the problem associated with nitrogen mobility and environmental protection has resulted in the development, testing, and use of several controlled-release or slow-release fertilizers. Slow-release fertilizers have not been widely used in bare root tree seedling nurseries and Christmas tree production. The lack of research in this area causes growers to sometimes guess at fertilizer applications, which can result in economic losses and environmental degradation. Several kinds of slow-release fertilizers are being manufactured and used in the turf industry rather successfully.

Polyon-coated slow-release fertilizer trials were introduced in the state bare root nursery in spring 1999. The feasibility of slow-release efficient fertilizer use and prevention of groundwater contamination was compared with conventional fertilizer use. Monitoring input of nutrient added as fertilizers and losses of nutrient in leachates indicated lower losses in slow-release fertilizer beds compared to conventional fertilizer beds. However, the uptake of nitrogen and morphological characteristics of 1+0 white pine seedlings were similar in the conventional and the Polyon-coated slow-release fertilizer plots.

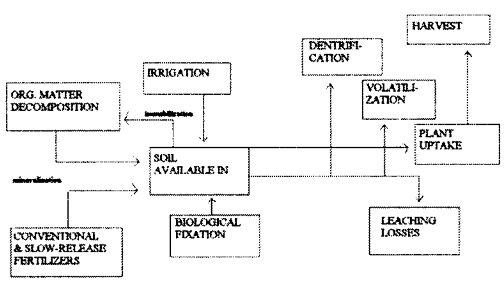
The goal of a soil fertility program is to maintain nutrient levels that will optimally suit the needs of the seedlings. We have confirmed that slow-release fertilizers added in lower amounts can yield trees comparable to those obtained with conventional fertilizer and can provide better ground-water protection.

Key Words

Nitrogen balance, cation balance, anion balance, nicronutrients, leachate, groundwater contamination

Slow-release fertilizers have not found wide application in tree seedling nurseries and Christmas tree production. The lack of research in this area causes growers to sometimes guess at fertilizer applications, which can result in economic losses and environmental degradation. Over-fertilization wastes growers' input dollars, and may contaminate the groundwater, while under-fertilization produces poor-quality seedlings and trees.

The efficiency of fertilizer use is measured in terms of percentage recovery of that applied. Nitrogen recovery is very variable and frequently tree crops do not recover the nitrogen from the applied fertilizer. Direct loss of N occurs from application in excess of seedling needs, or application at the wrong time, wrong place, or wrong material. Indirect N losses are caused by leaching, erosion, volatilization, denitrification and, to a lesser extent, fixation. Figure 1 illustrates the sources of input and output (losses) of nitrogen that can occur.



NITROGEN BALANCE IN SOIL

Figure 1.

SLOW RELEASE STUDY

Since the mid 1950s, a number of slow- or controlled-release products have been introduced as fertilizers. However, not much success was achieved with slow-release fertilizers in bare root tree nurseries. Over the years, several slow-release products with various types of coating materials have been available as fertilizers and successfully used in the turf industry as well as in the production of container-grown plants.

Slow-release fertilizers are relatively more expensive per unit than inorganic, conventional fertilizers, but there are a number of advantages due to their release rate. Slow-release fertilizers can be applied at the time of seeding or planting, which in turn, can supply the needed nutrients for a full growing season, thus eliminating additional fertilizer application and saving on labor; this offsets the increased cost of slow-release fertilizers. Use of slow-release fertilizers can reduce the loss of soluble materials through leaching and runoff and minimize contamination of the environment.

EXPERIMENTAL TRIAL

In spring 1999, slow-release fertilizer trials were established in raised 1+0 white pine beds at the Wilson State Nursery, Boscobel, WI. Slow-release fertilizers were applied to a coarse sandy soil of a quartzitic river terrace. Fertilizers used included a conventional fertilizer (15.5-0-0) calcium nitrate; Polyon, polymer-coated, slow-release fertilizer (12-0-42) potassium nitrate; Polyon, polymercoated, slow-release fertilizer (19-6-12) N+P+K mix, ammonium nitrate + ammonium phosphate + calcium phosphate + potassium sulfate. Two replicate rows of each of the three fertilizers were set up. Conventional fertilizer was added at the rate of 182 lb/acre and slow-release fertilizer at the rate of 42 lb/acre of actual N over the growing season.

Two porous-cup samplers were installed before fertilization in each row at the 1-m depth. Water leachate samples were collected every week over the entire spring, summer, and late fall.

Seedlings were collected at the end of the growing season for analysis of morphological and chemical characteristics. The morphological characteristics included height, diameter, and oven-dry weight of seedlings. The chemical characteristics included nutrient concentration of major and micronutrients in roots, stems, and needles. Average nutrient uptake per seedling was calculated based on the average oven-dry weight per seedling.

RESULTS AND DISCUSSION

First Growing Season

The morphological characteristics of 1+0 white pine did not show very great differences between slow-release and conventional fertilizer in seedling weight and height. Seedling weight ranged from 0.268 to 0.280 g in the slow-release fertilizer rows versus 0.290 g in the conventional fertilizer rows. Height ranged from 6.05 to 6.10 cm in slowrelease fertilizer rows versus 6.11 cm in conventional fertilizer rows. Diameter of seedlings in slow-release fertilizer rows ranged from 1.75 to 2.33 mm versus 2.60 mm in the conventional fertilizer rows. Results show that the diameters of seedlings were slightly higher in the conventional fertilizer rows for the first growing season (Table 1).

Table 1. Effect of conventional and slow-release fertilizer on the morphological characteristics of 1+0 white pine.

Treatment	Seedling Weight (g)	Height (cm)	Diameter (mm)
Conventional			
Calcium nitrate 15.5-0-0	0.290	6.11	2.60
Slow-release, Polymer-coated			
Potassium nitrate 12-0-42	0.287	6.05	1.75
N+P+K mix 19-6-12	0.268	6.10	2.33

The nutrient uptake of macronutrients by seedlings did not vary greatly between treatments. However, some nutrients did reflect the fertilizer source used; for example, calcium was highest at 1.50 mg Ca/seedling in the conventional fertilizer (calcium nitrate) treated rows versus 1.22 mg Ca/seedling in the slow-release (potassium nitrate) and 1.29 mg Ca/seedling in the slow-release (N+P+K mix). Potassium was highest at 2.35 mg K/seedling in the slow-release (potassium nitrate) versus 2.21 mg K/seedling in conventional fertilizer rows and 1.80 mg K/seedling in slow-release (N+P+K mix) fertilizer rows (Table 2). There were no conspicuous differences between the three fertilizer treatments in the uptake µg/seedling of micronutrients (Table 3).

Nitrate-N in Leacbate of Treated Rows

The leachate analyses for nitrates showed that, in spring, initially the nitrate in all three treatments ranged from 55.8 to 66.2 ppm. In early summer, an increase in nitrate-N was observed in all three treatments, ranging from 87.5 to 187.2 ppm.

Table 2. Nutrient uptake by and concentration in 1+0 white pine seedlings grown in beds treated with conventional and slow-release fertilizers.

Treatment	N	P	K	Ca	Mg	S
	Uptake (mg/seedling)					
Conventional						
Calcium Nitrate 15.5-0-0	5.05	0.87	2.21	1.50	0.75	0.58
Slow-release, Polymer-coated						
Potassium nitrate 12-0-42	4.95	0.84	2.35	1.22	0.75	0.80
N+P+K mix 19-6-12	4.84	0.81	1.80	1.29	0.77	0.51
	Concentration (%)					
Conventional						
Calcium nitrate 15.5-0-0	1.74	0.30	0.76	0.52	0.26	0.20
Slow-release, Polymer-coated						
Potassium nitrate 12-0-42	1.72	0.29	0.82	0.43	0.26	0.28
N+P+K mix 19-6-12	1.81	0.30	0.67	0.48	0.29	0.19

Table 3. Micronutrient uptake by and concentration in 1+0 white pine seedlings grown in beds treated with conventional and slow-release fertilizers.

Treatment	B	Cu	Fe	Mn	Zn
		Uptake (µg/seedling)			
Conventional					
Calcium nitrate					
15.5-0-0	4.08	2.45	451	32	30
Slow-release, Polymer-coated					
Potassium nitrate					
12-0-42	4.07	2.24	439	32	29
N+P+K mix					
19-6-12	3.79	2.20	525	34	28
		Concentration (ppm)			
Conventional					
Calcium nitrate					
15.5-0-0	14	8.4	1555	110	103
Slow-release, Polymer-coated					
Potassium nitrate					
12-0-42	14	7.8	1530	111	101
N+P+K mix					
19-6-12	14	8.2	1958	127	104

Further increase in nitrate-N continued in all three treatments until early fall, and in November, the nitrate-N in leachates of all fertilized rows ranged from 106.7 to 253.6 ppm. Towards winter, the nitrate-N in leachates of all fertilized plots decreased, with drops ranging from 80.7 to 195.3 ppm. Throughout the growing season, the nitrateN concentration in the leachates of conventional fertilizer rows was consistently higher than the leachates from slow-release fertilizer-treated rows (Table 4).

Figure 2 illustrates the nitrate-N concentration in the collected weekly leachate June through December. Highest amounts of nitrate-N concentration were observed during July and September in conventional fertilizer-treated rows followed by slow-release potassium nitrate, with slow-release N+P+K mix being the lowest of the three fertilizers. The nitrate-N concentration in the slow-release N+P+K mix leachates remained consistently lower than the leachate from the conventional (calcium nitrate) and slow-release potassium nitrate-treated rows throughout the growing season.

Mass Balance of Cations and Anions

Leaching of anions-nitrates (NO3) and sulfates ($SO_4^{=}$)-always includes cations Ca, Mg, and K as well. In order to compare anions plus cations present in the leachate samples of the fertilizertreated rows, the concentration of cations and anions in parts per million (ppm) were converted to meq/L (Table 5). Conventional fertilizer (15.50-0) calcium nitrate rows showed that, on average, 50% of the cations leached as nitrates and 30% as sulfates. Slow-release fertilizer rows of potassium nitrate (12-0-42) showed that, on the average, 30% of the cations leached as nitrates and 23% as sulfates. The slow-release fertilizer rows of N+P+K mix (19-6-12) showed that, on average,

Table 4. Nitrate-N in leachate from fertilizer-treated 1+0 white pine beds over the growing season.

		Slow-release	
Month	Conventional	12-0-42	19-6-12
	ppm	----------ppm--------	
June	66.2	55.8	59.4
July	187.2	91.4	87.5
August	270.4	171.1	116.5
September	265.9	182.3	135.8
October	271.8	193.5	180.5
November	253.6	143.7	106.7
December	195.3	119.2	80.7

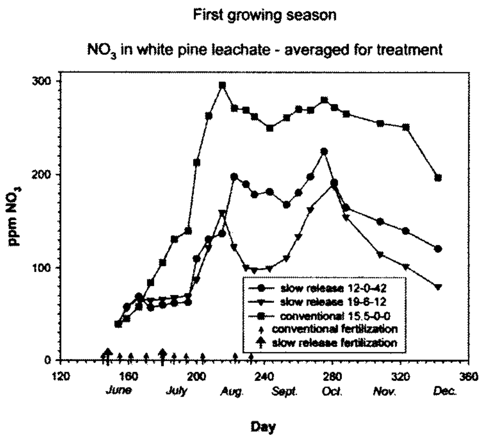


Figure 2.

32% of the cations leached as nitrates and 25% as sulfates. The slow-release N+P+K mix treated rows had the lowest amounts of cations (Ca, Mg, and K) and anions (nitrates and sulfates) in the leachates compared to the conventional fertilizer (calcium nitrate) and slow-release fertilizer (potassium nitrate) treated rows.

Second Growing Season

Conventional fertilizer (15.5-0-0) calcium nitrate; Polyon, polymer-coated, slow-release fertilizer (12-0-42) potassium nitrate; Polyon, polymercoated, slow-release (19-6-12) N+P+K mix, ammonium nitrate + ammonium phosphate + calcium phosphate + potassium sulfate were applied at the same rate as the first growing season. The rates were 158 and 42 lb N/acre for conventional (15.5-0-0) and slow-release (12-0-42 and 19-6-12), respectively. The seedlings were collected from the fertilizer-treated rows in early summer to document any changes in seedling morphology and chemical content between the three fertilizer treatments.

The conventional (15.5-0-0) and slow-release (196-12) N+P+K mix showed similar heights of 19.15 and 19.2 cm and diameters of 2.63 and 3.03 mm, respectively. The seedlings in the slow-release (12-0-42) were smaller in height (17 cm); diameters of 2.6 mm were similar to the seedlings in the conventional fertilizer rows (Table 6).

The uptake of nutrients by seedlings (Table 7) on average indicated that the seedlings growing in conventional fertilizer (15.5-0-0) rows took up 10.68 mg N, 7.31 mg K, and 4.90 mg Ca, which

Table 6. Effect of conventional and slow-release fertilizers on the morphological characteristics of rising 2+0 white pine.

Treatment	Seedling O.D. weight (g)	Height (cm)	Diameter (mm)
Conventional			
Calcium nitrate			
15.5-0-0	0.92	19.15	2.63
Slow-release, Polymer-coated			
Potassium nitrate			
12-0-42	0.77	17.00	2.69
N+P+K mix			
19-6-12	0.86	19.20	3.03

was higher than the amounts taken up by seedlings growing in the slow-release potassium nitrate and N+P+K mix (19-6-12) treated rows. The seedlings growing in the slow release fertilizer (19-6-12) N+P+K mix showed a higher uptake of N, P, Ca, and Mg than the seedlings growing in the slow-release fertilizer (12-0-42) potassium nitrate rows. The slow-release N+P+K mix also had the highest amounts of P (1.87 mg P/seedling) compared to the seedlings grown in the slow-release (potassium nitrate; 1.49 mg P/seedling) and conventional (1.31 mg P/seedling). In general, the micronutrient uptake by seedlings growing in the conventional fertilizer rows was lower than the seedlings growing in the slowrelease fertilizer (potassium nitrate) and N+P+K mix rows. However, uptake of micronutrients by seedlings growing in all three fertilizer treated rows was within the accepted range found for conifers (Table 8). Concentrations of nutrients in seedlings are also provided in Tables 7 and 8. Large amounts of approximately 158 to 180 lb/acre of actual N are added as conventional N fertilizers to conifers over the growing season. To reduce this amount, the feasibility of slow-release fertilizer trials were established on loamy sandy soil. Based on tissue analysis, seedling weight and density of 35 seedling/ft^2, about 15 lb/acre of nitrogen was taken up by 1+0 white pine at the end of the first growing season. Based on tissue analysis, seedling weight and density of 35 seedling/ft^2, during the early summer of the second growing season, the uptake of N varied

Table 5. Mass balance of cations, nitrates, and sulfates in leachates from conven-tional and slow-release fertilizer treated beds of 1+0 white pine.

Month	K+	Ca++	Mg++	Total Cations	NO3–	SO4=
		---------- meq/L ----------				
		Calcium Nitrate[1]				
June	0.006	1.95	2.97	4.91	1.07	1.24
July	0.055	3.63	3.08	6.50	3.02	1.77
August	0.263	3.08	4.79	8.11	4.36	2.57
September	0.245	2.90	4.89	8.00	4.29	2.56
October	0.235	2.94	4.96	7.49	4.38	2.38
November	0.297	2.92	4.14	7.34	4.09	2.06
December	0.176	2.50	3.21	6.89	3.15	1.85
		Potassium Nitrate (12-0-42)[2]				
June	0.007	2.93	2.63	5.57	0.899	1.18
July	0.089	3.04	3.33	7.32	1.47	1.83
August	0.252	3.30	5.53	9.05	2.86	1.89
September	0.240	3.16	5.40	8.78	2.94	1.91
October	0.218	3.21	5.12	8.53	3.12	1.80
November	0.184	2.55	4.65	7.36	2.32	1.76
December	0.134	2.01	3.28	7.63	1.92	1.46
		N+P+K Mix (19-6-12)[2]				
June	0.001	2.48	2.90	5.37	0.957	0.88
July	0.083	3.27	2.48	6.24	1.41	2.11
August	0.269	2.93	3.27	6.46	1.88	1.90
September	0.246	2.58	3.28	6.09	2.19	1.37
October	0.224	2.39	3.36	5.96	2.91	1.13
November	0.179	2.38	2.53	5.09	1.72	1.16
December	0.149	1.87	1.80	5.57	1.30	1.22

[1] Conventional fertilizers
[2] Slow-release fertilizers

Table 7. Nutrient uptake by and concentration in rising 2+0 white pine seedlings grown in beds treated with conventional and slow-release fertilizers.

Treatment	N	P	K	Ca	Mg	S
		Uptake (mg/seedling)				
Conventional						
Calcium nitrate						
15.5-0-0	10.68	1.31	7.31	4.90	2.10	1.41
Slow-release, Polymer-coated						
Potassium nitrate						
12-0-42	4.41	1.49	5.11	3.23	1.82	1.53
N+P+K mix						
19-6-12	7.75	1.87	5.24	3.81	2.10	1.53
		Concentration (%)				
Conventional						
Calcium nitrate						
15.5-0-0	1.16	0.14	0.79	0.44	0.23	0.15
Slow-release, Polymer-coated						
Potassium nitrate						
12-0-42	0.57	0.19	0.66	0.42	0.24	0.20
N+P+K mix						
19-6-12	0.90	0.22	0.61	0.44	0.24	0.18

Table 8. Micronutrient uptake by and concentration in rising 2+0 white pine seedlings grown in beds treated with conventional and slow-release fertilizers.

Treatment	B	Cu	Fe	Mn	Zn
		Uptake (µg/seedling)			
Conventional					
Calcium nitrate					
15.5-0-0	2.82	6.08	127	85	76
Slow-release, Polymer-coated					
Potassium nitrate					
12-0-42	7.29	5.28	502	196	84
N+P+K mix					
19-6-12	13.85	6.14	394	107	85
		Concentration (ppm)			
Conventional					
Calcium nitrate					
15.5-0-0	3.1	6.6	1000	92	83
Slow-release, Polymer-coated					
Potassium nitrate					
12-0-42	9.5	6.9	652	255	109
N+P+K mix					
19-6-12	16	7.1	1000	124	99

between fertilizer treatments. The seedlings growing in conventional fertilizer rows took up the highest amount of nitrogen (34 lb N/acre), followed by slow-release N+P+K mix at 23.6 lb N/acre. The lowest amount of nitrogen was taken up by the seedlings growing in slow-release fertilizer (potassium nitrate) at 13.4 lb N/acre. The final amounts of nitrogen taken up by 2+0 white pine seedlings growing in the three fertilizer-treated rows will be determined at the end of the second growing season in August or September 2000.

CONCLUSIONS

1. Certain slow-release fertilizers appear to be promising for use in bare root conifer nurseries.
2. Slow-release fertilizers can be added in substantially lower amounts compared to the amounts added as conventional fertilizers.
3. Slow-release fertilizers are usually more expensive than conventional nitrogen fertilizers, but their use may be justified where fertilizer application is required at frequent intervals, especially in sandy textured soils.
4. Leaching of nitrates to groundwater is considerably reduced and nitrogen fertilizer can be cost-effectively used.
5. Results obtained to date clearly show considerable amounts of nitrate leaching in the conventional fertilizer rows versus the slow-release fertilizer rows.
6. Leaching of nitrates is always accompanied by leaching of cations (Ca, Mg, and P), which are also essential nutrients for seedlings.
7. Reducing annual application of fertilizer may contribute directly to overall energy savings, both in fertilizer energy and energy of application.
8. Based solely on the amounts added, the comparison of fertilizer cost clearly shows that slow-release fertilizer was $41 per acre cheaper than the conventional fertilizer. This did not take into account the cost of fuel, labor, number of applications, and compaction.
9. Slow-release N+P+K mix appears to be very suitable for use as a fertilizer source for white pine.

Seedlings appeared slightly paler in July in the slow-release rows. However, towards the end of August, seedlings greened up in the slow-release fertilizer rows and the differences between seedlings evened out visually between the slow-release and conventional fertilizer rows.

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