FREQUENCY OF FERTILIZATION AND GROWTH OF CONTAINERIZED SEEDLINGS

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ABSTRACT

Lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and white spruce (*Picea glauca* (Moench) Voss) were grown in the greenhouse for 18 weeks and under three nutrient regimes: 1) weekly fertilization; 2) continuous fertilization, i.e., fertilizer applied whenever cavities were sufficiently dry (two to three times per week); and 3) continuous fertilization at half strength. Lodgepole pine showed no difference in height and root-collar diameter due to treatment. White spruce was taller under continuous fertilization, but root-collar diameter was similar with all treatments. Shoot:root ratio of white spruce also increased significantly with continuous fertilization. After 18 weeks, pH of the growing medium had decreased and salinity had increased significantly under continuous fertilization, and there was heavy moss growth and salt accumulation on the surface of the medium. Continuous fertilization resulted in greater uptake of N, K, Fe, and Mn, but only N in lodgepole pine was improved significantly compared to weekly application. Continuous fertilization is unnecessary; the practice results in morphologically inferior spruce and exposes both species to great physiological risk.

INTRODUCTION

In the production of containerized seedlings, different frequencies of fertilization have been used. A frequency of twice per week has been used in British Columbia (Brix and van den Driessche 1974), and application once per week was the practice in the Pacific Northwest (Owston 1974), the Canadian prairie provinces (Carlson 1983; Edwards and Huber 1981), and the Maritimes (Hallett 1981). Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings grown in shade frames in British Columbia (van Eerden 1974) showed a positive response to increased frequency of fertilizer application, and it was later reported (Matthews 1981) that growers were advised to inject soluble fertilizer into the irrigation system at almost every watering. In a greenhouse trial in Alberta[1], weekly fertilization produced superior lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and white spruce (*Picea glauca* (Moench) Voss) seedlings

[1] Edwards, I.K. 1982. A CFS-Grace fertilizer trial using containerized conifer seedlings. Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. File Rep. NOR-10-35.

compared to continuous fertilization (application whenever the cavities required watering). Seedlings grown under continuous fertilization were characterized by succulent foliage, flaccid stems, and high shoot:root ratios. In 1986, satisfactory growth of black spruce (*Picea mariana* (Mill.) B.S.P.) with continuous fertilization was reported at Pineland Provincial Forest Nursery in Hadashville, Manitoba[2], and continuous fertilization was being recommended by sources within the fertilizer sales community. In 1987, a greenhouse experiment was set up to determine the effect of frequency of fertilization on growth of containerized lodgepole pine and white spruce.

MATERIALS AND METHODS

Lodgepole pine and white spruce were sown in peat-filled Spencer-Lemaire Five containers (cavity volume = 55 cm; 70 cavities per tray) in mid-February and allowed to grow for 18 weeks. Prior to filling the trays, the peat was adjusted to pH 5.2 using calcium carbonate. The greenhouse environment was as follows: temperature, 24°C day and 16°C night; relative humidity, 62-65%; light intensity (high pressure sodium lamps), PAR = 260 $mol \cdot m^{-2} \cdot s^{-1}$; and photoperiod, 18 hours.

Beginning 21 days after germination, three fertilization regimes were imposed as follows: 1) weekly application of the formulation recommended (Carlson 1983) for pine and spruce, 125 ppm nitrogen (N) + 60 ppm phos phorus (P) + 159 ppm potassium (K); 2) continuous application of the formulation recommended in 1); and 3) continuous application of the formulation at half strength, i.e., 63 ppm N + 30 ppm P + 80 ppm K. Fertilization consisted of complete saturation of each cavity, at which time excess nutrient solution drained away. The fertilizer solution recommended by Carlson (1983) also contained micronutrients at the following concentrations: iron (Fe), 5.5 mg/L; manganese (Mn), 0.34 mg/L; boron (B), 0.30 mg/L; zinc (Zn), 0.11 mg/L; copper (Cu), 0.02 mg/L, and molybdenum (Mo), 0.01 mg/L. Trays receiving weekly fertilization were watered one to two times between each application; those receiving continuous feeding were never watered but received the fertilizer solution whenever they were judged to be sufficiently dry.

Measurements of height and root-collar diameter (RCD) were made at seedling ages of 6, 12, and 18 weeks. In addition, at 18 weeks, mean shoot dry weight and root dry weight were recorded for 25 seedlings. Observations on the appearance of seedlings and growing medium were recorded, and after 18 weeks the pH (paste method) and electrical conductivity (saturated extract) were determined (McKeague 1978). Following harvest, the foliage was analyzed for N (Kjeldahl method), P, K, Ca, Mg, S, Fe, Mn, and Cu, using ICAP spectrometry after nitric acid digestion[3]. Significance of the difference between means was compared using Student's *t*-test (Steel and Torrie 1980).

RESULTS AND DISCUSSION

Lodgepole pine at 6 weeks was taller with continuous feeding, but there was no significant difference in height between nutrient regimes at 18 weeks (Table 1). Root-collar diameter

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[2] Personal communication from R. Cameron, Superintendent, Pineland Provincial Forest Nursery, Hadashville, Manitoba, June 1987.

[3] Personal communication from Y.P. Kalra, chemist, For. Can., North. For. Cent., Edmonton, Alberta, September 1986.

was also similar for all treatments. Results for white spruce (Table 2) indicated significantly taller seedlings under continuous fertilization, but there was no significant difference in root-collar diameter. Shoot: root ratio of lodgepole pine was least under a continuous nutrient regime, but it was not significantly different from that receiving weekly fertilization (Table 3). In white spruce, shoot:root ratio was least under weekly fertilization and significantly greater with continuous feeding.

Whereas the morphology of lodgepole pine was not affected significantly by frequency of fertilization, there was an important implication for white spruce. Continuous application of nutrient solution at full strength resulted in spindly seedlings, i.e., taller but with no larger stems, and the seedlings were more unbalanced (top-heavy). Both characteristics (spindliness and high shoot:root ratio) render these seedlings less desirable for outplanting. Continuous fertilization at half strength did not improve seedling morphology relative to weekly application. Although there was no difference in the morphology of pine, less acceptable spruce in terms of spindliness and shoot:root ratio was produced.

Following 18 weeks of culture, the pH of the growing medium decreased under a full-strength continuous regime, and electrical conductivity increased significantly compared to the peat fertilized weekly (Table 4). In the half-strength continuous regime, pH and electrical conductivity of the medium were similar to those in the weekly regime. The ideal pH for growing prairie conifers is 5.0-6.0, and the implication for seedling growth in this case is obvious. The high level of salinity that accumulated under full-strength continuous fertilization is potentially deleterious. At an electrical conductivity of 4 mS/cm, all but the most salt-tolerant plant species will suffer toxic effects (Richards 1954). As the growing medium dries between applications, salts are concentrated in the material and conductivity readings may increase by a factor of four (Richards 1954). The practice of continuous feeding at full strength leaves little room for error in the event that an application is delayed unduly.

Physical observations made on the seedlings and growing medium indicated that under continuous feeding at full strength there was a heavy accumulation of salt and thick moss growth on the surface (Table 5). Continuous feeding at half strength resulted in no surface build-up of salt, but there was a moderate amount of moss growth. Weekly application of nutrients resulted in no salt accumulation, and only a trace of moss appeared following increased density of foliage. In all cases, the seedlings had a normal green color. White spruce had an average of 10, 12, and 15 side branches under the weekly, half-strength continuous, and full strength continuous regimes, respectively.

Nutrient concentration in the foliage of lodgepole pine (Table 6) indicated that seedlings grown under the weekly regime were lower in N, K, Fe, and Mn than those receiving continuous feed at full strength. All other nutrients were similar in foliar concentration regardless of nutrient regime; however, only N concentration was below the range of sufficiency for lodgepole pine (Table 7), based on suggested standards (Swan 1972). Iron and manganese are found in tree species in wide ranges of concentration, and although no sufficiency levels exist per se, the present levels are within the ranges of concentration that have been reported.

In the case of white spruce, foliar concentration of nitrogen, potassium, iron, and manganese in seedlings from the weekly regime were also lower than the levels that developed from continuous treatments (Table 8), but no

Table 1. Height and root-collar diameter (RCD) of lodgepole pine seedlings at 6, 12, and 18 weeks under different nutrient regimes

Nutrient regime	Height (cm)			RCD (mm)		
	6 wk	12 wk	18 wk	6 wk	12 wk	18 wk
Weekly	5.5 a[1]	7.2 a	8.4 a	1.2 a	2.4 a	3.1 a
Full-strength continuous	6.4 b	7.5 a	8.3 a	1.3 a	2.4 a	3.3 a
Half-strength continuous	5.3 a	7.3 a	8.6 a	1.2 a	2.4 a	3.3 a

[1] Within columns, means followed by the same letter are not significantly different (5%) according to Student's *t*-test; n = 25.

Table 2. Height and root-collar diameter (RCD) of white spruce seedlings at 6, 12, and 18 weeks under different nutrient regimes

Nutrient regime	Height (cm)			RCD (mm)		
	6 wk	12 wk	18 wk	6 wk	12 wk	18 wk
Weekly	5.3 a[1]	11.9 a	17.8 a	0.8 a	2.0 a	3.1 a
Full-strength continuous	5.8 b	11.5 a	19.2 b	0.9 a	1.9 a	3.0 a
Half-strength continuous	5.1 a	11.8 a	18.6 b	0.8 a	2.2 a	3.0 a

[1] Within columns, means followed by the same letter are not significantly different (5%) according to Student's *t*-test; n = 25.

Table 3. Shoot:root ratio of lodgepole pine and white spruce at 18 weeks under different nutrient regimes

Nutrient regime	Lodgepole pine shoot:root ratio	White spruce shoot:root ratio
Weekly	3.7 ab[1]	4.2 a
Full-strength continuous	3.3 a	6.1 b
Half-strength continuous	4.2 b	5.9 b

[1] Means followed by the same letter are not significantly different (5%) according to Student's *t*-test; n = 25.

Table 4. The pH and electrical conductivity (EC) of growing medium (peat) in trays after 18 weeks

Nutrient regime	pH	EC (mS/cm)
Weekly	5.45	0.75
Full-strength continuous	4.58	2.20
Half-strength continuous	5.66	0.72

Table 5. Observations of spruce seedlings and growing medium from trays in different nutrient regimes

Nutrient regime	Observations
Weekly	No evidence of salt build-up; trace of surface moss only; appearance normal; an average of 10 side branches per spruce seedling.
Full-strength continuous	All cavities had heavy salt build-up (white appearance); also thick moss layer on surface of peat; deep green foliage; 15 side branches per spruce seedling.
Half-strength continuous	No salt accumulation; some moss growth; appearance normal; 12 side branches per spruce seedling.

Table 6. Nutrient concentration in foliage of lodgepole pine seedlings at 18 weeks under different nutrient regimes

Nutrient element	Nutrient regime		
	Weekly	Full-strength continuous	Half-strength continuous
N (%)	1.46	1.96	1.65
P (%)	0.21	0.22	0.22
K (%)	0.81	1.04	0.84
Ca (%)	0.33	0.41	0.33
Mg (%)	0.17	0.12	0.16
S (%)	0.16	0.17	0.17
Fe (mg/kg)	60	109	105
Mn (mg/kg)	53	142	66
Cu (mg/kg)	4	4	4

Table 7. Suggested standards[1] for evaluation of foliage analysis (%)

Nutrient element	Species	Range of deficiency	Range of sufficiency
N	Lodgepole pine	<1.20	1.70-3.00
	White spruce	<1.30	1.50-2.50
P	Lodgepole pine	<0.10	0.17-0.40
	White spruce	<0.14	0.18-0.32
K	Lodgepole pine	<0.30	0.50-1.10
	White spruce	<0.30	0.45-0.80
Ca	Lodgepole pine	<0.06	0.08-0.30
	White spruce	<0.10	0.15-0.40
Mg	Lodgepole pine	<0.07	0.09-0.16
	White spruce	<0.06	0.10-0.20

[1] Swan 1971, 1972.

Table 8. Nutrient concentration in foliage of white spruce seedlings at 18 weeks under different nutrient regimes

		Nutrient regime	
Nutrient element	Weekly	Full-strength continuous	Half-strength continuous
N (%)	1.69	2.23	1.88
P (%)	0.30	0.32	0.29
K (%)	0.97	1.27	0.97
Ca (%)	0.65	0.70	0.54
Mg (%)	0.18	0.15	0.14
S (%)	0.14	0.16	0.14
Fe (mg/kg)	73	164	74
Mn (mg/kg)	83	240	66
Cu (mg/kg)	3	3	3

element was below the range of sufficiency (Swan 1971). All other elements were similar in foliar concentration regardless of the nutrient regime in which the seedlings were reared. This demonstrated that in the context of seedling nutrition it is pointless to apply nutrient solution continuously in the culture of prairie provenances of lodgepole pine and white spruce. Although lodgepole pine could benefit from the weekly application of a nutrient solution containing a higher concentration of nitrogen, unfavorable morphological and physiological effects should be avoided.

CONCLUSIONS

Continuous application of fertilizer solution in the greenhouse culture of lodgepole pine and white spruce is counterproductive. The practice results in morphologically inferior white spruce seedlings, although the morphology of lodgepole pine is not affected. Under continuous fertilization, both species are physiologically put at risk because of the build-up of salts on the surface of the growing medium and, consequently, unacceptably high levels of salinity in the cavities, as expressed by electrical conductivity. When seedling nutrition is considered, there is no benefit to white spruce from continuous fertilization, and in lodgepole pine only the uptake of nitrogen is enhanced significantly.

Compared to weekly fertilization, the increased costs associated with fertilizer purchase and human resources (applicator, time) for continuous fertilization are not warranted. Even if financial considerations are ignored, crop quality is jeopardized, and this is unacceptable. Although the study did not involve induction of dormancy, electrical conductivity results indicated that leaching of salts from the cavities would occur less easily in trays subjected to continuous fertilization, and such seedlings would be at a disadvantage in the development of cold hardiness.

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