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Influence of Growth Medium pH on the Growth of Container-grown Fraser Fir Seedlings¹

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Abstract

Seedlings of Fraser fir (*Abies fraseri* (Pursh) Poir.) were grown in sphagnum peat amended with 0 to 8 kg dolomitic limestone/m³ (0 to 13.5 lb/yd³). Initial pH ranged from 3.9 to 6.7. Best growth (21.2 cm (8.3 in) mean height at 19 months) was achieved with 1 and 2 kg/m³ (1.7 and 3.4 lb/yd³), with initial mean pH 4.2 and 4.5. Seedlings grown in media amended with 4 and 8 kg/m³ (6.7 and 13.5 lb/yd³) grew more slowly (17.4 (6.9 in) and 9.5 cm (3.7 in) in 19 months), and many were chlorotic, with poorly formed, blackened roots. At the conclusion of the first growth cycle (10 months), the slowest growth occurred in the most heavily limed peat (8 kg/m³ (13.5 lb/yd³), initial pH 6.8). Slower growth at 4 kg/m³ (6.7 lb/yd³, initial pH 5.0) became evident only after three growth cycles. Seedlings grew best within a fairly narrow range of pH (4.2 to 4.5), which is considerably more acidic than is generally recommended for conifers.

Index words: *Abies fraseri*, container-production, lime, acidity, Christmas trees

Introduction

Growth medium acidity has long been recognized as important to successful conifer growth (2, 6, 8). The suitable pH ranges of conifer species are often narrow (8). Nevertheless, pH often goes unreported in nursery studies, and is sometimes ignored by researchers and growers alike. In some nurseries, commercial horticultural potting mix, amended with limestone, is used interchangeably with peat for growing conifers.

In a search of available literature, no pH recommendations for Fraser fir (*Abies fraseri* (Pursh) Poir.) were found, for either organic media or mineral soil. Recommendations of pH for closely related balsam fir (*Abies balsamea* (Linn.) Mill) are few, contradictory, and apparently limited to seedlings grown in mineral soils.

Goodwin (7) reported that the best growth of Fraser fir after 48 weeks, 5.8 cm (2.3 in) average height, occurred in sphagnum peat and vermiculite compared to an average height of 4.1 cm (1.6 in) in Pro-Mix B, a commercial horticultural potting mix of sphagnum peat and vermiculite with supplemental nutrients and limestone. While pH was not reported in Goodwin's study, the added limestone in Pro-Mix B was the only obvious factor which might be suspected as a possible cause of decreased growth.

Excess liming has been implicated in stunted conifer seedlings damaged by pathogenic fungi in mineral soil (2, 6). Pawuk (9) found that seedlings of shortleaf pine (*Pinus echinata* Mill.) grew better in a peat:vermiculite (1:1 by vol) mixture at pH 5.4 than in a similar mixture amended to pH 6.4. Longleaf pine (*Pinus palustris* Mill.) seedlings grew equally rapidly at either pH, but seedlings grown at the higher pH suffered more mortality due to pathogens.

The objective of this study was to compare the effects of five dolomitic limestone amendments to an acidic growth

medium, sphagnum peat, on seedling growth of Fraser fir, and thereby to determine the suitable pH range for seedlings grown in an organic medium.

Materials and Methods

Canadian sphagnum peat was amended with 0, 1, 2, 4, and 8 kg dolomitic limestone per cubic meter peat (0, 1.7, 3.4, 6.7, 13.5 lb/yd³), as suggested by Chrusic and Wright (5), placed in 20.3 cm (8 in) root-trainer books (Spencer-Lemaire Industries, Ltd., Edmonton, Alberta, Canada), and thoroughly watered. In December, 1986, two hundred forty 2-month-old seedlings were transplanted from a commercial horticultural potting mix (Pro-mix BX) into the five limestone treatments in root-trainer books randomly located in each of six trays.

Seedlings were grown in a greenhouse with natural photoperiods extended to 16 hours by the provision of supplemental sodium vapor lighting (approximately 150 μ M/m²s photosynthetic photon flux density at the level of the seedlings). The greenhouse was heated to a minimum of 19°C (68°F), and ventilated when temperatures exceeded 22°C (72°F). Summer temperatures in the greenhouse occasionally exceeded 40°C (104°F). Seedlings were watered as needed to maintain sufficient moisture for continuous growth: once or twice daily on hot sunny days, as little as once in 3 days in cloudy, cool weather. Ten ml liquid fertilizer (Peters General Purpose, Fogelsville, Pa.) was provided to each seedling weekly during the growing season at the concentration of 200 ppm N, 87 ppm P, and 166 ppm K, supplied as 20N-8.6P-16.6K (20-20-20).

At eleven and sixteen months age, supplementary light and nutrients were withheld for one month. Growth was then interrupted for six-week chilling periods in a room refrigerated to 3°C (35°F), after which seedlings were returned to the greenhouse growing conditions described above. Thus, seedlings had completed three periods of growth by the end of the experiment in May, 1988, when they were 19 months old.

Growth medium pH was determined by a displacement method as described by Wright (11). Seedling heights were

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recorded at the completion of each growth period. At the conclusion of the experiment, seedlings were severed at the root collar, and dried at 60°C (140°F) to a constant weight, for determination of root and shoot weights.

A randomized complete block design with 6 blocks was used. The average of an 8 tree plot was used as the experimental unit. Size-dependent variables were transformed logarithmically before regression analysis, in order to provide more uniformity of variance between small and large seedlings.

Results and Discussion

After three months, the dolomitic lime treatments resulted in a range of pH from 3.9 to 6.7 (Table 1). With all lime-stone treatments, the growth medium became more acidic during the course of the experiment. However, the 8 kg/m³ (13.5 lb/yd³) lime treatment maintained a pH of 6.4 even after 17 months (Table 1). By the time of harvest, the most heavily limed peat (8 kg/m³, 13.5 lb/yd³) had decomposed considerably. Leachate was dark, with many particles of peat. The leachate of the three lowest lime treatments (0, 1, and 2 kg/m³ (1.7 and 3.4 lb/yd³)) remained transparent yellow at the end of the experiment.

By month 10 and within the first growth cycle, two trends became apparent. First, the addition of a small amount of lime was beneficial to seedling growth. Second and more important, the addition of large amounts of lime was detrimental to seedling growth (Table 2). Seedlings growing in the 8 kg/m³ (13.5 lb/yd³) treatment (pH 6.4 to 6.9) were 21% shorter than any others, and 24% shorter than those with 1 kg/m³ (1.7 lb/yd³) (pH 3.5 to 4.2) (Table 2).

During the second growth cycle, the more heavily limed seedlings (4 and 8 kg/m³ (6.7 and 13.5 lb/yd³)) were slow to break bud and became chlorotic. Seedlings with 1 kg/m³ (1.7 lb/yd³) lime were the tallest, growing an average 8.4 cm (3.3 in) since the 10 months measurement (Table 2). The superiority of the 1 kg/m³ (1.7 lb/yd³) seedlings over seedlings with more lime is consistent with Pawuk's (9) results for shortleaf and longleaf pine. The high pH was not beneficial to Fraser fir growth. The advantage of 1 kg/m³ (1.7 lb/yd³) over 0 and over 2 kg/m³ (3.4 lb/yd³) supports Leyton's (8) work that the optimum pH range for conifer growth may be rather narrow.

At the time of harvest, after 19 months in the amended growth medium, differences in any of the parameters measured were slight between seedlings with 1 or 2 kg/m³ (1.7 or 3.4 lb/yd³) (Table 3). Shoots of seedlings grown in the 4 and 8 kg/m³ (6.7 and 13.5 lb/yd³) treatments (initial pH

Table 2. Effects of varying quantities of dolomitic lime in sphagnum peat on the height of container-grown Fraser fir seedlings.²

Lime added kg/m ³ (lb/yd ³)	Seedling age			
	5 months	10 months	15 months	19 months
	Height (cm)			
0 (0)	2.2ns ^y	4.3***	11.0**	19.5**
1 (1.7)	2.5	4.5	12.9	21.8
2 (3.4)	2.4	4.2	11.2	20.5
4 (6.7)	2.6	4.1	10.2	17.4
8 (13.5)	2.2	3.4	6.4	9.5

²Values are means of 6 replications.

^yTreatment not significant at alpha = .05 level.

***Treatment showed significant quadratic effects (p = .0001).

5.0 and 6.7, resp.) were significantly shorter (20.2% and 56.4%, resp.) and lighter (30.8% and 75.8%, resp.) than the seedlings grown in 1 kg/m³ (1.7 lb/yd³). Shoot dry weight responded similarly to the lime addition. Thus, the pH requirements of Fraser fir seedlings do not fall within the general pH range for conifer seedlings in organic media (pH 5.0 to 6.0) suggested by Tinus and McDonald (10), and Barnett and Brissette (1). Fraser fir seedlings appear to be adapted to a more acidic growth medium than most conifers.

Root dry weight was also greatest at the lower lime rates (Table 3). Root:shoot ratio (g:g) increased at lime rates of 2 kg/m³ (3.4 lb/yd³) and above reflecting a greater reduction in shoot growth than in root growth (Table 3). Seedlings grown at the three lowest lime treatments had root systems of golden-brown color, with white unsubsized laterals 1 to 3 cm in length. At 8 kg/m³ (13.5 lb/yd³) lime seedlings had thin black roots with 1 to 2 mm unsubsized tips at the end of short (1–3 mm) blackened laterals (data not reported). Roots of the 4 kg/m³ (6.7 lb/yd³) treatment were also blackened, and many had stunted, unsubsized root tips, like those of the 8 kg/m³ (13.5 lb/yd³) seedlings. The effects of high pH on Fraser fir roots appeared similar to those described by Leyton (8) for Sitka spruce (*Picea sitchensis* (Bong.) Carr.) grown at pH 7. Fraser fir seedlings in the present experiment showed none of the discoloration, abnormal thickening or stunting of Leyton's Sitka spruce rootlets at pH 3 to 4, indicating that Fraser fir may tolerate greater acidity.

Increased growth of Fraser fir at lower pH could result in part from the species preference for NH₄⁺ over NO₃⁻. Chrusctic and Wright (5), using 0, 1, 2, 4 and 8 kg dolomitic

Table 1. Mean pH of sphagnum peat amended with varying quantities of dolomitic lime.²

Lime added kg/m ³ (lb/yd ³)	Months since planting in sphagnum peat		
	3 months	8 months	17 months
	(pH)		
0 (0)	3.9***	3.9**	3.4**
1 (1.7)	4.2	4.1	3.5
2 (3.4)	4.5	4.4	3.7
4 (6.7)	5.0	5.0	4.3
8 (13.5)	6.7	6.9	6.4

²Values are means of 6 replications.

***Treatment showed significant linear effects (p = .0001).

Table 3. Effects of varying quantities of dolomitic lime in sphagnum peat on the growth of 19-month-old Fraser fir seedlings.²

Lime added kg/m ³ (lb/yd ³)	Ht (cm)	Root dry wt (g)	Shoot dry wt (g)	Root:shoot ratio (g:g)
0 (0)	19.5***	.443**	1.863**	.24 ^y
1 (1.7)	21.8	.488	2.165	.23
2 (3.4)	20.5	.489	1.949	.26
4 (6.7)	17.4	.398	1.498	.27
8 (13.5)	9.5	.165	0.523	.33

²Values are means of 6 replications.

***Treatment showed significant quadratic effects (p = .0001).

**Treatment showed significant linear effects (p = .0001).

limestone amendments per m³ pine bark growth medium, found a higher concentration of NH₄⁺ available in the leachate of more acidic media. Black (3) found Fraser fir to grow best using NH₄⁺ as a N source.

The increase in growth medium acidity during the experiment (Table 1) did not appear to have an adverse affect on seedling growth. Even in the most acidic medium, the Fraser fir seedlings appeared to thrive. However, the benefit of 1 kg/m³ (1.7 lb/yd³) lime especially for the youngest seedlings, suggests the possible advantage of continued lime applications during growth. Extremely low lime applications would be consistent with the recommendation of Brix and van den Driesch (4) that pH should be regulated during the growing period because of the acidity changes caused by fertilization and leaching of the growth medium. The possible benefit of continued light liming is further suggested by the growth advantage of the 2 kg/m³ (3.4 lb/yd³) seedlings in the final growth cycle. Seedlings in the 2 kg/m³ (3.4 lb/yd³) treatment averaged 9.3 cm (3.7 in) growth in the last growth period, compared to 8.9 cm (3.5 in) for seedlings in the 1 kg/m³ (1.7 lb/yd³) treatment (Table 2). In this last period of growth, however, the greatest differences were still between seedlings grown in 0, 1, or 2 kg/m³ (0, 1.7 and 3.4 lb/yd³) (final pH of 3.4 to 3.7) and those grown with 4 or 8 kg/m³ (6.7 and 13.5 lb/yd³) (final pH of 4.3 and 6.4).

Significance to the Nursery Industry

Assessment of a desirable pH range for growth of a given species is quicker and easier than many growth factors often investigated for improving plant growth and should be one of the first factor investigated. General recommendations for pH do not necessarily apply to a given species. Some of the pH ranges suggested for conifers result in slow growth and unhealthy seedlings, when used for growing Fraser fir.

Based on these results in organic media, Fraser fir should not be grown at a pH above 4.5. Best growth occurred at an initial pH of approximately 4.2 which can be obtained by adding 1 kg/m³ (1.6 lb/yd³) dolomitic lime to sphagnum peat.

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