Nitrogen Fertilization Requirements of Douglas-fir Container Seedlings Vary by Seed Source

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Growth of container Douglas fir (Pseudotsuga menzesii *(Mirb.) Franco) from different seed sources from western Washington to western Montana was evaluated following application of 100, 150, or 200 ppm nitrogen (N) during the rapid growth phase. The optimal level of N varied between seed sources for height, caliper, and bud growth, as well as for shoot-to-root ratio. Target seedling specifications were met adequately for the westernmost sources at 100 and 150 ppm N, whereas eastern sources required 150 or 200 ppm. Nitrogen levels should thus be tailored to individual Douglas fir seed sources to maximize the number of shippable seedlings per lot.* Tree Planters' Notes 46(1): 15-18; 1995.

Nitrogen is the mineral nutrient that most affects seedling growth rate, and controlling N fertilization levels is an important cultural tool in container nurseries. Prescribed N levels in the published literature have varied tremendously over the years, ranging from as low as 50 ppm to as high as 300 ppm, with recent guidelines of 150 ppm for container tree seedlings (Landis and others 1989). However, nitrogen fertilizer rates need to be determined for individual species at each nursery prior to starting a fertilization program.

We know that seedlings from different seed sources often exhibit variable growth rates because of their individual response to the nursery environment. Applying one nitrogen fertilization rate for all seed sources of a particular species in a nursery may prevent individual seed sources from realizing their full growth potential or result in growth imbalances. Tailoring nitrogen regimes to the needs and potentials of individual seed sources can allow the grower to produce a more desirable seedling. Conversely, if the nutritional needs of different sources are quite similar, it may make better operational sense to apply one nitrogen rate to all sources and accept slightly less than optimal growth in some lots.

The objective of this study was to compare the growth response of Douglas-fir seedlings from six seed sources to three nitrogen regimes and determine the optimal regime for each source. Sources ranged in longitude on an west-to-east gradient and in elevation, from 914 m (3,000 ft) of elevation on the west side of the Cascade Range (Enumclaw, Washington) to 1,645 m (5,400 ft) of elevation in the Rocky Mountains (Seely Lake, Montana) (figure 1).

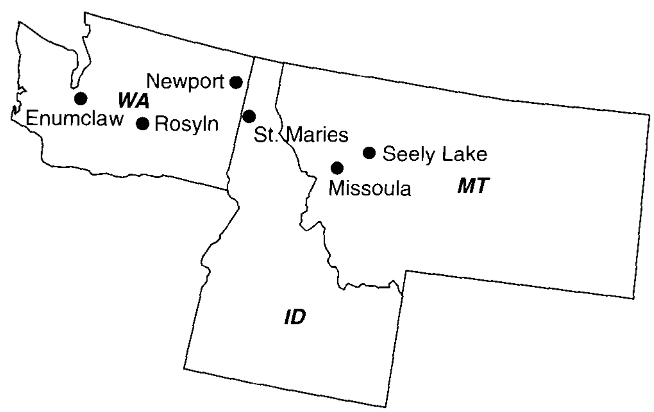

Figure 1—*Location of seed sources in the Pacific Northwest.*

Methods

Six lots of Douglas-fir from seed sources in Washington, Idaho, and Montana were grown at the Plum Creek container nursery at Pablo, Montana, under three different regimes of nitrogen supplementation: 100 ppm, 150 ppm, and 200 ppm. In total, the six seedlots and the three nitrogen rates resulted in 18 different treatments, one block each (160 seedlings/ block).

Three "Styro-4" Styrofoam® block containers (approximately 65.5 cm^3, or 4 in^3 in volume) were sown for each seed source, and one block container of each seed lot was grown under each of the three N rates. All six seed-source test blocks were placed together on the same bench in three different greenhouses and were grown with an operational crop of seedlings under one of the three N rates. The test blocks were placed in the interior of the greenhouse benches to minimize environmental effects. In this nursery it was common practice to use different N rates for different species: western larch (*Larix occidentalis* Nutt.) was grown at 100 ppm N, Englemann spruce *(Picea engelmannii* Parry ex Engelm.) at 150 ppm, and western white pine (*Pinus monticola* Dougl. ex D. Don) at 200 ppm N.

Seed was sown on March 29, 1989, in W.R. Grace Forestry Mix C media. All seedlings were provided a complete liquid fertilizer regime that had been custom-formulated to supply all 13 essential mineral nutrients. The fertilization regime consisted of 3 phases. During the establishment phase, the seedlings were given three applications of **starter feed** at the same N rate (80 ppm N) beginning about 2 weeks after sowing. The three different N levels began with the **growth feed** applications (table 1) approximately 3 to 4 weeks after sowing and continued for about 14 to 15 weeks until the target shoot height was reached. To initiate the hardening phase, all seedlings were leached twice with a **fresh water rinse** for 2 hours and then given a lowN **hardening-off feed** applied to all treatments with the next irrigation and continued through the end of the growing season in December.

Twenty-five seedlings randomly chosen from each treatment group were removed towards the end of the growing season and sent to International Paper Company's Seedling Testing Service in Lebanon, Oregon, for morphological measurements: shoot height, stem caliper, bud height, and shoot and root weights (table 2). Statistical significance between treatments for these attributes was determined using analysis of variance, Duncan's multiple range test, and t-tests.

Results and Discussion

Towards the end of the growing season, size differences between the seed sources became evident, and this was verified by the morphological analyses.

Shoot height. Seedling shoot height varied between the 6 seed sources and 3 N treatments (figure 2). For all seed sources, height increased with increasing N rates, although seedlings grown from seed from the westernmost source (Enumclaw, Washington) were consistently the tallest at all fertilization rates. Height response was more variable in the sources from eastern Washington, Idaho, and Montana. With respect to the target height specification, the best N fertilization level varied between the western and eastern sources. For example, 100 ppm N was adequate for Enumclaw, WA, Roslyn, WA, and St. Maries, ID, but 150 ppm was better for the 3 easternmost seed sources. For all seed sources, the 200-ppm N rate was excessive because it caused seedlings to grow too tall, creating problems with seedling balance and survival after outplanting.

Table 1—*Custom fertilizer recipes for growth feed at the three nitrogen test rates**

Medium (150-ppm) nitrogen rate (150:40:150)†

Add water to following ingredients to each tank to make 55 gallons:

Tank A		
Calcium nitrate	40	lb
Potassium nitrate	35	lb
Ammonium nitrate	12.5	lb
Iron chelate	2	lb
Manganese chelate	1	lb
Tank B		
Magnesium sulfate	20	lb
Micronutrient conc.	1	gal
Phosphoric acid	4	liters
Sulfuric acid	500	ml

High (200-ppm) nitrogen rate (200:40:150)

Tank A—Increase ammonium nitrate to 25 lbs
Tank B—Same as above

Low (100-ppm) nitrogen rate (100:40:150)

Tank A—Omit ammonium nitrate entirely
Tank B —Same as above

* = For use with 1:200 injector (1 part concentrate to 200 parts water).
† = ratio of $N:P_2O_5:K_2O$.

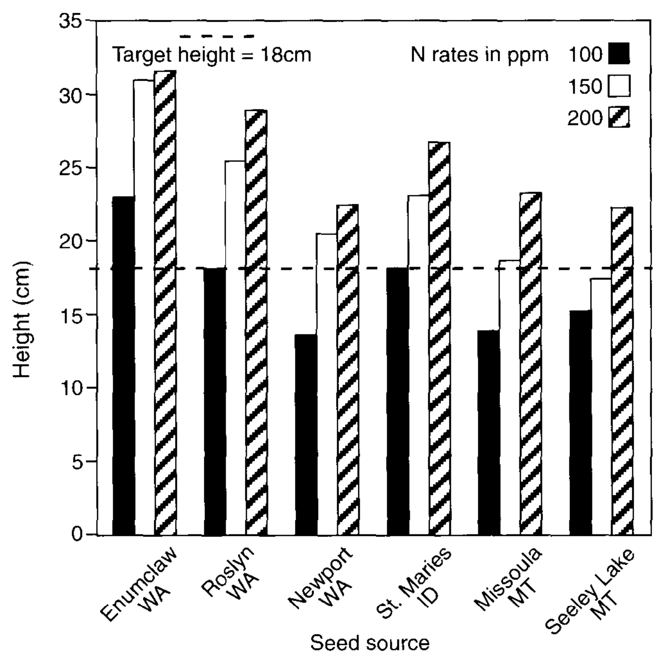

Figure 2—*Height growth of Douglas-fir container seedlings from various seed sources in response to three levels of N fertilization.*

Table 2-*Morphological quality indices of 6 Douglas-fir seed sources at 3 different nitrogen fertilizer rates*

Seed source/ N rate (ppm)	Shoot height (cm)	Stem caliper (mm)	Bud height (mm)	Ovendry weights Shoots (g)	Roots (g)	Shoot:root ratio
Enumclaw, WA						
100	23.1 a	3.2 a	5.3 a	1.36	0.87	1.56
150	31.2 b	3.5 b	5.8 b	1.96	0.95	2.06
200	31.8 b	3.9 c	5.5 ab	2.57	1.19	2.16
Roslyn, WA						
100	18.1 a	2.9 a	5.6 a	1.00	0.86	1.16
150	25.5 b	3.1 b	6.5 a	1.08	0.86	1.26
200	28.9 c	3.6 c	5.5 a	2.38	1.15	2.07
Newport, WA						
100	13.7 a	2.7 a	5.4 a	0.62	0.64	0.97
150	20.5 b	3.2 b	5.6 a	1.10	0.89	1.24
200	22.5 b	3.4 b	4.9 b	1.41	0.94	1.50
St. Maries, ID						
100	18.0 a	2.7 a	5.5 a	0.90	0.79	1.14
150	23.1 b	3.5 b	5.7 a	1.48	1.22	1.21
200	26.6 b	3.6 b	4.7 b	1.70	1.11	1.53
Missoula, MT						
100	13.8 a	2.9 a	5.3 a	0.69	0.76	0.91
150	18.7b	3.3b	5.7 a	1.13	0.99	1.14
200	23.2 c	3.5	4.5 b	1.43	0.96	1.49
Seely Lake MT						
100	15.1 a	2.8 a	5.4 a	0.80	0.73	1.10
150	17.3 b	3.2 b	5.6 a	1.00	0.92	1.09
200	22.1 c	3.6 c	5.2 a	1.62	1.02	1.59

Note: values for shoot height, stem caliper, and bud height in columns for each site followed by different letters differ significantly according to t-tests.

Stem caliper. The nitrogen fertilization treatments did not have as dramatic an effect on stem caliper. For each source, the stem caliper increased with increasing N fertilizer and even the lowest 100-ppm N rate produced seedlings that met the 2.5-mm target specification for all seed sources (figure 3). Growing seedlings with too much caliper is not a problem, because it is widely accepted that the larger the seedling caliper the better survival and growth (Mexal and Landis 1990). Nitrogen does affect stem caliper indirectly, however, because excessive N fertilization produces seedlings that are too tall in proportion to the size of the stems and root systems.

Shoot-to-root ratio and bud size. The ratio of the size of the seedling shoot to the size of the root system is important to seedling survival, especially on dry outplanting sites. In this trial, all treatments produced a good shoot-to-root (S:R) ratio of 2:1 or less, although

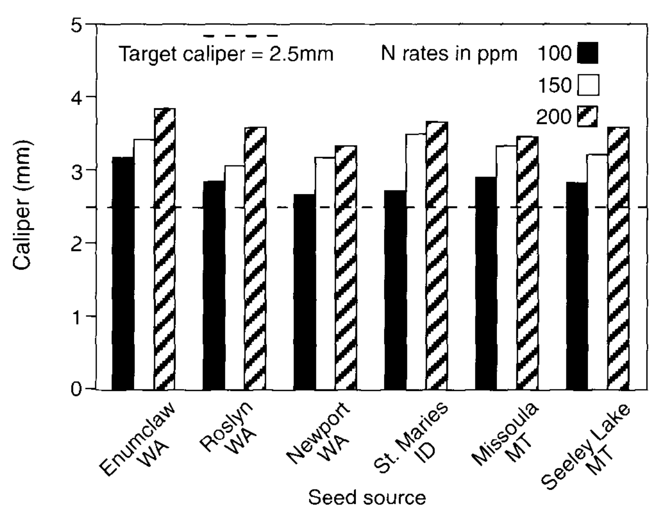

Figure 3—*Caliper growth of Douglas-fir container seedlings from various seed sources in response to three levels of N fertilization.*

on the drier sites in Montana a shorter, stockier seedling with a S:R ratio closer to 1:1 may survive and grow better. The height of the dormant terminal bud is another index of seedling quality, and the larger the bud the better (Thompson 1984). Bud height was greatest at the 150 ppm N rate and, for five of the six seed sources, lowest at 200 ppm.

Percentage of shippable seedlings. The effect of each nitrogen regime was also evaluated by the percentage of seedlings in each treatment that exceeded cull standards, which are the minimum acceptable size for shipping. The number of shippable seedlings is an quality index of seedling morphology, including height, caliper, root size and bud development. At Plum Creek Nursery, the goal was to produce 93% shippable seedlings. The Washington and Idaho seed sources achieved this goal at either 100 or 150 ppm N. The Montana sources exhibited considerable variation in shoot height however, and so the desired percentage of shippable seedlings was achieved only at the 200-ppm N rate.

Summary

Not surprisingly, seed sources of container Douglas-fir seedlings responded differently to different rates of nitrogen fertilization. The best N level for seedlings from western Washington sources (west of the Cascade Range) was 100 ppm because seedlings grew too tall at the higher fertilizer rates. For seed sources in eastern Washington and Idaho, the best N fertilization rate was 150 ppm. For the more variable Montana sources, the highest fertilization rate of 200 ppm N was used operationally at Plum Creek Nursery. This preliminary study indicates that container nurseries should consider seed source differences in N requirements when developing their growing schedules, and customize the rates to meet the demands of different species and seed sources. Each nursery may want to test its own species and seed sources to determine operational N levels.

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