Fertilizer Regimes for Container-Grown Conifers of the Intermountain West

R. Kasten Dumroese and David L. Wenny
Forest Research Nursery
Department of Forest Resources, University of Idaho
Idaho Forest, Wildlife and Range Experiment Station
Contribution No. 839.

Introduction

In the Intermountain West, defined here as eastern Washington, northern Idaho, and western Montana, nine nurseries grow about 12-18 million container seedlings annually for reforestation. Although as many as a dozen species may be grown for reforestation, the bulk of nursery production is represented by four species (Table 1). Nearly two-thirds of the nurseries have structures with roll-up sides or move crops to shadehouses for part of the growing season. Currently, most nurseries use a 1:1 peat:vermiculite growing medium, although a rapid conversion to a 70:30 peat:sawdust medium is occurring and will probably be the standard within three to five years, if not sooner. The preferred container consists of a styrofoam block separated into individual cavities. Volume of the cavities used in nurseries run the gamut from 2 to 20 in^3 (40 to 340 ml; i.e., Ventblock 240/40 to 45/340), although most seedlings are grown in containers with either a 4- or 5-in^3 volume cavity (65 or 90 ml; i.e., Ventblock 160/65 or 160/90) and 80 seedlings per ft^2 (890 per m^2). There is an emerging trend for larger volumes, with 10 in^3 (170 ml; i.e., Ventblock 77/170) being the most common. Only one nursery routinely uses copperblocks (styrofoam blocks treated with copper to chemically root prune seedlings).

Table 1. Annual number (in thousands) of container-grown seedlings produced in greenhouses in eastern Washington, northern Idaho, and western Montana.

Ownership	Number	Ponderosa Pine	Western White Pine	Douglas- fir	Western Larch	Others[1]	Total
Private	2	2700	700	1200	900	500	6000
Industry	2	1150	710	1080	650	620	4210
Tribal	2	630	0	10	290	40	970
State	2	410	275	25	50	30	790
Federal	1	700	700	700	525	875	3500
Total	9	5590	2385	3015	2415	2065	15470

[1]Includes Lodgepole Pine, Engelmann Spruce, Grand Fir, Western Redcedar, Whitebark Pine, and Subalpine Fir.

In eight of the nurseries, only one crop is grown per year. Most nurseries plant in March; seedlings not shipped for fall planting are extracted between late November and early January for refrigerated/freezer storage. Photoperiod control is necessary to grow most species to target heights. Most nurseries weigh an individual block when the medium is saturated and then reweigh the block as the medium dries out. Nursery managers determine irrigation frequency and duration based on the difference between saturated and dry block weights. Fertilizer is added during each irrigation, at least through bud initiation. One-third of the nurseries routinely custom-mix their fertilizers, while the other six nurseries use prepackaged formulations as their base fertilizer. Prepackaged formulations may or may not be amended with other fertilizers, particularly micronutrients. In general, nurseries start their crops with a low nitrogen (N) fertilizer, switch to a high-N fertilizer to achieve target heights, then return to a lower rate N fertilization regime through the hardening phase (Landis et al. 1989).

Each nursery has its own idiosyncrasies, and fertilizer regimes have developed in response to many variables, including species, seed sources, irrigation system, water quality, nursery elevation and subsequent microclimate, annual days of sunshine, age of roofs and subsequent light quality, feedback from customers, and the experience and philosophy of the nursery manager. The attributes of nursery managers run the extremes; some managers prefer to "grow-on-the-go," adjusting their regimes depending on seedling data and how they perceive the crop is growing. Other managers are much more formal, following more predetermined periods for particular fertilizers, block weights, nutrient concentrations, and seedling characteristics.

Elucidating *"the"* growing regime (for each of the four main species) that would work universally well in all nurseries is probably impossible, and providing detailed information for each species, ecotype, seed source, irrigation system, etc. would be overwhelming and beyond the scope of this paper. With that in mind, we provide sketches of basic regimes, focusing on N, phosphorus (P), potassium (K), and calcium (Ca) for ponderosa pine, showing the variability that exists between four nurseries, and some additional narrative on the other three main species. We assume one crop of seedlings is grown per year in 5 in^3 (Ventblock 160/90) containers in a 1:1 peat:vermiculite medium.

Growers in the Intermountain West like to joke that there are a thousand ways to kill a seedling, but only the first time matters. Similarly, there are a thousand ways to grow a seedling, but all that matters is field performance. All four nurseries used in the following example monitor seedling development, analyze seedling foliar nutrient concentrations and medium nutrient concentrations, and produce stock of high viability, with excellent survival and growth.

Ponderosa pine

For nursery managers, ponderosa pine *(Pin us ponderosa* var. *ponderosa)* is usually the easiest species to grow. Seedlots generally have high cumulative germination and high germination energy, and seedlings are rarely affected by insects or disease. Target seedling height is 15-25 cm with a root collar diameter (RCD) of 3.0+ mm. Most seed sources are between 2500-4500 ft (760-1360 m) so an elevational effect is usually lacking, although seed sources higher than 4500 ft (1360 m) or lower than 1800 ft (545 m) may need higher rates of N to achieve target size. Seedlots from the Clearwater River drainage in Idaho are perhaps the easiest to grow. Seedlots from the extreme western portions of the range (i.e., central Washington, north-central Oregon) also need higher rates of N to achieve target size. Before bud initiation, growers irrigate when block weights reach 75-85% of saturated weight. In an enclosed greenhouse with traveling boom, ponderosa pines from maritime-influenced sites receive about 60 ppm N in an average fertilization before bud initiation (Table 2a). In open-sided greenhouses with fixed overhead irrigation, ponderosa pines from similar sites receive an average ppm N of 125-155. Ponderosa pine from low elevation, dry sites, grown in an open-sided green-house with fixed overhead irrigation, may need as much as 300 ppm N per average fertilization to meet target characteristics. Usually, ponderosa pine will set bud at about 12 weeks after sowing without cultural adjustments, but light moisture stress and reduction in photoperiod result in prompt terminal bud formation (Wenny and Dumroese 1987b). Nutrient stress is usually unnecessary for bud initiation, and applying foliar fertilizers during bud initiation treatments improves RCD (Montville et al. 1996). Block weights drop to 70-80% of saturated weight before irrigation during bud initiation, and this level of moisture stress is usually continued to the end of the growing season. After bud initiation, N rates are reduced (Table 2b). Foliar fertiliza-tion is used at some nurseries to boost N levels while prolonging intervals between irrigations. Growers target a foliar N concentration around 2 to 2.5% at extraction.

Western white pine

Most western white pine *(Pin us monticola)* seeds are harvested from the Moscow Arboretum in Moscow, Idaho. Other orchards are rapidly coming on-line; all seeds used in the federal nursery are from orchards other than Moscow. Western white pine is unusual in that its seeds may be transferred without regard for elevation or geographic distance within the region (Rehfeldt et al. 1984). Therefore, western white pine seedlings can be expected to grow the same way each year: *slowly* (Wenny and Dumroese 1987c). Target seedling

Table 2a. Ratios of N:P:K:Ca (ppm) applied to ponderosa pine crops up to the time of bud initiation at four nurseries. Stock solution recipes for these rates provided below.

Nursery	Weeks after sowing									Foliar N concentration at bud initiation
	2	3	4	5	6	7-8-9	10	11-12	13	
1	70:120:110:140			110:80:120:140	140:80:120:140	185:80:105:120	230:80:120:120			2.5 - 3.0%
2	42:176:83:0					60:82:47:0 alt 81:0:0:42		81:0:0:42		1.5 - 1.8%
3	59:134:49:0	92:0:0:101 alt 163:0:452:0								2.5 - 3.0%
4	30:69:172:0	44:30:51:31	88:30:102:62	179:30:136:149 alt 186:30:0:198						3.0 - 3.5%

Nursery #1

1:200 twin injector
rates per 11000 gals
1.6 gals 75% H3PO4
every irrigation

Weeks 2-4

3 gals CAN-17
27 lbs KH2PO4
7 lbs K2SO4

Week 5

2.6 gals CAN-17
8 lbs NH4NO3
14 lbs KNO3
24 lbs CaCl2
11 lbs KH2PO4
6.5 lbs K2SO4

Week 6

3 gals CAN-17
13 lbs NH4NO3
14 lbs KNO3
23 lbs CaCl2
11 lbs KH2PO4
6.5 lbs K2SO4

Weeks 7-9

4.8 gals CAN-17
15 lbs NH4NO3
14 lbs KNO3
13 lbs CaCl2
11 lbs KH2PO4
6.5 lbs K2SO4

Weeks 10-12

5.5 gals CAN-17
22 lbs NH4NO3
14 lbs KNO3
9 lbs CaCl2
11 lbs K3PO4
6.5 lbs K2SO4

Nursery #2

1:100 single injector
rates per 1000 gals

Weeks 2-6

5 lbs Peters Conifer
Starter (7:40:17)
20 fluid oz 85% H3PO4

Weeks 7-10

2.5 lbs Peters Conifer
Grower (20:17:19)
alternated with 40 fluid
oz CAN-17
20 fluid oz 85% H3PO4
applied with Grower

Weeks 11-12

40 fluid oz CAN-17

Nursery #3

1:200 twin injector
rates per 100 gals

Week 2

8 oz 10:52:10

Weeks 3-13

8 oz Ca(NO3)2 alternated
with 16 oz KNO3

Nursery #4

1:200 twin injector
rates per 100 gals
1 fluid oz 75% H3PO4
each irrigation

Week 2

8 oz 5:15:35

Week 3

2.5 oz Ca(NO3)2
1.5 oz KNO3

Week 4

5 oz Ca(NO3)2
3 oz KNO3

Weeks 5-12

12 oz Ca(NO3)2
4 oz KNO3
alternated with
16 oz Ca(NO3)2

Table 2b. Ratios of N:P:K:Ca (ppm) applied to ponderosa pine crops at four nurseries from bud initiation to extraction. Stock solution recipes for these rates provided below.

Nursery	Weeks after sowing							Foliar N concentration at extraction
	13	14	15	16	17-19	20-22	23-extraction (30-35)	
1	20:90:120:190 foliar once each week @ 963:234:355				60:90:120:185 foliar once every three weeks @ 963:234:355			1.8 - 2.0%
2	81:0:0:42 foliar once every two weeks @ 963:234:355				24:138:173:0 alt 162:0:0:84 once every two weeks @ 963:234:355			1.8 - 2.0%
3		69:0:0:75 alt 61:0:169:0						2.0 - 2.5%
4	0:30:94:106 alt 0:165:169:0 alt 0:30:314:0		44:30:51:31		88:30:102:62	133:30:136:99	179:30:136:149 alt 186:30:0:4198	2.0 - 2.5%

Nursery #1

1:200 twin injector
rates per 11000 gals
1.6 gals 75% H_3PO_4 each irrigation

Weeks 13-16

0.8 gal CAN-17
45 lbs $CaCl_2$
17 lbs KH_2PO_4
14 lbs K_2SO_4

3 lbs Peters Foliar Feed (27:15:12) per 100 gals once each week

Weeks 17-extraction

2.4 gals CAN-17
5 lbs KNO_3
38 lbs $CaCl_2$
17 lbs KH_2PO_4
10 lbs K_2SO_4

3 lbs Peters Foliar Feed (27:15: 12) per 100 gals once every three weeks

Nursery #2

1:100 single injector
rates per 1000 gals

Weeks 13-16

40 fluid oz CAN-17

3 lbs Peters Foliar Feed (27:15: 12) per 100 gals once every two weeks

Weeks 17-extraction

5 lbs Peters Conifer Finisher (4:25:35)
20 fluid oz 85% H_3PO_4

3 lbs Peters Foliar Feed like Weeks 13-16

Nursery #3

1:200 twin injector
rates per 100 gals

Week 14-extraction

6 oz $Ca(NO_3)_2$ alternated with 6 oz KNO_3

Nursery #4

1:200 twin injector
rates per 100 gals
1 fluid oz 75% H_3PO_4

Weeks 13-14

4 oz $CaCl_2$
2.4 oz KCl
alternated with
8 oz K_3PO_4
alternated with
8 oz KCl

Weeks 15-16

2.5 oz $Ca(NO_3)_2$
1.5 oz KNO_3

Weeks 17-19

5 oz $Ca(NO_3)_2$
3 oz KNO_3

Weeks 20-22

8 oz $Ca(NO_3)_2$
4 oz KNO_3

Weeks 23-extraction

12 oz $Ca(NO_3)_2$
4 oz KNO_3
alternated with
16 oz $Ca(NO_3)_2$

Table 2c. Helpful conversions from English to metric units and fertilizer types and abbreviations for Tables 2a and 2b.

Conversions:

1 gal = 3.785 L

1 fluid oz = 30 ml

1 oz = 28 g

1 lb = **0.45 kg**

Abbreviations:

CaCl2	calcium chloride
CAN-17	liquid calcium ammonium nitrate
Ca(NO3)2	calcium nitrate
H3PO4	phosphoric acid
K2SO4	potassium sulfate
K3PO4	potassium phosphate
KCl	potassium chloride
KH2PO4	monopotassium phosphate (a.k.a. MKP)
KNO3	potassium nitrate
NH4NO3	ammonium nitrate

size ranges from 12-20 cm in height and 3.0+ RCD. Most growers like to sow white pine early (i.e., February) and grow it as long as possible, pushing height growth with high rates of N. The accelerated growth stage for western white pine seedlings and the amount of N they receive is about twice that as for ponderosa pine seedlings (Table 3). Block weights for irrigation are similar to ponderosa pine (75-85%). Photoperiod is extended, but seedlings will still set "temporary" or "resting" buds during the accelerated growth portion of the regime. Seedlings set buds promptly without photoperiod control and with slight moisture stress (70-80% block weights). Generally disease-free, white pine can be seriously affected by Cylindrocarpon root disease, which usually goes unnoticed until seedlings are extracted (James and Gilligan 1990; James 1992). Reducing irrigation frequency helps control this disease (Weeny and Dumroese 1994).

Table 3. For each nursery, the rate of N applied to ponderosa pine and the duration in weeks of pre-bud initiation fertilization is compared with those for western white pine, Douglas-fir, and western larch. The differences are expressed as percentage increases or decreases.

	Western white pine		Douglas-fir		Western larch	
Nursery	Rate More or (less)	Duration More or (less)	Rate More or (less)	Duration More or (less)	Rate More or (less)	Duration More or (less)
1	50%	100%	(10%) to 19%	0% to 25%	(30%)	0%
2	130%	100%	25%	(10%)	(7%)	(10%)
3	100%	50%	(60%)	0%	(60%)	0%
4	150%	66%	0% to 50%	0%	(85%) to (60%)	0%

Douglas-fir

Douglas-fir *(Pseudotsuga menziesii)* is perhaps the most enigmatic and challenging species for Intermountain West nursery managers. This species has distinctively different growth responses to fertilization and photoperiod as seed sources move from the coast *(P menziesii var. menziesii)* to the east slope of the Cascades (var. *glauca),* through Idaho, to eastern Montana (Thompson 1995). Moving from west to east across the range of this species requires at least an additional 100 ppm N during the accelerated growth phase to meet target seedling size. Within these ecotypes, fertilization schedules may also vary with elevation, especially above 5000 ft (1515 m). The variation is evident in Table 3; nurseries 2 and 3 grow stock from specific ranges in Idaho but nurseries 1 and 4 grow seedlots stretching from the western edge of Douglas-fir's range to the eastern edge. Target seedling size is 20-25 cm in height with a RCD of 2.8+. Before bud initiation, growers irrigate when block weights reach 75-85% of saturated weight. Stopping Douglas-fir height growth can be difficult; moderate to high moisture stress is required to initiate terminal bud formation (Wenny and Dumroese 1992); some nurseries allow block weights to drop to 60% of saturated weight. One nursery uses drastic nutrient stress to achieve bud initiation. Douglas-fir may be the most sensitive species in the region to root disease, especially those caused by *Fusarium*, so care must be taken to reduce stressful conditions, especially those associated with too much or too little moisture (James et al. 1991). Although growers fertilize with appreciable amounts of calcium to increase RCD and bud size, dolomite added to the growing medium before sowing caused twisting and abnormal growth of needles, branches, and even the main stem (Dumroese et al. 1990).

Western larch

Western larch *(Larix occidentalis)* is a difficult species to grow because it grows too well. Some nursery managers joke that you only need to rustle the fertilizer bag to get larch to grow a cm or two taller. Growers apply about half the rate of N to larch as they apply to ponderosa pine (Table 3). Strict attention to fertilizer rate, especially N, along with several other cultural practices (growing this species outdoors, high moisture stress levels (60-70% block weights for irrigation), late sowing, and photoperiod control) help control height growth. Western larch can exhibit a very long "coasting" phase, where height growth will continue even without additional fertilization, so managers must compensate their fertilizer applications to achieve bud set at target height (Wenny and Dumroese 1987a; 1995). Some nurseries allow blocks to dry down to 50% saturated weight before irrigating during bud initiation. Target height is 20-30 cm with a RCD of 3.0+. *Botrytis* can be a problem later in the growing cycle, especially when needles begin to shed.

Conclusions

Producing container-grown conifers in the Intermountain West is challenging because of elevational and longitudinal effects, and the maritime influence on part of the region. Finding a "one-glove-fits-all" growing regime for any species is unlikely because of variability in greenhouse structures, nursery climate, water quality, irrigation systems, container types, seed sources, client concerns, and experience of the nursery managers. However, the basic regimes presented should provide growers a starting point from which to manipulate fertilizers to achieve target seedling characteristics at their nurseries.

Acknowledgements

Our sincere thanks to the following nursery managers for sharing their fertilizer regimes: Abbie Acuff, Potlatch Corporation, Lewiston, Idaho; Mark Montville, Plum Creek Timber Company, Pablo, Montana; Janice Schaefer, Western Forest Systems, Inc., Lewiston, Idaho. Other helpful information we are thankful for was provided by Tom Corse, Cathy Covington, Kent Eggleston, John Justin, and Marla Schwartz.

Other Information

A series of more detailed growing regimes were published by the University of Idaho Forest Research Nursery between 1986 and 1992 for ponderosa pine, western white pine, western larch, Douglas-fir, spruces, western redcedar, Scotch and Austrian pines, and grand fir (Wenny and Dumroese 1987a, 1987b, 1987c, 1988, 1990a, 1990b, 1991, 1992). Some additional modifications for western larch (Dumroese and Wenny 1995) and western white pine and western redcedar (Wenny and Dumroese 1994) are also available. Copies of these publications are available for a modest charge from: Editor, Idaho Forest Wildlife and Range Experiment Station, University of Idaho, Moscow, Idaho, 83844-1130 (telephone 208/885-6673; fax 208/885-6226; Web site: www.uidaho.edu/cfwr).

Literature Cited

Dumroese, R.K.; Wenny, D.L. 1995. Growing western larch in a container nursery. Pages 213-219 *in* Schmidt, W.C.; McDonald, K.J. (comps.) Proceedings — International Symposium on Ecology and Management of Larix Forests: A Look Ahead; Oct. 5-9, 1992; Whitefish, Montana. Ogden, Utah: USDA Forest Service, Intermountain Research Station, General Technical Report INT-319.

Dumroese, R.K.; Thompson, G.; Wenny, D.L. 1990. Container-grown seedlings with lime-induced stunting. 'free Planters' Notes 41(3):12-17.

Dumroese, R.K.; Page-Dumroese, D.S.; Wenny, D.L. 1991. Describing and managing pesticide and fertilizer runoff in a container nursery. Pages 27-33 *in* Landis, T.D. (tech. coord.) Proceedings: Intermountain Forest Nursery Association Meeting; Aug. 12-16, 1991; Park City, Utah. Fort Collins, Colorado: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-211.

Dumroese, R.K.; Wenny, D.L.; Page-Dumroese, D.S. 1995. Nursery waste water: the problem and a possible remedy. Pages 89-97 *in* Landis, T.D.; Cregg, B. (tech. coords.) National Proceedings, Forest and Conservation Nursery Associations. Portland, Oregon: USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-365.

James, R.L. 1992. Root disease of container-grown Engelmann spruce and western white pine seedlings - Plum Creek Nursery, Pablo, MT. Missoula, Montana: USDA Forest Service Northern Region Report 92-9.

James, R.L.; Gilligan, C.J. 1990. Root decay of container-grown western white pine seedlings - Plum Creek Nursery, Pablo, MT. Missoula, Montana: USDA Forest Service Northern Region Report 90-10.

James, R.L.; Dumroese, R.K.; Wenny, D.L. 1991. *Fusarium* disease of conifer seedlings. Pages 181-190 *in* Sutherland, J.R.; Glover, S.G. (eds.) Proceedings of the First Meeting of IUFRO Working Party S2.07-09 (Diseases and Insects in Forest Nurseries). Aug. 23-30, 1990; Victoria, British Columbia. Forestry Canada, Pacific Forestry Centre, Information Report BC-X-331.

Landis, T.D.; Tinus, R.W.; McDonald, S.E.; Barnett, J.P. 1989. Seedling Nutrition and Irrigation, Vol. 4, The Container 'free Nursery Manual. Agriculture Handbook 674. Washington, DC: USDA Forest Service.

Montville, M.E.; Wenny, D.L.; Dumroese, R.K. 1996. Impact of foliar fertilization on container-grown ponderosa pine seedling viability. Western Journal of Applied Forestry 11:114-119.

Rehfeldt, G.E.; Hoff, R.J.; Steinhoff, R.J. 1984. Geographic patterns of genetic variation in *Pinus monticola.* Botanical Gazette 145:229-239.

Thompson, G. 1995. Nitrogen fertilization requirements of Douglas-fir container seedlings vary by seed source. Tree Planters' Notes 46:15-18.

Wenny, D.L.; Dumroese, R.K. 1987a. A growing regime for containerized western larch seedlings. Moscow, Idaho: University of Idaho, Idaho Forest, Wildlife and Range Experiment Station Bulletin No. 42.

Wenny, D.L.; Dumroese, R.K. 1987b. A growing regime for containerized ponderosa pine seedlings. Moscow, Idaho: University of Idaho, Idaho Forest, Wildlife and Range Experiment Station Bulletin No. 43.

Wenny, D.L.; Dumroese, R.K. 1987c. A growing regime for containerized western white pine seedlings. Moscow, Idaho: University of Idaho, Idaho Forest, Wildlife and Range Experiment Station Bulletin No. 44.

Wenny, D.L.; Dumroese, R.K. 1988. A growing regime for containerized grand fir seedlings. Moscow, Idaho: University of Idaho, Idaho Forest, Wildlife and Range Experiment Station Bulletin No. 45.

Wenny, D.L.; Dumroese, R.K. 1990a. A growing regime for container-grown western redcedar seedlings. Moscow, Idaho: University of Idaho, Idaho Forest, Wildlife and Range Experiment Station Bulletin No. 46.

Wenny, D.L.; Dumroese, R.K. 1990b. A growing regime for container grown spruce seedlings. Moscow, Idaho: University of Idaho, Idaho Forest, Wildlife and Range Experiment Station Bulletin No. 47.

Wenny, D.L.; Dumroese, R.K. 1991. A growing regime for container-grown Scotch and Austrian pine seedlings. Moscow, Idaho: University of Idaho, Idaho Forest, Wildlife and Range Experiment Station Bulletin No. 48.

Wenny, D.L.; Dumroese, R.K. 1992. A growing regime for container-grown Douglas-fir seedlings. Moscow, Idaho: University of Idaho, Idaho Forest, Wildlife and Range Experiment Station Bulletin No. 49.

Wenny, D.L.; Dumroese, R.K. 1994. Nursery production: growing western white pine and western redcedar in greenhouses. Pages 261-266 *in* Baumgartner, D.M.; Lotan, J.E.; Tonn, J.R. (eds.) Interior Cedar-Hemlock-White Pine Forests: Ecology and Management -- Symposium Proceedings; Mar. 2-4, 1993; Spokane, Washington. Pullman, Washington: Washington State University Cooperative Extension.