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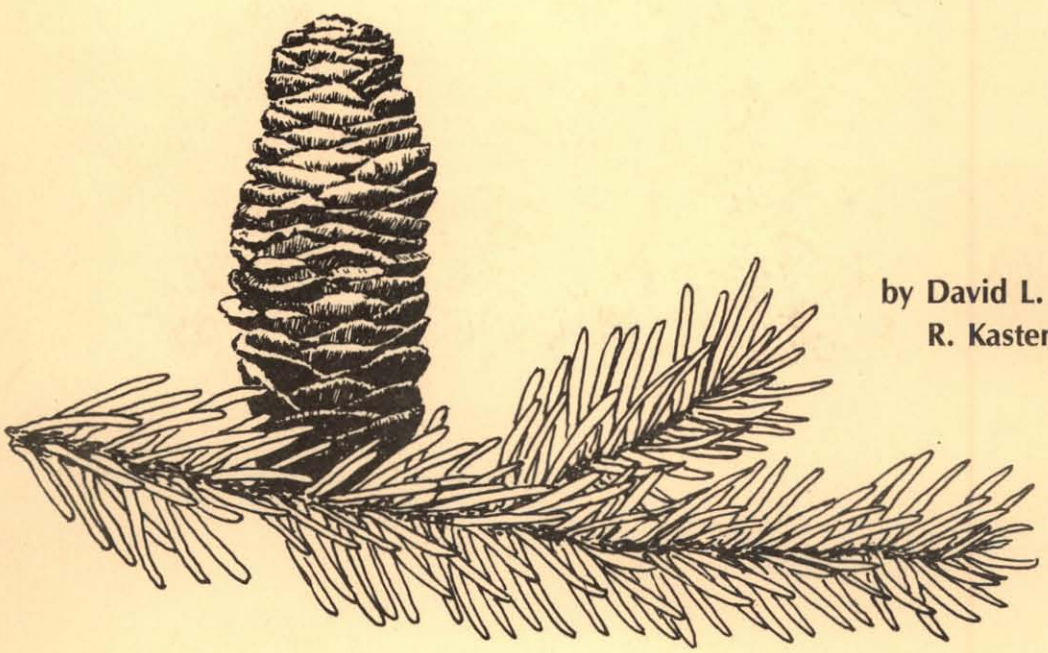
A Growing Regime for Containerized Grand Fir Seedlings



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Introduction

The University of Idaho College of Forestry, Wildlife and Range Sciences operates a research nursery producing 850,000 containerized seedlings annually. The facility serves as a laboratory and offers practical experience to students in agriculture, forestry, and forest nursery management. Reforestation seedlings produced at the nursery are annually planted on state lands, private forest industry lands, and on the University of Idaho Experimental Forest. Field data on outplanted seedlings coupled with detailed crop histories maintained by the nursery produce feedback for future crops. Microcomputers are used to monitor seedling development and to guide cultural practices yielding seedlings with high survivability and growth.

Grand Fir

Grand fir (*Abies grandis* (Dougl.) Lindl.) occurs most frequently on deep, moist, alluvial soils in gulches, along streams, and on gentle mountain slopes. This species occasionally forms pure stands, but is most often found with Douglas-fir, western larch, and ponderosa pine in the Rocky Mountains (Harlow et al. 1979). Mature tree heights range from 115 to 200 feet (35 to 61 m), and stems are 1 to 4 feet (0.3 to 1.2 m) in diameter at breast height.

This true fir begins to bear cones at about 20 years of age. The number of seeds per pound for northern Idaho grand fir ranges from 16,500 to 28,800, with a mean of 19,750.

Grand fir has been cultivated since 1830 (Franklin 1974). The following is a synopsis of the methodology used at the University of Idaho Forest Research Nursery to produce containerized grand fir seedlings for research, conservation, and reforestation.

The Forest Research Nursery

Seedlings are grown in two 34- by 108-foot fiberglass greenhouses and one 30- by 96-foot double-poly greenhouse, all connected by a head house. Each greenhouse is heated by two natural gas heaters and vented with two 48-inch exhaust fan and louver systems. Two 24-inch ventilating fans provide air and heat circulation through poly-tubes placed beneath the growing benches in each house. We feel poly-tubes placed in this manner rather than overhead aid in air circulation and drying beneath the benches and allow supplemental heat to rise through the trays. An evaporative cooling system and shutters along the north side of the facility are used for cooling. Photoperiod is extended by incandescent lamps at an intensity of 500 lux.

The pH of the well water averages 6.8. Irrigation is applied through an overhead traveling boom system. We generally sow numerous small lots of several species, and the boom allows us to attend to the specific irrigation, fertilization, and pesticide needs of the individual lots. There are two booms per greenhouse, with nozzles every 8 inches. Fertilizers and pesticides are applied through the irrigation water by using a 1:100 injector.

Seed Quality Tests

Each lot of seed is evaluated for quality upon receipt. The evaluation includes seeds per pound, purity percentage, soundness, and germination.

Seeds per Pound

The number of seeds per pound is calculated by weighing each of five replications of 100 seeds to the nearest 0.01 gram. The mean weight is then placed into this equation:

$$\text{Seeds per pound} = \frac{45{,}360}{\text{mean weight in grams of 100 seeds}}$$

Purity Percentage

Purity is determined by removing the "debris" from a 55-gram (2,500-seed) sample of seed. Grand fir should be cleaned during processing and should have at least 95-percent pure seed.

$$\text{Purity \%} = \frac{\text{Clean seed weight}}{\text{Clean seed weight + debris weight}} \times 100$$

Soundness Percentage

The percentage of hollow seeds is determined by x-raying a 100- to 200-seed sample. This could also be

achieved by cutting the same number of seeds. It is very difficult to mechanically remove seeds that lack gametophytic tissue, because these seeds fill with resin, making them weigh about the same as good seed.

Stratification and Germination Tests

The most important aspect of seed quality is seed germination. Seed germination is tested using greenhouse rather than optimum laboratory temperature conditions so that accurate amounts of seed can be prepared for sowing.

The seed sample is placed into a fine mesh bag and soaked for 48 hours in running tap water to ensure imbibition. The mesh bags are placed into plastic bags, and a sample of seed is stratified for each of three periods: 14, 28, and 40 days at 33-36°F (1-2°C).

At the end of the stratification period, seed is removed and soaked for 24 hours in running tap water. Four 100-seed replicates of each lot for each stratification period are placed into germination trays. Non-stratified seed for each lot (four 100-seed replications) is also germinated. Seed is germinated under 8 hours light at 75°F (24°C) and 16 hours dark at 65°F (18°C). Cumulative counts are made at 7, 14, 21, and 28 days. At 28 days, any ungerminated seeds are cut to determine whether they are hollow or sound.

Sowing Calculations

After determining which stratification period gives the highest cumulative germination at 21 days, the total amount of seed needed for the crop can be determined. Using probability tables (see Tinus and McDonald 1979), the number of seed needed per cell to achieve around 95-percent cell occupancy is determined. We then mathematically add 0.5 seed per cell to cover handling and sowing losses. Each lot is oversown 10 percent at the research nursery. With a given germination, desired number of seedlings, purity, sound seed percentage, and seeds per pound, we calculate the pounds of seed needed as follows:

$$\frac{\text{(Desired seedlings) * (Oversow factor) * (Seeds per cell)}}{\text{(Seeds per pound) * (Purity percent) * (Soundness percent)}}$$

Example:

From the probability tables we find that with 70-percent germination, three seeds per cell will give 96 percent of the cells filled. To make sure there is enough seed to account for handling and sowing losses, we add 0.5 seed per cell for an average of 3.5 seeds per cell.

Given: 19,750 seeds per pound, 95-percent purity, 80-percent soundness, 25,000 trees desired, and 10-percent oversow.

$$\frac{(25{,}000) * (1.1) * (3.5)}{(19{,}750) * (0.95) * (0.80)} = \frac{96{,}250}{15{,}010} = 6.4 \text{ lbs}$$

The required amount of seed is placed into mesh bags with no more than 2 pounds per bag. The seed is stratified as discussed previously, using the stratification period that gave the best germination. Experience at the nursery shows most grand fir lots perform best with 28 days of cold stratification.

Growing Regime (Fig. 1)

Environmental Monitoring

The basic environmental factors are minimum and maximum air temperatures, medium temperature, humidity, and the pH and electrical conductivity of irrigation water, fertigation water (irrigation water with injected liquid fertilizer in solution), and leachate from the growing medium.

Figure 1. Growing regime for grand fir.

Month		April	May	June
Week	-1	0 1	2 3 4 5 6	7 8 9 10 11
Growth Stage	Sow	Germ.	Initial Growth	Accelerated Growth
Day Temp		75-85	75-80	70-75
Night Temp		65-70	65-70	60-65
Outside Temp	Max	55	65	70
	Min	34	40	46
Supplemental Light			500 - lux Incandescent bulb	
Irrigation	Mist during heat of day.		Twice per week with nutrient solutions. Medium near field capacity.	
Fertilization		Acid-ify	Peters Conifer Starter and calcium nitrate.	Peters Conifer Grower and calcium nitrate.

Four maximum/minimum thermometers are distributed in each greenhouse to record the daily temperature range. A hygrothermograph charts the temperature and relative humidity patterns weekly. Medium temperatures are obtained with a soil thermometer. Irrigation and fertigation water are monitored to keep the applied solution between pH 5.5 and 6.0. Growing medium leachate is also monitored to detect increases in medium pH. Leachate conductivity will indicate any serious increases in salt accumulation within the medium that may become detrimental to the seedlings. Tinus and McDonald (1979) discuss these topics and instruments in great detail, including calibration of hygrothermographs.

Desired Seedling Characteristics

Outplanting data for grand fir indicate the need for seedlings with large root collar diameters (caliper), well-formed buds, high root growth potential, and a low ratio between shoot and root dry weights. This regime produces seedlings averaging 15 cm in height, 2.3 to 2.8 mm in caliper, with well-formed buds and high root growth potential.

Container Type, Growing Medium, and Tray Filling

Grand fir is grown in 4-cubic-inch Ray Leach Pine Cells, which have 200 cells per tray or 100 cells per square foot. Seedlings can also be grown in styrofoam containers. In general, seedlings with larger root collar diameters will be produced in containers with wider spaces between cells. Before seeds are sown, previously used trays and cells are thoroughly washed and dipped into a 10-percent bleach solution (1 part laundry bleach to 9 parts water). After the trays and cells have dried, the bottom 1 inch of the cells is remoistened with tap water, and the tray and cells are run through the filling machine. Moistening the bottom of the cells causes dry

July	August	September	October	November	December	January	February
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43							
Bud Initiation and Natural Hardening						Lifting for Refrig. Storage	
	60-70	50-60	45-55		32-35	32-35	
	50-60	45-55	40-45		30-32	30-32	
74	84	68	57	38	29	35	38
50	50	42	36	27	17	24	26
None							
Leach with water and dry to wilting.	Irrigate when rootplug is barely moist.					Irrigate rootplugs to field capacity prior to refrigerated storage.	
Micro-nutrients	Apply Peters Conifer Finisher every other irrigation and micro-nutrients each irrigation.	Add calcium nitrate to each irrigation containing Peters Finisher.					

growing medium to adhere, keeping it from falling through the drainage holes. Cells are machine filled with a 50/50 peat-vermiculite growing medium. The pH of this mix averages around 4.2. Seeds are sown with a vacuum seeder and covered with about 1/5- to 3/8-inch of either Target Forestry Sand® or washed white grit.

Germination Phase

Once sowing is complete, the containers are irrigated until the medium is thoroughly moist. Phosphoric acid is injected into the irrigation water to adjust pH to around 6.0. Light mists of acidified irrigation water are applied to keep the zone around the germinating seeds slightly moist. Vigorous lots of grand fir show through the grit in as little as three days.

Some germinants may show symptoms of damping-off fungi. Common fungi associated with damping-off include *Pythium, Rhizoctonia, Phytopthora,* and *Fusarium*. Symptoms of damping-off are rotted stems at the groundline, often accompanied by apparently healthy tops lying on their sides. The infected germinants, and preferably their cells, should be removed from the greenhouse to prevent disease spread. Irrigation water can cause spores to splash to other seedlings, thereby spreading the disease. Disease incidence declines as soon as the stems begin to lignify, generally in three to four weeks (Tinus and McDonald 1979).

At the research nursery we rely on these proper cultural practices to reduce damping-off: maintaining low medium pH with acidified irrigation water, using grit to allow air circulation around the root collar zone, keeping relative humidity low, delaying nitrogen fertilization until germination is complete, and using medium fungicide drenches. We apply one dose of the fungicide Banrot® (a soil drench) at 4 ounces per 100 gallons immediately after germination is complete as a preventative method against root rots.

Germination is generally complete within 14 to 21 days, and seed coats are shed within 28 days. Cells are thinned to one seedling each by removing the extra germinants with tweezers or fingers as soon as the majority of seedlings have shed their seed coats. Seedlots with high germination energy tend to shed their seed coats rapidly. During seed coat shed, at about week 2, seedlings enter the "initial growth phase."

Initial Growth Phase

The objective of this phase is to develop root systems on the germinants, making them capable of incorporating large amounts of nutrients and producing rapid shoot growth during the accelerated growth phase. Large concentrations of phosphorus and potassium are applied to achieve the desired growth.

Nutrients are applied during each twice-weekly irrigation to meet targeted growth (Fig. 2 and 3). During the initial growth phase, week 2 through week 6, we inject a liquid fertilizer solution of Peters Conifer Starter® (7-40-17) at a rate of 84 ppm N and calcium nitrate (15.5-0-0-10) at a rate of 46 ppm N supplemented with phosphoric acid to adjust fertigation water pH to below 6.0 (Table 1).

During this growth phase day temperatures of 75-80°F (24-27°C) and night temperatures around 65°F (18°C) are maintained. Medium temperature (recorded at 8 a.m. daily) averages 68°F (20°C). Photoperiod is extended to 18 hours. At the end of week 6 the medium is leached with copious amounts of irrigation water to remove any salt build-up prior to beginning the accelerated growth phase. During week 6, seedling foliage samples are sent to a commercial laboratory for nutrient analysis.

Weather conditions, particularly the amount of sunshine, have a strong influence on initial growth of seedlings. Weekly height and caliper measurements are taken on ten pre-determined sample trees within each lot. If height growth is exceeding target levels, we reduce nitrogen by lowering the rate of calcium nitrate in the fertilizer solution to around 23 ppm. Conversely, if growth is behind targeted levels, we apply additional nitrogen by increasing the rate of calcium nitrate to as much as 69 ppm.

During this phase, seedlings may show symptoms of *Fusarium* root rot: chlorotic needles that turn necrotic, resulting in the seedlings turning brown to red-brown and dying. The seedling tip may also wilt into a shepherd's crook. Infected seedlings and cells should be removed as soon as evident.

Accelerated Growth Phase

The objective of this phase is to achieve target seedling height while increasing root collar diameter. This phase begins during the seventh week. Levels of phosphorus and potassium are reduced and nitrogen concentrations increased to promote shoot growth.

Peters Conifer Grower® (20-7-19) is the main fertilizer, applied at 120 ppm N, supplemented with calcium nitrate (15.5-0-0-10) at 46 ppm N, micronutrients, and phosphoric acid (Table 2). Nutrients are still applied during the twice-weekly irrigations. Photoperiod and temperatures are the same as for the initial growth phase.

Seedling heights are compared with heights on the target height growth curve, and if heights exceed targets, nitrogen is reduced by decreasing the rate of calcium nitrate in the fertilizer solution to 23 ppm N. Conversely, if growth is lagging behind the target level, calcium nitrate can be applied at 69 ppm N.

During week 12, if height growth is at the desired level, the medium is leached with copious amounts of irrigation water to remove any salt build-up and excessive fertilizer. The medium is then allowed to dry down until it is barely moist. If the seedlings are shorter than the target height, fertilizer calcium nitrate levels are

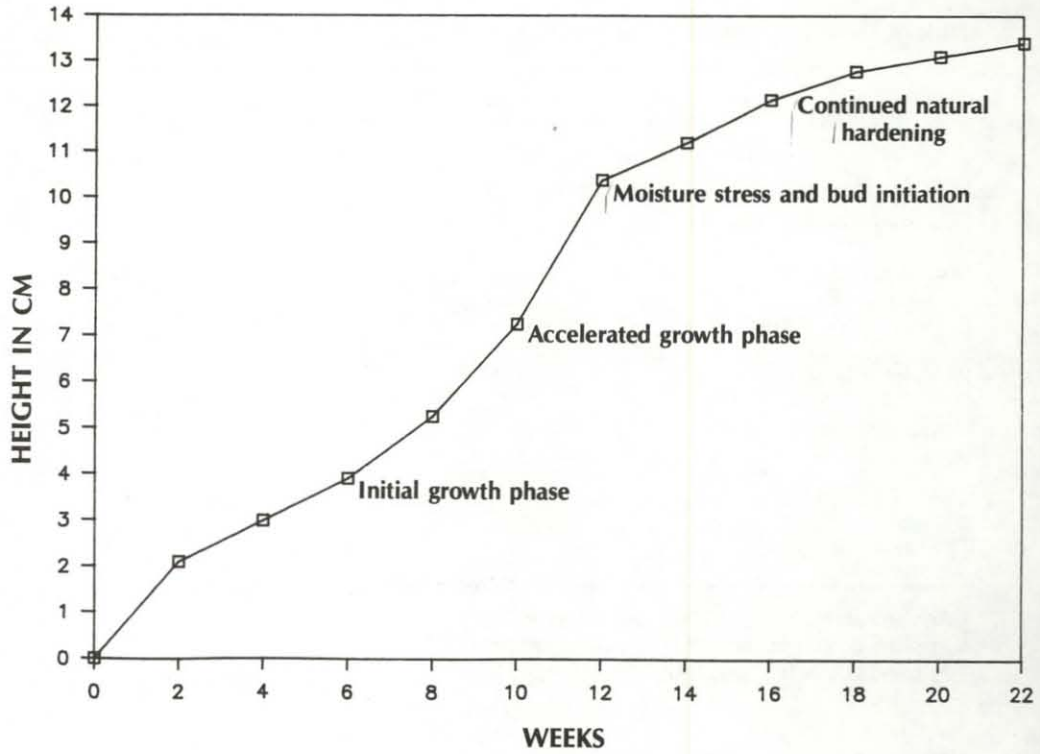

Figure 2. Grand fir target height growth.

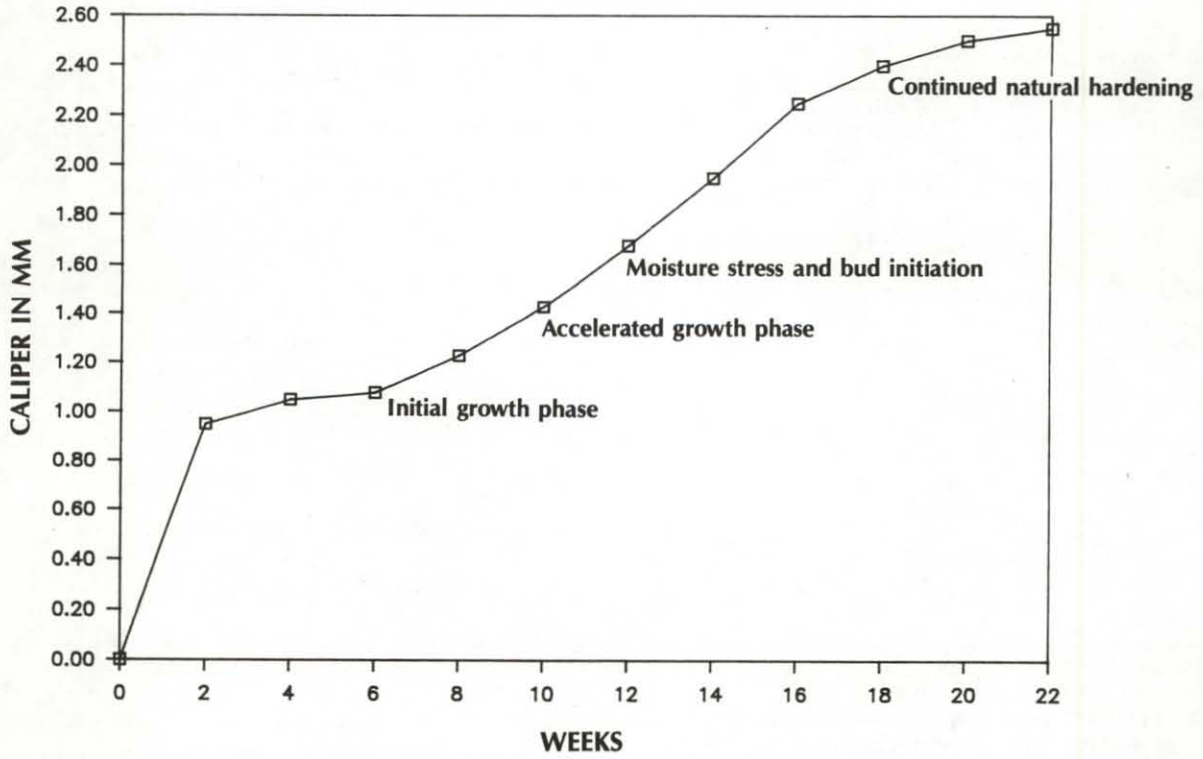

Figure 3. Grand fir target caliper growth.

Table 1. Fertilizer levels for initial growth phase.

	Nutrients in ppm													
Mineral Nutrient Sources	**NO_3**	**NH_4**	**P**	**K**	**S**	**Ca**	**Mg**	**Fe**	**Cl**	**B**	**Mn**	**Zn**	**Cu**	**Mo**
Well water	2		2		15	28	10	0.24	2		0.07	0.40	0.01	
Peters Conifer Starter[1]	41	43	210	169	2		1.8	2.40		0.18	0.36	0.36	0.36	0.04
Phosphoric acid[2]			41											
Calcium nitrate[3]	43	3				57								
Total	86	46	253	169	17	85	11.8	2.64	2	0.18	0.43	0.76	0.37	0.04

[1] Applied at 10 lbs. per 1000 gal. (84 ppm N).
[2] Applied at 20 oz. per 1000 gal. (41 ppm P).
[3] Applied at 2.5 lbs. per 1000 gal. (46 ppm N).

Table 2. Fertilizer target levels for accelerated growth phase.

	Nutrients in ppm													
Mineral Nutrient Sources	**NO_3**	**NH_4**	**P**	**K**	**S**	**Ca**	**Mg**	**Fe**	**Cl**	**B**	**Mn**	**Zn**	**Cu**	**Mo**
Well water	2		2		15	28	10.0	0.24	2		0.07	0.40	0.01	
Peters Conifer Grower[1]	70	50	18	95			1.8	2.40		0.15	0.36	0.36	0.36	0.03
Phosphoric acid[2]			41											
Magnesium sulfate[3]					24		31.0							
Manganous sulfate[4]					11						18.00			
Solubor (Boron)[5]										0.46				
Sequestrene 330 (Chelated iron)[6]								2.25						
Calcium nitrate[7]	43	3				57								
Total	115	53	61	95	50	85	42.8	4.89	2	0.61	18.43	0.76	0.37	0.03

[1] Applied at 5 lbs. per 1000 gal. (120 ppm N).
[2] Applied at 20 oz. per 1000 gal. (41 ppm P).
[3] Applied at 2 lbs. per 1000 gal. (24 ppm S and 31 ppm Mg).
[4] Applied at 10 oz. per 1000 gal. (11 ppm S and 18 ppm Mn).
[5] Applied at 0.3 oz. per 1000 gal. (0.46 ppm B).
[6] Applied at 3 oz. per 1000 gal. (2.25 ppm Fe).
[7] Applied at 2.5 lbs. per 1000 gal. (46 ppm N).

increased and the leach is postponed until the target is met. Foliage is again tested for nutrient deficiencies at this time.

Bud Initiation and Root Collar Diameter Growth

The objective of this phase is to withhold nutrients and moisture, creating stress in the seedlings so that height growth will cease, terminal buds will develop, and root collar diameter will increase. During this growth phase, the seedlings are taken off the twice-weekly irrigation/fertilization schedule. Levels of applied nitrogen are reduced, and phosphorus and potassium levels are increased.

Seedlings are now irrigated only when the medium has become barely moist. Our greenhouse technicians daily select seedlings at random, remove the root plugs from the cells, and inspect and feel the medium for dryness. Although the method is quite subjective, we feel it has some advantages. Disease and insects can be surveyed at the same time, and, because of random selection, the seedlings that are seldom examined because of inaccessibility also are checked. By inspecting the root plugs, we also gain some insight into how the root system is developing.

When irrigation is necessary, Peters Conifer Finisher® (4-25-35) is the main fertilizer, along with calcium nitrate (15.5-0-0-10), micronutrients, and phosphoric acid (Table 3). Micronutrients, calcium nitrate, and phosphoric acid are applied during each irrigation, and the conifer finisher is applied every other irrigation.

The extended photoperiod is discontinued. Day temperatures are set for 60-70°F (16-21°C) and night temperatures for 50-60°F (10-16°C). We maintain medium temperatures between 62°F and 68°F (17-20°C) within these air temperature ranges.

Cold-Hardiness Induction Phase

The objective of this phase is to physiologically prepare the trees for freezing temperatures. We accomplish this by subjecting the trees to ambient temperatures and thus allowing normal cold-hardiness to develop. The grand fir may appear slightly chlorotic, and in some lots they may begin to show a purplish color in their needles and stems as an indicator of carbohydrate accumulation and the beginning of physiological changes preparing the seedlings for winter.

Beginning around mid-October, we allow air temperatures within the greenhouses to reach ambient

Table 3. Fertilizer target levels for bud initiation phase.

	Nutrients in ppm													
Mineral Nutrient Sources	**NO_3**	**NH_4**	**P**	**K**	**S**	**Ca**	**Mg**	**Fe**	**Cl**	**B**	**Mn**	**Zn**	**Cu**	**Mo**
Well water	2		2		15	28	10	0.24	2		0.07	0.40	0.01	
Peters Conifer Finisher[1]		24	66	174	2		2	2.40		0.15	0.36	0.36	0.36	0.03
Phosphoric acid[2]			41											
Magnesium sulfate[3]					24		31							
Manganous sulfate[4]					11						18.00			
Solubor (Boron)[5]										0.46				
Sequestrene 330 (Chelated iron)[6]								2.25						
Calcium nitrate[7]	21	2				28								
Total	23	26	109	174	52	56	43	4.89	2	0.61	18.43	0.76	0.37	0.03

[1] Applied at 5 lbs. per 1000 gal. (24 ppm N).
[2] Applied at 20 oz. per 1000 gal. (41 ppm P).
[3] Applied at 2 lbs. per 1000 gal. (24 ppm S and 31 ppm Mg).
[4] Applied at 10 oz. per 1000 gal. (11 ppm S and 18 ppm Mn).
[5] Applied at 0.3 oz. per 1000 gal. (0.46 ppm B).
[6] Applied at 3 oz. per 1000 gal. (2.25 ppm Fe).
[7] Applied at 1.25 lbs. per 1000 gal. (23 ppm N).

levels (Fig. 1). However, the minimum temperature allowed in the greenhouses is 28°F (-2°C), and the root plug is not allowed to remain frozen. Temperatures remain about ambient until the seedlings are packed for cold storage in January. From late October until the trees are put into cold storage, irrigation is necessary only about once every three to four weeks. During these irrigations, fertilizer is applied at accelerated growth phase rates. The fertilizer acts as a nutrient reserve within the medium for use by the tree when outplanted.

Extraction and Cold Storage

Seedlings are well watered before being removed from their containers and wrapped with a Saran-like plastic in bundles of 25. The stickiness of the plastic keeps the bundle firmly packed, which maintains plug integrity and prevents moisture loss. Bundles of trees for public conservation sales are placed four to a poly bag (100 seedlings total), which is sealed before going into refrigerated storage. Bundles of trees for large reforestation working agreements are placed into poly-lined wax boxes, which are also sealed air-tight before being placed into cold storage. The refrigerated storage area is kept at 33-34°F (0.5-1°C) with relative humidity near 100 percent. Seedlings have been stored successfully in this manner for five months without needing irrigation.

Seedlings in cold storage are routinely inspected for disease problems. The most serious disease is caused by fungi of the genus *Botrytis*. The symptoms are webs of gray to gray-brown mycelium growing through the tops of the seedlings, especially in the center of bundles. Tan or brown-watery stem lesions may also be present. Preventative methods are best for controlling this problem and include the following: (1) pulling, wrapping, and storing only vigorous, disease-free seedlings, (2) storing seedlings for the shortest time possible, (3) routinely inspecting a sample from each lot, especially lots containing significant quantities of dead needles that can serve as an initial food base for the pathogen, and (4) shipping seedlings showing mold problems immediately, if possible (Sutherland and Van Eerden 1980). Mold growth can also be reduced by dropping the storage temperature for fully hardened seedlings to below freezing.

Conclusions

This regime has been very successful. Requested quantities of seedlings meeting strict physiological and morphological requirements are achieved or exceeded with a minimum oversow. Seedlings grown under this regime average 15 cm in height and 2.3 to 2.8 mm in caliper.

We feel the most important aspect of any growing regime is continually monitoring seedling growth as the regime progresses. Height and caliper measurements can then be used to modify or change the regime during one growing season or between growing seasons. This regime was developed from six years of records on fertilizer application rates and resultant seedling growth, and will certainly be modified in the pursuit of high-quality grand fir seedlings.

Literature Cited

Franklin, J.F. 1974. *Abies* Mill. *In:* Seeds of woody plants in the United States. C.S. Schopmeyer, Tech. Coord. USDA Agriculture Handbook 450. U.S. Dept. of Agriculture, Washington, D.C. 883 pp.

Harlow, W.M., E.S. Harrar, and F.M. White. 1979. Textbook of dendrology. 6th ed. McGraw-Hill Book Company, New York. 510 pp.

Sutherland, J.R., and E. Van Eerden. 1980. Diseases and insect pests in British Columbia forest nurseries. British Columbia Ministry of Forests/Canadian Forestry Service Joint Report No. 12. 55 pp.

Tinus, R.W., and S.E. McDonald. 1979. How to grow tree seedlings in containers in greenhouses. USDA Forest Service General Technical Report RM-60. 256 pp.