Nursery and Field Evaluation of Compost-Grown Conifer Seedlings

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*Three conifer species-Douglas-fir (*Pseudotsuga menziesii *(Mirb.) Franco), noble fir (*Abies procera *Rehd.), and ponderosa pine* (Pinus ponderosa *Dougl. ex Laws.)-were grown in four levels (control, 2, 4, and 6 inches) of composted sludge. Seedlings given the 2- and 4-inch treatments showed the best response after the first year in the nursery. Of the three species, Douglas-fir seedlings responded best. Immobilization of nutrients and heavy metal accumulations resulting from compost application are discussed.* Tree Planters' Notes 38(2):22-27; 1987.

An essential part of forest tree nursery culture is the use of organic amendments. Organic matter maintains soil characteristics such as low bulk density, high water- and nutrient-holding capacities, improved soil structure, and optimal environments for beneficial rhizosphere microorganisms (nitrifying bacteria, mycorrhizae, etc.) (7).

Common organic amendments include green manure from cover crops, sawdust, and peatmoss. Unfortunately, all have a high carbon to nitrogen ratio, may cause net nutrient immobilization, and may release phytotoxic compounds. The availability of sawdust and peatmoss is limited, for they are used in other markets. Cover cropping requires additional nursery acreage.

Composted material derived from manure, sawdust, or spent mushroom compost results in less immobilization and little or no phytotoxic effects while still providing the desired organic input (3). Municipal sewage is an abundantly available organic nutrient source and has been favorably utilized in conifer seedling production (1,4).

Addition of sludge provides supraoptimal nitrogen levels and will increase heavy metal levels in soils and plants (3). However, the use of both sludge and sawdust that have been composted together combines the beneficial characteristics of each and mitigates the less desirable properties.

The purpose of this experiment was to investigate the potential use of a sawdust-sludge compost in forest tree nurseries.

Methods

Nursery. Nursery beds at the USDA Forest Service Wind River Nursery, Carson, WA, were amended with compost (fir-hemlock sawdust municipal sewage sludge, 3:1 from METRO, Seattle, WA). Density = 0.2 grams per cubic centimeter, nitrogen = 0.5 percent; other characteristics are listed in Bledsoe (3).

Each of 12 nursery beds (330 feet long) were randomly selected for a particular compost treatment-tree species combination. The four compost treatments were application of 0, 2, 4, and 6 inches (0, 270, 528, and` 805 cubic yards per acre, equivalent to 0, 513, 1,000, and 1,530 cubic meters per hectare).

The three tree species were Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), noble fir (*Abies procera* Rehd.), and ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.). Compost was disked into the soil and seeds were sown in spring 1982. Seedlings were raised according to standard nursery procedures. In fall 1983, the 2 + 0 nursery stock was lifted and stored at 3 °C until spring 1984, when seedlings were outplanted at three sites.

Field. Douglas-fir seedlings were planted with hoedads on the southeast side of Mt. St. Helens in the blast zone on a site (3,000-foot elevation and 35-percent slope) that had been salvage-logged. Planting occurred 4 years after the May 18, 1980, eruption. Tephra, 12 to

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20 inches deep, covered the surface. Roots of planted seedlings did not extend into mineral soil.

Noble fir seedlings were planted near Estacada, OR, on a site with an elevation of 3,800 feet and slope of approximately 20 percent. The site had been logged in 1980, and slash had been hand piled and burned. Considerable brush covered the area. Seedlings were planted with hoedads in mineral soil.

Ponderosa pine seedlings were planted east of the Cascade crest at 3,400 feet elevation, near Leavenworth, WA. The area had been tractor-logged for mixed ponderosa pine and Douglas-fir and broadcast-burned in fall 1983. Slopes were approximately 45 percent. Seedlings were planted with power augers in mineral soil.

The experimental design for all three sites was a randomized complete block (table 1). Each row consisted of seedlings from a single treatment with four treatments in each block. Rows and seedlings within rows were spaced 8 feet apart.

Measurements and Analyses. Twenty-four seedlings from each compost treatment were measured for height, diameter, and dry weight after 1 and 2 years in the nursery. Nutrient (nitrogen, phosphorus, and potassium) and heavy metal (zinc, copper, lead, nickel, and cadmium) concentrations in roots were measured after 1 year on four pooled samples of 24 seedlings each. Data were analyzed using a fixed-effects one-way ANOVA model of ponderosa pine, Douglas-fir, and noble fir, respectively.

Field measurements of initial seedling height and diameter were made after planting in the spring of 1984. Seedling survival, height, and diameter were measured in the fall of 1984 and 1985. In these cases, a fixed-effect two-way ANOVA model was used for data analysis; compost treatment and blocks were the two factors used.

Table 1—*Design of nursery experiment*

Site	Trees/row	Rows/block	Blocks	Total trees
Mt. St. Helens	30	4	5	600
Estacada	12	4	12	576
Leavenworth	24	4	6	576

Table 2—*Height and biomass of conifer seedlings grown for 1 year in nursery beds treated with 2, 4, or 6 inches of compost*

Species	Control (0)		2 inches		4 inches		6 inches		mean
Douglas-fir									
Height (cm)	15.0	b	18.0	a	16.0	b	17.0	b	16.0
Shoot DW (g)	0.78	a	0.81	a	0.72	a	0.88	a	0.80
Root DW (g)	0.39	a	0.32	a	0.31	a	0.35	a	0.34
Root/shoot	0.51	a	0.41	b	0.44	b	0.42	b	0.44
Noble fir									
Height (cm)	9.4	a	9.4	a	9.9	a	9.3	a	9.5
Shoot DW (g)	0.31	a	0.36	a	0.37	a	0.31	a	0.34
Root DW (g)	0.18	a	0.22	a	0.23	a	0.20	a	0.21
Root/shoot	0.56	b	0.62	a	0.65	a	0.68	a	0.63
Ponderosa pine									
Height (cm)	13.0	b	14.0	a	14.0	a	15.0	a	14.0
Shoot DW (g)	0.98	b	1.3	a	1.3	a	1.2	a	1.2
Root DW (g)	0.45	b	0.61	a	0.56	a	0.61	a	0.56
Root/shoot	0.49	a	0.48	a	0.43	a	0.50	a	0.48

Values are the means of 24 samples; values for each row followed by the same letter do not differ significantly (alpha = 0.05)

Results and Discussion

Nursery. Growth. In general, Douglas-fir 1 + 0 seedlings were tallest and ponderosa pine had the greatest biomass (table 2). Ponderosa pine seedlings responded favorably to compost application, with significant treatment effects of height and dry weight. Noble fir and Douglas fir did not show any significant effects of compost treatment on growth parameters. Root collar diameter data are not presented because there were no significant treatment effects.

Mean diameters were 2.4, 1.9, and 2.8 centimeters for Douglas-fir, noble fir, and ponderosa pine, respectively. Growth data from year 2 nursery phase are not presented because treatment effects of 2+0 seedlings in the nursery were similar to results from the outplanting phase.

When seedlings were lifted, average dry weights (in grams) of seedling shoots and roots were: Douglas-fir, 3.6 and 1.7; noble fir, 2.5 and 1.5; ponderosa pine, 7.1 and 1.7. Compost-grown seedlings were generally similar to control seedlings in height, diameter, and shoot and root weights. However, compost-grown Douglas-fir and noble fir were 5 to 30 percent shorter than control seedlings. Compost-grown seedlings also had slightly higher root to shoot ratios than did controls.

Nutrients and metals. Nutrient concentrations in 1 + 0 seedlings did not differ among species with two exceptions. Potassium levels in noble fir roots were high (1.3 percent) as were nitrogen levels in pine shoots (2.3 percent). Potassium levels were not altered by compost treatment so these data were not included. Average potassium concentrations were 0.64, 1.0, and 0.62 percent for Douglas-fir, noble fir, and ponderosa pine, respectively.

The average root and shoot concentrations for all species combined were 1.5 and 1.9 percent (N), and 0.26 and 0.24 percent (P). A significant increase in nitrogen and phosphorus due to compost application was observed for Douglas-fir and noble fir (table 3). This enhancement in root and foliar phosphorus and in foliar nitrogen was not observed in pine.

Root heavy metal levels (in parts per million) averaged over all species were 4.7 for zinc, 6.0 for copper, 8.1 for lead, 3.4 for nickel, and 1.0 for cadmium. Cadmium and zinc values were as much as six times greater in compost-treated seedlings, but only the cadmium values were significant (table 4).

Other metals (copper, lead, and nickel) did not accumulate above levels found in the control treatment, with one exception. In noble fir, copper levels steadily increased with increasing compost application rate.

There is little information on heavy metal levels in conifer seedlings (4-6). Burton and others (5) found that root growth of Sitka spruce was inhibited at root concentrations greater than

Table 3—*Percent nutrient concentrations in roots and shoots of seedlings grown for 1 year in nursery beds treated with 2, 4, or 6 inches of compost*

Species	Control (0)		2 inches		4 inches		6 inches	
Roots								
Douglas-Fir								
Nitrogen	1.4	a	1.6	a	1.6	a	1.5	a
Phosphorus	0.22	c	0.31	a	0.26	a	0.25	b
Noble fir								
Nitrogen	1.3	b	1.5	a	1.5	a	1.5	a
Phosphorus	0.19	b	0.25	a	0.25	a	0.25	a
Ponderosa pine								
Nitrogen	1.3	c	1.6	ab	1.8	a	1.5	b
Phosphorus	0.27	a	0.27	a	0.28	a	0.28	a
Shoots								
Douglas-fir								
Nitrogen	1.5	c	1.7	ab	1.8	a	1.5	b
Phosphorus	0.17	c	0.24	a	0.21	b	0.19	b
Noble fir								
Nitrogen	1.4	b	1.9	a	1.9	a	1.7	a
Phosphorus	0.20	b	0.27	a	0.26	a	0.25	a
Ponderosa pine								
Nitrogen	2.1	a	2.2	a	2.3	a	2.4	a
Phosphorus	0.27	a	0.27	a	0.27	a	0.26	a

Values are means of four tissue analyses, which each were pooled samples from 24 seedlings; values in each row followed by the same letter do not differ significantly (alpha = 0.05).

Table 4—*Heavy metal concentrations in parts per million of roots of seedlings grown for 1 year in nursery beds treated with 2, 4, or 6 inches of compost*

Species	Control (0)		2 inches		4 inches		6 inches		Mean
Douglas-fir									
Zinc	T		0.88	a	1.8	a	3.2	a	2.0
Copper	5.0	a	5.7	a	5.8	a	4.4	a	5.2
Lead	4.4	a	6.2	a	5.2	a	4.4	a	5.0
Nickel	3.5	a	1.6	b	T		1.7	b	2.3
Cadmium	T		0.25	b	0.31	b	0.63	a	0.4
Noble fir									
Zinc	1.2	a	8.6	a	5.9	a	5.6	a	5.3
Copper	3.7	d	5.7	c	6.8	b	7.9	a	6.0
Lead	5.7	a	6.6	a	8.1	a	8.5	a	7.2
Nickel	2.2	a	1.6	a	T		1.7	a	1.9
Cadmium	0.56	b	0.63	b	1.8	a	2.1	a	1.3
Ponderosa pine									
Zinc	4.8	a	11.0	a	5.1	a	T		6.8
Copper	7.2	a	6.1	a	7.3	a	7.0	a	6.9
Lead	12.0	a	11.0	a	9.1	a	16.0	a	12.0
Nickel	6.0	a	5.9	a	5.8	a	6.7	a	6.1
Cadmium	0.50	c	0.13	c	1.3	b	3.5	a	1.4

Values are means of four tissue analyses, which each were pooled samples from 24 seedlings; values for each row followed by the same letter do not differ significantly (alpha = 0.05). T = trace: zinc <0.001; nickel <0.01; cadmium <0.025 ppm.

61 parts per million of cadmium and 228 parts per million of lead. Rolfe and Bazzaz (9) measured inhibition of loblolly pine photosynthesis at similar tissue levels. The values for growth inhibition reported by Burton and others (5) were greater than ten times the cadmium and lead concentrations measured in this study (table 4). Wind River Nursery could accept more composted sludge before toxic levels of these two elements are reached.

Field. After one season's growth in the field, average survival ranged from 97 percent for Douglas-fir to 93 percent for noble fir and 88 percent for Ponderosa pine. For Douglas-fir, field survival of seedlings grown in compost-treated nursery beds was similar to control seedlings, except at the heaviest (6-inch) application rate. Here, year 1 and year 2 survival was reduced from 93 percent (year 1) to 84 percent (year 2, table 5).

For noble fir, survival for compost-grown trees was slightly reduced in year 1, but this effect was not present by year 2. For ponderosa pine, survival effects were complex and seemingly unrelated to compost application rates. Survival was significantly reduced by the 2-inch and 6-inch treatments, but inexplicably, survival in the control and 4-inch treatment was similar.

Douglas-fir height data show that growth in year 1 was much greater than growth in year 2. Reduced second year growth may have been due to low nutrient availability in the tephra. Height increase for the 2-inch treatment was significantly greater than the control treatment.

For noble fir, seedling heights were significantly lower in composted treatments, due to differences developed in the nursery. Percent height increase in compost treatments was significantly greater than controls, suggesting that compost-treated seedlings grew well in the field.

Ponderosa pine seedlings initially were identical in height, but later the composted seedlings were shorter than controls. This trend was carried through the 1985 season. By the end of 1985, height increase of controls exceeded 80 percent whereas that of composted seedlings was only 50 percent. Thus pine may not be suited for treatment with compost.

Conclusions

This study indicates that although initial growth of compost-treated nursery seedlings is improved, probably due to increased nutrient availability,

Table 5—*Two-year height and survival data for 2–0 seedlings grown for 1 year in nursery beds treated with 2, 4, or 6 inches of compost, then outplanted on three sites in Washington and Oregon*

Species	Control (0)		2 inches		4 inches		6 inches	
Douglas-fir (Mt. St. Helens, WA)								
Height (cm)								
Spring 84	25.2	a	20.4	b	24.4	b	21.9	b
Fall 84	28.7	a	24.0	b	28.6	a	23.9	b
Fall 85	29.5	a	25.8	b	29.1	a	25.0	b
Total % increase	17.5	b	27.0	a	19.5	ab	14.7	b
Survival (%)								
Fall 84	97.9	a	99.3	a	99.3	a	93.4	b
Fall 85	98.0	a	95.9	a	96.9	a	84.2	b
Noble fir (Estacada, OR)								
Height (cm)								
Spring 84	22.1	a	13.7	b	14.7	b	14.5	b
Fall 84	24.3	a	15.9	b	16.4	b	16.5	b
Fall 85	26.5	a	18.1	b	18.5	b	18.8	b
Total % increase	20.6	b	34.6	a	26.9	a	29.7	a
Survival (%)								
Fall 84	99.2	a	90.9	b	87.2	b	98.3	b
Fall 85	95.4	a	90.2	a	85.9	a	87.3	a
Ponderosa pine (Leavenworth, WA)								
Height (cm)								
Spring 84	17.1	a	18.3	a	17.7	a	16.7	a
Fall 84	23.3	a	20.7	b	21.5	b	19.3	c
Fall 85	30.9	a	27.4	b	27.9	b	25.8	b
Total % increase	81.7	a	49.7	b	58.3	b	54.5	b
Survival (%)								
Fall 84	97.5	a	71.5	c	100.0	a	81.3	b
Fall 85	93.5	a	49.6	c	83.8	a	66.0	b

Seedlings were grown at the Wind River Nursery. Values for each row followed by the same letter do not differ significantly (alpha = 0.05).

subsequent nursery growth seems to be reduced. Nutrient immobilization in the high C/N compost may cause reduced growth. This process is no different than processes that occur after incorporation of traditional organic amendments such as peat, sawdust, or cover crops.

Despite the suspected immobilization effects of compost applications, especially on noble fir and ponderosa pine, the use of compost as an organic amendment appears promising. This is especially true for Douglas-fir, which responded well to compost application as compared to controls. The optimal compost application rate for nursery phase seedlings appears to be either the 2- or 4-inch treatment. Six-inch treatments produced consistently smaller seedlings than did the other compost treatments.

Sludge or composted sawdust/sludge mixtures should be applied with caution, since this study showed increased cadmium and zinc concentrations in roots of compost-grown trees. Addition of toxic heavy metals should be monitored, because these metals will accumulate in nursery soils. Fortunately, these environmentally hazardous materials often remain in the soil in close association with the applied organic compounds (10). The problem with this soil retention is the possible buildup of these compounds to toxic levels. Lake and others (8) listed annual loading rates of cadmium in Scandinavia at 22 grams per hectare, in the United Kingdom at 167 grams per hectare, and in the United States at 1,250 grams per hectare.

Rather than discussing annual application rates, Bicklehaupt (2) referred to cumulative levels for several different heavy metals. Cadmium levels should not exceed 20 kilograms per hectare, whereas zinc levels should not exceed 1,000 kilograms per hectare for soils with high cation exchange capacities. In soils with lower cation exchange capacities, such as sandy soils or soils that are low in organics, these maximum levels are cut by a factor of four. It therefore appears evident that use of sludge or composted sludge compounds in forest nurseries for organic inputs will require careful monitoring of soil and tissue levels so that toxic levels and seedling growth inhibition do not occur.

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