Nursery and Field Evaluation of Compost-Grown Coniferous Seedlings[1]

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INTRODUCTION

An essential part of forest tree nursery culture is the use of organic amendments. Organic matter maintains soil characteristics like low bulk density, high water and nutrient holding capacities, improved soil structure and optimal environments for beneficial rhizosphere microorganisms (nitrifying bacteria, mycorrhizae, etc., Davey and Krause, 1980). 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. Sawdust and peatmoss availability are limited and 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 (Bledsoe 1981). Municipal sewage is an abundantly available organic nutrient source and has been favorably utilized in coniferous seedling production (Berry, 1985; Bledsoe and Zasoski, 1981). Addition of sludge provides supraoptimal nitrogen levels and will increase heavy metal levels in soils and plants`(Bledsoe, 1981). However, the use of both sludge and sawdust, which 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 USFS Wind River nursery, Carson, WA were amended with compost (3:1 fir-hemlock sawdust: municipal sewage sludge from METRO, Seattle, WA). Additional characteristics of the compost, density 0.2 g/cm , 0.5% N, are found in Bledsoe (1981).

Each of 12 nursery beds (330') were randomly selected for a particular compost treatment-tree species combination. The four compost treatments were 0, 2, 4 and 6 inch (0, 270, 528, and 805 cu. yds./acre, equivalent to 0, 513, 1000, and 1530 m^3 /ha). The 3 tree species were Douglas-fir *(Pseudotsuga menziesii),* noble fir *(Abies rr ocera)* and ponderosa pine *(Pinus ponderosa).* Compost was disced 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 they were outplanted at three sites.

Field

Douglas-fir was planted with hoedads on the southeast side of Mt. St. Helens in the blast zone on a 3000' elevation site (35% slope) which had been salvage-logged. Planting occurred 4 years after the May 18, 1980 eruption. Tefra, 12-20 inches deep, covered the surface. Roots of planted seedlings did not extend into mineral soil.

Noble fir was planted near Estacada, Ore, at an elevation of 3800' and slope of approximately 207. The site had been logged in 1980, slash was 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 3400' 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%. Seedlings were planted with power augers in mineral soil.

The experimental design for all 3 sites was a randomized complete block. Each row consisted of seedlings from a single treatment with 4 treatments in each block. Rows and seedlings within rows were spaced 8' apart. The design was arranged as follows:

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

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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 (N, P, K) and heavy metal (Zn, Cu, Pb, Ni, Cd) concentrations in roots were measured after 1 year on 4 pooled samples of 24 seedlings. Data were analyzed using a fixed-effects one-way ANOVA model for 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 taken 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.

RESULTS AND DISCUSSION Nursery: Growth

In general, Douglas-fir 1-0 seedlings were tallest while ponderosa pine had the greatest biomass (Table 1). Ponderosa pine seedlings responded favorably to compost application, with significant treatment effects on 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 since there were no significant treatment effects. Mean diameters were 2.4, 1.9 and 2.8 cm for Douglas-fir, noble fir and ponderosa pine respectively. Growth data from year 2 nursery phase are not presented since treatment effects for 2-0 seedlings in the nursery were similar to results from the outplanting phase.

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

Nursery: Nutrients and Metals

Nutrient concentrations in 1-0 seedlings did not differ among species with 2 exceptions. Potassium levels in noble fir roots were high (1.3%) as were N levels in pine shoots (2.3%). Potassium levels were not altered by compost treatment so these data were not included. Average K concentrations were 0.64%, 1.0%, 0.62% 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% (N), .26% and .24% (P). A significant increase in N and P due to compost application was observed for Douglas-fir and noble fir (Table 2). This enhancement in root and foliar P and in foliar N was not observed in pine.

Root heavy metal levels, averaged over all species, were 4.7 ppm for Zn, 6.0 ppm for Cu, 8.1 ppm for Pb, 3.4 ppm Ni and 1.0 ppm for Cd. Cadmium and Zn values were as much as 6 times greater in compost-treated seedlings but only the Cd values were significant (Table 3).

Table 1.--Height and biomass of conifer seedlings grown in compost-amended nursery beds for one year. Values are means of 24 samples. Values for each row followed by the same letter are not significantly different (alpha = .05)

	COMPOST TREATMENT				
Species	**0"**	**2"**	**4"**	**6"**	**MEAN**
Douglas-fir					
Height, cm	15. b	18. a	16. b	17. b	16.
Shoot, g DW	0.78 a	0.81 a	0.72 a	0.88 a	0.80
Root, g DW	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, g DW	0.31 a	0.36 a	0.37 a	0.31 a	0.34
Root, g DW	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. b	14. a	14. a	15. a	14.
Shoot, g DW	0.98 b	1.3 a	1.3 a	1.2 a	1.2
Root, g DW	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

Table 2. Percent nutrient concentrations in roots and shoots of seedlings grown in compost-amended nursery beds for one year. Values are means of four tissue analyses which were pooled samples from 24 seedlings. For root and shoot data, values for each row followed by the same letter are not significantly different (alpha = .05).

Species		**Compost Treatment, Roots**				**Compost Treatment, Shoots**			
		0"	2"	4"	6"	0"	2"	4"	6"
		- % -				- % -			
Douglas-fir									
	N	1.4 a	1.6 a	1.6 a	1.5 a	1.5 c	1.7 ab	1.8 a	1.5 b
	P	0.22 c	0.31 a	0.26 b	0.25 b	0.17 c	0.24 a	0.21 b	0.19 b
Noble fir									
	N	1.3 b	1.5 a	1.5 a	1.5 a	1.4 b	1.9 a	1.9 a	1.7 a
	P	0.19 b	0.25 a	0.25 a	0.25 a	0.20 b	0.27 a	0.26 a	0.25 a
Ponderosa pine									
	N	1.3 c	1.6 ab	1.8 a	1.5 b	2.1 a	2.2 a	2.3 a	2.4 a
	P	0.27 a	0.27 a	0.28 a	0.28 a	0.27 a	0.27 a	0.27 a	0.26 a

Table 3. Heavy metal content in ppm in roots of seedlings grown in compost-amended nursery beds for one year. Values are means of four tissue analyses which were pooled samples from 24 seedlings.
Trace levels: Zn <.001, Ni <.01, Cd<.025 ppm. Values for each row followed by the same letter are not significantly different (alpha = .05).

Species	**Compost Treatment**				
	0"	2"	4"	6"	MEAN
		- ppm -			
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 b	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	0.40
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. a	5.1 a	T	6.8
Copper	7.2 a	6.1 a	7.3 a	7.0 a	6.9
Lead	12. a	11. a	9.1 a	16. a	12.
Nickel	6.0 a	5.9 a	5.8 a	6.7 a	6.1
Cadmium	0.50c	0.13 c	1.3 b	3.5 a	1.4

Other metals (Cu, Pb, Ni) 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 coniferous seedlings (Bledsoe and Zasoski 1981; Burton et al. 1984, 1986). Burton et al. 1984 found that root growth of Sitka spruce was inhibited at root concentrations >61 ppm Cd and 228 ppm Pb. Rolfe & Bazzaz (1975) measured inhibition of loblolly pine photosynthesis at similar tissue levels. The values for growth inhibition reported by Burton et al. (1984) were greater than 10 times the Cd and Pb concentrations measured in this study (Table 3). 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% for Douglas-fir to 93% for noble fir and 88% 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") application rate. Here, year 1 and year 2 survival was reduced from 93% (yr 1) to 84% (yr 2, Table 4). 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" and 6" treatments, but, inexplicably, survival in the control and 4" treatment was similar.

Douglas-fir height data show that growth in year 1 was much greater than growth in year 2.

Table 4. Two year height and survival data for 2-0 seedlings outplanted in spring 1984 on three sites in Washington and Oregon. Seedlings were previously grown at the Wind River nursery in beds amended with 0,2, 4 or 6 inches of compost. Values for each row followed by the same letter are not significantly different (alpha - .05).

Species, Site		**Compost Treatments**			
		0"	**2"**	**4"**	**6"**
Douglas-fir, Mt. St. Helens WA					
Height, cm					
	Spring 1984	25.2a	20.4b	24.4b	21.9b
	Fall 1984	28.7a	24.0b	28.6a	23.9b
	Fall 1985	29.5a	25.8b	29.1a	25.0b
	Total Inc. %	17.5b	27.0a	19.5ab	14.7b
Survival, %					
	Fall 1984	97.9a	99.3a	99.3a	93.4b
	Fall 1985	98.0a	95.9a	96.9a	84.2b
Noble fir, Estacada OR					
Height, cm					
	Spring 1984	22.1a	13.7b	14.7b	14.5b
	Fall 1984	24.3a	15.9b	16.4b	16.5b
	Fall 1985	26.5a	18.1b	18.5b	18.8b
	Total Inc. %	20.6b	34.6a	26.9a	29.7a
Survival, %					
	Fall 1984	99.2a	90.9b	87.2b	93.3b
	Fall 1985	95.4a	90.2a	85.9a	87.3a
Ponderosa pine, Leavenworth WA					
Height, cm					
	Spring 1984	17.1a	18.3a	17.7a	16.7a
	Fall 1984	23.3a	20.7b	21.5b	19.3c
	Fall 1985	30.9a	27.4b	27.9b	25.8b
	Total Inc. %	81.7a	49.7b	58.3b	54.5b
Survival, %					
	Fall 1984	97.5a	71.5c	100.0a	81.3b
	Fall 1985	93.5a	49.6c	83.8a	66.0b

Reduced second year growth may have been due to low nutrient availability in the tephra. Height increase for the 2 inch treatment was signficantly 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 composted seedlings were shorter than controls. This trend was carried through the 1985 season. By the end of 1985, height increase in the control exceed 80%, whereas composted seedlings only grew 50%. Thus pine may not be suited for compost applications.

CONCLUSIONS

This study indicates that although initial growth of compost-treated nursery seedlings is improved, probably due to increased nutrient availability, 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 which 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" treatment. Six inch treatments produced consistently smaller seedlings than did the other compost treatments.

Use of 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 (Zasoski 1981). The problem with this soil retention is the possible buildup of these compounds to toxic levels. Lake et al. (1984) listed annual loading rates of Cd in Scandinavia - 22 g/ha, in the U.K. - 167 g/ha and in the U.S. - 1250 g/ha. Rather than discussing annual application rates, Bicklehaupt (1980) referred to cumulative levels for several different heavy metals. Cadmium levels should not exceed 20 kg/ha, while zinc levels should not exceed 1000 kg/ha for soils with high cation exchange capacities. In soils with lower cation exchange capacities, such as sandy soils or soils sandy soils or soils low in organics, these maximum levels are cut by a factor of 4. 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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