Comparative Growth of Black Spruce Container Seedlings Grown in Worm-Casting-Amended Soilless Media

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Black spruce (Picea mariana (Mill.) B.S.P.) container seedlings grown in peat vermiculite amended with pig manure worm castings at two concentrations and sewage sludge worm castings at three concentrations were compared with and without fertilization to seedlings grown in peat-vermiculite without amendments. In general, we found that non-fertilized seedlings grown in medium amended with 10% pig manure castings showed the best growth of any of the seedlings. Concentrations of foliar macroelements and microelements (except zinc) were within an acceptable range for container seedlings. Tree Planters' Notes 43(2):43-47; 1992.

Organic soil amendments are commonly used in nursery soils to reduce bulk-density, increase water and nutrient-holding capacities, and change the relative availability of nutrient elements (Armson and Sadreika 1974). Composted sewage sludge, an abundant waste product rich in nitrogen, has been evaluated as an amendment to nursery soils (Coleman *et al*. 1987) and to soilless mixes used in producing containerized nursery stock (Smith and Treaster 1985).

One method of composting, **vermicomposting,** uses earthworms to treat organic wastes, such as sewage sludge and manure. Earthworms break down complex substances in waste material by digestion and their feeding enhances microbial action through aeration (Hamilton et al. 1988). Worm castings are an inexpensive alternative to commercial fertilizers and contain substances that favor root growth and plant development (Grappelli *et al*. 1985). However, sewage sludge is also a potential source of toxic heavy metals that are not always removed during composting (Coleman *et al*. 1987).

This study compared the morphology of containerized black spruce (*Picea mariana* (Mill.) B.S.P.) seedlings grown in fertilized and non-fertilized worm-casting-amended media to seedlings grown in anon-amended fertilized peat-vermiculite mix. The comparison was made to determine if various media amended with castings could produce seedlings equivalent to those produced using a standard nursery growing medium.

Material and Methods

Black spruce seeds from northern Ontario site region 3E (Hills 1960) were sown in 12 Fh 408 Japanese Paperpot® trays and germinated in a greenhouse at the Ontario Ministry of Natural Resources Provincial Forest Tree Nursery at Swastika (Lat. N 48° 06', Long. W 80° 06') on May 25, 1982.

The growing media consisted of a standard peat-vermiculite mix (3:1 by volume) amended as shown (table 1). In addition to a non-amended control treatment, there were two amendments using pig manure castings (10% and 30% by volume) and three amendments using sewage sludge castings (10%, 30%, and 50% by volume). Castings were obtained from Shamrock Industries (Norwich, Ontario).

Seedlings were grown under 2 fertilization regimes. One group was fertilized according to a normal production schedule. Under this schedule, seedlings were fertilized once with 75 ppm nitrogen (10:52:10, N:P:K, Plant Products Co. Ltd.) when the primary needles emerged and 150 ppm nitrogen (20:8:20 N:P:K, Plant Products Co., Ltd.) with every subsequent watering. The second group of seedlings was not fertilized during the trial. However, these seedlings were accidentally fertilized with 75 ppm nitrogen (10:52:10 N:P:K) once at the start of the trial. In total, the 2 levels of fertilization and the 6 media types accounted for 12 treatments, one paperpot tray per treatment. Seedlings grown with various worm casting amendments (table 1) were contrasted with each other and treatment FN, which represented normal production seedlings grown operationally in non-amended peat-vermiculite media and fertilized on demand according to a normal production schedule.

Table 1—*Chemical analyses of worm-casting-amended peat–vermiculite (3:1 by volume) nursery mixes*

Treatment	Code	Total %N	Inorganic nutrients (ppm) P	K	Ca	Mg
Unfertilized						
Control (mix only)	NFN	.433	105	445	3,875	1,884
Pig manure castings						
10%	NFP_{10}	.577	402	433	5,413	936
30%	NFP_{30}	.950	744	640	8,318	986
Sewage sludge castings						
10%	NFS_{10}	.795	569	498	7,963	1,142
30%	NFS_{30}	1.548	715	728	11,160	1,113
50%	NFS_{50}	1.465	984	855	12,528	1,088
Fertilized						
Control (mix only)	FN	.488	303	820	2,875	1,294
Pig manure castings						
10%	FP_{10}	.933	569	896	5,400	904
30%	FP_{30}	1.070	919	995	9,388	974
Sewage sludge castings						
10%	FS_{10}	.865	766	825	7,595	1,025
30%	FS_{30}	1.300	1,141	1,033	10,913	1,066
50%	FS_{50}	1.660	1,238	1,123	12,368	1,046

The trial was carried out in an operational greenhouse. The 6 treatments were randomized within the two fertilization regimes, but the two fertilization treatments were separated in the greenhouse. Although the treatments and seedlings within treatments were not completely randomized, it was felt that the partially randomized design was acceptable given the high degree of uniformity in growing conditions throughout the greenhouse.

Seedlings were moved outside in preparation for overwintering on August 5th, about 10 weeks after sowing. At that time 125 seedlings were randomly sampled from about 290 seedlings in each treatment: 100 seedlings were used for morphological assessments (shoot length, root collar diameter, root dry weight, shoot dry weight, and total dry weight), and 25 seedlings were bulked for foliar nutrient analysis. Total foliar nitrogen was determined by the Kjeldahl method (Black 1965). Total phosphorous was determined colorimetrically using ammonium (meta) vanadate and the cations were analyzed by atomic absorption spectrophotometry after wet digestion of the foliar sample (Black 1965). The growing media were analyzed for percentage organic matter (Kalra and Maynard 1991: 27-30), percentage nitrogen using the Kjeldahl method (Black 1965), extractable phosphorous. Kalra and Maynard 1991: 74-77), and exchangeable K, Ca, and Mg using neutral normal ammonium acetate (Kalra and Maynard 1991: 84-85).

The trial was analyzed as a completely randomized design. Each seedling was treated as a replication.

Morphological data were analyzed by a one-way ANOVA after a logarithmic transformation (log x+1) to homogenize variances of shoot length, root dry weight, shoot dry weight, and total dry weight. Root collar diameters did not require transformation. All treatment means across both fertilization classes were compared by Tukey's studentized range test (HSD).

Results and Discussion

Fertilized seedlings grown in worm-casting-amended media were generally larger than non-fertilized seedlings grown in similar media. Fertilized seedlings grown in amended media had larger shoot lengths (figure 1), root collar diameters (figure 2), shoot dry weights (figure 3), and total dry weights (figure 5) than non-fertilized seedlings grown in similarly amended media. The only exception was treatment NFP_{10}, which had shoot lengths, root collar diameters, shoot dry weights, and total dry weights equal to the best of the fertilized treatments. Root dry weights (figure 4) of fertilized seedlings grown in amended media were as large as or larger than those of non-fertilized seedlings grown in sewage sludge castings but were often smaller than the root dry weights of non-fertilized seedlings grown in pig manure castings.

Seedlings that were both fertilized and grown in casting-amended media were not always the largest. The shoot lengths (figure 1) and shoot dry weights (figure 3) of fertilized seedlings grown in amended media were often smaller than the shoot lengths of

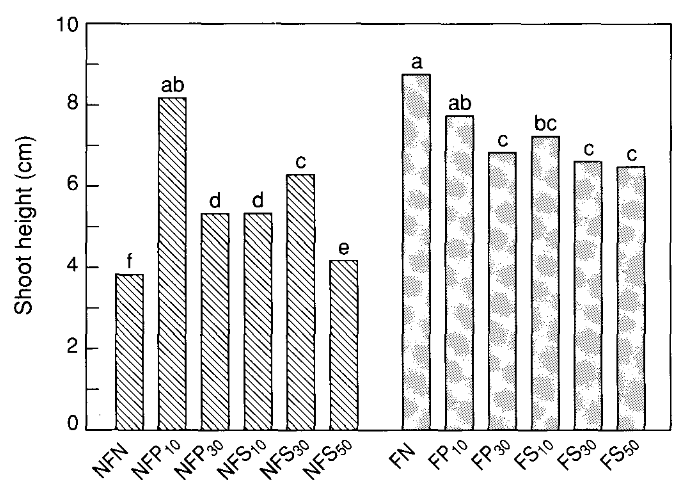

Figure 1—*Shoot heights of black spruce seedlings grown in a peat–vermiculite (3:1 by volume) nursery mix only or amended with worm castings. Bars with common letters are not significantly different* ($P \leq 0.05$).

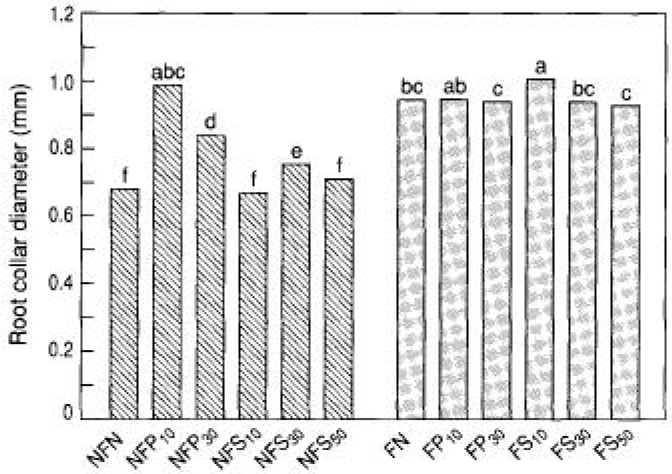

Figure 2—*Root collar diameters of black spruce seedlings grown in a peat–vermiculite (3:1 by volume) nursery mix only or amended with worm castings. Bars with common letters are not significantly different* ($P \leq 0.05$).

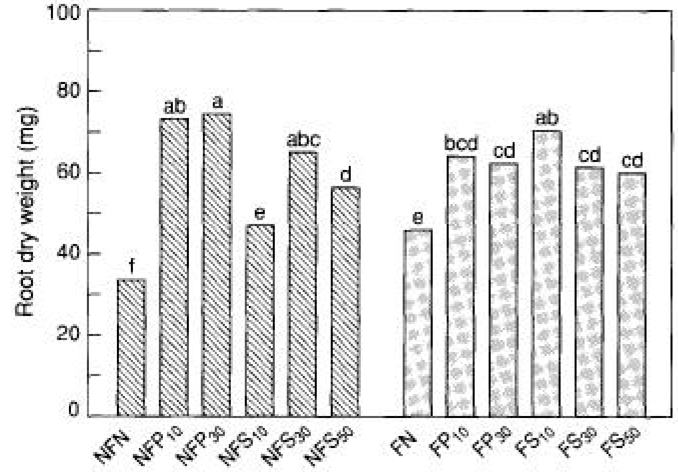

Figure 4—*Root dry weights of black spruce seedlings grown in a peat–vermiculite (3:1 by volume) nursery mix only or amended with worm castings. Bars with common letters are not significantly different* ($P \leq 0.05$).

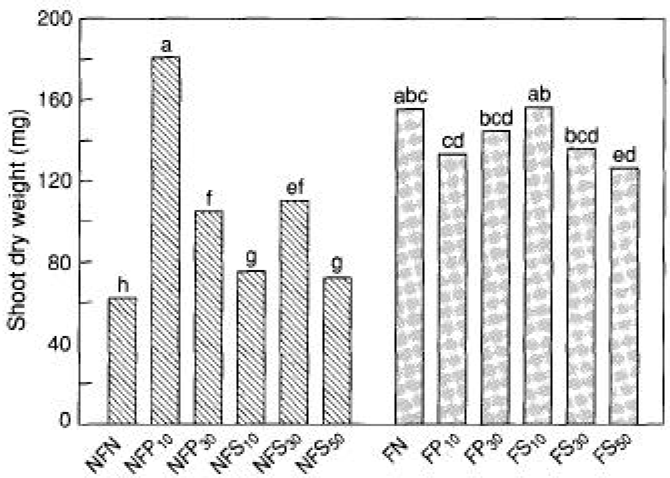

Figure 3—*Shoot dry weights of black spruce seedlings grown in a peat–vermiculite (3:1 by volume) nursery mix only or amended with worm castings. Bars with common letters are not significantly different* ($P \leq 0.05$).

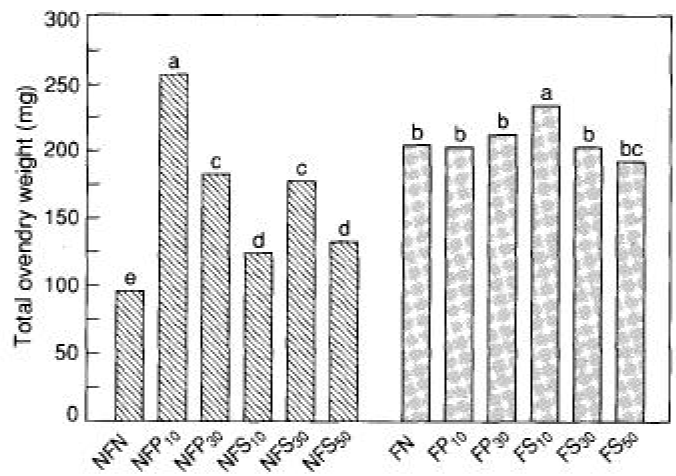

Figure 5—*Total dry weights of black spruce seedlings grown in a peat–vermiculite (3:1 by volume) nursery mix only or amended with worm castings. Bars with common letters are not significantly different* ($P \leq 0.05$).

seedlings grown in a non-amended peat-vermiculite media, treatment FN. But, the root collar diameters (figure 2), root dry weights (figure 4), and total dry weights (figure 5) of fertilized seedlings grown in amended media were as large as or larger than those of FN seedlings.

Non-fertilized seedlings grown in amended media generally did not grow as well as treatment FN, normal production seedlings; they had significantly smaller shoot lengths, root collar diameters, shoot dry weights, and total dry weights than normal production stock (figures 1-3, 5). The only exception was treatment NFP_{10}, which grew seedlings with similar shoot lengths, root collar diameters, and shoot dry weights, but significantly greater root dry weights and total dry weights than treatment FN (figures 1-5). The root dry weights (figure 4) of non-fertilized seedlings grown in amended media were equal to or significantly larger than FN seedlings.

Seedlings grown in non-fertilized pig manure castings were generally larger than seedlings grown in non-fertilized sewage sludge castings. The shoot lengths, root collar diameters, shoot dry weights, root dry weights, and total dry weights of non-fertilized seedlings grown in media amended with pig manure castings were generally as large as or significantly larger than non-fertilized seedlings grown in sewage sludge castings (figures 1-5). Fertilization reduced most of the differences in seedling growth between casting-amended media. The only exception was treatment FS_{10}, whose seedlings had shoot lengths, root collar diameters, shoot dry weights, root dry weights, and total dry weights as large as or significantly larger than fertilized seedlings grown in pig manure castings.

Increasing the percentage of castings in the media mix did not always increase seedling growth. Increasing the percentage of pig manure castings in a non-fertilized media mix reduced seedling shoot length, root collar diameter, shoot dry weight, and total dry weight (figures 1-3, 5), but did not appear to affect root dry weight (figure 4). For fertilized seedlings, increasing the percentage of pig manure castings in the media significantly decreased seedling shoot length and root collar diameter, but had no effect on shoot, root, or total dry weights (figures 1-5).

Similarly, increasing the percentage of sewage sludge castings in the media did not always increase seedling growth. Non-fertilized seedlings grown in media amended with 30% sewage sludge castings had significantly larger shoot lengths, root collar diameters, shoot, root, and total dry weights (figures 1-5) than non-fertilized seedlings grown in media amended with 10 or 50% sewage sludge castings. Within the fertilized treatments, the largest seedlings were grown in media amended with a lower percentage of sewage sludge castings. Fertilized seedlings grown in media amended with 10% sewage sludge castings had similar shoot lengths and shoot dry weights (figures 1 & 3), but had significantly larger root collar diameters, root, and total dry weights (figures 2, 4, & 5) than fertilized seedlings grown in media amended with 30 or 50% sewage sludge castings.

Analysis of the growing media (table 1) showed that the levels of N, P, and Ca were higher in casting-amended media than in the control (FN), but the levels of Mg were lower in casting-amended media than treatment FN. With the exceptions of NFS_{30} (Mg), NFS_{50} (N and Mg), and FS_{50} (Mg), levels of N, P, K, Ca, and Mg in the media generally increased with the proportion of castings in the mix (table 1). The levels of N, P, and K were generally higher, and Ca and Mg were generally lower in the fertilized treatments than the levels in the non-fertilized treatments similarly amended.

Levels of inorganic nutrients in the media alone could not explain the observed differences in seedling growth. For example, total seedling dry weight (figure 5) did not always increase with an increase in the level of inorganic nutrients. When the proportion of castings in the media increased from 10 to 30% in treatments NFP_{10} and NFP_{30}, total seedling dry weight decreased, even though the levels of N, P, K, Ca, and Mg in the media increased. There is a possibility that other substances may be present in worm castings. For example, enhanced root growth associated with the use of worm castings may be related to the presence of growth-promoting substances in castings (Grappelli *et al*. 1985).

Concentrations of foliar macroelements (table 2) were within an acceptable range for container grown seedlings (Landis 1985). Seedlings grown in casting-amended media had higher foliar concentrations of Ca than seedlings grown in non-amended media. Except for zinc, concentrations of foliar microelements (table 2) were within acceptable ranges for seedling growth (Stone 1968), although the concentrations of manganese were higher than normal Landis (1985). Foliar manganese concentrations declined in fertilized and non-fertilized seedlings grown in media containing a higher percentage of sewage sludge castings and in fertilized seedlings grown in a higher percentage of pig manure castings. Differences in foliar calcium or manganese did not appear to be related to differences in seedling growth.

In this trial, foliar zinc concentrations (240 to 300 ppm) were highest in seedlings grown in media amended with 10% pig manure and 10% sewage sludge castings and exceeded the upper critical tissue concentration of zinc (226 ppm) reported for Sitka spruce (Burton *et al*. 1983). Foliar zinc concentrations were also high in treatment NFP_{30}. Although no symptoms of toxicity were observed in this trial, seedling growth can be reduced by toxic concentrations of microelements, especially heavy metals. As foliar zinc concentrations declined when a higher percentage of castings was used, it is possible that the availability of zinc changed with the proportion of castings used in the media mix, perhaps due to differences in soil pH (Milner and Barker 1989). As heavy metals in sewage sludge are not always removed by composting (Coleman *et al*. 1987), caution should therefore be exercised in their use.

A potential advantage of a suitable amendment over a non-amended peat-vermiculite mix is that there would be no need to prepare and apply water

Table 2—*Foliar nutrient analyses of shoots of black spruce container seedlings grown in media amended with worm castings*

Treatment	Total %N	Percent inorganic nutrients							
		P	K	Ca	Mg	Mn	Fe	Zn	Cu
NFN	2.05	.249	.846	.482	.146	.101	.0120	.0173	.00133
NFP_{10}	2.29	.283	.839	.499	.136	.108	.0118	.0242	.00098
NFP_{30}	2.26	.281	.726	.776	.165	.119	.0132	.0221	.00066
NFS_{10}	2.48	.353	1.135	.752	.180	.112	.0143	.0301	.00098
NFS_{30}	1.69	.316	.996	.705	.155	.015	.0120	.0148	.00138
NFS_{50}	2.04	.289	.773	.790	.151	.012	.0199	.0141	.00137
FN	2.86	.285	972	.410	.166	.050	.0100	.0134	.00122
FP_{10}	2.90	.261	1.111	.822	.205	.129	.0164	.0306	.00129
FP_{30}	2.31	.361	.896	.701	.145	.052	.0154	.0156	.00130
FS_{10}	2.26	.298	.947	.661	.177	.094	.0215	.0246	.00095
FS_{30}	2.25	.297	.831	.697	.153	.015	.0136	.0136	.00101
FS_{50}	2.32	.260	.850	.833	.154	.009	.0128	.0116	.00097

soluble fertilizers. However, a potential disadvantage is that there is a loss of ability to manage crop growth by decreasing fertilizer rates once a soil amendment has been made. To be a feasible alternative, worm-casting amendments must produce superior seedlings at comparable cost when compared to normal seedling production practices. The root growth simulating properties of worm-castings potentially may offer a means of producing superior seedlings. These results indicate that further work is needed to determine whether a beneficial worm-casting medium amendment exists for tree seedling production.

Summary

Trial results can be summarized as follows:

1. Non-fertilized seedlings grown in media amended with 10% pig manure castings (NFP_{10}) had the best growth of any treatment.
2. Except for treatment NFP_{10}, fertilized treatments grew larger seedlings than non-fertilized treatments.
3. Fertilization reduced differences in seedling growth between casting-amended and non amended treatments.
4. Within the fertilized treatments, media amended with 10% sewage sludge castings (FS_{10}) grew the largest seedlings.
5. All casting-amended treatments enhanced root growth.

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