Northeastern Forest and Conservation Nursery Association Meeting

Grand Rapids, Michigan

July 20 to 23, 2009

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Effects of Pine Sawdust, Hardwood Sawdust, and Peat on Bareroot Soil Properties

Paul Koll, Martin F Jurgensen, R Kasten Dumroese

Paul Koll is Nursery Forester at USDA Forest Service JW Toumey Nursery, Old US Highway 2 East, Watersmeet, MI 49969; Tel: 906.358.4523; E-mail: pkoll@fs.fed.us. **Martin F Jurgensen** is a Professor with the School of Forest Resources and Environmental Science, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931. **Kas Dumroese** is the National Nursery Specialist with the USDA Forest Service, Rocky Mountain Research Station, 1221 South Main Street, Moscow, ID 83843; Tel: 208.883.2324; E-mail: kdumroese@fs.fed.us.

Koll P, Jurgensen MF, Dumroese RK. 2010. Effects of pine sawdust, hardwood sawdust, and peat on bareroot soil properties. In: Riley LE, Pinto JR, Dumroese RK, technical coordinators. National Proceedings: Forest and Conservation Nursery Associations—2009. Proc. RMRS-P-62. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station: 69-73. Online:http://www.fs.fed.us/rm/pubs/rmrs_p062.html.

Abstract: We investigated the effects of three organic amendments on soil properties and seedling growth at the USDA Forest Service JW Toumey Nursery in Watersmeet, MI. Pine sawdust (red pine, *Pinus resinosa*), hardwood sawdust (maple [*Acer* spp.] and aspen [*Populus* spp.]), and peat were individually incorporated into a loamy sand nursery soil in August 2006, and soil properties were sampled periodically for the next 14 months. Red, jack (*Pinus banksiana*), and white pine (*Pinus strobus*) were sown into test plots in June 2007 and sampled for growth responses at the end of the growing season. We hypothesized that pine sawdust and peat could be used as satisfactory soil amendments to improve soil conditions and reduce costs when compared to hardwood sawdust in bareroot nursery soils.

The addition of peat and pine sawdust increased soil organic matter above control soil conditions after 14 months. Hardwood sawdust-amended soils did not differ from control soils after the same time period. High nitrogen (N) concentrations in peat increased total soil N over the other treatments. We are currently analyzing seedling growth data; our preliminary observations suggest that addition of peat as a soil amendment enhanced soil properties, but no amendments increased 1-year seedling growth over control soils.

Keywords: soil amendments, bareroot nursery, organic matter, soil fertility

Introduction

Organic amendments are commonly used to improve bareroot nursery soil conditions for increased seedling growth. Few studies, however, have compared the effects of organic amendments on soil conditions, and even fewer have compared subsequent effects on seedling growth. Declining availability and increased cost of conventional soil amendments, such as sawdust, have prompted a search for alternate sources of organic matter (OM) (Munson 1983; May and Gilmore 1985). For example, the USDA Forest Service J Herbert Stone Nursery in Central Point, OR explored the use of yard wastes as a soil amendment due to the rising cost of sawdust and the necessary supplemental N fertilization (Riley and Steinfeld 2005). The USDA Forest Service JW Toumey Nursery, located in northern Michigan, has been using hardwood sawdust of various species as an organic amendment for more than 25 years. This sawdust was readily available from many local sawmills at little or no cost. However, with the closing of several small local mills and the demand from wood pellet companies for wood residues, sawdust prices have increased significantly (Holland 2008). In 2008, 20 tonnes (22 tons), or approximately 50 to 61 m^3 (65 to 80 yd^3) of hardwood sawdust delivered to Toumey Nursery cost nearly US$ 1350, as compared to US$ 300 in 2005 (Makuck 2008). The nursery uses around 765 m^3 (1000 yd^3) of sawdust each year. This recent increase in the cost of hardwood sawdust will increase growing costs by an estimated US$ 16,900 annually (Moilenen 2008).

Pine sawdust is much more abundant locally and lower in cost. Many bareroot nurseries have used pine sawdust with success; Toumey Nursery, however, has not used it in the past due to its generally higher carbon to nitrogen ratio (C:N) and lower pH (Williams and Hanks 1976; Follett and others 1981; Rose and others 1995). Peat has also not been used as a soil amendment at Toumey Nursery, although the nursery is uniquely located where peat can be acquired locally at a minimal cost. In the 1940s, large amounts of peat were mined from bogs to the east of the nursery, and have remained untouched in piles since then. Nursery personnel, however, were worried about the impact of acidic peat on soil pH. This study examined the effects of using hardwood sawdust, pine sawdust, and peat as organic amendments on: 1) soil physical and chemical properties; and 2) the growth response of three bareroot species commonly grown at Toumey Nursery—jack pine (*Pinus banksiana*), red pine (*P. resinosa*), and white pine (*P. strobus*).

Materials and Methods

Study Site

The study was conducted on the USDA Forest Service JW Toumey Nursery in Watersmeet, MI (T45N R39W Sec. 27 [46.2719 N, 89.1709 W]). The nursery soil is a Pence-Vilas loamy sand (NRCS 2008), and has supported rigorous seedling cultivation for more than 70 years. Production consists largely of conifer species, such as jack, red, and white pine seedlings; however, many other conifer and hardwood species are also grown. Most seedlings are grown on a 4-year rotation, consisting of three growing seasons and 1 year for soil organic amendments and soil fumigation. Jack pine is grown on a 3-year cycle. Hardwood sawdust has been used as the primary organic amendment for the past 25 years.

Organic Amendments

Three organic amendment treatments, pine sawdust, hardwood sawdust, peat, and a non-amended control were used in this study. Specific information on the source of the hardwood sawdust was not obtainable, but nursery personnel indicated that mills cutting sugar maple (*Acer saccharum*), red maple (*A. rubrum*), quaking aspen (*Populus tremuloides*), and big-toothed aspen (*P. grandidentata*) were the likely sources. Pine sawdust, composed solely of red pine, was supplied by Triple L Lumber, a small mill in Marengo, WI. Peat was mined from a bog on the nursery property, piled, and aged about 60 years. Each amendment was analyzed by the USDA Forest Service Rocky Mountain Research Station Laboratory (Moscow, ID) for carbon (C) and nitrogen (N). Toumey Nursery normally adds a 2.5-cm (1-in) deep layer of hardwood sawdust to each bed 1 year before seeds are sown (every 3 to 4 years). Using a series of 0.3-m^2 (3-ft^2) collection boxes in fields outside the study area, the hardwood sawdust application rate, in concert with its C analysis, was converted to total C applied. Once the C content of hardwood sawdust, as applied, was determined, the quantities of pine sawdust and peat needed to add similar amounts of C were calculated and applied accordingly. All applications were checked in the field using the same collection boxes to determine the applied amounts, and a second application was used to refine applications. All three amendments were added to each plot on 3 August 2006 (Table 1).

Table 1. Carbon and nitrogen application rates in organic amendments added to bareroot nursery beds at Toumey Nursery in August 2006. All values in kg/ha.

	Conifer Sawdust	Hardwood Sawdust	Peat
	kg/ha Carbon*		
Application Rate	17126	15166	15572
% of Desired	110%	97%	100%
Actual Nitrogen Rate	26.2	53.6	584.9

* 1 kg/ha = 0.89 lb/ac

Results and Discussion

Organic Matter and Carbon

Peat was the most effective organic amendment for increasing soil organic matter (SOM) (Figure 1). Adding peat to the nursery soil increased the SOM by 27% over the control after 14 months. Munson (1983) also reported an increase in SOM of 40% after 18 months in a Florida nursery with a similar peat application rate. In contrast, 2 years after amending soils with nearly twice as much peat moss as applied in this study, Mexal and Fisher (1987) did not find any significant SOM differences in New Mexico. Mined peat may have lower nutrient concentrations than the commercial peat moss used by Mexal and Fisher, and may have slowed decomposition in this study. Although long-term effects of peat on SOM have yet to be studied in bareroot nursery applications, it has a greater potential to persist than most other forms of OM amendments added to bareroot nursery soils (May and Gilmore 1985).

Application of red pine sawdust raised SOM concentration by 21% over the control after 14 months, which was similar to results reported by Munson (1983). Mexal and Fisher (1987), however, found no significant

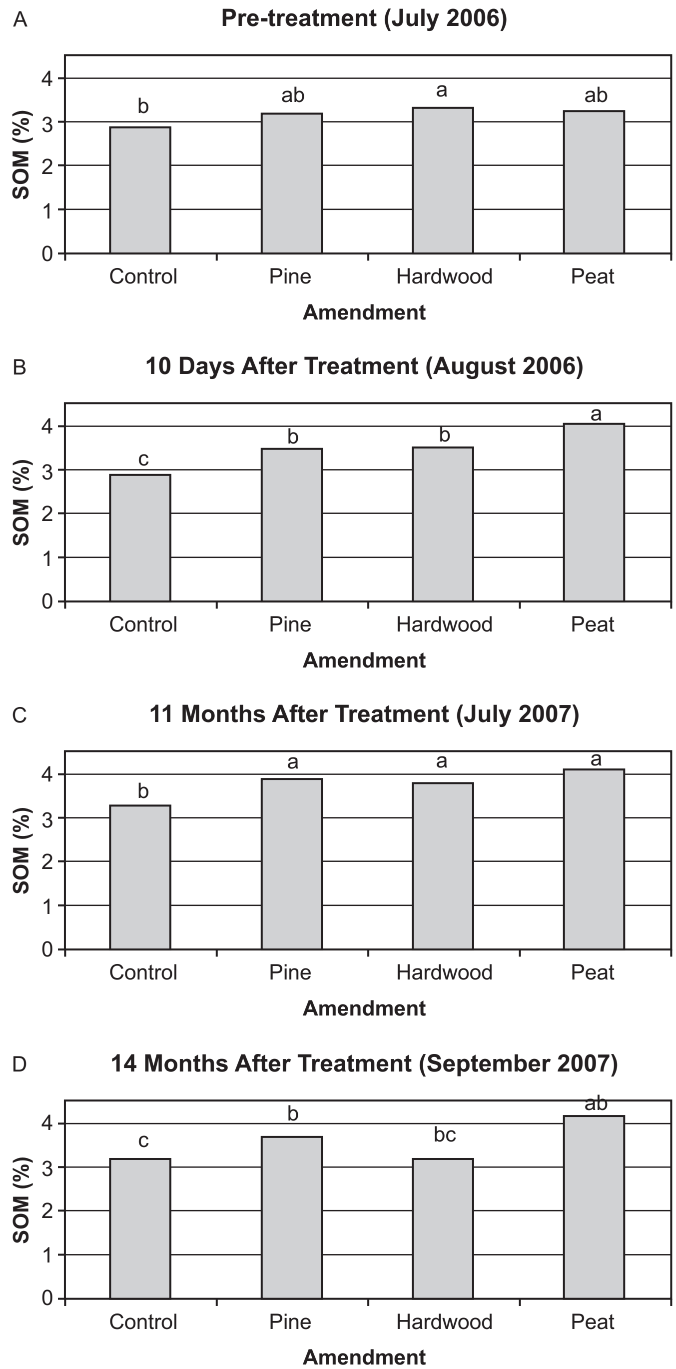

Figure 1. Differences in SOM concentration among control soil and soils amended with red pine sawdust, hardwood sawdust, and peat. (Lowercase letters represent significant differences at $P < 0.05$); A) $P = 0.0346$; B) $P < 0.0001$; C) $P = 0.0003$; and D) $P < 0.0001$.)

difference in SOM 2 years after applying pine sawdust. May and Gilmore (1985) found it took nearly five times as much pine sawdust, applied over a 6-year period, to achieve similar rates of increase in SOM as achieved in this study. Larger increases may have been observed earlier in their study, but sawdust can decompose quickly, and no earlier results were presented. Even though sawdusts have a high C:N, their low lignin concentrations can allow for rapid decomposition (Davey 1984; Mexal and Fisher 1987).

Although Starbuck (1994) reported a 95% increase in SOM after amending soil with hardwood sawdust, the hardwood sawdust used in this study did not increase SOM content. Hardwood sawdust decomposes more rapidly than conifer sawdust due to its lower C:N. The short duration of Starbuck's study may explain the contradictory findings to this study, but further study is needed to support this hypothesis.

Williams and Hanks (1976) and Gulde and others (2007) indicated that soils may have an equilibrium SOM level, or a C saturation point, above which higher values cannot be maintained. This study was conducted on a sandy Pence-Vilas Complex soil, which normally contains between 0.5% and 3% SOM (NRCS 2008). Pre-treatment SOM levels were near 3%, and exceeded 4% in peat-amended soils after 14 months. The minimal response of SOM in these amended soils could be due to a C saturation point, although the actual level of this property in these soils requires further analysis.

Total Soil Nitrogen

Peat-amended soils had higher concentrations of total N than the other treatments (Figure 2). Total N concentrations in soils amended with either hardwood or pine sawdust were not significantly different from the control soils. No other nursery studies were found that investigated the effect of sawdust additions on total soil N. Mexal and Fisher (1987) did find available soil N was rapidly depleted in sawdust-amended plots. Sawdust of any species is not recommended as an OM amendment due to its immobilization of soil N (Allison and Anderson 1951; Davey 1965; Armson and Sandreika 1974; Williams and Hanks 1976; Abd-el-malek and others 1979; Cogger 2005). When low lignin, high C:N sawdust is consumed by soil microbes, available soil N is immobilized, which may result in growth-limiting N deficiencies. This loss of available N can begin as quickly as 40 days after application of sawdust with high C:N, or may take up to 160 days from sawdust with lower C:N. These N deficiencies can persist from 1 to 4 years or longer with high rates of sawdust application (Roberts and Stephenson 1948; Allison 1973). Consequently, large quantities of additional N are necessary with sawdust to offset this immobilization. Allison and Clover (1959) recommend adding N to sawdust until the N concentrations reach 0.75% to 1%. Although 141 kg/ha (126 lb/ac) of N (as $21N{:}0P_2O_5{:}0K_2O$) was added to the OM amendments in this study as part of the nursery routine fertilization program, amendment N concentrations (amendment + fertilizer) did not reach the recommended concentration of Allison and Clover (1959) (pine sawdust 0.4%, hardwood sawdust 0.6%, and peat 1.0%). Even using that conservative recommendation, the N fertilization rate used in this study was likely not high enough to offset N immobilization by sawdust.

Soil pH

Soil pH decreased significantly in all treatments from a maximum of 5.3 to a minimum of 4.6 over the study duration. These values are still within the acceptable range for jack, red, or white pine growth. Follett and others (1981) and May and Gilmore (1984) also reported slight, but not specified, reductions in soil pH after addition of sawdust and peat. In contrast, Mexal and Fisher (1987) found no significant change in soil acidity, and speculated this was due to high levels of calcium carbonate buffering the pH of their study soils.

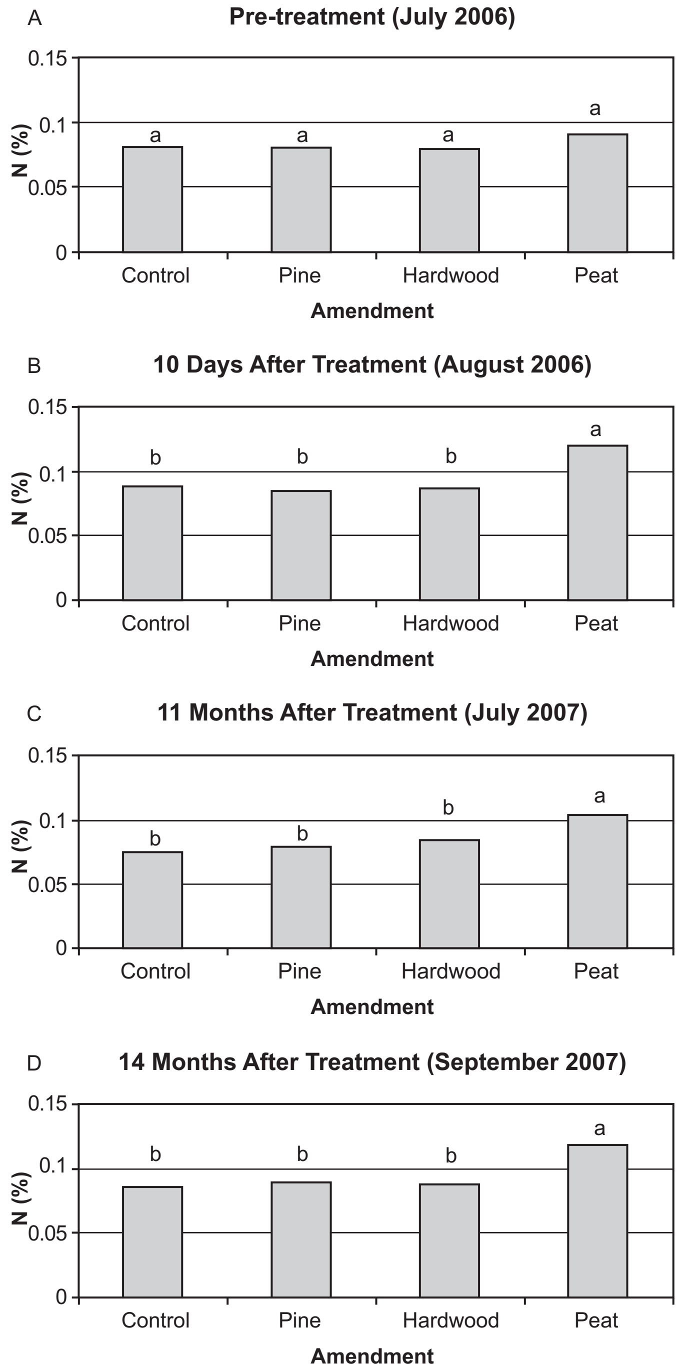

Figure 2. Differences in total soil N concentration among control soil and soils amended with red pine sawdust, hardwood sawdust, and peat. (Lowercase letters represent significant differences at $P < 0.05$); A) $P = 0.274$; B) $P < 0.0001$; C) $P < 0.0001$; and D) $P < 0.0001$.)

Matric Potential and Available Water

It is often stated that high levels of OM in nursery soil will increase soil water-holding potential (Bollen 1969; Allison 1973; Rose and others 1995; Christopher 1996; Jacobs and others 2003; Cogger 2005; Riley and Steinfeld 2005). The results of this study indicated that addition of peat increased soil matric potential and available water after 14 months, but not with either red pine or hardwood sawdust (Figure 3). No other studies were found reporting specific results of the effects of soil amendments on matric potential or available water.

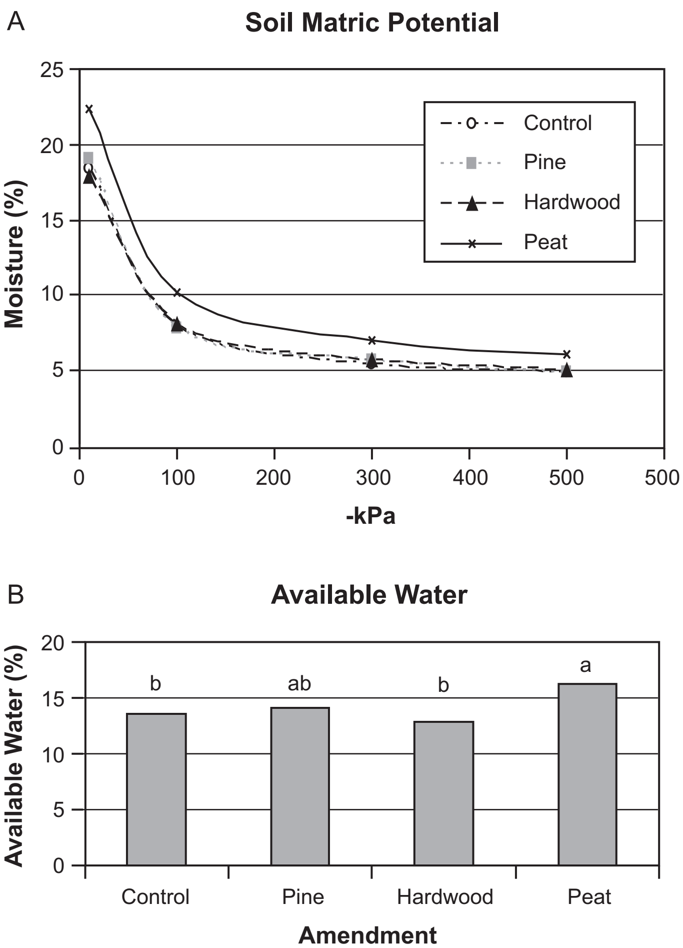

Figure 3: Matric potential (A) and available water (B) 14 months after amending soil with nothing (control), pine sawdust, hardwood sawdust, and peat. (Lowercase letters represent significant differences at $P < 0.05$); A) -10 kPa, $P = 0.006$; -100 kPa, $P = 0.002$; -300 kPa, $P = 0.01$; and -500 kPa, $P = 0.004$; and B) $P = 0.01$.)

Seedling Response: Preliminary Observations

We are in the process of analyzing our seedling data. We noted some differences in growth, and it will be interesting to see if these differences will be significant. Growers may, however, find our preliminary observations interesting. First, even though pine seedlings in this study appeared to grow poorer in soils amended with red pine sawdust and hardwood sawdust as compared to seedlings grown in control soil, sawdust-amended soils contained similar amounts of total soil N as the control, and seedling N concentrations were within normal and acceptable ranges for each species (Armson and Sandreika 1974). The potential immobilization of soil nitrogen by sawdust may be responsible for this difference in growth. Starbuck (1994) found similar reductions in *Forsythia* spp. height growth after the addition of oak sawdust. May and Gilmore (1985) observed, but did not quantify, reduced growth after soil was amended with pine sawdust. In contrast, no growth differences were found when Mexal and Fisher (1987) added conifer sawdust or peat moss to nursery beds where ponderosa pine (*Pinus ponderosa*) seedlings were grown. That study indicated that the depletion of soil available N in sawdust-amended plots may have reduced seedling growth, but the results were not significant. As discussed earlier, addition of sawdust lowers the amount of available soil N, which can reduce seedling growth. In future studies of this nature, available soil N data should be collected.

Seedlings grown in soils amended with peat appeared to grow taller with larger stem diameters than those grown in soils amended with either hardwood or pine sawdust. This could be because the peat amendment added large quantities of N to the soil. Similarly, the low C:N and high lignin content of peat does not create available soil N deficiencies from immobilization as can occur with sawdust treatments. As seedling N demand increases with age, it is expected that seedlings in the peat-amended soil will outperform those in the non-amended soil, as suggested in other studies (for example, Bollen 1969; Allison 1973; Armson and Sandreika 1974; Riley and Steinfeld 2005). Jacobs and others (2003) reported an increase in Douglas-fir (*Pseudotsuga menziesii*) seedling height and stem diameter over control seedlings when applying peat supplemented with pumice, perlite, vermiculite, and coconut fiber. The nutrient concentration of such a peat mixture may have been beneficial to seedling growth. Mexal and Fisher (1987) found no significant growth differences between ponderosa pine seedlings grown in soils amended with peat moss, sawdust, and the control. Again, this result may be related to the higher nutrient content and quicker decomposition rate of commercial peat moss.

Conclusions

The results of this 14-month study at the USDA Forest Service JW Toumey Nursery on the effects of three organic amendments on soil properties and conifer seedling response showed that the addition of peat and pine sawdust increased SOM above an untreated control soil. The addition of hardwood sawdust did not, however, result in any change in SOM concentration. Total soil N concentration, matric potential, and available water-holding capacity increased in the peat-amended soil, but not in soils where sawdust was added. Other chemical and physical properties were generally similar across the three organic-amended and control soils after 14 months. Seedlings appeared to grow tallest and have the largest stem diameter, and obtained the greatest biomass in soil amended with peat as compared to either sawdust treatment. Seedlings grown in the control soil were, however, as large as seedlings grown with peat additions, which may be a reflection on the low available N requirements of 1+0 seedlings or the lack of N immobilization.

References

Abd-el-Malek Y, Monib M, Hosny I, Girgis SA. 1979. Effect of organic matter supplementation on nitrogen transformations in soils. I. Chemical and bacteriological changes. Zentralbl Bakteriol Naturwiss 134:209-216.

Allison FE. 1973. Soil organic matter and its role in crop production. New York (NY): Elsevier Scientific.

Allison FE, Clover RG. 1959. Rates of decomposition of shortleaf pine sawdust in soil at various levels of nitrogen and lime. Soil Science 89:194-201.

Allison FE, Anderson MS. 1951. The use of sawdust for mulches and soil improvement. Washington (DC): USDA Agricultural Research Administration. Circular 891. p 1-19.

Armson KA, Sandreika V. 1974. Forest tree soil management and related practices. Toronto (Ontario): Ontario Ministry of Natural Resources, Public Service Centre. 179 p.

Bollen WB. 1969. Properties of tree barks in relation to their agricultural utilization. Portland (OR): USDA Forest Service, Pacific Northwest Forest and Range Experiment Station. Research Paper PNW-77. 36 p.

Christopher TBS. 1996. Stabilizing effect of organic matter. URL: http://www.agri.upm.edu.my/~chris/as/om_stable.html (accessed 28 Mar 2008).

Cogger C. 2005. Home gardener's guide to soils and fertilizers. Pullman (WA): Washington State University. URL: http://www.ci.olympia.wa.us/~/media/Files/PublicWorks/PDFs/WaterResources/Guideto-Soils-and-Fertilizers.ashx (accessed 1 Dec 2009).

Davey CB. 1965. Functions and management of organic matter in forest nursery soil. In: Leaf AL, editor. Proceedings nursery soil improvement sessions; 1965 Jan 25-28; Syracuse, New York. Syracuse (NY): State University College of Forestry at Syracuse University, Department of Silviculture.

Davey CB. 1984. Nursery soil organic matter: management and importance. In: Duryea ML, Landis TD, editors. Forest nursery manual: production of bareroot seedlings. Boston (MA): Martinus Nijhoff/Dr W Junk Publishers. p 81-86.

Follett RH, Murphy LS, Donahue RL. 1981. Fertilizers and soil amendments. Englewood Cliffs (NJ): Prentice Hall, Incorporated.

Gulde S, Chung H, Amelung W, Chang C, Six J. 2007. Soil carbon saturation controls labile and stable carbon pool dynamics. Soil Science Society of America Journal 72:605-612.

Holland A. 2008. Personal communication. Watersmeet (MI): USDA Forest Service JW Toumey Nursery, Manager.

Jacobs DF, Rose R, Haase DL, Morgan PD. 2003. Influence of nursery soil amendments on water relations, root architectural development, and field performance of Douglas-fir transplants. New Forests 26:263-277.

May JT, Gilmore AR. 1985. Continuous cropping at the Stauffer Nursery in Alabama. In: South DB, editor. Proceedings, international symposium on nursery management practices for the southern pines; 1985 Aug 4-9; Montgomery, AL. Auburn University (AL): Alabama Agricultural Experiment Station. p 213-243.

Makuck C. 2008. Personal communication. Watersmeet (MI): USDA Forest Service JW Toumey Nursery, Nursery Forester.

Mexal JG, Fisher JT. 1987. Organic matter amendments to a calcareous forest nursery soil. New Forests 4:311-323.

Moilenen R. 2008. Personal communication. Watersmeet (MI): USDA Forest Service JW Toumey Nursery, Field Manager.

Munson KR. 1983. Decomposition and effect on pH of various organic soil amendments. In: Brissette J, Lantz C, compilers. Proceedings: 1982 Southern Nursery Conferences. Atlanta (GA): USDA Forest Service. Technical Publication R8-TP4.

[NRCS] Natural Resources Conservation Service. 2008. Web soil survey. URL: http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx (accessed 27 Mar 2008).

Paustain K, Parton WF, Persson J. 1992. Modeling soil organic matter in organic-amended and nitrogen-fertilized long-term plots. Soil Science Society of America Journal 56:476-488.

Riley LE, Steinfeld D. 2005. Effects of bareroot nursery practices on tree seedling root development: an evolution of cultural practices at J Herbert Stone Nursery. New Forests 30:107-126.

Roberts AN, Stephenson RE. 1948. Sawdust and other wood wastes as mulches for horticultural crops. Corvallis (OR): Oregon State Horticultural Society Proceedings. Annual Report 40. p 28-35.

Rose R, Haase D, Boyer D. 1995. Organic matter management in forest nurseries: theory and practices. Corvallis (OR): Oregon State University, Nursery Technology Cooperative. p 20-24.

Starbuck C. 1994. Applying research in forestry. Report 6. Using sawdust as a soil amendment. Jefferson City (MO): Missouri Department of Conservation. p 4.

Williams RD, Hanks SH. 1976. (slightly revised 1994) Hardwood nursery guide. Washington (DC): USDA Forest Service. Agriculture Handbook 473. p 5.

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