Organic Matter Amendment of Fallow Forest Tree Seedling Nursery Soils Influences Soil Properties and Biomass of a Sorghum Cover Crop

REFEREED PAPER

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Abstract

To maintain adequate soil organic matter, bareroot nurseries may add organic amendments, grow and incorporate cover crops between seedling production cycles, or both. We examined the influence of amendment of nursery soils with organic materials on both soil properties and biomass production of a sorghum (*Sorghum* spp.) cover crop. Level of organic matter, pH, cation exchange capacity, and concentrations of P, K, Ca, and Mg were all significantly influenced by application of chicken manure, sawdust, compost, or leaves. Above-ground biomass of the sorghum cover crop was highest with application of chicken manure at 8,700 kg ha^{-1} (7,670 lb ac^{-1}) together with sawdust at 12,000 kg ha^{-1} (10,580 lb ac^{-1}). We observed a negative influence of sawdust on sorghum biomass production, illustrating the importance of maintaining adequate C:N ratios. Our results suggest that integrating a combination of soil amendments and cover crops could potentially increase long-term organic matter levels, helping to sustain nursery soil productivity.

Introduction

The majority of hardwood seedlings produced in the central hardwood forest region of the United States are grown as bareroot stocktypes. Effective management of nursery soils can be a major influence on seedling quality. Whereas residual roots and other plant material of most agronomic crops are often incorporated into soil after harvest, bareroot forest tree seedling production results in removal of the entire plant, which can deplete soil organic matter. Organic matter influences soil chemical and physical properties, and incorporation of organic matter may benefit these properties and improve forest tree seedling growth (Rose and others 1995; Davis and others 2006).

To manage soil organic matter levels, bareroot seedling nurseries often grow annual cover crops in rotation with seedling crops (Williams and Hanks 1976; Davey 1984). While there are potential short-term benefits associated with using cover crops (Williams and Hanks 1976), their use may decrease soil organic matter over time (South and Davey 1983) because of their rapid decomposition. Therefore, most hardwood nurseries use cover crops in association with other organic amendments to supplement soil organic matter (Williams and Hanks 1976). Peat moss, tree bark, sawdust, various forms of manure, and compost all have been used as organic matter amendments in seedling nurseries (Williams and Hanks 1976; Iyer and Benson 1981; Rose and others 1995; Davis and others 2006).

It is recognized that adequate organic matter management in bareroot hardwood tree seedling nurseries is a critical component in ensuring production of high-quality seedlings. Therefore, it is likely necessary to increase soil organic matter for a longer term by coupling soil amendments with use of cover crops. Despite the importance of soil amendments and cover crops (as well as potential interactive effects) in bareroot hardwood seedling nursery production, little research has been conducted in this area. Thus, the objectives of this study were to determine the influence of organic soil amendments on soil chemistry and to assess the contribution of those amendments to biomass production of a sorghum cover crop grown as green manure in bareroot hardwood seedling nursery soils.

Materials and Methods

This study was established at the Indiana Department of Natural Resources Division of Forestry Vallonia Nursery near Vallonia, IN (38º 85 N., 86º 10 W.). An overview of cultural practices for nursery production of hardwood species in this region can be found in Jacobs (2003). The soil in the experimental nursery beds is a Bloomfield-Alvin complex with a 1 to 6 percent slope and a loamy sand texture (Nagel 1990). Taxonomically, Bloomfield soils are sandy, mixed, mesic Psammentic Hapludalfs, and Alvin soils are coarse-loamy, mixed, mesic Typic Hapludalfs (Nagel 1990). Clay mineralogy is mixed and of Eolian deposits. Currently, this nursery uses a 1-yr corn (Zea spp.) or sorghum (*Sorghum* spp.) cover crop following a 2-yr tree crop cycle, which is then incorporated into the soil 2 to 8 mo prior to sowing the next seedling crop.

Chicken manure (CM), containing no bedding and having undergone thermophilic decomposition, was obtained from a poultry farm near the nursery. Hardwood sawdust (S) was obtained from a nearby sawmill. Compost (Cp), consisting of ground leaves, trees, and lawn trimmings from a municipal collection service, was obtained from a nearby city; materials had been composted for at least 2 yr at the time of incorporation into the study. Leaves (Lv) were obtained from the same source but had not undergone thermophilic decomposition. CM was applied by itself at a rate of 1,450 kg ha $^{-1}$ (1,275 lb ac $^{-1}$) (CM4) and together with 12,000 kg ha $^{-1}$ (10,580 lb ac $^{-1}$) sawdust at rates of 4,350 kg ha $^{-1}$ (3,840 lb ac $^{-1}$) (CM12S) and 8,700 kg ha $^{-1}$ (7,670 lb ac $^{-1}$) (CM24S). Both Cp and Lv were applied at a rate of 200 m ^{3} ha $^{-1}$ (2,825 ft ^{3} ac $^{-1}$). In addition to the aforementioned treatments, an unamended control was included in the study.

This study was established as a randomized complete block design with five soil amendment treatments and the control plots, replicated three times. Each row of sorghum was a treatment, and each set of six rows formed a block. Soil amendment materials were applied to the nursery beds on 5 May 2003. On 6 May 2003, CM, S, Cp, and Lv were incorporated to an approximate uniform depth of 7.5 cm (3 in) with a disked bed former. Sorghum was sown at a uniform rate of 1.12 kg ha $^{-1}$ (1 lb ac $^{-1}$) into all nursery beds following incorporation of soil amendments.

Soil samples were collected immediately following incorporation of soil amendments. A&L Great Lakes Laboratories, Inc. (Ft. Wayne, IN), analyzed soil amendments and amended soils (tables 1 and 2) according to standard analytical protocols. Percent organic matter, cation exchange capacity (CEC), soil pH, and P, K, Mg, and Ca (parts per million, ppm) were determined for the soil samples. Available P was determined according to Bray and Kurtz

Table 1. Composition of chicken manure, compost, and leaves prior to incorporation into study plots.

Property	Chicken manure	Compost Compost	Leaves
Moisture content (%)	15.68	52.25	32.01
pH	8.60	8.20	6.80
N (%)	3.93	1.39	0.83
P (%)	2.08	0.21	0.08
PO_4^{3} (%)	4.78	0.48	0.19
K (%)	3.39	0.30	0.17
K_2CO_3 (%)	4.07	0.36	0.20
S (%)	0.58	0.18	0.09
Mg (%)	0.80	1.98	0.27
Ca (%)	13.31	8.24	2.27
Na (%)	0.68	0.01	0.01
Fe (%)	0.24	0.74	0.14
Al (%)	0.10	0.49	0.11
B (ppm)	45	36	32
Cu (ppm)	165	48	9
Mn (ppm)	538	433	136
Zn (ppm)	573	165	80
Soluble salt (dS m $^{-1}$)	10.62	0.69	0.57
(dS ft $^{-1}$)	3.24	0.21	0.17
Ash (%)	45.85	55.83	15.81
Organic matter (%)	54.15	44.17	52.18
C (%)	27.08	22.09	26.09
C:N	7:1	16:1	32:2

Table 2. Composition of sawdust before incorporation into study plots.

Property	Value
Moisture content (%)	60.0
Organic matter (%)	99.7
pH	6.7
Cation exchange capacity (meq 100 g^{-1})	1.4
Cation exchange capacity (meq oz^{-1})	0.4
P (ppm)	1.0
K (ppm)	114.0
Mg (ppm)	40.0
Ca (ppm)	150.0
C (%)	57.8
C:N	239:1

(1945), and cations were determined from extracted aliquots by atomic absorption. Total N is reported for the soil amendments.

On 3 August 2003, the aboveground portions of 20 sorghum plants were randomly selected for harvest within each treatment replication. Stems were harvested at ground level and were not collected within 0.3 m (1 ft) of the plot boundary, and roots were not sampled, given operational difficulties in separating plants from each other. Each stem was harvested, tagged, and then transported to Purdue University; there they were dried for 72 h at 80 °C (176 °F). Stems were then weighed and mean above-ground biomass per stem for each treatment was estimated.

Data were analyzed by analysis of variance (ANOVA) for a randomized complete block design to identify effects of amendment treatments in aboveground biomass. ANOVA was also used to identify treatment effects in soil physical and chemical properties. Significant differences (α=0.05) were identified by Tukey's mean separation test. SAS® software (SAS Institute, Cary, NC, USA) was used for all data analysis.

Results and Discussion

Addition of CM, S, Cp, or Lv significantly altered soil properties compared with control plots. Application of CM12S, CM24S, Cp, or Lv significantly (p<0.0001) influenced organic matter levels; the CM4 treatment was not different from control plots. Cp raised organic matter levels by 93 percent over control plots (table 3). These results concur with those of Davis and others (2006), who found that organic matter was greater when Cp was applied to nursery beds than after application of different levels of CM. The resulting differences in soil chemical properties show the influence, at least in the short-term, of the amendments used. Increased organic matter resulting from application of Lv, Cp, CM12S, and CM24S can be beneficial to hardwood seedlings, given the positive changes to soil physical and chemical properties.

Application of Cp, Lv, CM12S, and CM24S raised pH significantly (p<0.0001) above control plots (table 3). Comparatively, application of a sewage sludge/wood chip compost raised nursery soil pH (Gouin and Walker 1977); Iyer and Oilschlager (1977) found a similar result for greenhouse soils amended with organic matter. Most hardwood species in the CHFR grow optimally with a soil pH of 6.0-7.2 (Ponder and Pope 2003), and therefore the aforementioned amendments would be highly beneficial in this regard. Incorporation of sawdust along with chicken manure (CM12S and CM24S) reduced CEC; the Cp treatment exhibited the highest CEC (table 3). High C:N likely resulted in lack of a positive influence of CM12S and

Table 3. Soil properties (mean ± SE) immediately following incorporation of soil amendments of control plots (Ctrl) and plots amended with leaves (Lv) at 200 m^3 ha^{-1} (2,825 ft^3 ac^{-1}); compost (Cp) at 200 m^3 ha^{-1} (2,825 ft^3 ac^{-1}); chicken manure (CM) at a rate of 1,450 kg ha^{-1} (1,275 lb ac^{-1}) (CM4); or CM at 4,350 kg ha^{-1} (3,840 lb ac^{-1}) and 8,700 kg ha^{-1} (7,670 lb ac^{-1}) each with sawdust (s) at 12,000 kg ha^{-1} (10,580 lb ac^{-1}) (CM12S and CM24S, respectively). For each property, different letters within a row indicate significant differences among treatments at =0.05.

Property	Ctrl	Lv	Cp	CM4	CM12S	CM24S
Organic matter (%)	1.23±0.03c	1.8±0.06b	2.37±0.09a	1.30±0.10c	1.67±0.04b	1.57±0.04b
pH	4.83±0.07c	6.23±0.07b	6.87±0.07a	5.35±0.30c	6.50±0.20ab	6.80±0.16ab
CEC (meq 100g^{-1})	5.37±0.50bc	6.63±0.07ab	8.07±0.58a	6.80±0.30ab	4.93±0.45c	5.73±0.20bc
CEC (meq oz^{-1})	1.52±0.14bc	1.88±0.02ab	2.29±0.16a	1.93±0.09ab	1.40±0.13c	1.62±0.06bc
P (ppm)	193.33±10.04c	217.00±7.64bc	229.33±3.28bc	306.50±10.50a	247.00±26.13bc	268.00±25.72ab
K (ppm)	87.00±9.54d	180.67±2.60c	199.33±3.67bc	240.00±31.00b	227.00±8.98bc	310.67±17.55a
Ca (ppm)	266.67±16.67d	750.00±0.00b	1166.67±83.33a	475.00±25.00cd	533.33±0.00bc	700.00±102.06bc
Mg (ppm)	71.67±6.67d	145.00±7.64b	185.00±10.41a	92.50±12.50cd	105.00±2.04cd	116.67±8.16bc

CM24S on CEC in the short term. As the sawdust decomposes, it is likely that soil conditions will benefit from the added organic matter.

The amount of available P (p=0.002) differed significantly between treatments and was highest when CM4 was applied (table 3). CM24S was also higher than control plots, but CM12S was not, indicating the need for proper balance between chicken manure and sawdust to avoid binding P. In contrast, K levels were significantly higher (p<0.0001) in plots that received CM24S than in any other treatment; however, all treatments resulted in higher K levels than control plots (table 3). Both Mg (p<0.0001) and Ca (p<0.0001) were highest for those treatments that received Cp (table 3), indicating it is likely a more balanced mixture. The influence of amendments on soil chemical properties clearly depends on the inherent chemical properties of the materials used, which must be accounted for in selection of organic nursery soil amendments. Our results identify potential positive and negative influences of organic matter addition on nutrient management in hardwood seedling nursery soils.

Sorghum biomass production (figure 1) differed significantly (p=0.0008) among treatments, with CM24S having the highest above-ground biomass and control plots the lowest. This illustrates the positive influence of these organic matter amendments on sorghum biomass, which could in turn help further raise nursery soil organic matter once incorporated. CM12S tended to have lower mean biomass than CM4 and CM24S, though the difference was not significant. This may have been associated with the high C:N resulting from sawdust incorporation, which could limit plant nutrient availability in the short term. In addition to raising organic matter levels, however, C:N may become more balanced as the sawdust decomposes over time. Furthermore, excessive soluble salt levels in the CM (table 1) could also negatively influence plant development (Jacobs and Timmer 2005). Addition of Cp and Lv at the rates used was not sufficient to elicit a positive growth response; therefore, higher rates of those amendments should be examined in the future.

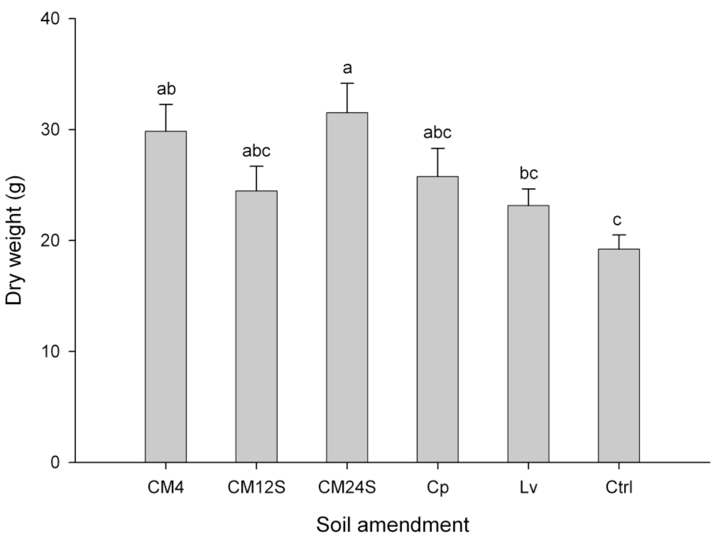

Figure 1. Influence of soil amendments on mean above-ground sorghum dry weight in control plots (Ctrl) and plots amended with chicken manure (CM) at a rate of 1,450 kg ha^{-1} (1,275 lb ac^{-1}) (CM4), CM at 4,350 kg ha^{-1} (3,840 lb ac^{-1}) and 8,700 kg ha^{-1} (7,670 lb ac^{-1}) each with sawdust (s) at 12,000 kg ha^{-1} (10,580 lb ac^{-1}) (CM12S and CM24S, respectively), compost (Cp) at 200 m^3 ha^{-1} (2,825 ft^3 ac^{-1}) and leaves (Lv) at 200 m^3 ha^{-1} (2,825 ft3 ac^{-1}). Bars represent standard errors; for each treatment, different letters represent differences significant at α=0.05.

Conclusion

Soil chemical properties in bareroot nursery beds can be improved through organic matter application. Care must be taken, however, particularly with the use of sawdust, to ensure appropriate nutrient ratios. Increased growth of sorghum indicates a likely long-term benefit, as this green manure crop will promote higher soil organic matter in the subsequent growing season. These findings indicate that a combination of soil amendments and cover crops could potentially increase nursery soil organic matter for a longer term, which could lead to improved seedling growth, decreased dependence on inorganic fertilizers, and an additional viable market for composted organic materials.

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