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Effect of pine bark, pine straw and red oak amendments on pH of potting medium

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Abstract

Our objective was to determine temporal effects on medium pH caused by decomposition of three organic amendments incorporated with topsoil. Pine (*Pinus taeda* L.) bark, pine (*Pinus taeda* L.) straw, and red oak (*Quercus falcata* Michx. var. *falcata*) were ground to uniform particle size, incorporated with a silt loam topsoil at two rates (1:29 and 1:10 amendment:soil, w:w basis, referred to as 1X and 3X, respectively), placed into greenhouse pots, and sampled during 12 months to determine medium pH in comparison to an unamended topsoil (control). Compared to the control, pine straw, pine bark, and red oak 3X increased soil medium pH. All media except pine straw increased pH during the study. At any given sampling date, pine straw 3X had lower pH than the control, while red oak either did not differ from, or had higher pH than the control. By the end of the sampling period, pine bark and pine straw media had lower pH than the control. While statistically significant, change in medium pH caused by any of these substances would be trivial for most horticultural crops, and easily corrected by use of other liming or acidifying amendments.

Key words: Growth media, *Pinus taeda*, *Quercus falcata*, soil amendments

Introduction

Components of a potting mixture are often selected based on their cost, availability, and physical and chemical effectiveness in mixture (Bilderback, 1982). About one-third to one-half of the total volume of the growing medium is occupied by solids and organic matter, the rest is pore space (Bilderback, 1982). The organic matter constituent(s) has numerous beneficial effects on soil quality, including storage and supply of plant nutrients, stabilization of soil aggregates, aids water infiltration and retention, and improves soil porosity (Brady, 1974). Of the array of possible organic choices, pine bark, pine straw, and hardwood chips are commonly-used, surface-applied mulches. Pine bark and sawdust also are commonly used sources of organic matter as soil-incorporated amendments. Milled pine bark and sawdust are acidic in the raw state (Starbuck, 1994; Thomas and Schumann, 1993), but their effect on soil pH as amendments has not been sufficiently investigated. It is commonly assumed that pine straw mulch acidifies soil (Meyer, 1997), perhaps because of observations at forest scale. Loblolly pine (*Pinus taeda* L.) plantations exhibit a decrease in topsoil pH after decades of tree growth (Adams *et al.*, 1999; Markewitz *et al.*, 1998), with long-term decreases as great as 1 pH unit (Richter *et al.*, 1994).

Short-term effects of organic amendments on soil pH are contradictory. Anecdotal information suggests that freshly-fallen oak (*Quercus* L. sp.) leaves and pine needles are relatively more acidic than some other common forest tree species. (http://asecular.com/forests/phleaves.htm, verified 20 January 2010), and that garden applications of sawdust, composted leaves, and wood chips will lower the soil pH (http://www.thegardenhelper.com/acidsoil.html, verified 20 January 2010). A 9-cm thick layer of surface-applied slash pine (*P. elliottii* Engelm.) straw caused a decrease in topsoil pH from 5.0 to 4.4 after 1 year (Duryea *et al.*, 1999). Longleaf pine (*P. palustris* Mill.) straw mulch caused a reduction of 0.56 pH units when surface-applied in two consecutive years on one soil (a total of 16.5 t ha^{-1}), but a single application of 11 t ha^{-1} loblolly pine straw on another soil caused no change in pH after one year (Makus *et al.*, 1994).

Mulches typically have large particle size and are surface applied, so it is difficult to compare their decomposition effects on soil properties to those of incorporated amendments. The objective of this experiment was to determine temporal effects on medium pH caused by decomposition of three organic amendments incorporated with a silt loam topsoil. Our hypothesis was that amendments would not significantly affect medium pH compared to the control.

Materials and methods

The experiment was conducted in potting containers near Booneville, AR (35° N, 94° W, 150 m above sea level). This was a randomized complete block design with seven amendment-rate (media) treatments, eight sampling dates, three replications within repetitions, and two repetitions. The two repetitions of the experiment were conducted concurrently. There were three fresh (not composted) amendments used in the experiment: pine bark [a mixture of bark and sapwood of loblolly pine], loblolly pine straw, and sawdust of southern red oak. Amendments were air dried (20 to 30 °C) and ground to 2 mm particle size in a Wiley mill. The topsoil was a Leadvale silt loam (fine-silty, siliceous, thermic Typic Fragiudult) freshly obtained from the surface 8 cm of a field site cultivated with wheat (*Triticum aestivum* L.). Air dried topsoil, ground in a mortar to 1.4 mm, and amendments were blended in a clean cement mixer.

There were three topsoil-amendment rates: control (no amendment), 1X, and 3X rates. The control rate (topsoil) was equivalent for each amendment, so only one control treatment was retained. The treatments consisted of control, pine bark at 1X and 3X rates, pine straw at 1X and 3X rates, and red oak at 1X and 3X rates (336 containers total). The 1X rate was equivalent to 39 Mg ha^{-1} of surface-applied amendment incorporated (to hasten decomposition) into topsoil to a 15-cm depth (Starbuck, undated; Taylor and Foster, 2003). Amendments were mixed with topsoil using a cement mixer. The 1X and 3X rates were equivalent to 1:29 and 1:10 ratios (w:w) of amendment:topsoil, respectively. Containers were 9.5 cm square (350 mL capacity) and were filled about 7-cm deep with designated medium mixture. Excess water was allowed to exit through drainage holes in the bottom of each container.

Containers were placed on metal greenhouse benches in the field under a loblolly pine tree canopy. The shaded environment provided a cooler, more humid environment during summer than could be achieved in the greenhouse. A removable, porous weed barrier fabric (PAK Masterscape 475, Hummert Int., Earth City, Missouri) was draped loosely across the containers to retain moisture, allow rainfall penetration and air exchange, exclude fallen pine needles from the tree canopy from contaminating the treatments, and exclude light to prevent weed growth. Soil was kept moist by removing the fabric and applying tap water to each container at least twice weekly.

Air temperature and rainfall, measured 1.4 m above soil surface, were continuously recorded at 0.5 h intervals from March 2005 through March 2006 at an unofficial weather station located in a meadow adjacent to the experimental site. Long-term (1971 to 2000) air temperature and rainfall data were obtained from an official weather station (NOAA, 2002) located 2.6 km from the experimental site for comparison.

Sampling dates were t_0 (23 March 2005), 30 and 60 d after initiation (t_1 and t_2, respectively), and every 60 d thereafter (120 d (t_3), 180 d (t_4), 240 d (t_5), 300 d (t_6), and 360 d (t_7)] for 12 months. There were 42 containers collected at each sampling date. Pots were removed from the bench at designated intervals, media was air dried (20 to 30°C), and ground in a mortar to 1.4 mm. To minimize laboratory error, samples were completely randomized at the termination of the experiment and medium pH was measured on duplicate samples in a single-blind manner in comparison to a reference pH standard. Media samples and distilled water (25°C) were mixed in a 1:2 soil:water ratio (w:v), and manually stirred with a glass rod for 20 min. before measuring the slurry pH.

Individual amendments were analyzed at t_0 for C, N, mineral (Ca and Mg) composition, and pH. Carbon and N were analyzed by combustion (Elementar Vario Macro, Hanau, Germany). Concentrations of Ca and Mg were determined by HNO_3 digestion and detection by inductively coupled plasma spectrometry (University of Arkansas Agriculture Diagnostics Laboratory, Fayetteville, Arkansas). The pH was measured on a 1:4 amendment:water (w:v) slurry. Tap water was analyzed at t_7 for Ca, Mg (University of Arkansas Water Quality Laboratory, Fayetteville), and pH.

Analyses of variance of spatially replicated media pH data were conducted using a mixed linear model, Proc Mixed (Littell *et al.*, 1996; SAS Inst., 2002). There were no missing data. Fixed effects were amendment-rate (6 df), sampling date (7 df), and the amendment-rate x sampling date interaction (42 df). Sampling date within repetition and amendment-rate was analyzed as a repeated measure with a variance component covariance structure (Littell *et al.*, 1996). Random effects were repetition, replication within repetition and amendment-rate, and sample date within repetition and amendment-rate. Main amendment-rate effects were compared by single df contrasts. Means of the amendment-rate x sampling date interaction were separated using the Tukey HSD test at $P \leq 0.05$ using (SAS Inst., 2002). Amendment-rate x sampling date interaction responses were also analyzed by regression (SAS Inst., 2002).

Results

For any given month, mean monthly air temperature (but not rainfall) during the 2005-2006 study period was similar to the long term mean (Fig. 1). Rainfall was less than the long-term mean for any given month during the study period, except in September 2005 and March 2006.

Initial C:N ratios were 340:1, 20:1, and 250:1 for pine bark, pine straw, and red oak, respectively, while unamended topsoil had a C:N ratio of 20:1. Further, pine bark, pine straw, and red oak had pH 4.38, 4.14, and 4.82, respectively. Pine bark, pine straw, and red oak had Ca concentrations of 3.2, 6.2, and 1.1 g kg^{-1}, respectively, and Mg concentrations of 0.5, 0.7, and 0.2 g kg^{-1}, respectively. Tap water had pH 7.21, and had Ca and Mg concentrations of 17.2 and 8.09 mg L^{-1}.

Analysis of variance indicated that amendment-rate, sampling date, and the amendment-rate x sampling date interaction significantly affected medium pH ($P \leq 0.001$). At t_0, before irrigation, the control (pH 6.59) had higher pH than most other media ($P \leq 0.05$), while the pine bark 3X (pH 5.49) and pine straw 3X (pH 5.18) amendments had the lowest media pH. Further, pine bark 3X and pine straw 3X had lower medium pH at t_0 than their respective 1X treatments. This suggested that medium pH at t_0 was generally related to pH of the pure amendments before mixing (except for red oak 1X), because all the amendments were considerably more acidic (pH $\leq$ 4.82) than the control soil (pH 6.59).

Some amendments caused a rapid decrease in medium pH from t_0 to t_1: pine straw (both rates), pine bark (both rates), and red oak 3X decreased medium pH at t_1 compared to the control (Table 1). As at t_0, this appeared to have been a function of pH of the unmixed amendments. Further, the red oak 1X and 3X rates did not differ from each other in their effects on pH ($P > 0.05$) at t_0, but the 3X rate had lower pH (6.05) than the control.

At any given sampling date, pine straw 3X had lower pH than the control, while red oak either did not differ from, or had higher pH than the control. Mean pH of pine straw and pine bark 1X media did not differ ($P \geq 0.05$) from the control until t_7 (300 d incubation). At t_7, pH of the pine straw 1X medium was 0.48 units lower than that of the control, and the pine bark 1X medium was 0.40 units lower than the control. The pine straw 3X medium had a lower pH than the control at each sampling date, and also had lower pH than the pine straw 1X medium at each sampling date except t_3 and t_4. From t_1 through t_7, the control (pH ≥ 6.94) and/or red oak (pH ≥ 6.74) media consistently had higher mean pH values than that of the pine straw 3X medium (pH ≤ 6.57). At t_7, red oak media did not differ from the control, although at t_4 and t_5 pH was higher in the red oak 1X medium (pH ≥ 7.26) than in the control (pH ≥ 6.83). By the end of the sampling period, pine bark and pine straw media had lower pH than the control. Thus, pine straw at either rate, and to lesser extent pine bark, had an acidifying effect, while red oak generally had little effect on medium pH compared to the control.

During the study, pH increased in all media, except pine straw ($P \geq 0.06$) in (Fig. 2). Regression analysis of the amendment-rate x sampling date interaction showed that the control and pine bark 1X media had linear responses with time, pine straw 1X tended ($P = 0.06$) to have a linear response, and the other treatments had quadratic responses with time. Shape of the quadratic responses suggested that the pH increase may have been transient, perhaps decreasing to the t_0 level at some future time.

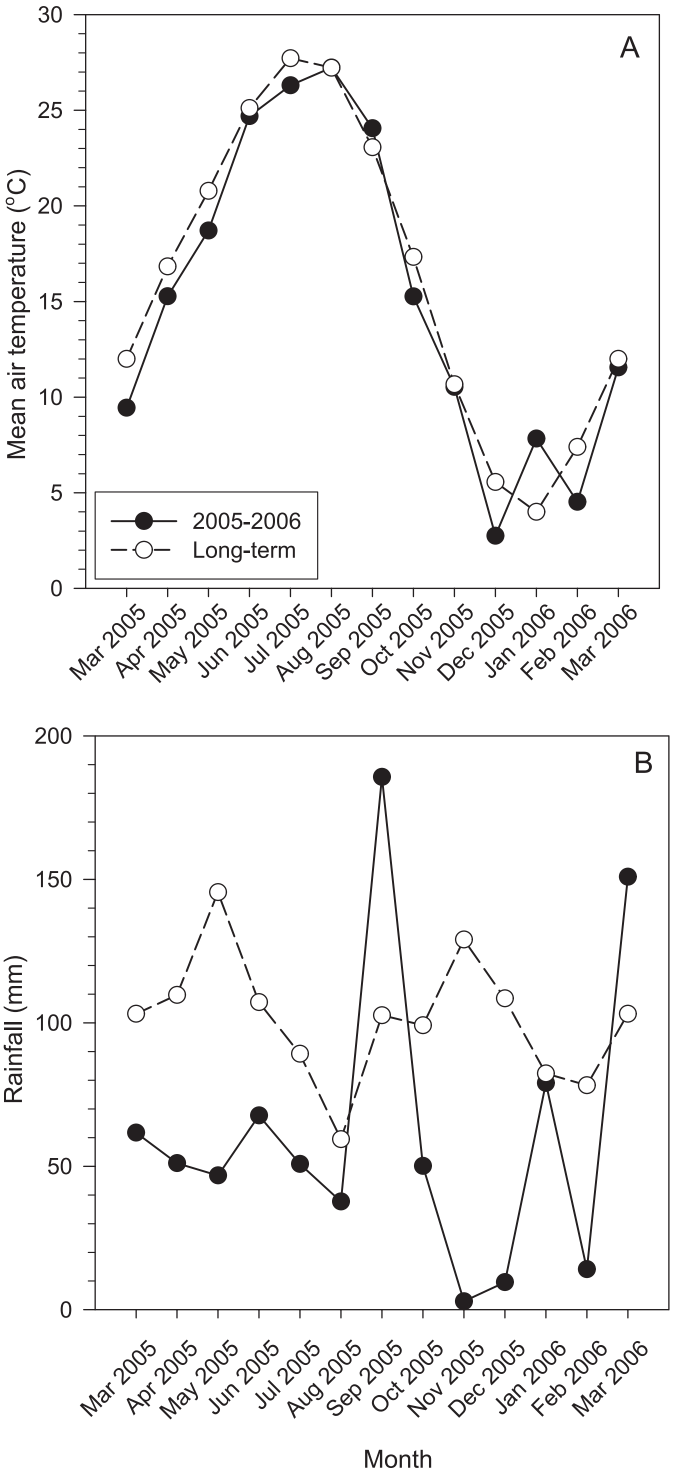

Fig. 1. Mean monthly air temperature (A) and total rainfall (B) at an unofficial weather station located in a meadow adjacent to the experimental site in 2005 and 2006 (solid circles). The long-term means (open circles) for the period 1971 to 2000 were from an official station located 2.5 km from the experimental site near Booneville, Arkansas (NOAA, 2002).

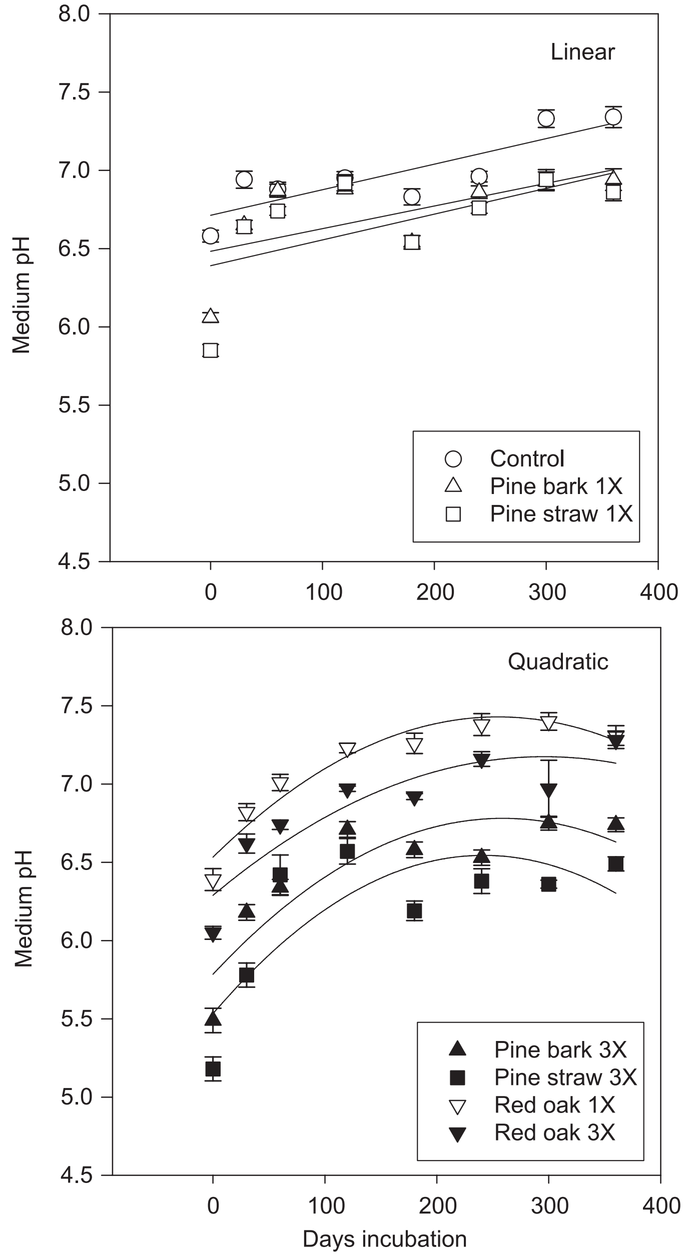

Fig. 2. Effect of amendment-rate on medium pH during 360 d sampling period. Linear regression responses were Control, $Y = 6.67 + 0.0871X$, $R^2 = 0.73$; Pine bark 1X, $Y = 6.42 + 0.0856X$, $R^2 = 0.49$; Pine straw 1X, $Y = 6.31 + 0.0982X$, $R^2 = 0.46$. Quadratic regression responses were Red oak 1X, $Y = 6.43 + 0.354X - 0.0327X^2$, $R^2 = 0.99$; Red oak 3X, $Y = 6.18 + 0.315X - 0.0253X^2$, $R^2 = 0.89$; Pine bark 3X, $Y = 5.64 + 0.415X - 0.0388X^2$, $R^2 = 0.88$; and Pine straw 3X, $Y = 5.34 + 0.486X - 0.0498X^2$, $R^2 = 0.79$. Equations were significant at $P \leq 0.05$, except for Pine straw 1X ($P = 0.06$). Vertical bars at data points are SE ($n = 12$).

Table 1. Temporal changes in pH of a silt loam soil amended with two rates (1X and 3X[a]) of three organic constituents

Sampling period	Sampling date (d)	Control	Pine bark		Pine straw		Red oak	
			1X	3X	1X	3X	1X	3X
t_0	0	6.59a[b]	6.06bc	5.49d	5.85c	5.18d	6.39ab	6.05bc
t_1	30	6.94a	6.65a	6.18b	6.64a	5.78c	6.82a	6.62a
t_2	60	6.88a	6.87a	6.34c	6.74ab	6.42bc	7.01a	6.74ab
t_3	120	6.95ab	6.88abc	6.71bc	6.92abc	6.57c	7.23a	6.97ab
t_4	180	6.83bc	6.54cd	6.58bcd	6.54cd	6.19d	7.26a	6.92ab
t_5	240	6.96bc	6.86bc	6.53cd	6.76c	6.38d	7.38a	7.16ab
t_6	300	7.33a	6.93b	6.75b	6.94b	6.36c	7.40a	6.97b
t_7	360	7.34a	6.94b	6.74bc	6.86b	6.49c	7.31a	7.28ab

[a] 1X and 3X rates correspond to 1:29 and 1:10 ratios (w:w) of amendment: topsoil, respectively.
[b] Means within rows followed by a common letter do not differ at $P \leq 0.05$ using the Tukey HSD test (SAS Inst., 2002).

Discussion

We studied the effect on medium pH when pine bark, pine straw, and red oak amendments were ground and incorporated with mineral soil. Some forest by-products have considerable economic value to the horticultural industry as landscape mulches, but their decomposition effects on soil properties are not always clear. Loblolly pine straw decomposes very slowly on the soil surface, and has about 55% of its initial mass after 26 months (Piatek and Allen, 2001). Surface-applied oak sawdust mulch did not decrease soil pH one year after application (Starbuck, 1994). Pine bark and red oak amendments might have slow decomposition rates given their high C:N ratios (http://www.compostinfo.com/tutorial/ElementOfComposting.htm, verified 20 January 2010; Starbuck, 1994). Pine straw had the same C:N ratio as the topsoil, so it should decompose more rapidly than the other amendments. High C:N ratio and slow decomposition can limit soil N availability (Starbuck, 1994).

Contrary to expectation, there was a transient increase in pH regardless of amendment which might have been affected by the basic pH (7.21) of the tap water. However, even rainfall varies in pH. Rainfall (pH 5.6 to 8.3) at El Reno, Oklahoma (400 km west of the experiment location) tends to be more basic than 'pure' rain (pH 5.6, Smith *et al.*, 1984). Purified water might have been preferred to tap water to eliminate this potentially confounding factor from the study.

Soil amended with various leaf litters increased linearly in pH during an 8 week incubation, in direct relationship to tissue $CaCO_3$ concentrations (Noble and Randall, 1999). It seemed unlikely, however, that the early, transient increase in media pH was solely due to media Ca and Mg concentrations. Concentrations of these cations were relatively low ($\leq$ 6.2 g kg^{-1}) in the amendments, especially in red oak. The Ca and Mg concentrations of pine straw were roughly comparable to those reported by Wells *et al.* (1975).

Any of these organic materials could be used to amend potting soil. We rejected our hypothesis that amendments would not significantly affect medium pH. Pine straw and pine bark amendments decreased media pH by as much as 0.48 units. Red oak generally had no effect on pH compared to the control. While statistically significant, changes in pH caused by pine straw or pine bark amendments were trivial for most horticultural crops, and could easily be corrected by liming. However, the pH decrease could be exacerbated if other commonly-used amendments such as NH_4NO_3, $Al_2(SO_4)_3$, and elemental S were included in the media formulation.

In conclusion, media blends consisting of 1 part amendment to 10 or 29 parts soil caused little change in medium pH during 12 month incubation. Results suggested that pH effects on horticultural crops should be trivial and easily corrected by use of other liming or acidifying amendments. It also seemed unlikely that any of these mulches would substantially alter soil pH when surface applied at typical landscaping rates.

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