

PINESTRAW RAKING, FERTILIZATION AND POULTRY LITTER AMENDMENT EFFECTS ON SOIL PHYSICAL PROPERTIES FOR A MID-ROTATION LOBLOLLY PINE PLANTATION

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Abstract—Frequent pinestraw raking and removal in pine plantations has led to concerns about nutrient removal from the stand. While soil chemistry of raked stands has been studied, little attention has been placed on potential compaction from raking operations. Four treatments were applied to a 16-year-old loblolly pine plantation at the Louisiana State University AgCenter Calhoun Research Station in Calhoun, LA: 1) No Rake and No Fertilizer, 2) Rake and No Fertilizer, 3) Rake and Commercial Fertilizer, and 4) Rake and Poultry Litter. Surface soil cores were sampled to assess treatment effects on soil bulk density, total porosity, moisture content, air-filled porosity, organic matter, and available water holding capacity. Raking significantly compacted the surface soil. Poultry litter significantly increased the soil moisture content over that of the commercially fertilized treatment. The unraked and unfertilized treatment and the commercially fertilized treatment had significantly greater air-filled porosity compared to the other two treatments. Raking with commercial fertilizer significantly reduced soil organic matter content from that of the control, but only from 0 to 2 inches depth. Trafficking effects from raking and fertilization operations are likely responsible for compaction effects on surface soils.

INTRODUCTION

Some forest landowners bolster forest products revenues of Southern pine plantations with occasional pinestraw raking. Fertilization of frequently raked stands has been recommended due to concerns about nutrient removals and alterations to soil chemistry. Fertilizing annually raked stands has been shown to maintain (Haywood and others 1995) or increase longleaf pine (*Pinus palustris* Mill.) pinestraw production (Dickens and others 1999) over that of unfertilized raked stands, presumably due to maintaining soil nutrition. However, little attention has been paid to potential compaction from raking and other non-harvesting operations.

Pinestraw has several possible impacts on soil physical properties, including increased water infiltration, reduced runoff and erosion, insulation of temperature and moisture regimes, increased available water-holding capacity, reduced evaporation, and decreased compaction (Duryea 2003, Taylor and Foster 2004). In a 16-year-old AR loblolly pine plantation, Pote and others (2004) found that annual pinestraw raking decreased infiltration rates, increased runoff, and increased erosion relative to less frequent raking. Within two weeks of complete litter removal in a longleaf pine stand, trees had lower xylem pressure potential and the soils had less moisture content than the unraked control (Ginter and others 1979). Longleaf pine growth was reduced in their study as well, and McLeod and others (1979) attributed the growth reduction to a disruption in the hydrologic cycle, rather than nutrient removals.

Poultry litter is generated in large quantities in many locations within the South, and it is being explored as a source for forest fertilization. There is concern that application of poultry litter will adversely impact water quality (Friend and others 2006). Not much information is available in the literature concerning poultry litter effects on soil physical properties (Brye and others 2004) or possible amelioration of raked soils by organic inputs such as poultry litter.

The objective of this study was to examine the effects of pinestraw raking and fertilizer source on soil physical properties of soil strength, bulk density, porosity, aeration, soil moisture content, organic matter, and available water holding capacity.

METHODS

The study was conducted in Calhoun, LA within a 16-year-old loblolly pine (*Pinus taeda* L.) plantation on the Calhoun Research Station of the Louisiana State University Agricultural Center. The trees were planted on a 16 by 6 feet spacing. The experimental design is randomized complete block design, with two blocks (soil type), each having eight 0.2-acre plots. Four treatments were imposed on four plots each: control (no raking and no fertilization), raking with no fertilization, raking with commercial fertilization (urea and diammonium phosphate), and raking with poultry litter as fertilizer.

The soils of the study area are the Ora and Savannah series, both fine-loamy, siliceous, thermic Typic Fragiudults (Matthews and others 1974). The study area was pasture (cattle paddocks) until 1990, when it was machine planted with loblolly pine, with no site preparation. The site was thinned in 2000 to a density of 250 trees per acre. Starting in fall 2000, the plantation was raked each fall using a tractor and mechanical raker and baler. Diammonium phosphate and urea (172 lbs per acre nitrogen, 115 lbs per acre phosphorus) were applied in spring 2003, spring 2004, and fall 2005. Poultry litter was applied at those same times, at the same rates of nitrogen and phosphorus. Fertilizers were applied with a litter spreader.

Six surface (0-4 inches) soil cores were randomly sampled using the impact coring method (Blake and Hartge 1986) in April 2006 in each of the 0.2-acre plots. From these cores, the following were analyzed: bulk density, porosity, soil moisture content, and air-filled porosity. Six four-inch

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deep cores were randomly sampled within each plot in January 2007, using a soil probe. Each core was divided into 0-2 inch and 2-4 inch depths, which were analyzed for organic matter using the loss on ignition method (Nelson and Sommers 1996). Soil from additional randomly sampled 0-4-inch probe cores (six per plot) was composited by plot for construction of soil moisture retention curves, using the WP4 dewpoint potentiometer (Decagon Devices, Pullman, WA). Available water holding capacity was predicted from those curves. Soil strength was measured from April 28 to May 1, 2006, using the Field Scout SC 900 Soil Compaction Meter penetrometer (Spectrum Technologies, Inc., Plainfield, IL), with a mean of 18 randomly located profiles down to 12-inches depth within each plot. SAS (SAS Institute, Inc. 2006) was used to conduct analyses of variance of soil physical properties among the four treatments at a significance level of $P < 0.05$, using the protected Fisher's LSD procedure for mean comparison.

RESULTS

Mean surface bulk density for all treatments was compacted (greater than 1.65 g/cm^3), but the unraked and unfertilized control treatment had significantly lower bulk density as compared with that of the three raked treatments (table 1). Consequently, the control treatment had significantly higher total porosity compared with that of the three raked treatments. The raked and commercially fertilized treatment contained the lowest soil moisture content. The control and raked + commercial fertilizer treatments had significantly more mean air-filled porosity than that of the raked without fertilization and raked with poultry litter treatments.

The raked with poultry litter treatment had the lowest mean soil strength at 0-2 inches depth, and the raked with commercial fertilizer treatment had the highest mean soil strength (table 2). At 2-4 inches depth, soil strength was lowest in the control and raked with poultry litter treatments, and again highest in the raked with commercial fertilizer treatment, although not significantly different ($P = 0.1292$). The unraked and unfertilized control had significantly higher organic matter content relative to that of the raked + commercial fertilizer treatment, but at the 0-2 inches depth only. The unraked and unfertilized control contained the highest mean available water holding capacity, although not significantly different from the raked treatments ($P = 0.0561$).

DISCUSSION

Haywood and others (1995) found that winter and summer burning and annual harvesting of longleaf pine straw on a Rapides Parish LA sandy loam soil (fine-loamy, siliceous, thermic Typic Paleudults) significantly increased bulk density over that of the unraked and unburned control, but fertilization did not. In a continuation of that study, Haywood and others (1998) found recovery of bulk density four years after halting annual pine straw harvesting. On a Leadvale soil (fine-silty, siliceous, thermic Typic Fragiuudults) in Logan County, AR, Pote and others (2004) investigated soil processes and water quality changes after annual raking of pine straw from a 16-year-old loblolly pine plantation. Annual raking decreased infiltration, and increased runoff and erosion versus that of less frequently raked plots. However, where pine straw had accumulated for at least two years,

infiltration and erosion rates and runoff volume were similar to that of the control. Pote and others (2004) noted that after three years, pine straw becomes matted by fungal growth. Raking less frequently (than annually) left significant amounts of partially decayed residue on the surface immediately after raking. The compaction and reduction in porosity observed in our study (table 1) resulting from annual pine straw raking would undoubtedly influence infiltration and runoff, as was found in AR by Pote and others (2004). Similar to our finding of no significant change in organic matter (at 2-4 inches) from raking, commercial fertilizer, and poultry litter treatments, Ross and others (1995) found no effect from raking pine straw or prescribed burning on surface soils under loblolly or longleaf pine plantations.

In the Delta region of eastern AR, Brye and others (2004) investigated effects of poultry litter form and rate on bulk density and soil water content for two silt loam soils and one silty clay soil. Only one of the silt loam soils experienced a bulk density decrease in the upper four inches as litter rate increased. None of the three soils' volumetric water content was increased by increasing poultry litter rates. Nonetheless, the authors concluded that poultry litter has positive short-term effects on soil physical properties, and that the water content may be more sensitive for coarser-textured soils. Five years after application of sewage-sludge compost with beef manure on a sandy MD upland Coastal Plain soil, soil strength and bulk density were significantly reduced, and soil water content was increased as compared with that of the control (Tester 1990). For our study, poultry litter application significantly increased volumetric soil water content over that of raking with commercial fertilization (table 2). Poultry litter application also greatly reduced soil strength in the upper four inches, as compared with the other two raking treatments (table 2).

The main effects of raking pine straw at the Calhoun Research Station on soil physical properties were increased bulk density and decreased porosity. The raked treatment with commercial fertilization had the lowest soil moisture content. Poultry litter application on raked soils increased the organic matter relative to the other two treatments that included raking, but not significantly. Although poultry litter addition reduced soil strength, it also had significantly lower air-filled porosity than the control and raking with commercial fertilizer. Poultry litter ameliorated some soil physical properties resulting from raking pine straw, but not significantly. These effects on the soil physical properties are important factors when considering their impacts on soil microbial biomass and activity. The soil's capacity to provide favorable conditions, particularly adequate soil oxygen and moisture, for biological activity are fundamental to sustaining forest productivity. It remains to be seen what effects continued annual pine straw raking and fertilization will have on surface soils, and for how long. Ongoing research on the relationship between observed soil physical effects as well as chemical effects from pine straw removal and chemical amendments on microbial processes will increase

Table 1—Means of surface (0-4 in. core) soil physical properties for four treatments applied to a mid-rotation loblolly pine plantation at Calhoun, LA. Means with the same letter within a column are not significantly different at $\alpha=0.05$

Treatment	Bulk Density	Porosity	Moisture	Air-filled Porosity
	<i>g/cm³</i>	<i>volume %</i>	<i>volume %</i>	<i>volume %</i>
Control (No Rake, No Fertilize)	1.67 b	36.9 a	27.0 ab	9.9 a
Rake, No Fertilize	1.81 a	31.8 b	26.8 ab	5.0 b
Rake, Commercial Fertilize	1.76 a	33.4 b	24.8 b	8.6 a
Rake, Poultry Litter	1.78 a	32.8 b	28.1 a	4.8 b

Table 2—Means of surface soil properties for four treatments applied to a mid-rotation loblolly pine plantation at Calhoun, LA. Means with the same letter within a column are not significantly different at $\alpha=0.05$

Treatment	Soil Strength		Organic Matter		Available Water Holding Capacity
	<i>psi</i> (0-2 in.)	<i>psi</i> (2-4 in.)	<i>%</i> (0-2 in.)	<i>%</i> (2-4 in.)	<i>%</i> (0-4 in.)
Control (No Rake, No Fertilize)	180.6 b	341.7 a	2.78 a	2.31 a	42.65 a
Rake, No Fertilize	334.5 a	506.9 a	2.58 ab	2.01 a	36.65 a
Rake, Commercial Fertilize	355.8 a	522.3 a	2.25 b	1.90 a	35.35 a
Rake, Poultry Litter	144.0 b	358.2 a	2.58 ab	2.19 a	38.40 a

our understanding of the ecological sustainability of these practices.

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