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Using Poultry Litter in Black Walnut Nutrient Management

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ABSTRACT

Poultry litter was evaluated as a fertilizer in a young (three-year-old) and an old (35-year-old) black walnut (*Juglans nigra* L.) plantation in southwest Missouri. The older planting had a fescue (*Festuca arundinaceae* Schreb.) ground cover that is grazed by cattle. In the young plantation, weeds were mowed and sprayed with herbicides once annually in the spring. Litter was applied at rates of 6.72 Mg ha^{-1} and 13.44 Mg ha^{-1} for one year in the spring in the young plantation and at 8.96 Mg ha^{-1} for two years in the spring and once in late summer in the older plantation. Height growth and leaf nitrogen (N) concentrations were improved during the summer following litter applications in the young plantation, but neither diameter growth nor nut production increased in the older plantation. Second-year height growth treatment differences for the young plantation were not significant. The number of nuts increased in the second year, but differences between treatments were not significant.

Keywords: organic fertilizer, tree growth, nut production, tree nutrition

INTRODUCTION

Black walnut (*Juglans nigra* L.) is known for its desirable wood characteristics, as exhibited in furniture, paneling, lumber, and other products. The better-growing trees are most abundant on deep, well-drained soils with good available moisture. Many acres of black walnut are being planted in old fields,

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which may lack adequate nutrient supply for good growth. In addition to requiring sufficient nutrients, these plantings grow best when soils, site, and cultural treatments are adequate.

Black walnut also ranks high as a nut tree. Trees can begin to produce nuts at about age 10. Aside from genetics, cultural treatments can also affect nut-bearing age and nut production. Commercial fertilizers can increase nut production (Ponder, 1976; Garrett et al., 1991; Jones et al., 1995). While much more improvement has been reported for nut production than for growth, there may be growth benefits associated with slow-release fertilizer materials such as poultry litter. It has been reported that pole-size black walnut fertilized with a slow-release urea fertilizer had better diameter growth than unfertilized trees and that the duration of the response was longer with slow-release fertilizer than with commercial fertilizer (Ponder, 1994).

Chicken- and turkey-rearing houses are common features in the rural areas of many landscapes in the United States. They are concentrated in Arkansas, North Carolina, Georgia, and Alabama (Moore et al., 1995). Many tons of the litter are being distributed over crop and pasture lands annually. Many more tons are dry-stored under roofed structures or well-secured impermeable covers. Depending on the composition of individual poultry litters, these materials can enhance crop production via their capacity to supply nutrients and increase soil quality (Edwards and Daniels, 1992). The nutrient content of the litter is variable. On a Mg ha^{-1} basis, litter materials can contain considerable amounts of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), sulfur (S), iron (Fe), boron (B), copper (Cu), zinc (Zn), and sodium (Na) (Stephenson et al., 1990; Kpomblekou–A et al., 2002). The continuous application of poultry litter could have negative environmental consequences on groundwater quality due to contamination caused by runoff or leaching of nitrate, P, or other elements (Liebhardt et al., 1979; Ritter and Chirnside, 1987; Sims and Wolf, 1994). Nearly 90% of the poultry litter produced is applied to agricultural lands as a low-cost alternative to commercial fertilizers (Moore et al., 1995). Unfortunately, little experimental information is available on treating trees with poultry litter.

The overall purpose of this study was to determine the response of black walnut trees to broadcast applications of poultry litter. The litter was applied to determine its impact on (1) nut production and diameter growth of black walnut trees in a 35-year-old plantation and (2) height growth of black walnut trees in a three-year-old plantation.

MATERIALS AND METHODS

Keen Plantation (35-Year-Old Trees)

The plantation is located along route 76/86 about a mile west of Exter, MO, west of Cassville in Barry County (lat 36.4°N, long 93.6°W). Mean annual air temperature is 12.8°C, with minimum mean temperatures in January (−7.7°C) and maximum mean temperatures in July (31.9°C). Mean annual precipitation is 1100 mm, with about half occurring between May and September, but extended droughts often occur during the growing season. Trees were approximately 35 years old when the study began and the litter was applied. They were planted on deep, gently rolling, moderately well-drained upland soils of the Tonti-Scholten complex (fine-loamy, mixed, mesic Typic Fragiudults-Loamy-skeletal, siliceous, mesic ultic Hapludalfs). Slopes ranged from 2% to 6%, and soils were silt loam in texture. The soils had a fragipan of mottled, very firm and brittle, and very gravelly silty-clay loam at the 64 cm depth. The fragipan ranged from 30 to 36 cm thick. The plantation had a ground covering of fescue grass grazed by cattle annually.

The trees were of the nut-producing type, probably a Thomas variety. The plantation contained grafts and seedlings planted in rows approximately 12.2 m apart and approximately 12.2 m within the row. Most trees were about 9 m tall or taller, with crowns that averaged 9 m in diameter. Trunk diameter of trees at breast height (1.4 m from the ground) averaged 29.2 cm at the beginning of the study. For this study, trees that developed from below grafts were removed. Trees that seemed out of place or did not fit within the general spacing range were considered voluntary and were also removed. No other efforts were made to ensure that all study trees were grafts.

Of the trees in the plantation, 160 were selected for the study. All measurement trees in the study were numbered using numbered tags and aluminum nails. White diameter marks were painted on trees to locate consistently where to measure diameters. Diameter measurements were recorded in the spring before litter application and in the fall after leaf fall. Nut counts were taken visually in late July to early August before nut drop.

The study was a randomized design with treatments applied to rows. Treatments included two rates of litter, zero and 8.96 Mg ha^{-1}, one application each applied in the spring and late summer. Litter treatments were applied to groups of trees of two rows each, and randomly between the 12 rows (four rows per treatment), with one group fertilized in the spring (mid-April) and another group in late summer (late August) of 1997. The four rows in the control treatment were designated in the spring. Only the spring application was also made the following year. Litter used was classified as broiler litter because it was a mixture of manure, bedding material, wasted feed, feathers, and soil picked up during removal (Moore et al., 1995). Litter was broadcast applied using a commercial spreader-truck. The spreader calibration on the spreader-truck was set to deliver 4.48 Mg ha^{-1} at one passing. Rate calibrations on the truck were accepted as the rate of delivery. Four samples of the litter were collected and sent to the Agricultural Services Laboratory at the University of Arkansas—Fayetteville for elemental analysis.

Prior to treatment application, soil samples were taken across all rows at two trees per row (Table 1). Soil samples were oven-dried, sieved, labeled, and

Table 1
Soil chemical characteristics of the Keen and Marcules plantings at two depths before litter applications

	Keen		Marcules	
Property[1]	0–15 cm	18–30 cm	0–15 cm	18–30 cm
PH	5.6a[2]	5.9b	6.1a	6.2a
CEC[3]	13.0a	6.1b	8.0a	7.2b
Phosphorus	59.0a	42.0a	70.0a	59.0a
Potassium	103.0a	58.0b	155.0a	110.0b
Calcium	1742.0a	1097.0b	1386.0a	1284.0a
Magnesium	94.0a	33.0b	60.0a	38.0b
NO_3^-N	5.4a	3.1b	3.4a	3.1b

[1]All properties except pH and CEC are expressed in mg kg^{-1}.
[2]Values for a property at a location followed by the same letter are not significantly different at the 0.05 level.
[3]CEC (cation exchange capacity) is expressed as cmol kg^{-1} of oven dry soil.

analyzed for pH, organic matter, cation exchange capacity (CEC), NO_3^-N, P, K, Ca, and Mg. In late June, leaf samples were also collected from walnut trees designated for soil sampling, oven-dried, ground in a Wiley mill to pass through a 2 mm sieve, and analyzed for N, P, K, Ca, Mg, and micronutrients at a commercial laboratory.

Marcules Plantation (3-Year-Old Trees)

The plantation is located on property owned by Paul Marcules near Pierce City, MO in Newton County (lat 36.4°N, long 94.1°W), 40 m northwest of the Keen plantation. Mean annual air temperature is 14.4°C with mean minimum temperatures in January (−5.2°C) and mean maximum temperatures in July (32.9°C). Mean annual precipitation is 1038 mm, with about half of the amount occurring between May and September, but extended droughts often occur during the growing season. The trees were three years old. Soils were of the Huntington series (fine-silty, mixed, mesic Fluventic Hapludolls) and are silt loam in texture. The study area contained more than 5400 young trees. Soil samples were collected and analyzed for chemical properties in the same manner as they were for the Keen plantation (Table 1). Trees were planted using a tractor-drawn mechanical planter. Rows were 3.6 m apart, with trees approximately 2.4 to 3.1 m apart within rows. Treatments consisted of a control, litter applied at 6.72 Mg ha^{-1}, and litter applied at 13.44 Mg ha^{-1} in the spring. Personnel of the Hammons Products Company, Stockton, MO, imposed weed control procedures in early spring. The plantation was mowed and sprayed with a mixture of glyphosate (N-phosphonomethyl glycine) and simazine (6-chloro-N′, N′-diethyl-1,3,5-triazine-2,4-diamine) in 1.5-m-wide bands along both sides of the row, using a tractor-drawn sprayer. Treatments were usually applied over the top of trees before they leafed out. Black walnut is usually one of the last tree species in the region to leaf out.

For this study, approximately 540 trees were used (3 treatments × 6 rows × 30 trees). Each treatment was assigned to two rows. Litter was applied using the spreader-truck and method of calibration used at the Keen plantation in the spring of 1997. Leaf samples were collected and growth measurements were estimated at approximately the same time as for the trees in the Keen plantation and were processed in the same manner.

Data from the Keen plantation were analyzed as a two-by-two factor factorial [two treatments (with and without litter) × two application times (spring and late summer)]. Data for trees in the Marcules plantation were analyzed as a single-factor experiment with three treatments. Analysis of variance (ANOVA) was used to test for treatment effects (SAS, 1987). Unless otherwise noted, all statistical tests were performed at the $\alpha = 0.05$ level of significance.

RESULTS AND DISCUSSION

Soil chemical properties for the two plantations are presented in Table 1. Soil nutrition differed between plantations. Soils in the Marcules plantation had higher P and K concentrations than soils at the Keen plantation, and soil nutrient concentrations decreased more with depth at the Keen plantation than at the Marcules plantation. This result indicates that soils in the Marcules plantation have better nutrient storage in the upper 30.48 cm than do the soils in the Keen plantation.

Data collected in the fall of the first treatment-year show that height growth of black walnut trees treated with poultry litter at 6.72 and 13.44 Mg ha^{-1} rates in the Marcules plantation was greater than that of the control trees (Table 2). Also, trees receiving the 13.44 Mg ha^{-1} rate had better height growth than trees receiving the 6.72 Mg ha^{-1} rate. The increase amounted to 21% and 33% over the control trees for the 6.72 and 13.44 Mg ha^{-1} rates, respectively. However, in the second year, height growth of trees under the treatments was not significantly different (Table 2). The lack of response to treatments in year 2 might have been associated with increased weed competition that occurred in year 1 in response to litter application. In some cases, there was little evidence of weed control by mid-summer.

Neither diameter growth nor nut production was improved by litter applications to trees in the Keen plantation (Table 2). Overall, nut production for the second year improved over the previous year, but the differences between treatments were not significant. The rate of 8.96 Mg ha^{-1} may not have been sufficient to cause a significant increase in both diameter growth and

Table 2
Mean height growth of trees in the Marcules plantation and diameter growth and nut production of trees in the Keen plantation for year 1 and year 2 of the study

	Height growth (cm)			Diameter growth (cm)			Avg. no. nuts per tree		
Treatment	Year 1	Year 2	Total	Year 1	Year 2	Total	Year 1	Year 2	Total
Marcules									
Control	61.5a[1]	73.5a	135.0a	—[2]	—	—	—	—	—
6.72 Mg ha^{-1}	77.4b	69.3a	146.7b	—	—	—	—	—	—
13.44 Mg ha^{-1}	91.3c	68.8a	160.1c	—	—	—	—	—	—
Keen									
Control	—	—	—	0.64a	0.48a	1.12a	169a	203a	372a
Spring[3]	—	—	—	0.59a	0.70a	1.29a	179a	245a	424a
Fall[3]	—	—	—	0.60a	0.55a	1.15a	139a	235a	374a

[1]Values in a column followed by the same letter are not significantly different at the 0.05 level.
[2]Values not determined.
[3]8.96 Mg ha^{-1}.

nut production because of the quantity of nutrients used by the grazed fescue at the site. On a per-ton basis, the litter used contained approximately 30.42 kg of N, 55.39 kg of P as P_2O_5, 30.87 kg of K as K_2O, 38.59 kg of Ca, 5.90 kg of Mg, and 6.81 kg each of Na and S. The litter also contained about 0.81 kg of Mn, 0.64 kg of Zn, and less than 0.45 kg of Fe, Cu, and B. The litter used in this study was generally higher in nutrient amounts than quantities reported by Edwards and Daniel (1992) for broiler poultry litter. Ammonia volatilization probably resulted in some N losses. Wolf et al. (1988) estimated that 37% of the total N applied on the surface of a pasture could be lost to volatilization after 11 d.

Leaf N concentrations were also affected by treatments at the Marcules plantation (Table 3). The mean N concentrations in walnut leaves from trees in the 13.44 Mg ha^{-1} treatment were higher than the N concentration in leaves from trees under the control treatment. Iron and Na concentrations were apparently also affected by litter applications. Iron concentrations in leaves from trees under litter treatments were higher than Fe concentrations in leaves from control trees. The opposite was true for Na. For trees in the Keen plantation, both P and Mg concentrations tended to be higher in leaves from trees treated with litter than from trees not treated with litter (Table 4).

For year 2, except for leaf concentrations of Mn, Cu, and Zn for trees at the Marcules plantation, differences between treatments were not apparent (Tables 3 and 4). The reason for the lower-than-normal leaf Ca concentrations

Table 3
Leaf nutrient concentrations for trees in the Marcules plantation measured in late June in the first year after poultry-litter application and one year later

	Treatment		
Element	Control	6.72 Mg ha^{-1}	13.44 Mg ha^{-1}
		g kg^{-1}	
Year 1			
N	27.44a[1]	28.36ab	31.23b
P	2.26a	2.09a	2.30a
K	12.38a	11.61a	13.41a
Ca	17.39a	17.00a	15.48a
Mg	25.31a	25.04a	23.09a
		mg kg^{-1}	
Mn	57.92a	55.86a	59.42a
Fe	38.63a	41.73b	43.13b
B	27.55a	26.12a	31.37a
Cu	8.54a	9.44a	9.23a
Al	21.51a	20.59a	18.18a
Zn	34.93a	40.93a	37.66a
Na	18.97a	11.28b	11.94b
		g kg^{-1}	
Year 2			
N	26.30a	27.45a	26.63a
P	2.42a	2.61a	2.38a
K	13.40a	13.00a	14.28a
Ca	18.31a	21.92a	21.26a
Mg	25.37a	31.26a	31.47a
		mg kg^{-1}	
Mn	40.10a	40.70a	56.50b
Fe[2]	194.00a	168.00a	206.00a
Cu	10.30a	14.80b	10.40a
Zn	29.60a	39.10ab	46.30b

[1]Values for an element in a row followed by the same letter are not significantly different at the 0.05 level.
[2]Values reported are outside the norm for this variable for black walnut (Ponder, 1994).

and the higher-than-normal leaf Fe and Zn concentration is not known (Mills and Jones, 1996), but is believed to be in error and can be attributed to contamination or equipment adjustment. All samples were analyzed at a commercial laboratory.

The results indicate the potential benefit of poultry litter for improving the growth of young trees. These early results are highly encouraging, especially the

Table 4
Leaf nutrient concentrations for trees in the Keen plantation measured in late June in the first year after poultry-litter application and one year later

	Treatment		
Element	Control	Spring application	Fall application
		g kg^{-1}	
Year 1			
N	25.25a[1]	26.26a	25.36a
P	2.24a	2.61b	2.44ab
K	18.07a	17.75a	16.85a
Ca	19.47a	18.99a	21.86a
Mg	3.97a	2.86b	3.13ab
		mg kg^{-1}	
Mn	89.91a	73.34a	83.64a
Fe	40.43a	41.28a	41.15a
B	23.84a	22.14a	22.62a
Cu	8.81a	9.31a	8.73a
Al	35.12a	34.76a	37.34a
Zn	21.58a	22.94a	23.33a
Na	8.82a	10.94a	9.98a
		g kg^{-1}	
Year 2			
N	19.64a	20.32a	18.87a
P	3.11a	3.42a	2.69a
K	21.30a	22.42a	18.92a
Ca[2]	6.18a	5.42a	5.52a
Mg	1.86a	1.91a	1.48a
		mg kg^{-1}	
Mn	79.00a	68.00a	85.80a
Fe[2]	350.00a	216.00a	434.00a
Cu	11.80a	12.20a	11.40a
Zn[2]	244.40a	300.20a	388.60a

[1]Values for an element followed by the same letter are not significantly different at the 0.05 level.
[2]Values reported are outside the norm for these variables for black walnut (Ponder, 1994).

height growth and the increase in leaf N concentrations for trees in the Marcules plantation in year 1. The lack of response to litter application in diameter growth and nut production in trees at the Keen plantation is not surprising. For these trees, the nut crop had been primarily predetermined by the nutrition and other conditions of the trees during the year before treatment application. The trees were much older and, physiologically, they were at a very different growth stage than the much younger trees in the Marcules plantation. Because of the size of the trees in the Keen plantation, much higher rates of litter may be required for a significant response. Also, the thick fescue ground cover may have hindered growth and nut production responses to treatments. However, we did not measure characteristics of the fescue that might have been improved by litter application; such improvement could be an additional important attribute of using litter in agroforestry systems for black walnut nut production and grazing with older trees.

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