SOIL PROPERTIES UNDER PURE AND MIXED PLANTINGS OF YOUNG BLACK WALNUT

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Abstract.--Analysis of surface organic matter (litter) and soils under two 10-year-old black walnut plantations, one planted with walnut alone and one of walnut mixed with autumn-olive, showed that total litter accumulation, total N, and NO_3-N were higher in mixed plots than pure plots. Elemental components of litter and extractable soil cations differences were influenced by inherent soil properties on the two sites with minor differences attributed to whether the plots were pure or mixed. The addition of soil nitrogen in mixed plots has undoubtedly contributed to the larger black walnut trees on these plots compared to smaller trees on pure plots.

Additional keywords: Biomass, soil amelioration, nitrogen-fixing plants, organic matter.

Unfavorable soil conditions affect the growth of black walnut (*Juglans nigra* L.) on most old fields. Black walnut grows best on deep, well drained, moderately fertile soils. In general, abandoned agricultural fields are deficient in nutrients, poorly aerated, and too eroded and compacted to permit adequate water infiltration. These factors work against the establishment and good growth of black walnut. While commercial fertilizers and deep tillage or subsoiling can make these abandoned lands more productive, vegetation provides more durable soil changes (Carmean *et al*. 1976).

Auten (1945) and Ike and Stone (1958) concluded that black locust (*Robinia pseudoacacia* L.), even when young, produced litter that returned large amounts of nitrogen to the soil, improved soil structure, and stimulated the growth of associated species. Nitrogen-fixing plants such as black locust have been used occasionally to stimulate the growth of forest trees on old fields. Funk *et al*. (1979) showed that black walnut planted in mixture with autumn-olive (*Elaeagnus umbellata* Thunb.), a nitrogen-fixing plant, averaged 82% taller and 96% larger in diameter than black walnut planted alone.

This study compares litter accumulation and soil properties beneath pure plots of black walnut (walnut planted alone) and mixed plots (autumn-olive planted with black walnut) after 10 growing seasons in two plantations in southern Illinois.

THE STUDY AREAS

Plantations are located on a bottomland site (Ambeer Creek) in the Shawnee National Forest and an upland site (Camp Cadiz) in the Kaskaskia Experimental Forest. Both sites were formerly abandoned fields that had a cover of grasses and broadleaf weeds. The bottomland is bordered by Ambeer Creek on one side and an intermittent stream on the other. Soils of the Haymond series (Typic

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Udifluvents; coarse-silty, mixed, nonacid, mesic) dominate the bottomland site. These soils are deep, well drained, and have a surface layer 12 to 30 cm thick over silty sediments more than 5 m deep. Soils on the broad upland (7 to 12 percent slopes) consist primarily of the eroded phase of Hosmer series (Typic Fragiudalfs; fine, silty, mixed, mesic) and Lax series (Typic Fragiudalfs; silty, mixed, thermic) that developed in loess deposits. The soils are moderately well drained and 2 to 3 m thick over limestone or sandstone bedrock. Haymond soils are classified as suitable for growing black walnut while the Hosmer and Lax soils are listed as questionable because of a compacted layer in the soil profile (Losche et al. 1972).

Annual precipitation, generally distributed year-round, averages nearly 127 cm at Ambeer Creek and 114 cm at Camp Cadiz. The abandoned fields were tilled and planted in the spring of 1969 with black walnut and black walnut mixed with autumn-olive. Specific information on treatments and plot layout can be found elsewhere (Funk et al. 1979). The well developed broomsedge (*Andropogon virginicus* L.) cover in pure walnut plots has been mowed annually.

METHODS

All organic matter down to mineral soil (litter) and soil properties under pure and mixed plantings of black walnut were studies in 12 sample locations (3 pure and 3 mixed in each plantation). Litter weight was sampled on four 0.5 m square plots in each of the 12 sample locations in mid-July. All litter within the sample square was carefully removed, bagged and transported to the laboratory. Possible contaminants, such as fungi, other microorganisms and soil, were minimal. Core and bulk soil samples at depths of 0-10, 10-20, and 20-30 cm were taken in each square. Soil samples from the 30-60 and 60-90 cm depths were obtained from only one 0.5 square plot per sample location.

The litter samples were dried at 70° C for 48 hours. Litter from each plot was sorted into two diameter sizes--material <3 mm and >3 mm--and weighed. Composite samples of the two sizes were ground in a Wiley mill to pass through a 500μ mesh sieve and dry ashed at 500° C for nutrient analysis: P by colorimetric procedures; K, Ca, and Mg by atomic absorption spectrophotometry. Total N was determined on a separate 1 g sample by the Kjeldahl procedure.

Soil samples were oven dried at 55° C and crushed to pass a 500μ mesh sieve. Total N, including nitrates, was determined by Kjeldahl procedures (Brumner 1965). Both NO_3-N and P were estimated by colorimetric procedures (Carson 1975, Knudsen 1975). Soil K, Ca, and Mg were determined by atomic absorption. Soil organic matter content was determined by wet oxidation method of Walkley (1947). Soil pH was determined with a glass electrode in a 2:1 mixture of distilled water and soil. Bulk density measurements were made using the undisturbed core sample method described by Jamison et al. (1950).

RESULTS AND DISCUSSION

Weight and Nutrient Composition of Litter

After 10 years, total litter accumulation is greater in pure and mixed plots in the upland planting than in similar bottomland plots (fig. 1). Some of the litter weight difference may be due to the less favorable moisture

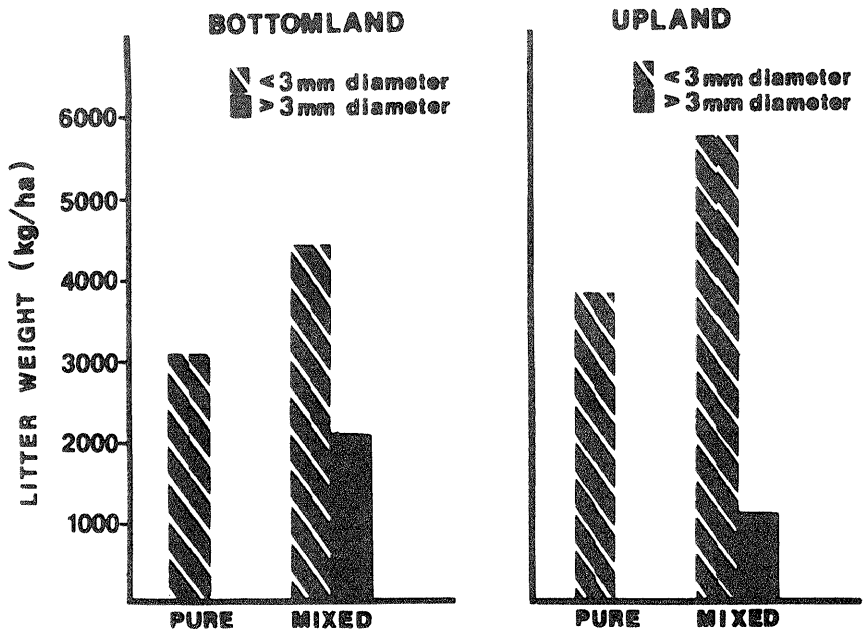

Figure 1.--Average weight of litter according to size in two 10-year-old plantings in southern Illinois.

condition for decomposition in the upland planting at Camp Cadiz compared with the bottomland planting. Ambeer Creek plots have been reported as having greater soil moisture content than Camp Cadiz (Funk et al. 1979).

Growth characteristics of the two plantings may help explain differences in litter accumulation. Black walnut trees at Ambeer Creek averaged 0.6 and 2.0 m taller in pure and mixed plots, respectively, than trees in similar plots at Camp Cadiz. Also, autumn-olive at Ambeer Creek are 24% taller than at Camp Cadiz. The larger autumn-olive and black walnut at Ambeer Creek form a closed canopy which excludes most ground cover while the partially closed canopy at Camp Cadiz permits more ground cover to develop in the mixed plantings. This one in 10-year sampling cannot determine if Camp Cadiz's higher litter accumulation reflects a greater contribution of annuals and other low growing vegetation combined with the major litter components, or slower decomposition, or a combination of these factors.

The weight of twigs and miscellaneous plant parts larger than 3 mm in diameter collected at Ambeer Creek was double the Camp Cadiz amount (fig. 1). Litter from pure plots was chiefly broomsedge parts, while mixed plots litter consisted mostly of autumn-olive and black walnut leaves and stems and annuals. The increase of litter greater than 3 mm in diameter at Ambeer Creek is undoubtedly due to the self pruning of the larger trees, while the absence of litter greater than 3 mm in pure plots is due to the black walnut's lack of self pruning.

Composite upland litter samples contained more of all nutrients tested than bottomland litter (table 1). Also, with the exception of calcium, the

Table 1.--Average weight, pH, and chemical composition of litter in two 10-year-old black walnut plantings in southern Illinois[a]

Site	Plot treatment	Weight[c]	pH	Nutrients[b]									
				N		P		K		Ca		Mg	
		kg/ha		%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha
Bottomland	Pure walnut	3100a	5.3a	0.35	10.9a	0.12	3.7a	0.46	14.3a	0.42	13.0a	0.15	4.7a
	Walnut/autumn-olive (mixed)	6575b	5.4a	1.62	106.5b	0.16	10.5a	0.55	36.2a	1.61	105.8b	0.41	27.0b
Upland	Pure walnut	3840a	5.6a	0.56	21.5a	0.13	5.0a	1.3	49.9ab	5.1	195.8c	0.57	21.9b
	Walnut/autumn-	6780b	5.8b	2.23	151.2b	0.25	17.0b	1.2	81.4b	2.8	189.8c	0.51	34.6b

a/ Figures in the same column followed by the same letter are not statistically different at the P = 0.05 level.

b/ Nutrient values are based on 3 composite samples.

c/ Weight based on 12 sample values.

average concentration of all nutrients was higher in mixed than pure plots in both plantings. The chemical differences in the litter showed in the pH values: 5.3 and 5.4 for pure and mixed plots, respectively, in the bottomland, and 5.6 and 5.8 for pure and mixed plots in the upland.

Nutrient content of the litter helps to evaluate the effects of vegetation in improving old fields. Leaf N of walnut trees in mixed plots averaged 2.8 percent compared to 1.6 percent for trees in pure plots. Thus, litter produced in the mixed plantings has a higher nitrogen content (average 129 kg/ha) and decomposes to enrich the mineral soil with humus and nitrogen. In contrast, broomsedge contributes very little N to the soil (average 16 kg/ha).

Soil Chemical Properties

Soil chemical properties for the two sites are given in table 2. The percent of organic matter in the upper 20 cm was higher in the upland planting. Below 20 cm, organic matter was higher in the bottomland soils.

Bottomland soils incorporated organic matter much better than the upland, a situation which may have existed before the study began. Also, bottomland soil moisture and temperature regimes encourage earthworms, fungi, and other decomposers to break down and incorporate the organic matter into the soil.

Upland soils had higher pH values than soils in the bottomland but differences within plantings for pure and mixed plots were less striking (table 2). Generally, soil pH decreased with depth at Camp Cadiz and increased at Ambeer Creek.

The average total N concentration in mixed plots was approximately twice that of pure plots in both plantings (table 2). While total nitrogen is a more accurate indicator of soil fertility, nitrate nitrogen indicates the available nitrogen. Comparisons of NO_3-N in the two plantings show similar concentrations in mixed plots. However, the difference between pure and mixed plots in the bottomland is greater. The similarity in NO_3-N concentrations between mixed and pure plots in the upland soils may be due to better conditions (including pH) for nitrifying bacteria and improved nutrients.

Phosphorus was present in greatest quantity in the 0-10 cm samples in both plantings. The amount of phosphorus in the bottomland site increased with depth following a decrease below the surface sample. In comparison, the amount of upland soil phosphorus steadily decreased with depth.

Potassium, calcium, and magnesium were found in greater proportions in the upland planting than in the bottomland, but there was little variance between pure and mixed plots in either soil (table 2). These nutrients were most prevalent in the surface soil and decreased with depth.

Lower bulk densities were recorded in upland soils than in bottomland soils (fig. 2). We did not find a compacted layer at or near the 65 cm depth as noted in earlier reports. Because of this inconsistency we dug several additional pits to look at root penetration. Roots were found at the 60-90 cm depth with similar distribution in both plantings.

Table 2.--Chemical composition at various depths of the soils from the Ambeer Creek and Camp Cadiz plantings in southern Illinois

Site	Plot treatment	Depth[a/] (cm)	pH	Organic matter (%)	Nutrients: Total N (%)	NO_3-N (%)	P (ug/g)	K	Ca	Mg
								Meq/100 g soil		
Bottomland	Pure walnut	0-10	5.33	2.45	0.12	0.004	27	2.65	5.28	0.62
		10-20	5.34	1.70	0.90	0.003	24	1.91	4.62	0.55
		20-30	5.52	1.28	0.04	0.003	25	1.67	4.10	0.68
		30-60	5.71	1.14	0.04	0.001	7	1.91	3.94	0.71
		60-90	5.62	0.89	0.02	0.001	6	1.48	3.66	0.65
	Mean		5.50	1.49	0.06	0.002	18	1.92	4.32	0.64
	(mixed) Walnut/ autumn-olive	0-10	4.93	2.73	0.16	0.009	24	3.20	4.42	0.60
		10-20	5.04	2.26	0.14	0.007	18	2.61	4.48	0.52
		20-30	5.31	1.29	0.12	0.005	21	2.10	3.86	0.66
		30-60	5.42	1.17	0.08	0.003	17	2.15	3.68	0.65
		60-90	5.32	0.89	0.06	0.002	9	1.64	3.52	0.70
	Mean		5.20	1.67	0.11	0.005	18	2.34	3.99	0.63
Upland	Pure walnut	0-10	6.13	5.23	0.08	0.008	24	4.10	23.20	1.24
		10-20	6.54	3.03	0.05	0.007	16	3.51	18.81	1.15
		20-30	6.03	0.97	0.04	0.002	7	3.28	12.66	0.95
		30-60	5.81	0.74	0.01	0.002	4	3.71	6.29	0.55
		60-90	5.73	0.71	0.01	0.001	3	3.59	2.28	0.53
	Mean		6.05	2.14	0.04	0.004	11	3.64	12.65	0.88
	(mixed) Walnut/ autumn-olive	0-10	6.23	4.56	0.12	0.009	19	5.85	20.41	1.21
		10-20	6.34	2.46	0.10	0.009	14	4.29	18.23	1.10
		20-30	6.32	0.80	0.06	0.003	12	3.28	11.24	0.62
		30-60	5.71	0.68	0.05	0.002	3	2.88	5.54	0.58
		60-90	5.44	0.61	0.05	0.001	6	2.65	2.16	0.55
	Mean		6.01	1.82	0.08	0.005	11	3.79	11.52	0.81

a/ Average of 12 values for depths 0-30 cm and mean of 3 values for depths 30-90 cm.

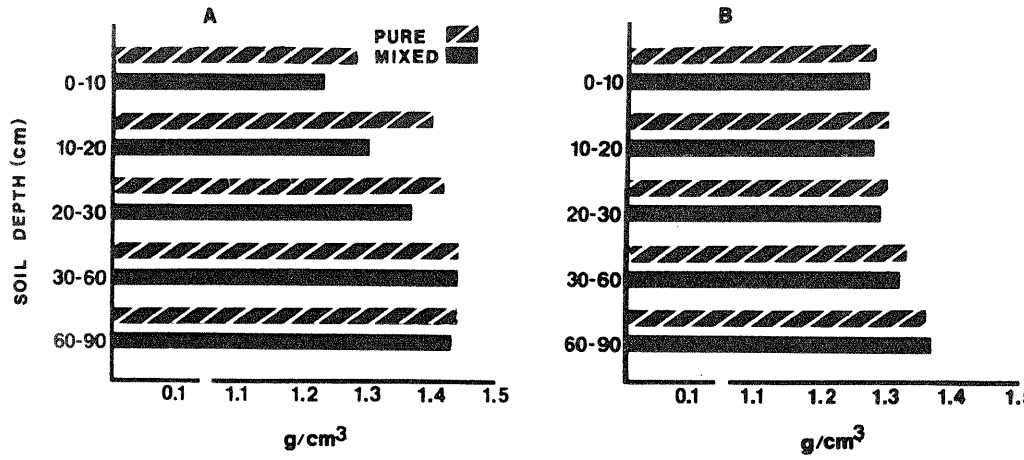

Figure 2.--Mean soil bulk density in (A) bottomland and (B) upland black walnut plantings.

SUMMARY

Analysis of litter and soils under two 10-year-old black walnut plantings consisting of pure plots (black walnut planted alone) and mixed plots (black walnut mixed with autumn-olive) shows that inherent soil chemical properties contribute to site variations in litter accumulation, elemental components of litter, and soil nutrients (with the exception of total N and NO_3-N). The small range of differences between pure and mixed plots seems due to the short stand histories.

Although growth differences in the two plantings cannot be completely explained by data presented here, sufficient evidence showed that planting autumn-olive with black walnut increased total litter accumulation and soil nitrogen. Undoubtedly these two factors help explain the improved growth of walnut trees in mixed plots compared with pure plots.

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