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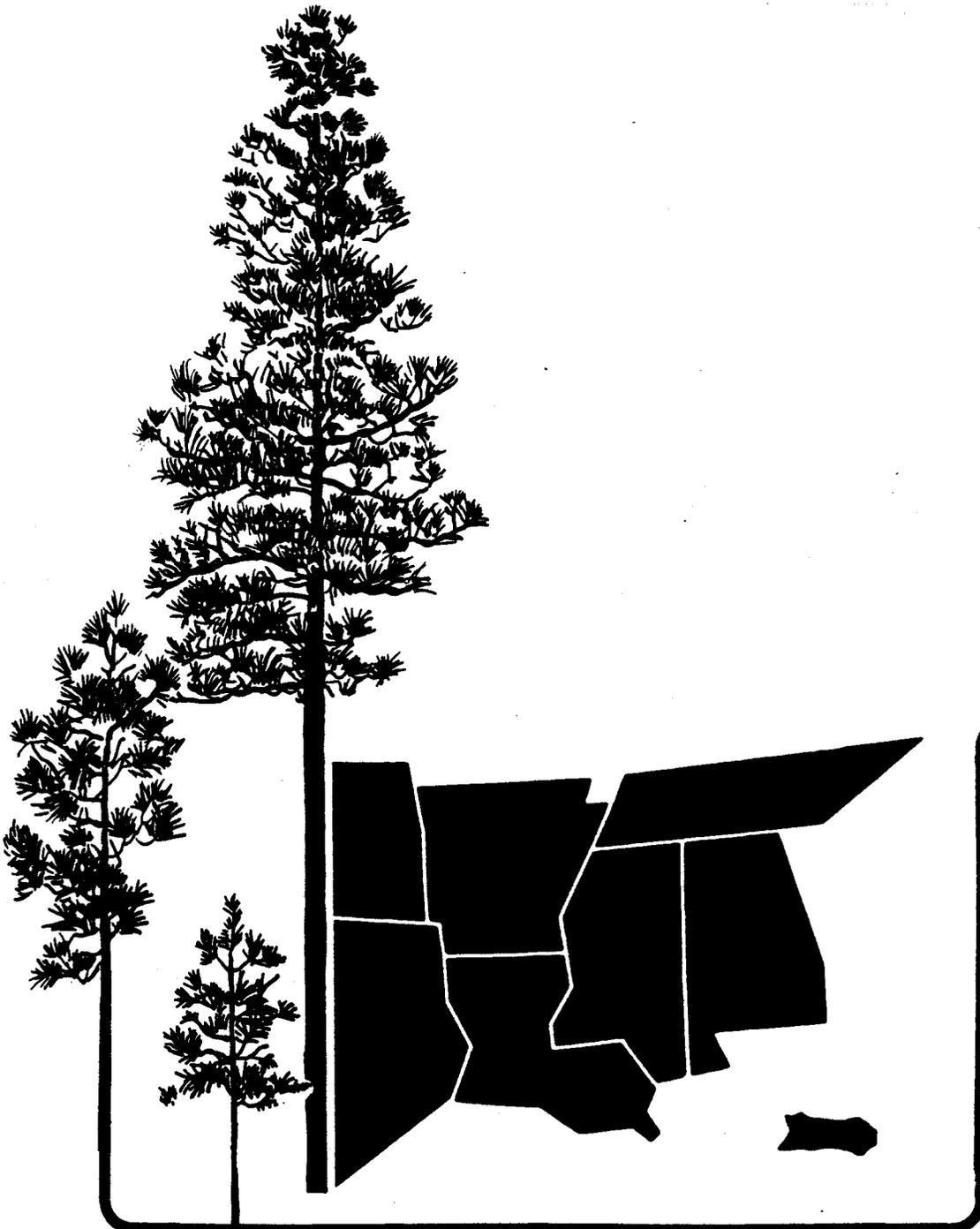
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BOTTOMLAND HARDWOOD FERTILIZATION--THE STONEVILLE EXPERIENCE

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BOTTOMLAND HARDWOOD FERTILIZATION--THE STONEVILLE EXPERIENCE^{1/}

John K. Francis^{2/}

Abstract.--A number of fertilization experiments have been conducted in plantations of cottonwood, sweetgum, and sycamore and in natural stands of oak and sweetgum. Responses to nitrogen or nitrogen + phosphorus have been obtained more frequently in stands established on old fields than on undisturbed sites. Accelerated growth was maintained only a year or two.

INTRODUCTION

The hardwood surplus is not permanent. Every demand projection shows increased use of wood products in the future. Much forest land continues to be withdrawn for uses other than timber production. Unless technology brings forth inexpensive alternatives to the many uses of hardwoods, tight supplies and higher prices will be the eventual result. The wood supply crunch may bring into use management techniques, such as fertilization, that usually have been too expensive. Potentially, fertilization could accelerate growth so that rotations would be shortened, and thus more hardwood timber could be harvested per acre of commercial forest.

Over the last 25 years in Stoneville, Mississippi, 20 studies were conducted by USDA Forest Service scientists to evaluate the response of bottomland hardwoods to fertilization. Nitrogen (N), phosphorus (P), potassium (K), and lime were applied to natural stands and to plantations in various combinations and at different rates. I shall summarize the results of these studies and comment on their relevance to bottomland hardwood management.

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COTTONWOOD STUDIES

Four greenhouse studies pointed to the possibility of responses of cottonwood to fertilizer in the field. The first, a solution culture study, demonstrated as much as 5.5 feet of height growth from seed in 9 weeks (Bonner and Broadfoot 1967). Normal growth in soil for this period might be 10 inches. The greatest dry weight was accumulated with solution concentrations of 100 ppm N, 75 ppm P, and 100 ppm K. Minimum foliar nutrient concentration for "good" growth was 3.0% N, 0.3% P, and 1.2% K. The best growth occurred with 4.2% N, 0.7% P, and 3.0% K. In three pot studies, cottonwood planted in fertile alluvial soils (Commerce, Sharkey, Adler, and Convent) from the Mississippi River floodplain either did not respond or responded little, even to high rates of N, P, or K. Cottonwood in a Coastal Plain alluvial soil (Bibb) having low natural fertility responded with 500% to 800% increases in total weight to lime or lime + complete fertilizer (N, P, and K) but not to complete fertilizer alone (Blackmon and Broadfoot 1969).

Foliar nutrient levels from the above studies, from fertilizer trials on plantations, and from natural stands growing on good and poor sites are summarized in table 1. These data tend to confirm the previously established threshold level of 2.0% for N (White and Carter 1970) but are not complete enough to establish critical levels of P and K.

In eight studies, some with multiple trials, fertilizer was applied to cottonwood in plantations. Soils represented were Commerce, Convent, Sharkey, and Urbo. Rates of N used ranged from zero to 600 lb/acre. The N source used in all these studies was NH_4NO_3 . In some of the studies, P and K were added to a treatment, and in one study a lime treatment was included. The most important cause of success or failure of a treatment was site history. Of the nine fertilizer trials

Table 1.--Representative foliar nutrient levels from cottonwood in several fertilizer experiments.

Stand description	Soil series	Treatment N-P-K	-----%-----		
			N	P	K
Natural stand (large trees)	Commerce	-	1.6	0.13	0.84
	Sharkey	-	1.6	.12	.85
Solution culture	-	25 ppm-50 ppm-100 ppm	2.4	.65	2.90
	-	100 ppm-75 ppm-100 ppm	4.3	.70	3.20
	-	100 ppm-50 ppm- 50 ppm	3.9	.70	1.95
Potted	Commerce	Control	1.4	.16	1.79
	Commerce	100 lb/ac-50 lb/ac-100 lb/ac	2.2	.21	1.95
Plantations (avg. 2-, 3-, & 4-yr-old)	Sharkey	Control	1.7	-	-
	Sharkey	300 lb/ac-0-0	2.1	-	-
	Commerce	Control	2.0	-	-
	Commerce	300 lb/ac-0-0	2.4	-	-
Plantation (6-yr-old)	Commerce	Control	1.6	.18	-
	Commerce	150 lb/ac-0-0	2.2	.17	-
Plantation (7-yr-old)	Commerce	Control	1.4	-	-
	Commerce	150 lb/ac-0-0	2.1	-	-
Plantation (10-yr-old)	Convent	Control	1.3	-	-
	Convent	150 lb/ac-0-0	1.7	-	-

in plantations established in sites recently cleared from forest, only one showed a significant response to fertilizer. Plantations on old fields fared considerably better; in three of four trials, significant growth increases were recorded. The greatest responses occurred on the medium-textured Commerce and Convent soils. The old-field plantations grew slowly, and fertilization stimulated them briefly to perform similarly to trees on cleared sites. Cottonwood in the first year on Urbo, a Coastal Plain alluvial soil (pH 4.5), did not respond to added N or P but did respond significantly to 3 tons of lime per acre.^{3/} Benefit was not derived from the addition of P or K in any of the trials. The best rates of N fertilizer were 150 or 300 lb/acre.

The significant increases in diameter growth obtained in these experiments ranged from 26% to over 200%. However, responses were short-lived. Most of the benefit was obtained in the first year

after treatment. Apparently, enhanced growth did not occur in the third year after fertilization. (Even though growth returns to normal, the volume advantage remains with the fertilized trees.) Blackmon (1977b) reported that fertilizer treatments of 84 to 672 kg N/ha produced from 0.15 m³ to 0.03 m³ of additional wood per kilogram of N applied. This translates to 1 lb of N producing an additional 60 lb of wood at the lowest rate and 12 lb of wood at the highest rate. An 8-year-old, slow-growing cottonwood plantation in another experiment contained 73 lb of N in 14 tons of dry mass of the trees, including roots.^{4/} Assuming the same N concentration, the additional wood and supporting tissue produced for each pound of N would contain only 0.15 and 0.03 lb of N for the low and high treatments. Thus efficiency of N use for this experiment ranged from about 3% to 15%.

The treatments in the Stoneville experiments were mostly applied in April and early May.

^{3/} Blackmon, B. G. The effect of fertilizer and lime on an eastern cottonwood plantation on a Coastal Plain alluvial site. Study FS-S0-1111-2.15. Data on file at Southern Hardwoods Laboratory, Stoneville, Mississippi. 1979.

^{4/} Francis, John K. Characterization of biomass and nutrient accumulation in a developing eastern cottonwood plantation. Study FS-S0-1110-43. Data on file at Southern Hardwoods Laboratory. 1981.

Research conducted by Crown Zellerbach Corporation in the same area suggests that better results could be obtained by fertilizing in March (Crown Zellerbach 1973). Blackmon (1977a) found that plantation cottonwood are more likely to respond at 4 years old than at younger ages.

OTHER SPECIES

Cherrybark oak seedlings grown in liquid culture achieved their best growth from 100 ppm N, 5-25 ppm P, and 50-100 ppm K in solution.^{5/} Sycamore planted in pots containing a sandy loam Coastal Plain soil were treated with various rates of N, P, K, and lime. Phosphorus at rates of 25 and 100 lb/acre caused a 250% increase in height growth. Potassium had no effect. Lime and N caused slight growth reductions.^{6/} In a contrasting example, sycamore recently planted on a Coastal Plain alluvial soil were treated with N, P, and lime. Heights at the end of the first growing season were significantly increased (29%) by 150 lb N/acre. Lime at 4,000 lb/acre increased growth when applied with N, but not alone. Phosphorus did not increase growth at any of the rates tried.^{7/} The reason for the difference in response of the two soils is unknown but presumably relates to nutritional differences.

Dominant willow oak in a green-tree reservoir were fertilized in 2 consecutive years with a complete fertilizer (8-24-24) in a 30-foot-diameter circle around their trunks at a rate of 1,000 lb/acre. Radial growth increased by 32% over a 4-year period. Production figures indicated an increase in acorns,

^{5/} Blackmon, B. G. Cherrybark oak nutrition. I. Response of seedlings to N, P, and K in solution culture. Establ. and Final Rep. FS-SO-1111-2.4. Data on file at Southern Hardwoods Laboratory. 1973.

^{6/} Blackmon, B. G. American sycamore nutrition. I. Soil fertility requirements on an alluvial soil of the Coastal Plains. Establ. and Final Rep. FS-SO-1111-1.4. Data on file at Southern Hardwoods Laboratory. 1972.

^{7/} Blackmon, B. G. American sycamore nutrition. II. Response of plantations on Coastal Plain alluvium to additions of N, P, and lime. Final Rep. FS-SO-1111-1.15. Data on file at Southern Hardwoods Laboratory. 1977.

although the counts were not thought to be reliable.^{8/}

A 20-year-old, naturally regenerated stand of sweetgum, willow oak, and water oak on an old field (Tunica soil) was treated at various rates with N and an N-P-K fertilizer. The fertilizer was applied each April for 5 years. All fertilizer treatments increased the diameter and height of both sweetgum and oak (Broadfoot 1966). Greatest diameter growth was obtained with 300 lb N/acre. During the next 5-year period, in which no fertilizer was applied, the previously treated plots grew no faster than the control. Two more fertilizer treatments were applied at the same rates (stand ages 30 and 35), but without effect.

Sweetgum in pots of Sharkey clay soil received treatments of 250 lb N/acre, 100 lb P/acre, 250 lb K/acre, or combinations of N, P, and K. Seedlings in pots with N-P or N-P-K grew better than either the control or seedlings with any single nutrient. A single fertilizer treatment (N-P-K formulated at the above rates) was applied to the old-field sweetgum stand from which the Sharkey soil was obtained. After 6 years, the pole-sized stand was thinned and re-fertilized. N and P were used this time, plus Mg, Zn, Cu, and B. Two years later, the stand was measured. Average height growth for the 8 years of the experiment was not significantly affected by the treatments. Average diameter growth was greater for treated plots, 0.30 inch/year versus 0.24 inch/year for paired controls. Foliar data indicate that N may have been responsible for the difference.^{9/}

Five-year-old sweetgum planted on Henry soil (an old field) were fertilized in March with 250 lb N/acre, 150 lb P/acre, N + P, or nothing (control). The trees responded to N and N + P (but not to P alone) with increased height and diameter growth and crown expansion. Acceleration of growth lasted just 1 year. Three years after fertilization, trees that had received N + P, the best treatment, contained 60% more dry weight than trees in the control treatment (Ku et al. 1981).

In the last study, wood ash was tested as a fertilizer alone and in combination with N. (Wood ash from wood-waste burning boilers, currently a waste product, is a useful liming agent;

^{8/} Blackmon, B. G. Fertilization of willow oak for mast production in a green-tree reservoir. Final Rep. FS-SO-1111-2.7. Data on file at Southern Hardwoods Laboratory. 1979.

^{9/} Francis, John K. Fertilization of sweetgum on an old-field soil. Final Rep. FS-SO-1110-46. Data on file at Southern Hardwoods Laboratory. 1981.

it contains about 4% K and small amounts of many other nutrients.) Rates used were 2,000 lb ash/acre and 200 lb N/acre. These treatments were applied to a cottonwood plantation on Commerce soil, a sycamore plantation on Erno soil, a natural bottomland hardwood stand on Alligator soil, and a natural hardwood stand on Loring soil. None of the stands grew better as a result of the wood ash or nitrogen. Potassium was not deficient except possibly on the Erno soil, where the sycamore were also growing poorly because of soil physical problems associated with a fragipan.^{10/}

DISCUSSION

Generally, alluvial soils of the South, the principal habitat of bottomland hardwood species, are nutritionally sound. These are normally young soils derived from sediment of diverse sources. Vegetation and organic matter help maintain nutrient reserves at relatively high and nearly stable levels. When bottomlands are cleared and farmed, not only are nutrients removed in the crops, but most of the organic matter quickly disappears, together with the nitrogen it held. Our research at Stoneville has shown a high probability of response from the fertilization of plantations or natural regeneration occurring on old fields. Our experience also suggests that sites that have never been cultivated are less likely to respond to fertilizer.

Species in natural stands more than a few years old have been through rigorous competition and, by virtue of their survival, are usually well adapted to local soil conditions. This may not be true in plantations where competition is controlled. Off-site and slow-growing plantations might sometimes be saved by fertilization. A better approach, however, is to plant species only on sites where they will do well without expensive amendments. A measured high site index is a good assurance of site adaptability by a species. Where site indexes cannot be determined directly, soil-site evaluation systems may be applied (Baker and Broadfoot 1979, Broadfoot 1976).

In one of our most successful fertilizer trials on old-field cottonwood (Blackmon 1977a), 75 to 600 lb N/acre resulted in 1.5 to 6 cords/acre of additional standing volume in 2 years' growth. With current pulpwood stumpage at less than \$8/cord, that response would not even pay for the cost of the fertilizer.

^{10/} Francis, John K. Response of southern hardwoods to wood ash and nitrogen. Final Rep. FS-SO-1110-50. Data on file at Southern Hardwoods Laboratory. 1983.

Twenty studies cannot answer all the questions that might be asked about best rates of fertilizer and how to predict where a response would occur and its magnitude. Nor do they give us the confidence we need to recommend fertilization. In fact, much of the evidence indicates that this expensive practice is unnecessary in the bottomland hardwoods except in special circumstances. Fertilization of bottomland hardwoods certainly remains in the research stage. Identifying those special circumstances where response will justify investment should be the continuing mission for research.

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