HARDWOOD FERTILIZATION: RESEARCH PROGRESS IN THE MIDSOUTH

B. G. Blackmon[1/]

Abstract

To meet the increasing demand for wood and wood products, the Southern Hardwoods Laboratory is investigating silvicultural techniques such as fertilization. Sweetgum, water oak, and willow oak have responded to N and NPK on clay soils of the Mississippi River floodplain. Yellow-poplar growth has been improved by NPK fertilizers on eroded sites in the Silty Uplands, and in the greenhouse sycamore on Coastal Plain alluvial soil has responded to additions of P. Largest fertilizer responses have been by cottonwood plantations on medium-textured old-field soils in the Mississippi River floodplain. Nitrogen has produced 200% increases in volume growth on these sites. The gain from fertilization appears to be greatest in stands older than 2 or 3 years.

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Forest fertilization is one of several relatively new silvicultural techniques being considered for increasing the productivity of hardwood stands in the Midsouth. Interest in fertilization has been stimulated by the ever-increasing agricultural demand for prime lands and the resulting need for the ability to produce hardwoods on sites that are not ideally suited for their culture.

For the past several years, the Southern Hardwoods Laboratory has been researching nutrient relations in hardwoods. This paper is a summary of that work. Literature citations have been given for published material. Unreferenced information is from experiments in progress.

1/ The author is Principal Soil Scientist at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Miss., by the Southern Forest Experiment Station, USDA Forest Service, in cooperation with the Mississippi Agricultural & Forestry Experiment Station and the Southern Hardwood Forest Research Group.

SWEETGUM AND OAK

One of the oldest forest fertilization studies in the South was initiated by W. M. Broadfoot during 1958 in a 20-year-old stand of sweetgum, water oak, and willow oak (5). The stand, growing on Tunica clay, was given five annual surface applications of ammonium nitrate. Three rates were tested: 75, 150, and 300 pounds of nitrogen per acre yearly; in addition, a fourth treatment consisted of 150, 35, and 66 pounds per acre of N, P, and K, respectively.

At the end of 5 years, all treatments had increased diameter and height growth. For the three species combined, 300 N produced a 65% increase in diameter growth, and NPK increased heights by 44%. Best sweetgum growth was 1.99 inches in d.b.h. (300 N) and 12.0 feet in height during the 5-year period (NPK). During the same period, maximum growth for the oaks was 2.51 inches in d.b.h. (300 N) and 10.5 feet in height (NPK).

A sixth application was made in 1967. In 1972, the stand was remeasured and the data were subjected to an economic analysis. The six increments of 150 pounds of nitrogen per acre resulted in a per-acre increase of 11 cords or 2.2 MBF (based on a complete conversion from cubic-foot volume) over the control at stand age 35. At a stumpage price of $90 per MBF, this increase provides a return of $198 per acre on an $81-per-acre fertilization investment--the equivalent of an 8% return over the 15-year period. Six applications of 75 pounds of nitrogen per acre failed to increase volume over the control, while 300 pounds of nitrogen per acre resulted in volume increases comparable to those from 150 pounds.

In a greenhouse study, various combinations of N, P, and K (250, 100, and 250 pounds per acre, respectively) were applied to sweetgum growing on old-field Sharkey clay. After 5 months, unfertilized controls averaged 18 inches tall and 14 grams in oven-dry weight, while seedlings fertilized with N and NP averaged 25 and 27 inches in height and contained 33 and 42 grams of dry matter. Field tests are being made in a 20-year-old stand.

Also in the greenhouse, a solution culture study obtained maximum growth of cherrybark oak at approximately 200 pounds per acre of N, 10-50 pounds of P, and 100-200 pounds of K.

YELLOW-POPLAR

In 1967, the effect of fertilization was tested on yellow-poplars field-planted on Memphis silt loam having three degrees of erosion (2). A complete fertilizer (13-13-13), at a rate equivalent to 1,000 pounds per acre, was placed in holes 8-10 inches below the soil surface adjacent to individual trees.

On the severely eroded site (1 to 2 inches of topsoil), total height growth averaged 12.2 feet for a 5-year period after treatment, while control trees averaged only 8.5 feet. The response occurred during the second through fourth years after treatment, resulting in 43, 125, and 69% increases in annual growth over the controls for these years. During the first year, root systems had probably not developed enough to fully utilize the added nutrients. By the fifth year, the fertilizer had apparently been depleted.

On the moderately eroded site (4 to 5 inches of topsoil), treatment had an effect on annual height growth only during the second year--a 61% increase over the controls.

Fertilization failed to influence height growth on the non-eroded site (6 to 8 inches of topsoil).

AMERICAN SYCAMORE

Little nutrition work has been done with American sycamore. A few years ago, the effect of N, P, K, and lime was tested on seedlings growing on an alluvial Coastal Plain soil in the greenhouse. Results indicated a growth response (ca. 250% over the controls) to 25 pounds of P per acre, with no additional response to the highest rate, 100 pounds. Nitrogen and lime had slight negative influences, while potassium had no effect. Increasing the rate of phosphorus tended to counteract the adverse effect of lime, an indication that lime had reduced P availability.

A field study has been installed in the Coastal Plain of Mississippi, but poor drainage appears to be masking or negating any fertilizer effect. Perhaps on such sites a combination of fertilization and bedding would be appropriate.

EASTERN COTTONWOOD

Research at the Southern Hardwoods Laboratory has concentrated on cottonwood more than any other species. The earliest work was that of Bonner and Broadfoot (4), who tested N, P, and K applications in sand culture. Maximum seedling development occurred at nutrient solution levels of 200, 150, and 200 pounds of N, P, and K per acre.

In cultures completely lacking nutrients, seedlings exhibited deficiency symptoms typical of those seen in agronomic crops. N deficiency was characterized by chlorosis, most pronounced between leaf veins. Slight chlorosis was evident even at the 50-pound level. On plants deficient in P, small shoots had red pigmentation, which was strongest on leaf margins and petioles. Deficiency in K was characterized by burning that began on leaf margins and extended between primary veins almost to the midrib. On K-deficient plants, entire leaf surfaces were crinkled.

In a soil-pot study (1), fertilizer treatments were applied to four bottom-land soils in which cottonwood seedlings were growing. Soils were: Sharkey clay and Commerce loam from the Mississippi River floodplain; Adler silt loam from a stream bottom in the Silty Uplands; and Bibb sandy loam, a strongly acid, poorly aerated, alluvial soil from the Coastal Plain. In addition to fertilizer, the Bibb soil was given 2 tons of lime per acre and a lime-plus-NPK treatment.

Seedlings in Adler and Sharkey soils did not respond to fertilizer, while plants in Commerce displayed a slight response to 100 pounds of N per acre. Although seedlings in Bibb soils grew considerably less than the others, they responded markedly to fertilizer, lime, and a combination of the two.

In the greenhouse, growth on the Sharkey soil was superior to that on Commerce. It is well known that the opposite is true in the field--Commerce outproduces Sharkey by perhaps a 2:1 margin. Sharkey is very high in montmorillonitic clay, which causes it to be poorly drained and poorly aerated. But because of its clay content, Sharkey has a high cation exchange capacity and base status, bases consisting primarily of Ca^{++} and Mg^{++}. The greenhouse study simply illustrates that if the undesirable physical condition could be alleviated, as was accomplished by drying and screening, Sharkey would probably become very productive. Such modification, however, will be extremely difficult to accomplish on an operational scale.

Greenhouse evidence that cottonwood would respond to lime on a Coastal Plain soil was tested in a field study on an Urbo silt loam in eastern Mississippi. Three tons of dolomitic limestone were applied in a 2-year-old plantation. Two years after treatment, limed plots had only a 17% height advantage over the controls, much less than in the greenhouse. This lesser response is possibly due to the method or time of application, or both. Limestone was spread between the rows of trees and the area was disked lightly, resulting in rather shallow incorporation. For best results in agronomic crops, lime is applied before planting and incorporated deeply. The reason, of course, is that in the soil calcium is relatively immobile and needs to be mixed thoroughly with the surface soil.

Tests in the Mississippi River floodplain produced mixed results. A 2-year-old cottonwood plantation on a recently cleared Commerce silt loam has shown no response to several rates of nitrogen and NPK.

The story was somewhat different, however, on an old-field Commerce silty clay loam supporting a 6-year-old cottonwood plantation (3). The treatments (per acre) were:

Check--no fertilizer.

100 pounds P from concentrated superphosphate.

150 pounds N from ammonium nitrate.

100 pounds P plus 150 pounds N.

After 4 weeks, all trees on N and NP plots had larger, darker green leaves and fuller crowns than trees on check and P-treated plots.

At the end of the growing season, average stem d.b.h. had increased by 0.63 inch on plots treated with N and by only 0.21 inch on check plots (table 1). N and P in combination resulted in slightly less diameter growth than N alone. P alone had no effect. Likewise, the greatest volume response resulted from the application of 150 pounds of N per acre. The N and NP treatments did not produce significantly different results; both were superior to the control and P treatment. N alone produced 156 cubic feet of stemwood per acre, three times as much as the control.

Fertilization also increased the biomass of understory vegetation (table 2). The actual quantity of nitrogen contained in this vegetation (primarily johnsongrass) ranged from 30 to 60 pounds per acre.

N fertilization increased foliar N from 1.6 to 2.3% in the upper crown and from 1.3 to 1.7% in the lower crown. P fertilization had no effect on foliage P. Foliar N in both crown positions was strongly correlated with all parameters of growth, an indication that either crown position is suitable for nitrogen analysis.

Other researchers (6, 7, 8) have suggested a nitrogen foliage level of 2% to be minimum for several species of poplars. Results of this study seem to support the proposed critical level. All N treatments raised foliar N to over 2% in the upper crown.

An important question, still largely unanswered, is how long the fertilizer response will last. In the present study, the 200% growth advantage of fertilized trees had diminished to 122% by the end of the second season.

Cottonwood on a clay soil has also responded to fertilization, but not so markedly. Three hundred pounds of N per acre resulted in a 30% increase in d.b.h. in a stand 4 years old at the time of treatment. In the same experiment, fertilizer was applied to 2- and 3-year-old cottonwood with no resultant increase in growth. Thus, it seems unlikely that cottonwood will respond to fertilization until the stand begins to utilize the site fully and trees are competing with each other for nutrients.

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Table 1.--Growth of a 6-year-old cottonwood plantation during year following fertilization[1/]

Fertilizer[2/]	Diameter[3/]	Basal area[3/]	Height[3/] (5 largest trees)	Volume[3/]
	----Inch----	Sq. ft./acre	----Ft.----	Cu. ft./acre
None	0.21 a	3.99 a	4.1 a	76.2 a
P	.23 a (10)	4.39 a (10)	4.4 a (7)	79.3 a (4)
N	.63 b (200)	11.77 b (195)	8.4 b (105)	231.7 b (204)
NP	.57 b (171)	11.13 b (179)	7.7 b (88)	211.4 b (178)

1/ Mean based on approximately 60 trees except for height. Means followed by the same letter (vertically) are not significantly different at the 0.05 level.

2/ 0 = check, no fertilizer; P = 100 pounds P per acre from concentrated superphosphate; N = 150 pounds N per acre from ammonium nitrate; NP = combination of the above.

3/ Numbers in parentheses indicate percentage increase over control.

Table 2.--Effect of fertilizer on competing vegetation (Johnsongrass)

Fertilizer	Vegetation
	Tons/acre
None	0.78 a
P	0.90 a
N	2.23 b
NP	2.72 b

Means followed by the same letter are not significantly different (0.05 level).

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