

Research Progress in Fertilizing Southern Hardwoods

W. M. Broadfoot and A. F. Ike¹

Soil Scientists
Forest Service, USDA

Fertilizing stimulated growth of eastern cottonwood, sweetgum, water and willow oak, yellow-poplar, and sycamore. In most cases, N appeared to be the key element.

If present trends continue, fertilizer may soon be required to increase growth in southern hardwood stands. Demands for the wood are rising, and the acreage allotted for growing it is steadily shrinking. To supply anticipated requests for information, the U. S. Forest Service has established tree nutrition studies at the Southern Hardwoods Laboratory in Stoneville, Mississippi, and the Forestry Sciences Laboratory in Athens, Georgia.

Responses to fertilizer, of course, vary with tree species, soil conditions, and individual trees. So far, experiments have been made with eastern cottonwood (*Populus deltoides* Bartr.), sweetgum (*Liquidambar styraciflua* L.), water oak (*Quercus nigra* L.), willow oak (*Q. phellos* L.), yellow-poplar (*Liriodendron tulipifera* L.) and sycamore (*Platanus occidentalis* L.). In this paper, the results of these experiments are discussed by species.

Cottonwood

Eastern cottonwood has been given the highest research priority at the Southern Hardwoods Laboratory because the paper industry is keenly interested in the intensive management of this species. Responses to various concentrations of nutrients were measured on seedlings in sand cultures and in four common alluvial soils of the Midsouth.

Sand culture—Cottonwood seeds were planted in 5-gallon glazed stone crocks containing sand that was leached with distilled water until the leachate had

¹Stationed, respectively, at the Southern Hardwoods Laboratory maintained at Stoneville, Mississippi, by the Southern Forest Experiment Station in cooperation with the Mississippi Agricultural Experiment Station and the Southern Hardwood Forest Research Group; and at the Forestry Sciences Laboratory maintained at Athens, Georgia, by the Southeastern Forest Experiment Station in cooperation with the School of Forestry, University of Georgia.

a specific conductance of less than 5×10^{-5} mhos per cm. After the seeds germinated, solutions were added to the crocks with one of seven concentrations of N, P, and K:

N—0, 10, 25, 50, 100, 200, and 300 ppm.

P—0, 5, 10, 25, 50, 75, and 100 ppm.

K—0, 25, 50, 100, 200, 300, and 400 ppm.

Treatments were arranged in a randomized block design. In groups of crocks where one element was varied, the other two elements were supplied at constant rates—100 ppm of N and K, and 50 ppm of P. Nutrient solutions were added for 90 seconds every 15 minutes with an automatic irrigating device. After 9 weeks, the experiment was terminated, and dry weights of seedlings and N, P, and K contents of foliage were measured.

With concentrations of the other two elements held constant, the concentrations of each element that resulted in the greatest average seedling weight were 100 ppm of N, 75 ppm of P, and 100 ppm of K (Table 1). However, differences in growth at these concentrations and at concentrations of 50 ppm of N, 5 ppm of P, and 25 ppm of K were not statistically significant at the 5% level of confidence. Addition of 300 ppm of N resulted in significantly less growth than addition of lesser amounts.

Plants that received none of a particular nutrient exhibited typical deficiency symptoms. N deficiency was characterized by chlorosis, which was most noticeable between veins. Some chlorosis was evident at 25 ppm of N. P-deficient shoots were small, and had red coloration which was most obvious on leaf margins and petioles. K deficiency was characterized by a pronounced "burning" that started at leaf margins and extended between primary veins almost to the midribs. The entire leaf surfaces were crinkled.

Four soils—Samples of four bottomland soils common in the Midsouth—Sharkey clay, Adler silt loam, Commerce fine sandy loam, and Bibb sandy loam—were collected from the surface 9 inches in forested areas. The soils were placed in crocks, and cottonwood seeds were sown. After the seeds germinated, various amounts of fertilizer were added: 0, 50, 100, or 150 pounds of N, 0 or 50 pounds of P and 0 or

Table 1. Foliar N, P, and K and seedling growth with changes in each nutrient.

Nutrient in solution (ppm)	Foliage concentration			Total plant dry weight Grams
	N	P	K	
Percent by weight				
N varied — P at 50 ppm and K at 100 ppm.				
0	1.58	0.78	1.97	0.1
10	2.09	.60	2.90	5
25	2.35	.65	2.90	45
50	2.94	.64	3.25	70
100	4.24	.69	3.00	81
200	4.44	.83	3.33	77
300	5.23	.83	3.10	37
P varied — N and K at 100 ppm.				
0	5.81	0.40	1.98	0.1
5	4.38	.30	3.90	56
10	4.20	.53	3.63	54
25	4.07	.50	3.00	60
50	4.30	.52	2.97	64
75	4.26	.70	3.20	68
100	4.00	.71	3.47	56
K varied — N at 100 ppm and P at 50 ppm.				
0	4.24	0.72	0.57	2
25	3.64	.75	1.20	62
50	3.86	.70	1.95	63
100	4.01	.77	3.35	79
200	3.84	.67	3.77	69
300	3.87	.66	4.42	63
400	3.86	.68	4.13	79

100 pounds of K per acre. Because the Bibb soil was strongly acid, the equivalents of either 2,000 or 4,000 pounds per acre of lime were added. Each treatment was replicated in a randomized block design, and seedling responses were measured after 3 to 5 months.

On Sharkey clay and Adler silt loam, fertilizer did not stimulate growth, although it did increase amounts of some nutrients in foliage. The lack of response is probably attributable to the relatively high concentrations of the nutrients present in the soils originally.

There was a slight but statistically significant (0.05 level) improvement in growth of fertilized seedlings on Commerce fine sandy loam. The best responses were from high N applications alone or in conjunction with K or P and K.

Complete fertilizer and lime increased growth on Bibb sandy loam, but growth was poor even with fertilizer and lime.

Table 2. Five-year growth by species and treatment¹.

Treatment (pounds per acre)	Sweetgum		Oak	
	D. b. h. Inches	Height Feet	D. b. h. Inches	Height Feet
0	1.07	6.9	1.64	8.8
75 N	1.50	9.8	1.96	8.9
150 N	1.59	10.0	2.62	9.1
300 N	1.99	11.4	2.51	8.9
150 N, 35 P, 66 K	1.80	12.0	2.31	10.5

¹Each value in the table is the average for 20 sample trees.

Sweetgum and Oak

Responses to surface application of fertilizer were measured in a natural sweetgum-oak stand on Sharkey clay near Tallulah, Louisiana (Broadfoot, 1966).

Annually for 5 years, 1/10-acre plots in a well-stocked 20-year-old stand of sweetgum, water oak, and willow oak were topdressed with fertilizer at five rates per acre: zero (control), 75 pounds of N, 150 pounds of N, 300 pounds of N, and 150 pounds of N plus 35 pounds of P and 66 pounds of K. Treatments were replicated four times. The source of N was ammonium nitrate, and the P and K were from a 0-20-20 mixed fertilizer.

Five dominant and codominant trees of sweetgum and five of oak were randomly selected on each plot. Because willow and water oak resembled each other in form and growth, oaks were combined and treated as one in the test.

At the beginning of the study, oak sample trees averaged 5.9 inches in diameter and 45 feet in height, and sweetgum trees averaged 4.6 inches in diameter and 37 feet in height. A year after the first fertilizer application, tree foliage and soil samples were analyzed for N, P, and K.

All fertilizer treatments increased diameter and height growth of both sweetgum and oaks (Table 2). The best diameter growth for the 5 years was 1.99 inches in sweetgum fertilized with 300 N, and the best height growth was 12 feet in sweetgum fertilized with 150N-35P-66K. Responses of the oaks, though smaller, were similar to those of sweetgum. For oak and sweetgum combined, 300 N produced a 65% increase in diameter growth, and 150N-35P-66K produced a 44% increase in height.

For diameter growth, 75 N was significantly better than none. There was no difference between 150N-

Table 3. Nutrient content of foliage.

Treatment (pounds per acre)	Sweetgum			Red oak		
	N	P	K	N	P	K
	Percent by weight					
0	1.507	0.186	0.59	1.564	0.089	0.71
75 N	1.449	.160	.52	1.521	.096	.62
150 N	1.687	.170	.62	1.670	.096	.58
300 N	1.868	.122	.68	2.149	.131	.63
150 N, 35 P, 66K	1.620	.170	.69	1.640	.115	.60

35P-66K and 150 N, but each was better than 75 N, and 300 N was best. For height growth, all N applications were better than none, but there was no significant (0.05 level) difference between rates of application; 150N-35P-66K was better than 75 N and 150 N, but not 300 N.

Leaves from trees fertilized with 150 N, 150N-35P-66K, and 300 N contained more N than leaves from unfertilized trees (Table 3). The N content of leaves from trees fertilized with 300 N was greater than that of other leaves.

Phosphorus content of foliage was not significantly affected by fertilizing. However, there was a slight decrease in P content of sweetgum as N was increased, whereas the reverse appeared to be true for oak. The K content of leaves was not affected by fertilizer treatment.

A year after the last fertilizer application, there were no differences in N or P contents of the soil. With increasing N application, however, the K content of soil decreased (Figure 1). The reason for this decrease is not known. An imbalance created by heavy N applications seems unlikely, since Sharkey clay soils usually have much exchangeable K and little N. Perhaps the trees grew faster when fertilized and used more exchangeable K as a result; or, more likely, K was lost by displacement and in solution.

Yellow-poplar

At Athens, yellow-poplar and sycamore have been studied because both species grow rapidly and make satisfactory paper pulp. Yellow-poplar is also highly valued as a furniture wood.

One experiment (McAlpine, 1959) tested the response of 1-year-old yellow-poplar seedlings to diammonium phosphate. The fertilizer was broadcast in May at rates of 0, 250, 500, and 1,000 pounds per acre, which supplied 0, 50, 100, and 200 pounds of N and 0, 130, 260, and 520 pounds of P.

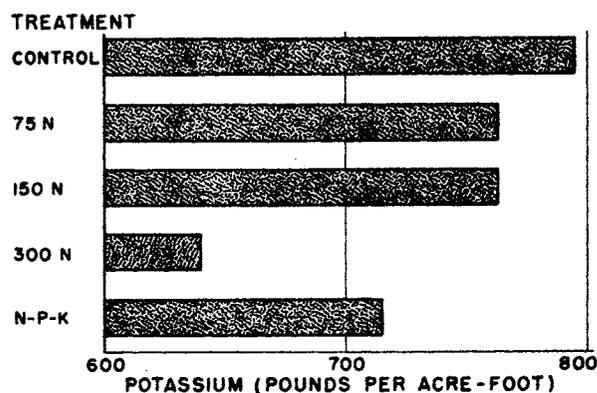


Fig. 1. Average exchangeable-potassium content of soil 1 year after treatment.

The two high rates of fertilizer application were more effective than the low rate in stimulating growth, and all treatments were better than none. Treatment-related differences in total height increased with time. At age 4, tree crowns on the most heavily fertilized plots were closing, thereby eliminating weed competition (Ike, 1962). Check plots and those that received only light fertilization were being invaded by volunteer sweetgum.

In a subsequent test, N proved to be the key element for increasing growth. Trees fertilized with N and P grew only slightly faster than trees fertilized with N alone.

These studies and several related greenhouse experiments indicate that yellow-poplar is more tolerant of heavy fertilizer application than are many hardwoods. A balanced nutrient supply seems to increase yellow-poplar's resistance to high fertilizer salt concentrations.

In nutrient deficiency studies, leaves of yellow-poplar that had a severely restricted N supply were usually yellowish-green. Phosphorus deficiency was most evident in immature leaves, which were thin, limp, translucent, and pinkish bronze in color.

Sycamore

Fertilization also stimulated the growth of sycamore. Site preparation and cultivation increased the response, which was greater in seedlings than in cuttings.

An experiment of particular interest tested the effects of broadcasting N, P, and K on 1-year-old seedlings. The site was a 7-acre overflow bottomland pasture on the Oconee River floodplain in northeastern Georgia, about 30 miles south of Athens. The alluvial soil was well drained but low in nutrients by agricultural standards. Texture varied from clay to silty clay loam.

Graded 1-0 seedlings were hand-planted in December 1960 at an 8- by 8-foot spacing. Plots containing 16 trees were separated from each other by two isolation rows. Ammonium nitrate was broadcast at rates equivalent to 0, 150, and 300 pounds of N; triple superphosphate at 0, 44, and 87 pounds of P; and muriate of potash, at 0, 83, and 166 pounds of K per acre. The equally spaced treatments in a factorial arrangement totaled 27 treatment combinations. They were replicated twice in a randomized complete block design.

Seedling growth was measured in September of the first year. Responses to N, P, and K were all statistically significant, but only that to N was silviculturally meaningful. The equation describing the response to N alone was quadratic:

$$\text{Height growth in feet} = 4.379 + 0.01616N - 0.00003557N^2$$

where N is N applied in pounds per acre. The equation indicates that a maximum height growth of 6.2 feet would be associated with an N application of 225 pounds per acre. If the N application were cut in half, the equation indicates that height growth would be 5.7 feet, a difference of only 6 inches. Unfertilized seedlings grew only 3.7 feet during the first year.

The height growth pattern in the second year followed closely that of the first. Again, only N produced meaningful responses. The mean height growth of seedlings fertilized with 300 N exceeded that of seedlings fertilized with 150 N by 0.8 foot. Corresponding means differed by 0.03 foot the first year. Apparently, the true optimum rate of N application was between 250 and 300 pounds per acre.

Conclusions drawn after the first year still apply after the sixth growing season: growth has been slowest on check plots, only N has produced meaningful responses, and 300 N has been only slightly more effective than 150 N.

Future Research

Research on soil fertility in relation to hardwood nutrition has barely begun. Information is needed on more species over a wider range of conditions. In addition, new approaches may be required. The methods that have been found most useful for field-crop research may not apply.

More knowledge about the time of application may be needed. Both season of year and age of stand may be important. It has been assumed that spring is the best season for application because this is thought to be the time of greatest demand. Is this assumption correct? Might there be a time later in the growing season when climate, physiological stage of development, and soil conditions are more conducive to efficient use of applied fertilizers? Should nutrients be applied the first year, or would they be better utilized at some time after establishment—perhaps at crown closure, perhaps later?

Haley (1966) states that fertilizing at planting time is justified economically only where it is necessary for seedling establishment. If he is correct, we must define the sites that require fertilization for seedling establishment.

McAlpine *et al.* (1966) have suggested that fast growing species like sycamore be grown at very close spacings on extremely short rotations. Such intensive culture for maximum fiber yield will demand much information not presently available. The grower will not be faced with the decision of whether or not to fertilize. Instead, he will be deciding how much of what types of fertilizer to apply, how often to apply them, in what manner, and how best to combine fertilization with other cultural practices. He will not expect exact recommendations immediately, but he will soon require reliable guidelines for fertilizing in an intensive management system.

More knowledge is needed about the influences of competing vegetation on responses to fertilizer. It is known that weeds can nullify benefits of fertilization, but perhaps the effect varies among weed species. Herbicides may be most practical for weed control, but is enough known about the interactions of specific fertilizer elements with specific herbicides—their influences on each other and on growth of trees? Possibly not.

Differences have been found among conifer seedlings from different seedlots in their ability to accumulate nutrients (Steinbeck, 1966). Similar differences have been observed among clones of yellow-poplar, sycamore, and cottonwood. More intensive investigations into genetic ability to utilize nutrients are planned.

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