

## SOIL MANAGEMENT IN HARDWOOD PLANTATIONS

B. G. Blackmon<sup>1</sup>

Abstract.--Several soil management techniques--fertilization, deep plowing, cover cropping, summer fallowing, irrigation, and cultivation--can benefit hardwood plantations. The applicability of the treatments to plantations of cottonwood, sweetgum, sycamore, green ash, yellow-poplar, and oaks depends largely on site conditions.

Additional keywords: Soil improvement, site amelioration, eastern cottonwood, sweetgum, American sycamore, green ash, yellow-poplar, oaks.

The demand for hardwood timber and fiber products continues to increase, but the land base available for hardwood production is declining. Many land managers now feel that demands can no longer be met efficiently in the remaining natural stands and during recent years have become interested in intensively cultured plantations.

Proper site selection and soil management are basic to good plantation culture. Hardwoods tend to be site-specific and make best growth on deep, fertile, moist, well-aerated alluvial soils. Broadfoot (1976) presented site-species and management recommendations for 20-30 hardwood species, and Baker and Broadfoot have developed a detailed system of estimating site index based on soil factors.<sup>2</sup> Their data indicate very high production potentials for hardwoods in plantations. Cottonwood, for example, is capable of producing as much as 400-450 cu. ft./a/year in pulpwood rotations on the best sites.

The most highly productive forest sites are also well suited for agricultural crops, and many have been cleared for farm use. Many of the sites now available for hardwood plantations can benefit from some type of soil management such as fertilization, deep plowing, cover cropping, fallowing, or irrigation. This paper deals with these soil management techniques as means for improving sites. Cultivation is required for hardwoods regardless of site quality and is therefore included in the discussion.

### PHYSICAL IMPROVEMENT OF SOIL

Broadfoot et al. (1972) states that physical condition as determined by soil structure is the key to soil excellence for the production of hardwoods. Medium-textured alluvial soils in their virgin condition usually have good structure but are susceptible to physical damage. Structural damage is less likely to be encountered on clays, particularly montmorillonitic, than on silty or loamy soils. Compaction by farm machinery, for example, increases bulk density and results in poor aeration, slow infiltration of

---

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

<sup>2</sup> Unpublished manuscript by James B. Baker and W. M. Broadfoot, in preparation.

water, and poor internal drainage.

Broadfoot and Bonner (1966) reported best cottonwood growth at a bulk density of 1.4. A bulk density of 1.6 (equivalent to 38% total porosity) restricted root and shoot development. Hidding and van den Berg (1961) noted root growth inhibition in certain agricultural crops if total porosity fell below 40%. Although bulk density and porosity have not been studied with species other than cottonwood, experience indicates that hardwoods such as sweetgum and green ash are probably better adapted to some of the conditions resulting from compaction than are cottonwood and sycamore.

Deep plowing prior to planting should improve hardwood growth on compacted soils. Indications are that for cottonwood and other poplars deep plowing to 16-20 inches would improve soils with a bulk density of 1.5 or greater (Blackmon, in press). For compacted surface layers as well as plow pans that have developed in old fields, McKnight (1970) recommended using the moldboard plow.

Another technique that is effective for cottonwood on old fields is fallowing the site during the summer before planting (Baker and Blackmon 1973). In an old field infested with Johnson grass, summer fallowing (disking four times, June-August) improved survival from 59% on controls to 82% on treated plots. After 2 years trees on fallowed plots averaged 23 feet in height, compared with 18 feet on controls. Computer projections indicate that by the end of an 11-year rotation summer-fallowed plots should yield 43 cords and nonfallowed plots 21 cords per acre. The large projected difference in volume is from the effect of summer fallowing on initial survival as well as growth. Baker and Blackmon (1973) attributed the influence of summer fallowing to improved soil structure, better water infiltration, and reduced weed competition. Repeated disking during the summer may also stimulate microbial activity, resulting in improved availability of nutrients, particularly nitrogen. On farms in the Great Plains, summer fallowing is used as a means of storing soil moisture (Falk 1975). Plantations of other hardwood species when established on certain sites--particularly those badly infested with herbaceous vegetation and in areas where moisture conservation is critical--can be expected to respond to summer fallowing. The benefit, however, would probably not be as great as with cottonwood.

Cover cropping with rye and vetch in combination with summer fallowing in the experiments with cottonwood provided no additional response. However, Haines et al. (1976), working in northern Alabama, found that Mississippi subterranean and crimson clovers grown in a 2-year-old sycamore plantation increased height and volume growth as well as foliar nitrogen content.

#### IRRIGATION

Irrigation of hardwoods is still in the experimental stage. After a severe drought in the mid-1950's, Broadfoot became interested in water relations in hardwoods and established a study of the effects of surface-water impoundment on several species (Broadfoot 1967). In a natural stand growing on Sharkey clay, he impounded water to a depth of 35 inches during the winter and spring for 4 successive years. Four-year radial growth for timber and pole-size material expressed as percent increase over unflooded controls was:

<u>Species</u>	<u>Percent increase</u>
Green ash	85
Cottonwood	90
American elm	35
Hackberry	45
Red maple	85
Nuttall oak	38
Persimmon	51
Sweetgum	82

Maintaining the flooded conditions caused the soil to be fully recharged with moisture at the beginning of the growing season.

Unpublished data from Stoneville indicate that growth of young cottonwood plantations can be increased perhaps as much as 50% by flood or sprinkler irrigation. These responses have occurred most often when water is given in late summer and in years with below-average rainfall during the growing season.

Meaningful responses to irrigation in hardwood plantations seem to be limited to arid regions of the world where supplemental water is necessary for survival of the plantation. The work of Rawitz et al. (1966) in Israel is a good example. In temperate regions irrigation is less promising because the cost of pumping and distributing water probably exceeds the value of the additional wood volume.

Perhaps the only feasible means of supplying additional water would be the construction of a series of dikes strategically located so that winter rain could be collected and stored on the plantation much as Broadfoot (1967) did in a natural stand. The possibility of attracting waterfowl (in the case of mast-producing tree species) would make the system more attractive. Water control structures would have to be built so that all water could be removed from the plantation early in the growing season. Such a system of water management would ensure that the soil had adequate moisture recharge at the beginning of the growing season, possibly a more efficient method than attempting to meet the tree's needs as moisture deficits occurred during the growing season.

#### CULTIVATION

Although there is some interest in the development of no-tillage soil management systems in hardwoods (Belanger and Saucier 1975), it is still generally accepted that hardwood plantations must be cultivated, at least during the first growing season. Kennedy and Henderson (in press) recently summarized proper cultivation practices for cottonwood, and the techniques apply to all hardwood plantations. However, some species, particularly green ash, sycamore, and sweetgum are able to tolerate slightly more competition than cottonwood. Plantations of these species may survive the first season with less intensive cultivation than cottonwood, but growth losses will definitely result.

#### FERTILIZATION

Of the soil factors that regulate the growth of hardwoods, nutrient

status is probably the easiest to alter. Thus, more research has been done in fertilization than in the other areas of soil improvement. Hardwoods have relatively high nutrient requirements and on certain sites require added nutrients for best growth.

At Stoneville, we have found that sycamore responds to rather low rates of P (25 lbs/a) when grown in the greenhouse on an infertile soil from the Southern Coastal Plain. In the Ohio River Valley, fertilization 3 successive years with 150 lbs/a N increased dry weight of sycamore slightly on a floodplain site and doubled dry weight on a terrace soil. Using 100 lbs/a P resulted in only about one-third more biomass than the unfertilized controls. Trends in height and diameter were similar to the trends for weight (Wood, et al. 1976). Saucier and Ike (1969) measured up to 50 percent increases in ring width after NPK applications to sycamore growing on a bottomland site in Georgia. They also studied wood properties and concluded that growth rate could be increased by fertilization without losses in wood quality.

Yellow-poplar has responded to fertilization on a variety of sites. McAlpine (1959) measured a large response by yellow-poplar to a broadcast application of diammonium phosphate applied in the year of planting. The site was in a small stream bottom in the Piedmont of Georgia. Responses to fertilization (NPK) have also been observed in yellow-poplar plantations on Silty Upland soils in Mississippi (Blackmon and Broadfoot 1970, Baker and Blackmon 1976). On eroded silty clay loam soils in eastern Tennessee, Farmer et al. (1970) measured growth responses to NP fertilization the first 2 years after planting. In southwestern Michigan, broadcasting 336 pounds of N, 73 pounds of P, and 139 pounds of K per acre in a 20-year-old plantation increased volume 200 percent over a 5-year period (Finn and White 1966).

Fertilization of sweetgum has been studied mostly in natural stands, but results are perhaps applicable to plantations. On a clayey soil in the Mississippi River floodplain in Louisiana, Broadfoot (1966) fertilized a 20-year-old natural stand of sweetgum, water oak, and willow oak. Several rates of nitrogen and a single NPK treatment were broadcast annually for 5 years. For the 5-year period, best diameter growth was 1.99 inches for sweetgum fertilized with 300 pounds of N per acre compared with 1.07 inches for the controls. Smaller responses were observed for the oaks. For the three species combined, 300 N produced a 65-percent increase in diameter growth, and NPK produced a 44-percent increase in height.

Cottonwood probably has the most exacting nutrient requirements of the southern hardwoods. Its rapid growth rate and economic importance have resulted in the species being planted on suboptimum sites, which in some cases require nutrient amendments. The Southern Forest Experiment Station began research on the fertilization of cottonwoods in the 1940's and established small-scale field trials (USDA--Forest Service 1947). Interest then lagged until the Station renewed its efforts in the 1960's. Even though the science of nutrition and fertilization is still in its infancy, more is known about cottonwood than the other species. Current status of knowledge for cottonwood and other poplars was recently summarized (Blackmon, in press).

On nitrogen-deficient old fields in the Mississippi River floodplain, broadcast applications of 150 to 300 lbs. of N per acre increased cottonwood

volume growth by as much as 200 percent (Blackmon and White 1972). Cottonwood did not respond to P, and combining N and P resulted in no more growth than N alone. Responses to N fertilization are most likely to occur if the foliar N level is below 2 percent and soil nitrogen is less than 1,000 lbs. per acre of total N.

Small responses have been observed on poorly drained clay soils in the Mississippi Delta<sup>3</sup>. Three hundred pounds of N per acre applied at age 4 resulted in a 30-percent increase in diameter growth. Fertilization at younger ages has not been beneficial.

Several experiments by industrial researchers have shown nitrogen responses varying from 40 to almost 500 percent, depending on site condition and history (Crown Zellerbach 1971a, 1971b, 1972a, 1972b, 1972c, 1973a, 1973b). In an economic analysis of the benefits of N fertilization, Crown Zellerbach (1974) found that increased growth from fertilization almost offset the cost of treatment during the first year. By the end of the second growing season, the value of the growth caused by fertilization was almost double the cost of the operation (Crown Zellerbach 1975). Crown Zellerbach (1971a) has also shown that continued cultivation during the second growing season caused large increases in foliar N levels and could be used as a substitute for N fertilization on some sites.

Cottonwoods planted in acid Coastal Plain soils usually require lime in addition to fertilizer (Blackmon 1974). Carter and White (1971) recommended that neither strongly acid soils (below pH 5) nor those low in exchangeable Ca (less than 1,000 ppm) be planted unless a heavy application of lime is included. Agricultural limestone is slowly soluble and relatively immobile in soil and should be applied at least several months before planting and deeply incorporated by disking.

#### CONCLUSION

From a practical standpoint, the land manager must distinguish between biological response and economic response. The economic feasibility of a particular management technique depends on many variables, including magnitude of the growth response, cost of the treatment, financial return possible from alternative investments, product being grown, prevailing market conditions, and others. Most of these variables are ever-changing; today's economic analysis may be totally invalid tomorrow. Research should provide sound biological information aimed at achieving maximum benefit from our forest resource. Land managers are fully capable of applying their own economic variables and making decisions as to the practicability of management techniques. As an industrial forester recently stated, "The task [of research] is to develop techniques now that can be implemented as they become economically feasible."<sup>4</sup>

<sup>3</sup> Unpublished manuscript by B. G. Blackmon, in preparation.

<sup>4</sup> From a speech delivered at the annual meeting of the Southern Hardwood Forest Research Group at Stoneville, Mississippi, January 20, 1977.

#### LITERATURE CITED

- Baker, J. B., and B. G. Blackmon. 1973. Summer fallowing improves survival and growth of cottonwood on old fields. USDA For. Serv. Res. Note SO-149, 3 p. South. For. Exp. Stn., New Orleans, La.
- Baker, J. B., and B. G. Blackmon. 1976. Growth of planted yellow-poplar after vertical mulching and fertilization on eroded soils. USDA For. Serv. Res. Note SO-215, 5 p. South. For. Exp. Stn., New Orleans, La.
- Belanger, R. P., and J. R. Saucier. 1975. Intensive culture of hardwoods in the South. Iowa State J. Res. 49: 339-344.
- Blackmon, B. G. 1974. Hardwood growth can be increased by fertilization. South. Lumberman 229(2848): 86-87.
- Blackmon, B. G. (In press.) Response of Aigeiros poplars to soil amelioration. Cottonwood Symp., Greenville, Miss. 1976.
- Blackmon, B. G., and W. M. Broadfoot. 1970. Fertilizer improves poplar growth. Miss. Farm Res. 33(11): 7.
- Blackmon, B. G., and E. H. White. 1972. Nitrogen fertilization increases cottonwood growth on old-field soil. USDA For. Serv. Res. Note SO-143, 5 p. South. For. Exp. Stn., New Orleans, La.
- Broadfoot, W. M. 1966. Five years of nitrogen fertilization in a sweetgum-oak stand. USDA For. Serv. Res. Note SO-34, 3 p. South. For. Exp. Stn., New Orleans, La.
- Broadfoot, W. M. 1967. Shallow-water impoundment increases soil moisture and growth of hardwoods. Soil Sci. Soc. Am. Proc. 31: 562-564.
- Broadfoot, W. M. 1976. Hardwood suitability for and properties of important Midsouth soils. USDA For. Serv. Res. Pap. SO-127, 84 p. South. For. Exp. Stn., New Orleans, La.
- Broadfoot, W. M., B. G. Blackmon, and J. B. Baker. 1972. Soil management for hardwood production. Southeast. Hardwoods Symp. Proc. 1972. p. 17-29. USDA For. Serv. Southeast. Area, State and Priv. For., Atlanta, Ga.
- Broadfoot, W. M., and F. T. Bonner. 1966. Soil compaction slows early growth of planted cottonwood. USDA For. Serv. Tree Plant. Notes 79: 13-14.
- Carter, M. C., and E. H. White. 1971. The necessity for intensive cultural treatment in cottonwood plantations. Circ. 189, 12 p. Agric. Exp. Stn., Auburn Univ., Auburn, Ala.
- Crown Zellerbach Corporation. 1971a. Second-year intensive cultivation of eastern cottonwood plantations. Crown Zellerbach South. Timber Div. Res. Note 71-3, 2 p.

- Crown Zellerbach Corporation. 1971b. Second-year response of eastern cottonwood to ammonium nitrate fertilizer. Crown Zellerbach South. Timber Div. Res. Note 71-8, 3 p.
- Crown Zellerbach Corporation. 1972a. Early intensive management of eastern cottonwood plantations. Crown Zellerbach South. Timber Div. Res. Note 72-13, 2 p.
- Crown Zellerbach Corporation. 1972b. Effect of site and age on response of eastern cottonwood to nitrogen. Crown Zellerbach South. Timber Div. Res. Note 72-12, 2 p.
- Crown Zellerbach Corporation. 1972c. First-year responses of eastern cottonwood to urea and ammonium nitrate. Crown Zellerbach South. Timber Div. Res. Note 72-6, 3 p.
- Crown Zellerbach Corporation. 1973a. Cottonwood stops responding to nitrogen three years after application. Crown Zellerbach South. Timber Div. Res. Note 73-1, 3 p.
- Crown Zellerbach Corporation. 1973b. Responses of eastern cottonwood to urea and ammonium nitrate. Crown Zellerbach South. Timber Div. Res. Note 73-2, 3 p.
- Crown Zellerbach Corporation. 1974. Economic response to operational fertilization of cottonwood is indicated by first season's growth. Crown Zellerbach South. Timber Div. Res. Note 74-4, 4 p.
- Crown Zellerbach Corporation. 1975. Payout on cottonwood fertilization shown by monitor study. Crown Zellerbach South. Timber Div. Res. Note 75-3, 5 p.
- Falk, D. E. 1975. Summer fallow is there a better way to store water? Crops and Soils 28(3): 9-11.
- Farmer, R. E., Jr., E. A. Snow, and J. W. Curlin. 1970. Effects of nitrogen and phosphorus fertilization on juvenile growth of planted yellow poplar on an eroded old field. Soil Sci. Soc. Am. Proc. 34: 312-313.
- Finn, R. F., and D. P. White. 1966. Commercial fertilizers increase growth in a yellow-poplar plantation. J. For. 64: 809-810.
- Haines, S. G., L. W. Haines, and G. White. 1976. Leguminous plants increase sycamore growth in northern Alabama. Agron. Abstr. 1976 Annu. Meet. Am. Soc. Agron., Houston, Tex.
- Hidding, A. P., and C. van den Berg. 1961. The relation between pore volume and the formation of root systems in soils with sandy layers. Inst. for Land and Water Manage. Res. Tech. Bull. 24, 5 p.
- Kennedy, H. E., Jr., and W. H. Henderson. (In press.) Cultivation in cottonwood plantations--practices and equipment. Cottonwood Symp., Greenville, Miss. 1976.

- McAlpine, R. G. 1959. Yellow poplar responds to fertilization. South. Lumberman 199(2489): 95-96.
- McKnight, J. S. 1970. Planting cottonwood cuttings for timber production in the South. USDA For. Serv. Res. Pap. SO-60, 17 p. South. For. Exp. Stn., New Orleans, La.
- Rawitz, E., R. Karschon, and K. Mitrani. 1966. Growth and consumptive water use of two poplar clones under different irrigation regimes. Isr. J. Agric. Res. 16(2): 77-88.
- Saucier, J. R., and A. F. Ike. 1969. Effects of fertilization on selected wood properties of sycamore. For. Prod. J. 19(9): 93-96.
- USDA Forest Service. 1947. Twenty-Sixth Annual Report Southern Forest Experiment Station 1946. p. 14-15, USDA For. Serv., South. For. Exp. Stn., New Orleans, La.
- Wood, B. W., S. B. Carpenter, and R. F. Wittner. 1976. Intensive culture of American sycamore in the Ohio River Valley. For. Sci. 22: 338-342.