POTENTIAL FOR INCREASING FIBER PRODUCTION THROUGH INTENSIVE CULTURE OF AMERICAN SYCAMORE IN THE CENTRAL HARDWOODS REGION

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ABSTRACT

Effects of intensive culture practices on biomass production were investigated for American sycamore plantations in the Ohio River Valley of western Kentucky. Nitrogen fertilization increased production of bole and branch components in 3-year-old coppice stands by 45 percent on a bottomland site and by 150 percent on a less-fertile terrace soil. Biomass production in 3-year-old stands of coppice origin was from approximately 50 to 150 percent greater than that of the 3-year-old stands of seedling origin previously harvested from these sites. Average annual yields of woody components increased with closer plantation spacing. Biomass yield data for the intensively cultured plantations are compared with data from conventional plantations and from a young natural stand of sweet gum on an old-field site.

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INTRODUCTION

Interest in the intensive culture of hardwood plantations for increased fiber production began more than 10 years ago with the development of the "silage" sycamore concept by scientists with the U.S. Forest Service and the University of Georgia (McAlpine et al. 1966). Cultural practices embodied in the concept include establishment of closely spaced plantations, repeated harvesting of coppice stands on relatively short rotations, fertilizing to optimize nutrients, control of competing vegetation, genetic improvement and utilization of most or all of the total above-ground tree components. Yields from American sycamore (*Platanus occidentalis* L.) have been studied in Georgia (Saucier et al. 1972, Kormanik et al. 1973) and Mississippi (Kennedy 1975). Researchers testing this concept with other species have reported yields for black cottonwood (*Populus trichocarpa* Torr. and Gray) in the Pacific Northwest (Heilman et al. 1972) and various poplar (*Populus*) hybrids in the northeast (Schreiner 1970, Bowersox and Ward 1976).

A major effort to study intensive plantation culture nearer to the geographic area associated with the Central Hardwood Forest is coordinated by a unit of the North Central Forest Experiment Station headquartered at Rhinelander, Wisconsin (Dawson 1976). The Department of Forestry, University of Kentucky, in cooperation with the Western Kraft Paper Group of Willamette Industries, Inc. has been conducting studies on the intensive culture of hardwood plantations for maximum fiber production in the Ohio Valley region of western Kentucky since 1971.

Biomass production of 3-, 4-, and 5-year-old sycamore plantations of seedling origin has been reported (Wittwer et al. 1978). Other species studied include European alder (*Alnus glutinosa* L.), river birch (*Betula nigra* L.), green ash (*Fraxinus pennsylvanica* Marsh.) and poplar hybrids (Wittwer and Immel 1978). This paper reports yields from coppice stands harvested 3 years after removal of the initial 3-year-old stand of seedling origin. Also reported, for comparison, are yield data from an unfertilized sycamore plantation established at a more conventional spacing (3.7 x 3.7 m) and an adjacent natural stand of young, densely stocked sweetgum (*Liquidambar styraciflua* L.).

In this paper we are primarily concerned with the biological aspects of increasing wood fiber production by various cultural methods. At the first Central Hardwoods Conference it was reported that removals of growing stock represented only 52 percent of the total growth of all growing stock in the region (Clark 1976) and we are well aware that economic and managerial considerations will determine if and when these techniques are implemented. It is our purpose to document the yields that may be achieved through utilization of some of the methods embodied in the "intensive culture" and "silage sycamore" concepts.

STUDY AREA

The study area is located in the Ohio Valley of western Kentucky, approximately 100 km west of Louisville and 75 km east of Evansville, Indiana. Hancock County, Kentucky is located near the geographic center of the Central Hardwoods Region as described in the Proceedings of the First Central Hardwood Conference (Clark 1976). Experimental plantings and adjacent natural stands were studied on sites representing two different topographic positions and soil conditions. Studies on the bottomland site are located within the floodplain of the Ohio River and are subject to periodic flooding during early spring. The terrace site occupies a stream terrace, parallel to the river and above the level of the bottomland site.

Soils on the bottomland site have been classified in the Ashton series (fine-silty, mixed mesic, Mollic Hapludalf) and are deep and well drained with high natural fertility and available moisture capacity (Cox 1974). The terrace soils are Elk (fine-silty mixed, mesic, Ultic Hapludalf) and Otwell (fine-silty, mixed, mesic, Typic Fragiudalf) silt loams. The Elk soil is deep and well drained while the Otwell is deep and moderately well drained with a fragipan beginning at about 65 cm. The natural fertility and available moisture capacity is rated high for the Elk and moderate for the Otwell series.

METHODS

Silage Sycamore Coppice Study

The experimental design for the silage sycamore study from which we are reporting coppice yields has been described in previous papers (Wood et al. 1976, Wittwer et al. 1978). The design utilized small plots (5.5 x 10.1 m) in a randomized block design with all treatment combinations replicated three times on each site (bottomland and terrace). Treatments included three spacings, 0.3 x 0.9 m, 0.9 x 0.9 m, and 1.8 x 0.9 m, and three fertilizer treatments, none, 169 kg/ha elemental N from ammonium nitrate (N), and a combined treatment consisting of the N treatment plus 112 kg/ha elemental P from concentrated superphosphate (N+P). Plots were initially established in the spring of 1971 with 1-0 seedlings and the seedling stand was harvested in the fall of 1973 to determine biomass yields after three growing seasons (Wood et al. 1976). Fertilizer treatments were applied annually in late spring during each year of the seedling rotation. No fertilizers were applied in the spring of 1974, the year of origin for the coppice stand, to reduce competition from herbaceous vegetation. Fertilizers were then applied to the coppice stand during the second and third growing seasons.

Entire plots were harvested in the fall of 1976 by cutting trees at about 8 cm above the ground. In previous studies we have observed that the size of edge trees was approximately 25 percent greater than interior trees; thus, the outside rows on each plot were excluded from our biomass determinations. Remaining trees were weighed in the field to determine total plot yields on a green weight basis. Three sample trees, selected to represent the size present on each plot, were divided into the biomass components, foliage, branches, and bole, transported to the laboratory and dried to constant weight at 65°C. Sample tree data were used to compute yields on a dry-weight basis and to determine the contribution of each biomass component to total biomass.

Widely-Spaced Sycamore Plantations

Growth and yield data for "normal" sycamore plantations were also collected. These plantations were established in the spring of 1973 using 1-0 seedling stock on the two previously mentioned sites (bottomland and terrace). Initial spacing (3.7 x 3.7 m) employed is more typical of those utilized in establishing hardwood plantations, in contrast to the close spacings in the silage plantings. The sites, which had been abandoned for agriculture, were prepared in a manner similar to that used for agricultural crops. After planting, occasional mowing to reduce competing vegetation was the only cultural treatment.

In the fall of 1977, after leaf drop, at the end of the fifth growing season, six sample trees were selected to represent the range of tree sizes present. These sample trees were harvested from an approximately 0.2 ha area near the center of each plantation on both sites. Sample trees were separated into bole and branch components, transported to the laboratory, dried to a constant weight at 65°C and weights recorded. Within each 0.2 ha plot, three 0.03 ha subplots were established and total height and diameters (dbh) recorded for all living trees.

Sample tree data were used to develop prediction equations for dry weights of component tree parts with basal area as the independent variable. These equations, in conjunction with diameter measurements collected on the three subplots on each site, were used to develop weight estimates for bole and branch components on each site.

Natural Sweetgum Stand

No native sycamore stands were present on these sites and a young, dense, sweetgum stand on the terrace was sampled to provide an indication of dry-matter accumulation in natural stands. Six sample trees, representing the range of size classes were selected and dbh, total height and dry weight of branches and bole determined. Stocking and individual tree sizes were determined on four small plots (3.0 x 3.0 m). Sample tree data were used to develop prediction equations for dry weight of individual component tree parts with basal area as the independent variable. These equations, in conjunction with the dbh measurements, were used to compute weights of all trees on each sample plot. These data were summed to determine biomass on an area basis.

RESULTS AND DISCUSSION

Coppice Sycamore Stands

Total above-ground biomass accumulation after three growing seasons ranged from about 8 to nearly 30 mt/ha for the various site and cultural treatment combinations (Table 1). Yields ranging from about 11 to 24 mt/ha have been reported in Georgia (Saucier et al. 1972) for unfertilized coppice sycamore stands harvested at the same age and planted at spacings similar to those used in our study. The distribution of above-ground biomass into the various components ranged from about 10 to 15 percent for foliage, 12 to 20 percent for branches and 65 to 78 percent for bole for the various cultural treatment combinations under investigation.

Analysis of variance indicated that biomass of each component tree part was significantly greater on the terrace site. The differences were approximately 60 percent for foliage, 30 percent for branches, 35 percent for the bole, and 35 percent for the total above-ground stand. This is the opposite of the site effect that was found for the 3-year-old seedling stands harvested from the same study plots (Wood et al. 1976). At that time biomass accumulation averaged over all treatments was about 35 percent greater on the bottomland site. Yield data for the 4- and 5-year-old seedling plantations have previously shown the trend toward decreasing differences between the two sites (Wittwer et al. 1978).

Table 1. Dry weight of 3-year-old American sycamore coppice stand component parts by site, spacing, and fertilizer treatment.

Site	Component	Spacing and Fertilizer Treatment[1]									Mean[2]
		0.3 x 0.9 m			0.9 x 0.9 m			1.8 x 0.9 m			
		0	N	NP	0	N	NP	0	N	NP	
		mt/ha									
Bottomland											
	Foliage	1.3	1.8	2.1	1.5	1.9	2.1	1.2	1.2	1.7	1.6
	Branches	1.6	2.5	3.3	2.0	2.6	2.9	1.8	2.9	3.8	2.6
	Bole	10.3	13.5	14.6	9.7	13.1	14.3	7.2	9.9	11.6	11.6
	TOTAL	13.2	17.8	20.0	13.2	17.6	19.3	10.2	14.0	17.1	15.8
Terrace											
	Foliage	2.0	2.6	2.6	1.7	3.6	2.8	1.5	3.2	3.7	2.6
	Branches	1.5	3.8	3.5	1.6	4.5	4.2	1.5	4.8	5.1	3.4
	Bole	10.6	23.4	19.0	7.2	21.1	21.2	4.9	16.2	14.8	15.4
	TOTAL	14.1	29.8	25.1	10.5	29.2	28.2	7.9	24.2	23.6	21.4

[1]0 = none; N = 169 kg/ha elemental N as ammonium nitrate; N+P = N treatment plus 112 kg/ha elemental P as concentrated superphosphate. Fertilizer treatments applied during late spring of second and third growing seasons.

[2]Means of 3 replicate plots for each site, spacing, and fertilizer treatment combination.

With the exception of the N treatment on the bottomland, statistically significant biomass increases due to fertilization were observed (Table 2). A significant site-fertilizer interaction was detected and the interactive influence of these factors on biomass production are reflected in the differential response to fertilization observed on the two sites. Yields on the unfertilized plots, averaged over all spacing levels, were about 13 percent greater (12.2 vs. 10.8 mt/ha) on the bottomland. Fertilization with N and P increased biomass by 6.6 mt/ha (55 percent) on the bottomland and by 15.8 mt/ha (137 percent) on the terrace. This increase on the bottomland resulted from increases of approximately 50 percent for foliage, 55 percent for branches, and 50 percent for the bole (Table 1). Increases on the terrace for foliage, branches, and bole were approximately 80, 180, and 160 percent, respectively. Thus, without fertilization the bottomland is more productive, but with fertilization, the terrace site ranks most productive.

As with other studies using similar spacings (Kennedy 1975, Kormanik et al. 1973) in young sycamore plantations, a trend toward decreasing biomass with increased spacing was observed (Table 2). The total standing crop was nearly 25 percent (17.0 vs 13.8 mt/ha) greater in the closely-spaced (0.3 x 0.9 m) plantations as compared with the widest spacing (1.8 x 0.9 m) on the bottomland. There was a similar difference between these two spacing levels on the terrace site although statistical significance was not indicated (Table 2).

Total biomass of the 3-year-old coppice stands exceeded that reported for the 3-year-old stands of seedling origin previously harvested (Wood et al. 1976) from these study areas by an average of 58 percent on the bottomland site and 190 percent on the terrace site (Table 3). Dutrow and Saucier (1976) found a somewhat lower yield ratio, reporting that 3-year-old coppice yields exceeded those for seedling stands by about 60 percent on good sites and 25 percent on average sites in Georgia. The magnitude of the yield gains for the coppice crop varied greatly with the various spacing treatments. For example, on the bottomland, coppice yields for the 0.3 x 0.9 m spaced plantings exceeded seedling yields by about 25 percent while for the widest spaced (1.8 x 0.9 m), the increase was nearly 200 percent. Absolute yield differences for the various spacings are much less for the coppice stands than were found in the seedling stands. Apparently the multiple stems developing from each root stock are decreasing differences in stand density among the various spacing levels.

Table 2. Effects of fertilizer treatments and spacing on total above-ground biomass (dry weight) of 3-year-old American sycamore coppice stands by sites.[1]

Treatment	Site	
	Bottomland	Terrace
	mt/ha	
Fertilizers[2]		
0	12.2 a	10.8 a
N	16.5 ab	27.8 b
N+P	18.8 b	25.6 b
Spacing		
0.3 x 0.9 m	17.0 a	23.0 a
0.9 x 0.9 m	16.7 a	22.6 a
1.8 x 0.9 m	13.8 b	18.6 a

[1]Means for each treatment and site not followed by the same letter are significantly different at the 0.05 level by analysis of variance and Duncan's New Multiple Range Test (n=9).

[2]0=none; N=169 kg/ha elemental N as ammonium nitrate. N+P=N treatment plus 112 kg/ha elemental P as concentrated superphosphate. Treatments applied during late spring of second and third growing seasons.

ble 3. Comparison[1] of dry-weight yields[2] for 3-year-old seedling (S) and coppice (C) stands of American sycamore as influenced by site, fertilizer treatment, and spacing.

te and rtilizer[3]	Spacing 0.3 x 0.9 m		0.9 x 0.9 m		1.8 x 0.9 m		Mean	
	S	C	S	C	S	C	S	C
	mt/ha							
tomland								
O	13.7	13.2 ns[4]	10.9	13.2 ns	4.3	10.2 ns	9.6	12.2
N	14.3	17.8 ns	11.2	17.6 ns	4.0	14.0 **	9.8	16.5
N+P	13.0	20.0 **	12.9	19.3 *	5.8	17.1 **	10.6	18.8
Mean	13.7	17.0	11.7	16.7	4.7	13.8	10.0	15.8
rrace								
O	9.2	14.1 ns	4.0	10.5 *	1.3	7.9 **	4.8	10.8
N	15.3	29.8 *	9.8	29.2 **	6.8	24.2 **	10.6	27.7
N+P	7.7	25.1 **	8.0	28.2 **	3.8	23.6 **	6.5	25.6
Mean	10.7	23.0	7.3	22.6	4.0	18.6	7.3	21.4

ield data for seedling stands have been reported by Wood et al. (1976). Coppice stands were arvested from the same study plots 3 years after harvest of the seedling stand.

ncludes total above-ground tree components.

none; N=169 kg/ha elemental N; N+P=N treatment plus 100 kg/ha elemental P from concentrated uperphosphate. Fertilizers applied annually during late spring to the seedling crop and uring the second and third growing seasons of the coppice rotation.

, **, and ns denote significant differences at the 0.05, 0.01 level, and no difference, espectively, as determined by "t" tests.

Survival

The life expectancy of stumps and root systems is an important consideration with coppice silvicultural systems when several harvests are contemplated before replanting. Survival 3 years after initial establishment of these plantations, with 1-0 seedlings, ranged from 68 to 91 percent (Wood et al. 1976). Survival was decreased by closer spacings and fertilization. Mortality during the coppice rotation showed similar trends. In the closely-spaced plots, the number of surviving stumps, as a percentage of the number of original seedlings, decreased by over 10 percent during the coppice rotation. Decreases were also observed in the N-fertilized plantations on the bottomland and in the N+P fertilized stands on the terrace site. Changes in the percentage of surviving stumps during the first coppice generation by site, spacing, and fertilizer treatments are presented below:

	Survival Changes (percent)					
site	spacing			fertilizer treatment		
	0.3 x 0.9 m	0.9 x 0.9 m	1.8 x 0.9 m	0	N	N+P
bottomland	-11	0	-1	0	-1	-7
terrace	-12	-1	-1	-1	-9	-2

Widely-Spaced Sycamore Plantations

Management problems associated with the establishment and culture of closely spaced plantations, such as those previously discussed, include: (1) the requirement for large quantities of planting stock and (2) the control of competing vegetation. There is a lack of information on the use of herbicides and most commercial size hardwood planting programs rely on mechanical cultivation, with initial spacing partially influenced by the need to provide access for tractors and cultivating equipment.

For these reasons most hardwood plantations are probably established at spacings ranging from 3.0 x 3.0 m to 4.5 x 4.5 m. Data from a 5-year-old 3.7 x 3.7 m spaced plantation on these sites provide an indication of dry matter accumulation and stand characteristics with more conventional cultural practices (Table 4). On the basis of total height, growth of these plantations seems to compare favorably with that reported from the southern portion of American sycamore's natural range. Average height of 4-year-old plantations in northern Alabama and southern Tennessee ranged from 1.6 to 4.5 m, depending on soils and site preparation techniques (Franklin 1977).

Table 4. Stand characteristics of 5-year-old American sycamore plantations in the Ohio River Valley.

Site	Total Height	Average Diameter	Basal Area	Trees per hectare	Survival[1] Percent	Woody[2] Biomass
	m	cm	m^2/ha			mt/ha
bottomland	5.3	5.9	1.79	657	88	5.71
terrace	5.3	5.8	1.84	697	93	5.22

[1]Based on initial establishment of 730 trees/ha at a 3.7 x 3.7 m spacing.

[2]Includes above-ground bark and wood of bole and branch components on a dry-weight basis.

The influence of spacing on dry-matter accumulation is evident when data from these plantations are compared with the yields from 5-year-old "silage plantations" (Table 5). Dry-matter accumulation of the bole and branch components declined with increased spacing. Average annual accumulation ranged from 1.1 mt/ha/year, when average growing space per tree at the time of establishment was approximately 14 m^2 (3.7 x 3.7 m spacing) to 3.2 mt/ha/year when the average growing space was approximately 0.3 m^2 (0.3 x 0.9 m spacing). These data are for unfertilized plantations and biomass yields have been approximately doubled by heavy N applications in closely-spaced plantations on these sites (Wittwer et al. 1978).

Natural Stand Productivity

When examining the yield gains associated with intensive cultural methods many investigators, including ourselves, compare data from 50 to 80 year-old natural stands. The mean annual biomass increment for these stands is typically in the range of 1 to 3 mt/ha/year. However, the stand structure of those older natural stands is considerably different from that of a young, intensively cultured plantation, and perhaps a better comparison would be a natural stand of similar age and stand structure. Stand characteristics of a young, naturally regenerated sweetgum stand of seedling origin, occupying an old field on the terrace site, provide data for such a comparison:

Total Height	dbh	Trees/ha	Biomass			
			leaves	branches	bole	total
m	cm		mt/ha			
6.3	4.7	13700	8.8	14.6	57.7	81.1

Table 5. Effects of spacing on biomass accumulation and stand characteristics in 5-year-old American sycamore plantations.

Spacing[1]	Biomass[2]	Total Height	Survival Percent	Trees/ha
	mt/ha	m		
0.3 x 0.9	15.8	3.8	88	32,590
0.9 x 0.9	11.8	3.8	90	11,110
1.8 x 0.9	7.4	3.5	89	5,490
3.7 x 3.7	5.5	5.3	91	677

[1]Includes unfertilized plots only.

[2]Includes dry weight of total above ground tree excluding foliage.

The stand was 7 years old, slightly older than any of our experimental plantations. Growing space for each tree averaged 0.73 m^2 for an average spacing of 0.85 x 0.85 m, assuming a square arrangement. Thus, stand density is very comparable to the 0.9 x 0.9 m spacing level in our experimental plantations. Mean annual weight increment of the bole and branch components averaged slightly more than 10 mt/ha/year, considerably greater than yields we have found from harvesting our experimental sycamore plantations of seedling origin. We would not expect to achieve these production levels over a significant land area because of the erratic stocking that would ordinarily result when reliance is placed on natural regeneration. However, this example illustrates the potential biological production for a fairly common ecological situation. The potential of sweetgum for biomass production is also illustrated; although, according to a recent review (Howlett and Gamache 1977) there is no quantitative information available on short-rotation biomass yields for this species.

SUMMARY

The potential for increasing hardwood fiber production by the intensive cultural practices of fertilization, coppicing, increased stand density and harvesting on short rotations has been demonstrated for American sycamore plantations on selected sites in the Central Hardwood region. Additions of N fertilizers increased biomass accumulation of bole and branch components in 3-year-old coppice stands by 45 percent on a fertile bottomland soil and by 150 percent on an inherently less-fertile terrace site. Biomass accumulation in 3-year-old coppice stands exceeded that of 3-year-old seedling stands previously harvested from the same study plots by 58 and 190 percent on the bottomland and terrace sites, respectively. Average annual increment of bole and branch components after five years was nearly three times greater (3.2 vs. 1.1 mt/ha/yr) in a closely-spaced (0.3 x 0.9 m) plantation as compared with a plantation established at a spacing more typical of conventional hardwood plantations. Estimates of biomass production in a young, dense, naturally regenerated stand of sweetgum on an old field site indicate that yields in these stands may approach those of intensively cultured plantations if adequately stocked.

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