EARLY STAND DEVELOPMENT IN CLOSELY SPACED, FERTILIZED AMERICAN SYCAMORE PLANTATIONS[1]

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In American sycamore plantations, the effect of a positive growth response to fertilization is to speed up the stand development, thus reducing the age at which competition for spacing develops.

The "silage sycamore" approach to increasing the production of wood fiber was proposed by McAlpine et al. (*3*) more than 10 years ago. This concept envisions the repeated harvesting, at relatively short intervals, of coppice stands of American sycamore (*Platanus occidentalis* L.) originating from closely spaced plantations (fig. 1). More recently, interest in this type of forest culture has broadened to include utilization of these plantations for fuels (*5*), and also chlorophyll-carotene paste, pro-vitamin paste, and essential oils derived from foliage and bark for medicinal and industrial purposes (*2*).

Yield data and responses to cultural treatments for young, closely spaced American sycamore plantations are usually measured in units of total aboveground biomass (*1, 4, 7*). This is a logical parameter since utilization of most or all of the total aboveground tree is usually envisioned with these silvicultural systems. However, other factors, such as the number and size of individual trees present and changes in these variables during stand development, are important considerations when developing the equipment and cultural techniques needed to implement fiber production systems. This study reports survival and height and diameter growth changes during the first 5 years in fertilized, closely spaced sycamore plantations of seedling origin.

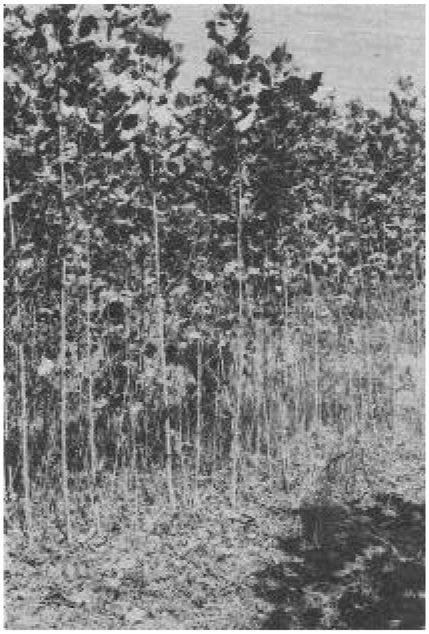

Figure 1.—*Five-year-old, closely spaced American sycamore plantation.*

The location, experimental design, cultural treatment, and biomass yields for these study plots have been previously reported (*7*). Treatments were: spacing-1 by 3 feet, 3 by 3 feet, 6 by 3 feet; fertilization—none (0), 150 pounds per acre of nitrogen applied annually (N), the nitrogen treatment plus 100 pounds per acre of phosphorus applied annually (NP); and rotation period—3, 4, and 5 years. All possible treatment combinations of spacing, fertilizers, and rotation age were replicated three times on two different sites. The bottomland site is adjacent to the Ohio river and subject to overflow flooding during early spring. The second site is on a terrace parallel to the river, but above the flooding level. Seedling stock (1-0) from Kentucky and Indiana nurseries was used.

Data Collection

Measurements of diameter near the groundline and total height were taken on all trees in the center two rows of each plot. These measurements were taken during the dormant season after each, of the first five growing seasons, with the exception of diameter measurements, which were not taken the 1st year. Survival was evaluated on the entire plot. The total number of plots from which data were collected varied after the third growing season. During the first 3 years, data were collected on all plots. After the third growing season, one-third of the plots representing three replicates of each treatment combination were harvested; and the data for the

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fourth growing season are based on observations on the plots remaining after this harvest. The 5-year data are based on measurements of the remaining one-third of the original plots that were not harvested after the 3- and 4-year rotation periods (*7*). Preliminary statistical analysis of the 3- year survival data in the transformed (arcsin $\sqrt{X}$) and untransformed state produced similar results, and the survival data were analyzed for statistical differences without transformation.

Results and Discussion

Survival

At the end of the 1st year, survival was 11 percent greater (79 instead of 90) on the bottomland site. This difference continued throughout the 5-year study period (table 1). Soil moisture conditions were not evaluated in this study; however, the bottomland soil probably has more moisture in the upper soil horizons during the growing season. Biomass yields on the two sites, averaged over all spacing and fertilizer treatments, were very similar; and the lower survival on the terrace was apparently not a significant factor influencing yields. The apparent increases in the number of surviving trees indicated for some years, especially between years 4 and 5, is due to data being collected on a variable number of plots. Survival decreased with fertilizer treatments and generally ranked as follows: no fertilizer $\geq$ N fertilizer $\geq$ NP fertilizer. This probably resulted from increased competition due to accelerated stand development as the trees responded to fertilizer treatments.

Table 1.—*Effects of site and fertilization on survival in 1- to 5-year-old sycamore plantations.*

Age	Site		Fertilizer treatment[1]		
	Bottom-land	Terrace	0	N	NP
	Survival percent				
1	90 a[2]	79 b	90 a	84 b	80 b
2	89 a	78 b	89 a	83 ab	79 b
3	89 a	75 b	88 a	82 ab	77 b
4	88 a	76 b	88 a	81 ab	78 b
5	88 a	77 b	89 a	81 b	77 b

[1] 0=no fertilizer; N=150 lbs/acre elemental N applied annually; NP=N treatment + 100 lbs/acre elemental P applied annually.

[2] Means for sites or fertilizer treatments, within an age class, followed by the same letter, are not significantly different at the 0.05 level.

Although initial spacing did not have a statistically significant effect on survival, as expected, a trend toward decreasing survival with increasing stand density was evident, especially in the fertilized plots. For example, after 5 years on the bottomland, the unfertilized plots at the closest spacing (1 by 3 feet) had 90 percent survival, while the widest spacing (6 by 3 feet) had 95 percent survival. On this site, survival in the N-fertilized plots at these spacings averaged 80 and 89 percent, respectively. If fertilization at or near planting time is contemplated in these closely spaced stands, a lower initial stand density may be recommended since fewer seedlings will survive very long under competition, as compared to slower developing, unfertilized stands. The projected rotation period would also need to be considered when making these decisions.

Height growth

Statistical analysis indicated no significant height growth differences due to site effects. However, mean values for the two sites reflect the influence of fertilizers and spacing as well as site effects. A significant site-fertilizer interaction was indicated. Classifications of the suitability of these soils for field crops and forestry rate the bottomland soil (Ashton series) as somewhat more productive than the Elk and Otwell soils on the terrace site (*6*). At the end of the first growing season, the height of seedlings on both sites subjected to the different treatments varied little and averaged approximately 2 feet (table 2). Seedling height at this time is probably a reflection of planting-stock size. Differences in site productivity are exemplified by height growth on the unfertilized plots where, after 5 years, total height was about 40 percent greater on the bottomland site.

On the less fertile terrace, a significant response to N fertilization was indicated in year 1, while on the bottomland site no response to added nutrients was evident until year 3. This response pattern suggests that timing, as well as application rate, could be a site specific consideration when prescribing fertilizer treatments.

Some influence of spacing on height was found during the study period, beginning in year 3, on the bottomland site. After the fourth and fifth growing seasons, tree height in the closely spaced plots was significantly reduced. Apparently competition is intensifying among the closely spaced individuals in these stands.

Table 2.—*Effects of fertilizers and spacing on height and diameter growth of 1- to 5-year old sycamore on a bottomland and a terrace site.* [1]

Site age	Fertilizer treatment[2]			Spacing		
	0	N	NP	1' by 3'	3' by 3'	6' by 3'
Bottomland			*Total height, in feet*			
1	2.0 a	2.1 a	2.1 a	2.0 a	2.0 a	2.1 a
2	5.0 a	5.4 a	5.2 a	5.2 a	5.5 a	5.0 a
3	9.3 a	11.1 b	10.8 b	10.2 ab	11.1 a	9.9 b
4	12.0 a	15.3 b	14.9 b	12.7 a	15.6 b	14.0 ab
5	14.1 a	18.1 b	17.0 b	14.2 a	16.9 b	18.1 b
Terrace						
1	1.8 a	2.2 b	2.0 ab	2.1 a	2.0 a	1.9 a
2	3.6 a	4.9 b	4.8 b	4.7 a	4.5 a	4.1 a
3	5.9 a	11.2 b	10.5 b	9.8 a	9.2 ab	8.5 b
4	8.0 a	15.2 b	16.2 b	13.7 a	13.2 a	12.6 a
5	10.0 a	18.1 b	17.9 b	14.8 a	16.0 a	15.2 a
Bottomland			*Diameter, in inches*[3]			
1	—	—	—	—	—	—
2	0.8 a	0.8 a	0.8 a	0.7 a	0.9 b	0.9 b
3	1.2 a	1.4 b	1.3 b	1.0 a	1.4 b	1.4 b
4	1.5 a	1.9 b	1.9 b	1.3 a	2.0 b	2.1 b
5	1.7 a	2.3 b	2.2 b	1.4 a	2.1 b	2.8 c
Terrace						
1	—	—	—	—	—	—
2	0.6 a	0.8b	0.8b	0.7 a	0.8 a	0.8 a
3	0.8 a	1.4 b	1.3 b	1.0 a	1.2 b	1.2 b
4	1.0 a	2.0 b	2.1b	1.4 a	1.7 b	1.9 b
5	1.3 a	2.4 b	2.4 b	1.5 a	2.1 b	2.4 c

[1] Means for fertilizer or spacing levels within each site and age class followed by the same letter are not significantly different (0.05 level).

[2] 0= no fertilizers; N=150 pounds per acre elemental N as ammonium nitrate applied annually; NP=N treatment, plus 100 pounds per acre elemental P as concentrated superphosphate.

[3] Diameter measurements were not taken at the end of year 1.

Diameter Growth

Diameter growth was significantly increased by the N and NP fertilizer treatments. On the bottomland site, diameter growth was increased 30 percent by fertilization, generally comparable to the 33 percent biomass increase (*7*). On the terrace, fertilization increased diameter growth by 85 percent, while the biomass increase exeeded 200 percent. This indicates that height growth response was a more important factor on this site in terms of contributing to increased biomass.

Diameter was influenced by stand density, although the two wider spacing levels did not vary significantly until the 5th year. Apparently, increased competition became an important factor in the 3-by-3-foot plantation at this age. For example, on the bottomland site, diameter growth for the 5th year in the 3-by 3-foot plantation was 0.1 inch and in the 6-by-3-foot plantation, 0.7 inch.

The preceding discussion emphasizes the importance and relationships of rotation age and stand density to growth and yield. The effect of a positive growth response to fertilization is to speed up the process of stand development, thus reducing the age at which competition develops for a given spacing. These interrelationships must be examined and considered by foresters attempting to maximize biomass production utilizing these unique silvicultural systems.

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