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ESTABLISHMENT AND EARLY CARE OF SYCAMORE PLANTATIONS

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Figure 1.—*These planted sycamores. just beginning their seventh growing season in the field, average 6.6 inches in diameter and 49 feet in height.*

ESTABLISHMENTANDEARLYCARE OFSYCAMOREPLANTATIONS

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American sycamore (*Platanus occidentalis* L.) has long been planted for soil reclamation and conservation (Clark 1954; DenUyl 1955; Freese 1954), for windbreaks (Read 1958), and for beautification (Li 1957). In 1955, slightly more than 200,000 sycamore seedlings were grown for such purposes (Abbott 1956).

Recently, however, sycamore has been found to provide a high yield of excellent pulp, and the characteristically straight, well-formed logs have come to command a premium wherever a market exists for commercial veneer. Sycamore is a minor component in natural forests, and the only hope of satisfying the burgeoning demand is the establishment of extensive plantations. The wood-using industry is fortunate that, as Michaux wrote in 1857, sycamore is "remarkable for-the rapidity of its growth and ease of propagation." A substantial acreage of young plantations now exists, and increasingly large areas are being planted yearly. Nursery production rose 1,500 percent in the past decade (Abbott and Eliason 1968), and demand for seedlings has exceeded supply for 4 consecutive years.

The experience gained by nurserymen, planters, and researchers is summarized in this paper. In order to include the most recent information, visits were made during the winter of 1967-68 to 21 State and industrial nurseries in 16 States; six nurseries in five States were revisited during the 1968 growing season. Plantations were visited at 18 major locations in 13 States.

It would be difficult for anyone to complete the same visits and not finish with an optimistic view of the future for sycamore management. In spite of the great diversity in climate, soils, industrial setting, and personnel, every nursery was producing healthy and vigorous stock, successful plantings were seen at every location, and no major problems had been encountered. Some differences in techniques were found and some minor difficulties had occurred; they are discussed in the appropriate sections of the text.

Production of Planting Stock

Sycamore planting stock is usually grown as 1-O seedlings. Cuttings from nursery or wild seedlings are usable on moist, well-aerated sites.

SEED

Sycamore seeds are light brown achenes in a round multiple fruit (fig. 2). The descriptive statistics in table 1 are from 17 seed lots gathered in Louisiana and Mississippi in the winter of 1967. The data are not definitive, but they agreed well when compared with information from other areas. Two seed lots from Jesup, Georgia, had only 106,000 and 109,000 seeds per pound,[2] outside the range reported in table 1 but not markedly so. The average yield for the lots represented in the table was almost 58 pounds of clean seed per 100 pounds of fruit-far in excess of a widely quoted figure of 7 pounds per 100 pounds of fruit (Engstrom and Stoeckeler 1941; USDA Forest Service 1948).

Yield.-Sycamores fruit abundantly every year or two (Engstrom and Stoeckeler 1941; McKnight 1969; Merz 1958). Although adverse weather in spring may cause local scarcities (USDA Forest Service

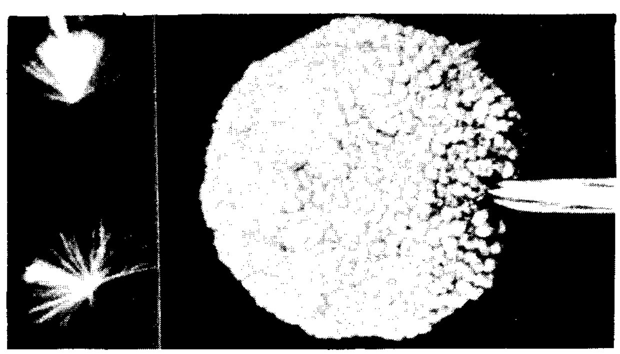

Figure 2.—*Seeds and fruit*

[1]The author is Principal Silviculturist 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 Experiment Station and the Southern Hardwood Forest Research Group.

[2]Personal correspondence with Frank Vande Linde, Brunswick Pulp and Paper Company, Jan. 31, 1968.

1965), no report has been found of widespread crop failure. Even locally, a few trees seem to have a light to fair crop in the worst of years.

For example, seed was very scarce in the vicinity of Licking, Missouri, in the winter of 1967; of 100 open-grown trees of seedbearing size, 86 had not a single fruit when checked in mid-November. Eight trees had less than 10 fruits each, three had 10 to 100 fruits, two had 100 to 1,000, and one had more than 1,000. Approximately 80 miles to the east, in the vicinity of Fredericktown, most trees had abundant fruits. The following year, the pattern was duplicated almost exactly throughout north-central Mississippi; most trees had no fruit but light to moderate crops occurred on scattered trees. To the north, west, and south of this region the crop was much more abundant.

Production per tree increases with advancing age and size; normal-looking fruits have been seen on trees 3 years after outplanting (4 years from seed), but only in the fifth or sixth year in the field do substantial numbers of trees begin to bear as many as 10 to 20 balls each. Abundance as well as age of fruiting seems to be associated with growing space. Dominant trees yield earlier and produce more fruit than trees of any lesser class, and open-grown trees far exceed forest-grown trees regardless of crown class (fig. 3). The reported minimum seedbearing age of 25 years (USDA Forest Service 1965, p. 491) probably refers to dense natural stands, not to open-grown trees or those in well-spaced plantations.

Site quality presumably influences seed production, with best yields expected on good sites. Information is fragmentary, however, and both precocious and abundant fruiting have been observed on acid spoil banks as well as on rich alluvium.

Estimating seed crop.-At least in the southern part of the range, seed crops can be estimated with fair reliability by counting the number of developing fruits in middle or late April. Few fruits are lost after late spring.

Viability of the seed varies with locality and year. In years when the crop is abundant, each multiple fruit can be expected to yield about 500 viable seeds. In poor years or at poor locations (as where pollen sources are scarce), fruits that appear sound and normal may contain no live seeds (Griggs 1909), or practically none. Lone sycamore trees, in a forest stand or in the open, yield seed of very low germinability because of inadequate cross-pollination combined with poor selfing (Beland and Jones 1967; Webb and Farmer 1968).

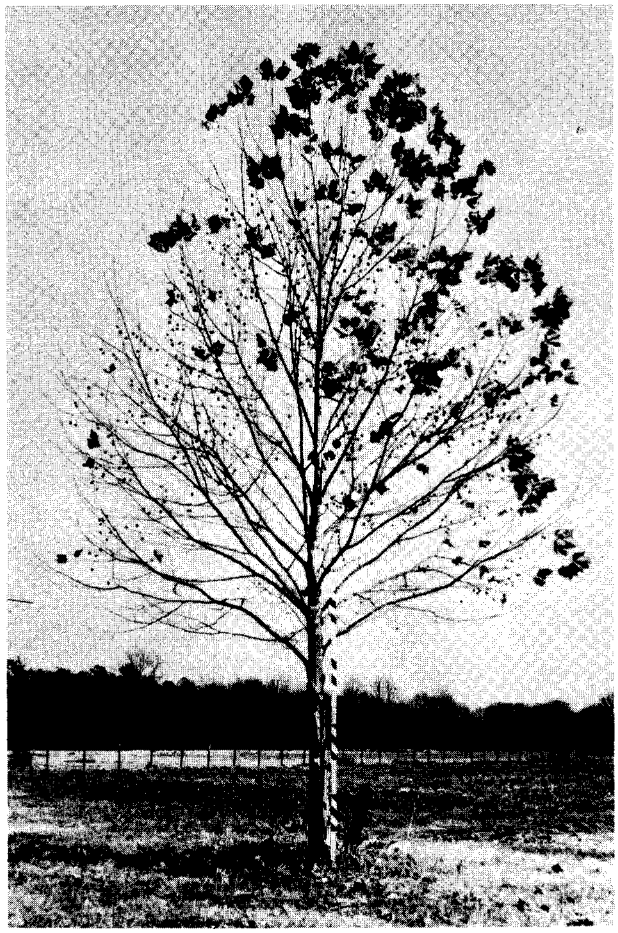

Figure 3.—*Sycamore with fruit, age 5 years.*

Collection and care of seeds.-Fruits can be collected any time after they turn from green to brown (Bonner 1966a), usually about the end of October near Stoneville, Mississippi (latitude 33°25' N.). There have been reports of deterioration of seeds as the season advances (Bonner 1966a). However, during the 1967-68 season, germination of seed sown immediately after collection improved as the season advanced and was best for collections made in mid-April. Germination of seed sown after 2 to 4 months' cold storage improved similarly, but was at maximum in seed collected during mid-February. Although some seed may persist on the tree through the summer following maturation, none of it is viable. This does not necessarily mean that seed cannot be kept viable at ambient temperatures; quite possibly only sterile seeds persist on the tree.

The most convenient collection is from trees felled after the fruit is ripe but before it shatters. Alternatives include forklift trucks or hydraulic cherry-pickers to raise the worker up in the branches, and a long-handled pruner for clipping the fruit stalk. Small quantities, especially for research, can be obtained by shooting down branches. Branches to be collected by shooting should be 3 to 5 inches in diameter and positioned within 45° of vertical; they then have enough weight to fall free of other branches, and their angle favors a clean break.

At the end of the season, seed on low branches can sometimes be collected by spreading sheets of material on the ground, then tapping the branches. Near the northern and western limits of sycamore's range intact balls can be collected late in the season from the ground, at least in some years. Great quantities can also be obtained from streets and sidewalks, but the amount of trash collected with such seed makes handling difficult and expensive. Moreover, seeds from known mother trees are to be preferred.

Cleaning seed.-Small quantities of seed are often cleaned by rubbing through hardware cloth (4 to 10 wires per inch) and using a natural or fan-generated breeze to remove the dust and fine hair which cling to the seed. .A special apparatus for cleaning small lots is described by Webb and Porterfield (1969). A dust mask must be worn to prevent discomfort, or even pneumonia. from inhaling the hairs. Large quantities are cleaned by passing them through a fertilizer distributor, a hammer mill, or centrifugal disks. The fertilizer distributor is the most widely used, either by pulling it along with the ejection gates closed or attaching a powered belt to a jacked-up wheel (fig. 4). In either case the seeds gravitate to the bottom while the fluff and fruit cores collect at the top or are blown away.

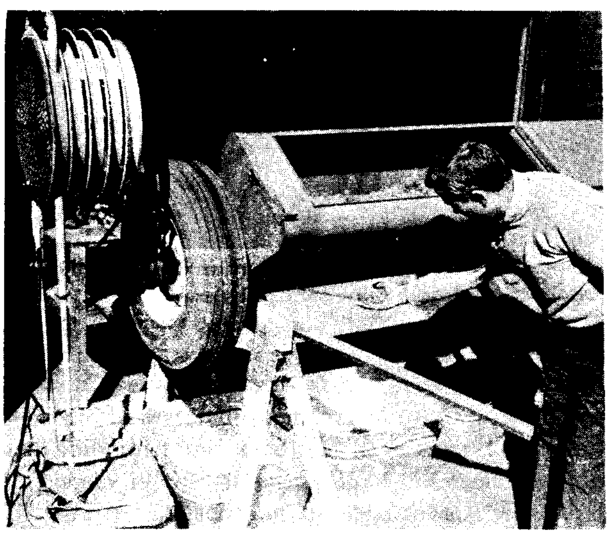

Figure 4.—*Cleaning seed by passing it through a fertilizer spreader.* (Photo by W. A. Chapman, Kimberly-Clark Corporation, Coosa Pines, Alabama.)

Storage.-If the seed is to be sown in the current year, either the fruit or seeds may be stored in a cool, well-ventilated place in an open-mesh bag or spread out on shelves. Seed to be held a year or more should be dried to a moisture content of 10 to 15 percent, placed in airtight containers, and stored at 20 to 38°F. (Belcher 1967).

Pregermination treatment.-Although there are contradictory reports (Bonner 1966a; Engstrom and Stoeckeler 1941; USDA Forest Service 1948), sycamore seed apparently does not have a dormant embryo and does not require stratification (McElwee 1966; Webb and Farmer 1968). If seed is to be stratified, it should be kept moist but well aerated and held between 35 and 38° F. for 20 to 30 days.

Testing.-At the Forest Service's Eastern Tree Seed Laboratory, percentage of sound seed and purity are determined from 1,000-seed samples. Number of seeds per pound is similarly determined, and is expressed on the basis of a 10-percent moisture content.[3] Germination tests are conducted with 100-seed lots, replicated four times. Seeds are placed on moist Kimpack[4] in a closed, transparent container in a room kept dark and at 68°F. for 16 hours of each day and lighted at 86" the other 8 hours. Tests are normally terminated 20 days after sowing.

Germination tests can also be made in water (Briscoe and DuBarry 1959), sand, peat moss, or any of the other media normally used. Some light is necessary for full germination (McDermott 1953).

More than with most species, the results must be interpreted with caution and in the light of local experience. Germination in the nursery may be one-fourth or less of the sound seed (Bonner and Gammage 1967). A rule of thumb at some commercial nurseries is to expect 3,000 seedlings for each pound of seed sown, an average of only 1.5 seedlings per 100 seed. Conversely, yields occasionally are much higher.

Seed purchase.-Platanus seed can normally be purchased from the larger seed companies, but unless special arrangements are made there is no guarantee of provenance and in some cases not even of species. In dealing with a genus which occurs completely around the northern hemisphere and a species (*P. occidentalis*) which occurs naturally in at least 34 States and 2 Canadian provinces, a certain amount of variation is to be expected. Seed of known origin should be insisted upon, and a nearby source probably should be chosen if available.

[3]Personal correspondence with Earl W. Belcher, Jr.. USDA Forest Service, Eastern Tree Seed Laboratory, Macon, Ga., Oct. 17, 1968.

[4]Here and elsewhere in this paper, mention of a product is for information only and does not constitute endorsement by the USDA Forest Service.

Several State nurseries will grow seedlings under contract or from seed provided by the potential planter, and this is a procedure with much to recommend it.

NURSERY SITE AND LAYOUT

Site and layout for a sycamore nursery are similar to those for any tree nursery, but certain requirements are different or more stringent. The small seeds and newly germinated seedlings are easily desiccated and killed. Thus, irrigation facilities are essential. Once wet, seed must be kept wet until germination (Engstrom and Stoeckeler 1941; Lobaev 1950), and the young seedlings require moisture daily until the leaves are about 0.8 inch long (Zmijanac 1956).

Seedlings in the cotyledon stage will not tolerate continuous wind greater than about IO miles per hour at the soil surface (Lobaev 1950); windbreaks therefore may be necessary in some areas.

Surface drainage must be adequate. Water flowing across the beds will almost invariably remove a substantial portion of the seed.

SEEDLING PRODUCTION

Sowing.—Sycamore seeds are occasionally sown in the fall or late winter, but germination is quicker and more complete if sowing is postponed until middle or late spring. Damping-off is more often a problem in warm soils, however, and drying must be watched carefully where winds tend to be strong and nearly continuous as the season advances.

Seedbed preparation is equivalent to that for any small-seeded species. The beds should be plowed or deep-disked in the fall, and shaped, rototilled, and rolled shortly before they are sown. The surface should be firm and level.

Seeds are commonly broadcast by hand, even in nurseries with annual production in the hundredsof thousands, but they are also broadcast with fertilizer distributors and seed sowers; two nurseries use drills, adding aluminum powder to improve seedflow. Formerly seedlings were often grown in single rows instead of beds (Engstrom and Stoeckeler 1941), but only one nursery is known to be using rows at present. Unless spacing is controlled carefully, seedlings in rows tend to crook severely just above the rootcollar; this may be an important reason why beds have become popular.

Desired density of seedlings varies considerably. Small seedlings are generally preferred for reclamation planting on spoil banks, and nurseries providing such stock may grow 25 to 35 seedlings per square foot of bed space. Larger stock is usually desired for other purposes, however, and recommended bed densities range from 5 to 10 per square foot (Engstrom and Stoeckeler 1941) up to 25 (Vande Linde 1960). Actual densities in State nurseries during the fall of 1967 varied from slightly more than one to as many as 70 per square foot, with eight to 12 the most common.

A final decision on bed density requires balancing nursery costs against anticipated field growth. Large stock costs more to produce, but field survival and growth both increase with increasing diameter at the rootcollar (Engstrom and Stoeckeler 1941; Ike 1962b; Knežević 1956). Among nurserymen providing stock for forest or shade tree plantings-as opposed to spoil bank reclamation—a diameter of 0.25 inch is almost universally agreed upon as the minimum desired. An industrial nursery producing for its own plantings prefers 0.5 inch as minimum. In the 21 nurseries checked, however, not a single bed-width plot was found with more than three 0.25-inch seedlings per square foot (regardless of whether or not smaller seedlings were also present). Existing objectives or practides will have to be changed in order to reconcile desired stocking with desired plant size, but the minimum rootcollar diameter should not be reduced without considerable justification, for large stock is needed in the field.

Sowing rate, in pounds per bed, can be calculated from the widely known formula:

$$\text{Weight} = \frac{o(d)}{(n)(g)(s)}$$

where A = area of bed in square feet; d = seedlings desired per square foot of bed; n = seeds per pound converted to the same moisture content at which the seed is to be weighed out for sowing; g = germination percent of the particular seed lot to be sown expressed as a decimal; and s = expected survival expressed as a decimal and referring to the number of plantable seedlings per 100 sound seeds sown.

Another method, much simpler and perhaps as useful, is to determine germination percentage, then sow at the following rates per 100 linear feet of 4-foot bed:

Germination percentage	Sow
	Ounces
10	16
20	8
40	4
80	2

These rates are for air-dry seed and are intended to provide five seedlings per square foot. They should be adjusted as local experience is accumulated. Seedbeds are nearly always mulched to reduce drying and blowing or washing of the light seed and newly germinated seedlings. Sawdust is an excellent mulch; pine needles, oat straw, rice straw, and chopped-up pine cones are also used. The last is unsatisfactory, because seedlings are killed by large fragments of cone.

Because the seedlings have short hypocotyls, thickness of the mulch is critical (fig. 5). Tests at the Forest Service's Southern Hardwoods Laboratory indicate that 0.25 inch of mulch is preferable to any greater thickness:

Thickness of mulch (inches)	Germination, as a percentage of that with ¼-inch mulch
0.00	30
.25	100
.50	76
.75	75
1.00	48
1.25	30
1.50	3

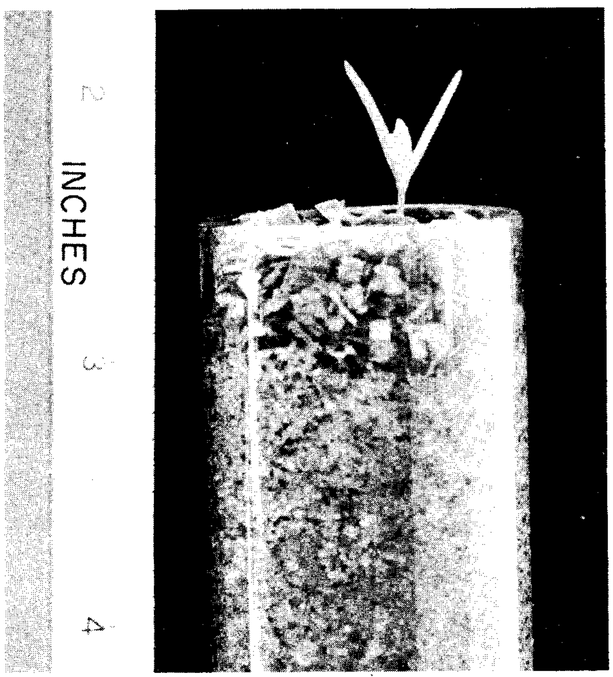

Figure 5.—*Newly* ***emerged seedling. The typically short hypocotyl has barely*** *lifted* ***the cotyledons above the*** *0.5-inch* ***mulch.***

Care in nursery.-As has been indicated, beds should be watered often enough to keep the top inch of soil moist until seedlings have several true leaves (Lobaev 1950; Zmijanac 1956). Continued watering is desirable until seedlings are near the size wanted, but amount of water applied can be increased and the period between applications lengthened as the root systems expand.

Shading has been recommended for the first month (Engstrom and Stoeckeler 1941; Zmijanac 1956), but it is rarely done and is apparently unnecessary if seeds and new seedlings are kept adequately watered.

If beds are overdense by the time the seedlings have three to five true leaves, thinning is necessary. Sycamore usually responds to overcrowding by reduction in growth, but mortality has been reported.[5]

Weed competition must be controlled. Presowing fumigation of the beds with methyl bromide, Vapam, Mylone, or Vorlex has controlled weeds, and also limited the development of fungi and nematodes, during the early growing season. Preemergence herbicides are less expensive than fumigants, and Carter and Martin (1967) reported that EPTC, DCPA, chloroxuron, trifluralin, diphenamid, norea, and dichlobenil reduced hand weeding by as much as one-half without damaging the seedlings. Currently, production nurseries depend primarily on hand weeding, but herbicides are likely to be used increasingly.

Cultivation, other than hand weeding, is rare. If seedbed density is held to the recommended level and the seeds sown in narrow rows, mechanical cultivation offers an obvious means of reducing hand weeding.

Fertilization is almost universal. Application is usually with or preceding a cover crop, but a few nurseries add nitrogen directly to the beds of trees. Amount and composition of the fertilizer vary tremendously. There is little information on the nutrient requirements of sycamore seedlings ***per se,*** other than that the species can be grown on alkaline as well as acid soils (Bonner and Broadfoot 1964).

Pruning.-In order to limit seedling size, tops may be pruned one or more times during the growing season. This type of pruning is normally done with a tractor-mounted rotary mower; height of cut varies from 6 to 10 inches above ground, and the time commonly is from about the first of July to the middle of August-early enough to permit healing of the cuts before the seedlings are lifted and shipped.

Alternatively, the tops may be unpruned during the growing season but trimmed with either a rotary or reciprocating mower prior to lifting; the latter makes a cleaner cut in most cases. Or tops may be trimmed off, usually with a rotary saw, during the packing process.

Seedlings pruned after the growing season are more convenient for packing and planting, particularly the larger seedlings. Early pruning promotes the development of large branches on the lower stem,

[5]Personal correspondence with C. E. Peevy, Louisiana Forestry Commission. Dec. 30. 1968.

whereas dormant-season pruning often removes all branches, leaving a clean, uncluttered stem that takes minimum space in packing and in the planter's box (fig. 6).

Figure 6. *Top-prunedseedling. The heavily branched stemwas pruned in July; the other, after lifting in January.*

Field checks have failed to show that pruning increases the proportion of forked or diseased stems. Height growth of the pruned seedlings is at least as great as for unpruned, but 1 to 3 years may be required for pruned trees to equal the total height of the unpruned.

Nurseries that top-prune during the growing season generally do not root-prune then; and those that root-prune during the growing season usually do not top-prune then.

Root pruning usually has one or more of three objectives: to limit top growth, to modify the pattern of root development, or to restrict size of the root systems. Although the first objective was attained at one nursery by pruning as soon as possible after a heavy irrigation, several nurseries reported no top reduction when root pruning was followed by irrigation; conversely, appreciable mortality occurred when follow-up irrigation was omitted. Thus, reduction of top growth appears to be possible but difficult to obtain.

The second and third objectives are attained without difficulty. Root pruning about mid-July almost Invariably promotes development of small laterals and reduces extension of major roots.

Whether or not roots are pruned in mid-season, they are inescapably pruned during lifting. The lifting blade is usually set as shallow as possible, about 6 to 8 inches. Abnormally large lateral roots are sometimes pruned between lifting and packing, and are often pruned by the planting crew. Tests to date indicate no loss in ability to survive and grow even when the taproot is trimmed to less than 4 inches and all laterals are removed. On the other hand, survival and early growth both suffer when seedlings have dried, debarked, or bruised roots.

Thus for sycamore the delivery of seedlings with a iarge mass of roots is far less important than delivering seedlings on which existing roots have not been allowed to dry. In view of the large investment that goes into production of nursery stock and the greater investments that go into forest plantings, it is important to insure that roots stay moist at every stage of handling.

Inventory.—Because stands of sycamore are generally more variable than those of most other species, more samples or larger plots may be required for a given degree of inventory precision.

Lifting, grading, and shipping.-Sycamore is tardily deciduous, and so is one of the last hardwoods lifted. Northern nurseries usually lift in the fall, heel in, then pack and ship in late winter. Southern nurseries omit heeling in, and commonly lift at any convenient time after December 1. In a Mississippi trial of lifting and planting monthly from August through April, February lifting resulted in slightly the best first-year field growth; survival was very low in August and low in September, but did not vary from October to April.

Culling and grading vary with nursery. A minimum acceptable rootcollar diameter is always established, but it varies from 1/16 to 3/8 inch, with about 1/8 inch the most common. Cull, medium, and large are the only three grades in use, not necessarily by these names. A very few nurseries grade on the basis of height and charge a premium for the largest class. Most grading standards appear to have been arrived at subjectively, rather than by measurement of field performance.

As mentioned earlier, small seedlings have been preferred by many planters for spoil banks. Interest is developing, however, in combining wood production with reclamation. The change is almost sure to bring demand for planting stock capable of fast early growth; this means large-diameter stock with roots pruned for easy planting and tops pruned to prevent wind whipping on these exposed sites.

Packing material and technique vary considerably, but individual nurserymen universally treat sycamore as they do other hardwoods of similar size. Peat moss is the most widely used material for keeping roots moist. A clay slurry is sometimes applied, wet sawdust is utilized by a few nurserymen, and one nursery ships the seedlings in closed paper bags. An industrial nursery that delivers direct to the planting site omits packaging completely by loading a truck with seedlings and covering the entire mass with moist sawdust; only a few minutes' work at the planting site is necessary to insure that roots are again covered with the sawdust after unloading.

Most bales contain 500 or 1,000 seedlings, depending on size of seedling.

No special measures are required for shipping sycamore, and initial field survival indicates that it stands shipping better than most species.

CUTTING PRODUCTION

Although cuttings generally are less desirable planting stock than seedlings, they can be nursery-grown for annual harvest. The procedure is about the same as for cottonwood cuttings: seedlings or cuttings are planted approximately 1 foot apart in rows 3 to 4 feet apart, to permit mechanical cultivation; they are fertilized as required by the particular soil and irrigated freely until about September 1 or a month before first frost, whichever is earlier. First-year height growth should be 8 to 12 feet in the South, providing four to six cuttings per stem. Cuttings can be harvested from bud-set in the fall until buds begin swelling in the spring.

Unless the planting site is extremely favorable, cuttings should be 16 to 20 inches long and at least 0.3 inch, preferably 0.5 inch, in diameter at the top. There is no known biological limit to the maximum diameter of cutting, but planting techniques usually restrict the usable maximum to about 1.5 inches. Cuttings longer than 20 inches may be required for certain sites.

NURSERY INJURIES

Although not especially prone to damage, American sycamore is attacked by several common nursery pests.

Damping-off may be severe on neutral to slightly alkaline soils. Prevention and control are whatever is standard for the nursery, with Captan 72-S perhaps the most widely used at present for prevention and methylmercury dicyandiamide for control.

The sycamore lace bug (*Corythucha ciliata* (Say)), salt-marsh caterpillar (*Estigmene acrea* (Drury)), tubeworms (***Tetralopha platinella*** Clemons, ***T. militella*** Zell.), and similar herbivores feed on sycamore. Control is by spraying with lindane or malathion either at 10-day intervals or whenever newly hatched larvae appear (Morris 1964).

Sting nematodes (Ruehle 1967) and root rots (Toole 1967) may cause extensive mortality. Proper nursery management, particularly fumigation before sowing, will control them and similar pests.

Young seedlings are resistant to soil flooding (McDermott 1954), and even to submersion (Hosner and Leaf 1962). Neither birds nor rodents prefer the seed or seedling, although there may be sporadic losses to either.

Tender young seedlings are susceptible to freezing (Lobaev 1950); sycamore should not be sown until all danger of hard frosts is past.

Planting

SITE

Selection of site is probably the single most important decision in establishing a sycamore plantation. Although sycamore occurs in nature most often and reaches its maximum size near streams and rivers, it is not confined to such sites and can be seen in coves and on steep siopes (Merz 1958) and even on ridgetops, particularly in the Ozark Mountains. It occurs naturally and grows vigorously on soils that are mildly alkaline (Broadfoot 1964), as well as on acid spoil banks (Einspahr ***et al.*** 1955; Merz and Plass 1952).

Although trees thrive where ground water is within the root zone, they do not grow well where the soil is flooded or saturated throughout most of the growing season (Bonner 1966b; Hall and Smith 1955).

Sycamore has been successfully planted both to the north (Rosendahl and Butters 1928) and west (Read 1958) of its natural range. It has grown well on sand dunes (Atay 1964), and in the Mississippi Delta has shown excellent initial survival on sandy soils so droughty that planted cottonwood (*Populus deltoides* Bartr.) died out.

For the Midsouth, Broadfoot (1964) recommended sycamore as one of the species to be favored on the soil series listed below. Not every site on the listed soil series is suitable, of course, and productivity of specific microsites will vary considerably within a single series.

Delta areas

Recent natural-levee soils: Commerce, Crevasse, Mhoon, Robinsonville.

Old natural-levee soils: Beulah, Bosket, Dubbs, Dundee, Forestdale.

Slackwater soils: Alligator, Bowdre, Sharkey, Tunica.

Loess areas

Uplands (moist sites only): Atwood, Brandon, Dulac, Grenada, Lax, Lexington, Memphis-Loring, Natchez, Providence, Tippah.

Terraces: Dexter, Lintonia.

Acid bottoms: Collins, Falaya, Vicksburg, Waverly .

Neutral to alkaline bottoms: Adler, Morganfield.

Coastal Plain bottoms: Bibb, Bruno, Chastain, Iuka, Mantachie, Ochlockonee, Urbo.

Blackland bottoms: Catalpa, Houlka, Kaufman, Leeper, Marietta, Trinity, Tuscumbia, Una, Verona.

Red areas

Terraces: Asa, McKamie, Morse, Muskogee.

Bottoms: Buxin, Gallion, Hebert, Lonoke, Mer Rouge, Miller, Norwood, Perry, Pledger, Portland, Pulaski, Roebuck, Yahola.

Productivity of the silty upland soils of the southern Mississippi Valley has been appraised as follows (Anonymous 1968):

Very high productivity:

Few or no management problems: Adler, Collins, Morganfield, Vicksburg.

Moderate or severe management problems: Arkabutla, Falaya, Routon, flooded Collins.

Highproductivity: Rosebloom, Waverly.

Moderateproductivity: Loring, Memphis.

Broadfoot[6] has devised a subjective method for appraising sycamore site quality by assessing four soil factors: physical condition, nutrient availability, moisture availability during growing season, and soil (table 1). Physical condition seems to be the most important in determining growth and development. On a site with all the "Best" characteristics, as listed in table 1, sycamore would grow about 120 feet in 50 years. Singly, or combined, the characteristics listed in the table under "Poorest" may limit productivity to something less than 90 feet in 50 years.

[6]Personal communication. Walter M. Broadfoot, USDA Forest Service, Southern Hardwoods Laboratory. Stoneville, Miss.. June 13, 1969.

Table 1 .-*Subjective approach to sycamoresite evaluation*

Factor	Determining influence	Characteristics: Best site quality	Characteristics: Poorest site quality
Physical condition of soil	Parent material, past use or history, morphology of surface 4 feet of soil	Medium to coarse soil texture Good structure Loose, porous Undisturbed, near-virgin Deep soils (without pans)	Clays Structureless Compacted Cultivated or grazed old fields Soils with pans
Nutrient availability	Past use or history, source of patent material	High in organic matter (> 2%) 6 inches or more A horizon Medium to high pH value (5.5 to 8.0) Alluvial soils Young, undeveloped soils	Low in organic matter (< 1%) Less than 6 inches A horizon Extremely alkaline (8.5 to 9.0) Extremely acid (< 4.5) Upland soils Old, leached soils
Moisture availability	Physiogtaphy and position, depth to water table, past use or history	With normal rainfall, soil is moist throughout entire growing season	With normal rainfall, site is dry much of the growing season
Soil aeration	Past use and history, internal drainage	Brightly colored (black, brown, red) soils unmottled to 18 inches	Gray soils Mottled to surface, or with standing water

SITE PREPARATION

Intensive site preparation is important to the best survival and growth of planted seedlings. Sycamore is a species that occurs early in forest successions (USDA Forest Service 1965, p. 490), appearing with other pioneer species that invade abandoned fields, newly formed lands along streams, and similar bared areas (McKnight 1969; Oosting 1942). In plantations, it survives and grows best on sites from which all other living seed plants have been removed. The necessity for such drastic site preparation depends on the productivity of the site. The better the site, the more natural competition there will be, and the more important it is to control such competition. The scattered weeds and occasional vines on a poor site provide little competition to a good seedling, but even unusually sturdy seedlings, as sycamores are, may succumb to the competition of weeds 8 to 12 feet tall or to a solid carpet of vines.

In southern bottom lands outside of the Piedmont, heavy plowing with disks that will cut 4 to 8 inches deep should precede planting of abandoned fields'or pastures; the disking should continue until all perennial competition has been thoroughly dried or turned under.

Where rocks or other hazards make such intensive preparation impossible, the site should be planted immediately after clearing in order to give the sycamore seedlings the best possible start on competition that will develop from sprouts and seeds. Only the sturdiest planting stock should be used in such a situation.

Sycamore has been successfully planted under light shade and in small openings, but growth is slow (Biswell 1935). Killing the overstory by girdling or poisoning permits the seedlings to survive, but the higher cost of clearing and burning will almost certainly be repaid by increased yields which will accompany postplanting cultivation. This is particularly true on high-quality sites, where debris must be removed during site preparation to allow for mechanical cultivation.

SEASON AND WEATHER

Like most deciduous trees, sycamore is best planted during the dormant season, with late winter apparently preferable in the Deep South. Preliminary tests have shown some survival from July planting[7] and substantial survival from planting in the period August through April, but only if soil moisture is plentiful at planting and for an extended period afterwards. The qualification cannot be disregarded, since soil moisture is not normally abundant on most sites in August and September. If the tree is in leaf at time of planting, leaves should be removed by stripping or pruning of the stem. Dormant seedlings can be kept in cold storage for at least 4 months, then planted successfully as late as August if ample moisture is provided by rainfall or irrigation.

[7]Personal correspondence with John A. Nugent, International Paper Company, Jan. 24. 1969.

PLANTING STOCK

Seedlings.-Planting stock should normally be seedlings. Stem diameter at the groundline should be at least 0.25 inch, and 0.5 inch is better. Little specific information is available on the relation of growth to initial diameter, but Ike (1962b) found that seedlings over 0.5 inch at the rootcollar grew more than twice as much the first year as did those less than 0.3 inch. In a test on two sites in the Mississippi Delta, seedlings with diameters less than 0.2 inch suffered 100 percent mortality while seedlings larger than 0.4 inch showed better than 80 percent survival. Both sites were old fields supporting dense stands of Johnson grass, *Sorghum halepense* (L.) Pers., not a recommended planting condition.

Cuttings.-Sycamore plantations can be established from cuttings (Briscoe 1963; McAlpine 1963; Nelson and Martindale 1957; Tourney 1931). Cuttings have been recommended over seedlings for the closely related oriental plane (Zmijanac 1956) and California sycamore (Mirov and Kraebel 1939), but American sycamore cuttings survive less well than seedlings, grow more slowly initially, are not adapted to as wide a variety of sites, and are generally more expensive to produce and handle. They are currently used much less than are seedlings. Their only apparent advantage, except in tree improvement, is that they can be harvested quickly if natural stands of seedlings or small saplings are available.

Cuttings should be from stems or sprouts less than 4 years old; first-year stems are preferred. Butts have been reported to give better growth than cuttings from the upper portion of the stem (Briscoe 1963; Nelson and Martindale 1957), but the apparent result may have been the effect of cutting size rather than position in the stem. Minimum top diameter should be at least 0.3 inch, with 0.5 inch or larger preferred. Length should be 16 to 20 inches on normal sites, and more on poor sites. In every case the cuttings should be kept moist from collection until planting. Soaking a dried cutting is useless; once dried, a cutting is dead.

PLANTING METHODS

Planting sycamore is essentially'like planting any other tree seedling. The objective is to place the existing root system in contact with moist soil, without damage or distortion. It is for this reason that pruning of the seedlings has been mentioned at such length and so often. The more nearly the root system resembles a carrot, the easier it is to care for, handle, and plant. For sycamore, good planting of the carrot is far preferable to poor planting of a larger root system (fig. 7) or careful planting of damaged roots.

Manual planting may be required by the site or the scale of operations. A shovel, mattock, dibble, or planting bar may be used, depending on the stock obtained, the site, and personal preference. The root should be planted at least as deep as it was in the nursery; planting as much as 6 inches deeper has no adverse effects if some of the stem is above the surface soil.

With cuttings, 2 to 4 inches should normally remain above ground. McAlpine[8] has suggested completely covering long horizontally planted cuttings, presumably for coppicing the resultant dense stands.

Mechanical tree planters usually permit faster, easier, and better planting than hand methods, and the tractor-mounted or tractor-drawn planters developed for pines serve well with sycamore. The utility of a particular model depends primarily on soil type and ground conditions.

Planting large seedlings in deep auger holes, as poplars are sometimes planted (Schreiner 1959; White 1968), has increased survival and height growth the first year (Kaszkurewicz 1967a) and promoted large root systems (Kaszkurewicz 1967b).

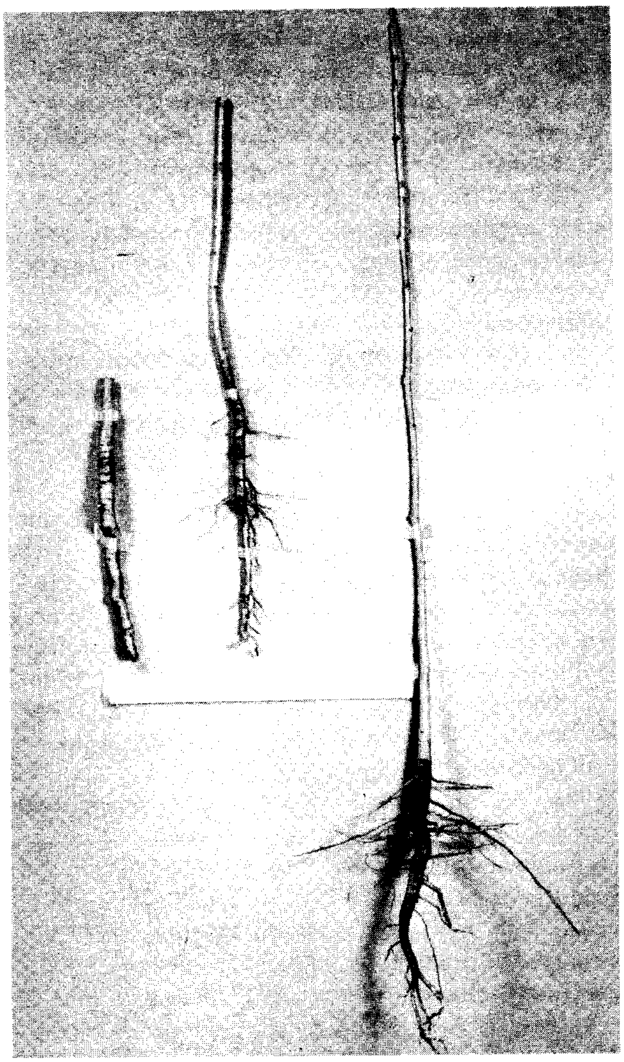

Figure I.-Sycamore seedlings, *left* **to** ***right: roots and tops severely pruned, lightly pruned, and unpruned. All three will survive and grow well, but the pruned trees are easier and more economical to handle.***

SPACING

Optimum spacing varies with management objectives. For example, a stand destined to be thinned for pulpwood should be planted more closely than a stand meant exclusively for saw logs and veneer. Similarly, trees to be cultivated and pruned may be spaced wider than trees not so treated.

On the basis of information now available, the spacings in table 2 are suggested. The number of trees

Table ***2.-Suggested spacings for sycamore plantations***

Desired mean stand d.b.h. at first thinning (inches) (1)	Anticipated stand at time of first cut[1] Trees per acre (2)	Anticipated stand at time of first cut[1] Equivalent square spacing (3)	Mean stand d.b.h. when natural pruning begins[2] (4)
	No.	**Feet**	**Inches**
4	538	9	2
6	360	11	3
8	239	13.5	4
10	170	16	5.5
12	134	18	6
14	104	20.5	7.5
16	82	23	9

[1] Surviving trees only. Based on basal area values reported for undisturbed stands by G. H. Lentz, whose 1928 informal reports and charts. entitled "Hardwood Reports, and Addenda," are on file at Southern Hardwoods Laboratory, Stoneville, Miss.

[2] Adapted from information reported by Krajicck (1967).

[8] Personal correspondence with Robert G. McAlpine, USDA Forest Service. Forestry Sciences Laboratory, Athens. Ga.. Feb. 6, 1969.

in column 2 and the spacings in column 3 refer to the trees desired at time of first thinning, with no allowance for mortality. If 90 percent survival is expected, the number of trees to plant can be approximated by multiplying 1.1 times the value in column 2. Other assumptions as to mortality will require different adjustment values. The values listed describe the stand characteristics at the time mean annual increment per acre culminates.

Time to reach a given diameter is shortened by adopting spacings wider than those suggested, but yield per acre will drop. Conversely, higher yields per acre can be obtained by closer spacings, but at a given diameter trees will be older and competition will reduce vigor.

Management of sycamore on very short coppice rotations (McAlpine et al. 1966) may involve spacings closer than 6 inches by 40 inches; not enough data have accumulated to permit even an informed guess.

REPLANTING AND MIXED PLANTINGS

Sycamore has been used for planting failed spots in plantations of cottonwood and of yellow-poplar, with initial success. It has also been used in mixed plantings, particularly on spoil banks, but it cannot be recommended for this purpose, as it outgrows and dominates most associates (Rodenbach and Olson 1962; Seidel and Brinkman 1962) and dies out or grows slowly if overtopped.

Plantation Care

CULTIVATION AND FERTILIZATION

Many sycamore plantations have been established without postplanting care of any kind. Where large and vigorous stock is used, survival is often excellent. However, consistently best survival and height growth-as much as 12 feet the first year-are obtained with clean cultivation. Observations indicate that cultivation as needed through the first year shortens the rotation by 2 to 3 years or, considered another way, increases the final yield on a good site by 1 to 2,000 board feet per acre.

Cultivation on well-prepared, reasonably level sites should begin as soon as weeds appear above ground. The best care can be obtained by straddle-cultivating until the trees are too large, then cultivating between the rows (fig. 8). Two to five cultivations are required during the first year. On good sites second-year cultivation is unnecessary; its economic effect is not yet known.

Heavy, well-built equipment is essential. Rubber-tired tractors of about 80 hp. are probably best; lighter ones cannot easily pull a heavy disk or a full gang of cultivating plows.

Fertilization may increase growth of sycamore seedlings (Broadfoot and Ike 1967; Funk and Krause 196.5; Gilmore and Boggess 1963; Huppuch 1960; Ike 1962a), and small-scale trials are worthwhile. No experimental information is available on the results of fertilizing established stands, nor is growth well correlated with nutrient composition of the leaves (Gilmore 1965).

Phosphorus is most likely to be deficient on coarse, poorly drained soils near the coast and in seedling stands. Addition of nitrogen may increase growth on finer, higher soils and in established stands (Bengtson 1968). Lime, phosphorus, and potassium may be applied up to a year or more before planting and should be incorporated into the soil. Nitrogen in readily available forms leaches rapidly, and hence

Figure 8.—*A plantation just after a cultivation at the beginning of thesecond growing season. Such a cultivation is not necessary, but it stimulates growth markedly.*

should be applied just before or sometime after planting, when soil moisture is abundant. If trials are to be carried out, weed competition must be controlled.

Although fertilization will undoubtedly become increasingly important in the future, large-scale application cannot be recommended now.

PROTECTION

Plantations of sycamore are resistant to most agents, but they are not immune. Therefore they must receive the care normally accorded to forest plantings. If fires are not extremely hot, the trees will sprout from the stumps (fig. 9). In plantations that have been heavily invaded by Johnson grass or other weeds, however, a fire during dry weather may destroy the sprouting ability of the rootstocks.

Neither deer nor domestic livestock prefer sycamore seedlings (McKnight 1969), but heavy concentrations of either will strip, trample, and eventually kill young trees. Livestock should be kept out of new plantations. Damage from deer can almost always be held to a tolerable level by planting in blocks of 40 acres or more. Where deer are numerous, small plantings may have to be fenced or established with seedlings more than 4 feet tall.

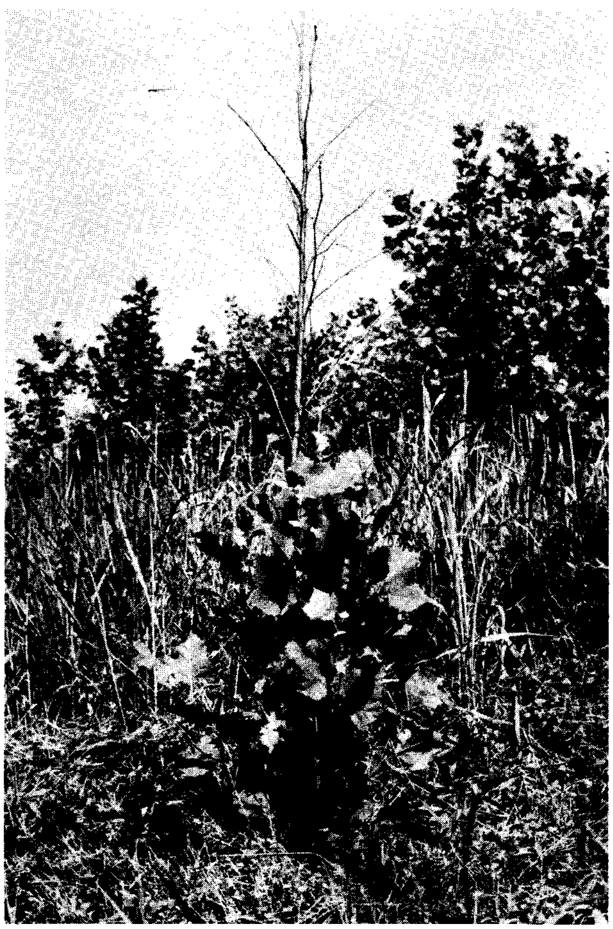

Figure 9.—*Multiple sprouts of a sycamore,* 2 years *after a hot* fire *killed the original stem.*

Rodents, presumably rabbits, may clip substantial numbers of seedlings in the spring, but stumps will sprout.

No insects are known to become epidemic on sycamore, although many include it as a host species. Among those causing noticeable damage to foliage of occasional trees are leafhoppers, lacebugs, fall webworm (*Hyphantria cunea* (Drury), aphids, and scale insects. The last are the major pests of the related California sycamore (Smith 1941). The wood is occasionally attacked by the Columbian timber beetle ***(Corthylus columbianus*** Hopk.), especially on droughty sites, and by the flat-headed sycamore-heartwood borer ***(Chalcophora campestris*** (Say)), and the hardwood stump borer ***(Stenodontes** dasystomus* (Say)). While these and other borers may severely damage individual trees, widespread infestations have not been reported (Craighead 1950).

Diseases are of two major types: those that attack leaves and twigs and those that attack the stem. Of the former, anthracnose, caused by ***Gnomonia veneta*** (Succ. and Speg.) Kleb., is the most common north of the Ohio River (Boewe ***et al.*** 1954; USDA Forest Service 1967). A light attack partially kills the leaves, so that they look frostbitten; a severe infestation may kill all the leaves and small twigs; growth is then reduced and occasional trees die. The disease is seen less often south of the Ohio River, probably because continuous cool (less than 55° F.), wet weather is requisite for epidemic development of the causal organism (Neely and Himelick 1963). When necessary, control is by application of fungicide (Hoffman 1953; Snyder 1959). American sycamore has been reported both less resistant (Selik 1964) and more resistant (Himelick and Neely 1959; Itô and Hosaka 1950) than related plane trees. Possibly, apparent resistance depends a great deal on the interaction of phenological stage with the weather.

Of stem diseases, the cankers are by far the most important (McAlpine 1961; Thompson 1951). The causal fungi may enter trees of any size through breaks in the bark (Filer 1965), and the cankers spread vertically through the cambium (fig. 10). Heart rot develops beneath the lesions, destroying or degrading the wood and weakening the stem until it is likely to break in a high wind. Fortunately, trees seem to be severely attacked only when drought or other factors have already weakened them, and when the

Figure IO.--Stem ***canker, caused by*** Botryodiplodia theobromae ***Pat.***

cause of stress disappears the periods of high incidence seem to come to a natural end (Michaux 1857; Toole 1961).

Established sycamores are more than ordinarily resistant to drought (Pool 1939) and high winds (Alden 1939; Westveld 1939).

THINNING

Thinning of sycamore plantings has received little attention, but there is no reason for expecting results different from those with other species. If the proper original spacing is adopted, no thinning need be made until a merchantable product can be harvested. Removing 25 to 40 percent of the stems will then provide an operable cut and release the remaining trees. Neither epicormic branching (Huppuch 1961) nor windfall (Alden 1939; Westveld 1939) has been important after thinning.

Maximum long-term cellulose yield is obtained by thinning from below, although initial financial return from stumpage is minimal. Maximum growth of selected stems only, as for veneer bolts, will be obtained through a crown thinning. Crown thinning will remove larger trees and increase diameter growth of stems released, but total cellulose yield is reduced.

Row thinning offers great advantages, particularly for pulpwood companies, as mechanized harvesters are improved and labor grows scarce.

PRUNING

Natural pruning of sycamore in closed stands is excellent, and dead branches normally fall within 12 to 18 months. In the open, lower branches live almost indefinitely. Thus if stands are kept open to obtain the remarkably rapid diameter growth of which sycamore is capable, artificial pruning will be necessary to hold the knotty core to a minimum.

General guides to pruning are:

1. Prune early. Costs are minimum and returns are maximum if the knotty core is kept small. Approximately 3 inches' diameter outside bark at time of pruning is best.
2. Prune only selected trees. Because complete healing of scars requires nearly an inch of wood outside the cut, 2 inches of growth in diameter outside bark are necessary before any clear wood results. Trees to be removed in early thinning should not be pruned. Pruning a few more than desired for the final crop, to provide for accidents and mortality, is good insurance.
3. Prune only vigorous trees, and prune them moderately. Heavy green pruning reduces growth and may cause epicormic sprouting (Doolittle 1950). But if pruning reduces live crown to not less than 50 percent of total tree height and growing space is adequate, growth is maintained and the epicormic sprouts soon disappear (Doolittle 1956). Stands should not be thinned in the same year they are pruned, as that would accentuate sprouting.
4. Market pruned logs separately under an arrangement that will provide the premium price they deserve.

No meaningful information is available on either the cost or benefit of pruning sycamore. In view of the trees' ability to prune naturally, it appears doubtful that artificial pruning will be justified where markets exist for small products, such as pulpwood. Wide initial spacing accompanied by pruning may well be profitable wherever there is a good market for quality timber but thinnings cannot be sold.

Costs

Although cost of establishing and caring for sycamore plantations will vary with locality, methods, size and type of operation, and weather, some typical costs in the Mississippi Delta are given below.

Operation		Cost per acre
Land clearing: shear, push and burn, rake, and cross-disk		$65.00
Planting:		
Seedlings, at $6 per thousand	$3.00	
Machine planting	5.00	
Total		8.00
Cultivation: l-way disking, three times		12.00
Total		$85.00

Returns depend on biological and business conditions, and on the assumptions and methods used in accounting. In most areas, mixed products yield much higher returns than pulpwood only (McKnight 1967).

Tree Improvement

Platanus is a promising genus for improvement work, combining a circumglobar range and a wide variety of sites with good interspecific crossability. It is easy to reproduce vegetatively (Kormanik and Brown 1966; Larsen 1946; Nelson 1957) and sexually (Beland and Jones 1967). Current tree improvement research includes wood properties, natural variation, vegetative propagation (Dorman 1966), and plus-tree selection, but no improvements have been reported yet.

Well-spaced sycamore yields abundant crops of fruit at an early age, and trees can be top-pruned for economical harvest of the seed. Thus the species is well adapted for establishing seed orchards of selected or improved trees. The seed orchards should be replicated at widely separated geographical points, to insure a regular supply of seed in spite of vagaries of local weather.

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