Volume, Weight, and Pulping Properties Of 5-Year-Old Hardwoods

R. M. Krinard **H. E. Kennedy, Jr.**

R. L. Johnson

Abstract

A hardwood plantation was established in an Arkansas small stream bottom at 10- by 10-foot spacing to obtain information on survival, growth, yield, and utilization possibilities on such Coastal Plain sites. The data are needed before the planting of hardwoods can be considered as an alternative to pine regeneration on these good hardwood sites. Seven hardwood species were sampled at age 5 to determine stem volumes, stem weight/branch weight and dry weight/green weight relationships, and pulping properties. Species were sweetgum *(Liquidambar styraciflua* L.), American sycamore *(Platanus occidentalis* L.), green ash *(Fraxinus pennsylvanica* Marsh.), cherrybark oak *(Quercus falcata* var. *pagodaefolia* Ell.), Nuttall oak *(Quercus nuttallii* Palmer), water oak *(Quercus nigra* L.), and yellow-poplar *(Liriodendron tulipifera* L.). Plantings' survival ranged from 47 percent for water oak to 94 percent for sycamore. Average DBH ranged from 1.6 inches for cherrybark oak to 3.1 inches for sycamore. Average height ranged from 13.4 feet for Nuttall oak to 20.5 feet for sycamore. Average stem volume ranged from 0.2 cubic feet for oaks to 0.7 cubic feet for sycamore. Average total tree dry weight ranged from 15 pounds for water oak to 51 pounds for sycamore. Stem weight accounted for 53 to 66 percent of total tree weight by species. Unbleached pulp from chips of each species did not have properties equal to the hardwood chip mixture now being used locally for facial tissue.

OVER A LARGE though scattered area of the Southeastern Coastal Plain of the United States, minor stream bottoms provide good growing sites for hardwoods. Cutting these hardwoods, however, has often led, either naturally or artificially, to regeneration to pine. Hardwoods of preferred species can probably be maintained on these sites through planting, but the process is expensive. Plantation volume or weight yields are needed before such investments can be encouraged. In this paper we provide data on volumes, weights, and pulping characteristics of 5-year-old trees of seven hardwood species planted in a Coastal Plain minor stream bottom. The planting was established to provide information on survival, growth, yield, and utilization possibilities of these species.

Species and Methods

Species measured were sweetgum, sycamore, green ash, cherrybark oak, Nuttall oak, water oak, and yellow-poplar. Trees were planted at 10- by 10-foot spacing to allow for mechanical weed control. Soils were Arkabutala in the bottom and Dulac on the adjoining lower slopes; the slopes were partially planted because of the irregular nature and narrowness of the bottom.

When the 20-acre plantation was established, replicated blocks were planted at right angles to contours. Each row within a block was randomly planted with a different species, and trees were cultivated annually by cross-disking. Multiple stemmed, forked, or misshapen trees, partly caused by either deer damage in the first year before fencing or by dieback from disease or insects, were considered atypical and eliminated as volume and weight sample trees.

In late March 1977, prior to the sixth growing season, 10 trees of each species were cut at ground level, measured for total length, measured for diameter at 2-foot intervals and at breast height (DBH), and delimbed. Stem and limbs from each tree were weighed immediately. Three- to four-inch-long samples were cut from stems at 3- to 4-foot intervals. A comparable quantity of 6-inch-long samples were cut from limbs. Sample sections were put immediately in plastic bags. Tree data and samples were labeled to maintain individual tree information.

An additional 10 trees per species (5 for water oak and 7 for yellow-poplar) were cut, measured for length and diameters, and weighed intact. The trees which had not been delimbed were then chipped in a whole-tree chipper.

The authors are, respectively, Mensurationist, and Principal Silviculturists, USDA Forest Serv., Southern Forest Expt. Sta., Southern Hardwoods Lab., Stoneville, Miss. This paper was received for publication in September 1978.

TABLE 1. — *Diameters, heights, and stem volumes of sample trees.*

Species	No. in sample	Diameter Avg. (in.)	Diameter Range (in.)	Height Avg. (ft.)	Height Range (ft.)	Volume Avg. ($ft.^3$)	Volume Range ($ft.^3$)
Sweetgum	20	2.3	1.2-4.1	16.3	11.3-20.8	0.37	0.13-1.03
American sycamore	20	3.1	1.2-5.9	20.5	11.9-27.1	0.72	0.15-2.56
Green ash	20	2.1	1.3-3.0	17.4	13.8-21.8	0.30	0.11-0.57
Cherrybark oak	20	1.6	1.0-2.5	13.9	10.8-17.8	0.18	0.07-0.39
Nuttall oak	20	1.8	1.3-2.3	13.4	11.2-17.2	0.20	0.12-0.29
Water oak	15	1.7	1.2-2.3	14.2	12.6-16.2	0.18	0.10-0.31
Yellow-poplar	17	2.3	1.0-4.9	17.6	11.0-29.7	0.41	0.08-1.72

TABLE 2. — *MC of stem wood, stem bark, and limbs.*

Species	No. in sample	MC[a] of Stem wood Avg. (%)	Stem wood Range (%)	Stem bark Avg. (%)	Stem bark Range (%)	Limbs[b] Avg. (%)	Limbs[b] Range (%)
Sweetgum	10	74	56- 97	100	74-139	102	95-111
American sycamore	10	85	59-108	112	92-139	98	86-109
Green ash	10	53	46- 64	96	66-133	54	50- 58
Cherrybark oak	10	60	52- 68	82	55-100	58	49- 68
Nuttall oak	10	66	52- 82	90	56-125	63	55- 68
Water oak	10	61	46- 92	82	50-100	59	53- 66
Yellow-poplar	10	83	54-131	137	88-180	128	116-143

[a]Dry weight basis
[b]Wood and bark combined.

Moisture contents (MCs) were determined from stem and limb samples; specific gravities (SGs) were determined from stem samples only. To determine SG on a dry weight, green volume basis, the procedure was as follows: separate bark from stem wood with a chisel; determine green sample weight; determine green volume by water immersion; dry sample in a walk-in dryer at 70°C for 2 days and then in a kiln for 48 hours at 105°C; and determine dry weight. Limb samples were weighed green, dried, and weighed without separating bark from wood. Stem cubic volume was obtained by Newton's prismoidal formula.

Regression equations were developed for total stem volume, using D^2H as the independent variable, where D = DBH and H = total height, and for total tree green and dry weight using powers and cross products of D and H as independent variables.

Chips of all species were sent to an industrial firm (Georgia-Pacific Corp., Toledo, Oreg.) for pulping research on suitability for manufacture of facial tissue (3). Chips were cooked in a small laboratory digester, and unbleached pulp was tested for yield, cleanliness, density, and physical strength. Hardwood chip samples currently used locally in production—mainly southern red oak, but also other oaks, sweetgum, elm, ash, and hickory—were tested simultaneously.

Results and Discussion

At the start of the fifth year, plantings' survival was 47 percent for water oak, 68 percent for yellow-poplar, 74 to 82 percent for cherrybark oak, Nuttall oak, and sweetgum, 90 percent for green ash, and 94 percent for sycamore.

Average DBH ranged from 1.6 inches for cherrybark oak to 3.1 inches for sycamore; average total height ranged from 13.4 feet for Nuttall oak to 20.5 feet for sycamore (Table 1). Average stem volume ranged from 0.2 cubic feet for oaks to 0.7 cubic feet for sycamore.

Green stems accounted for 54 to 62 percent and dry stems 53 to 66 percent of tree weight when averaged by species. Average dry weight was 53 percent of green weight for sweetgum and sycamore, 49 percent for yellow-poplar, and from 60 to 63 percent for oaks and green ash. Dry weight/green weight relationships may vary with time of year of cutting because of MC changes with season of year (1). Average total dry weight varied by species from 15 (water oak) to 27 (sweetgum) pounds. Sycamore, however, averaged 51 pounds with, and 40 pounds without, one exceptionally large tree.

On a dry weight basis, for three species close to leaf flush—sweetgum, sycamore, and yellow-poplar—average MC of stem bark and limbs (wood and bark combined) was similar within species varying from 98 to 137 percent, and was greater than stem wood MC, 74 to 85 percent (Table 2). For ash and oaks, average MC

TABLE 3. — *Stem wood volume and stem wood weight.*

Species	No. in. sample	Stem wood vol.[a]/ total stem vol. Avg. (%)	Stem wood vol.[a]/ total stem vol. Range (%)	Stem wood wt.[b]/ total stem wt. Avg. (%)	Stem wood wt.[b]/ total stem wt. Range (%)
Sweetgum	10	83	78-89	88	86-91
American sycamore	10	89	87-91	90	88-92
Green ash	10	83	78-86	88	83-90
Cherrybark oak	10	81	78-83	85	80-87
Nuttall oak	10	86	82-90	88	84-91
Water oak	10	82	77-84	85	78-89
Yellow-poplar	10	78	72-85	80	74-87

[a]Green volume basis
[b]Dry weight basis

TABLE 4. — *Total stem volume (V) outside bark, where* $V = b_0 + b_1 D^2H$.

Species	No. in sample	Avg. ($ft.^3$)	b_0	b_1	r^2	$S_{y.x}$
Sweetgum	20	0.37	0.093014	0.002784	0.977	0.040
American sycamore	20	0.72	0.123218	0.002544	0.987	0.062
Green ash	20	0.30	0.072970	0.002623	0.897	0.044
Cherrybark oak	20	0.18	0.044455	0.003214	0.969	0.018
Nuttall oak	20	0.20	0.052137	0.003254	0.811	0.026
Water oak	15	0.18	0.031127	0.003504	0.851	0.024
Yellow-poplar	17	0.41	0.105970	0.002344	0.988	0.044

of stem wood and limbs was similar, 53 to 66 percent, and less than that of stem bark, 82 to 96 percent.

On a green volume basis, stem wood averaged from 78 percent (yellow-poplar) to 89 percent (sycamore) of total stem volume (Table 3). On a dry weight basis, stem wood averaged from 80 percent (yellow-poplar) to 90 percent (sycamore) total stem dry weight. Since the percentage of bark on the limbs is probably higher than the percentage of bark on the main stem, the percentage of bark on the whole tree should be greater.

Regression equations for predicting total stem volume outside bark in cubic feet from D^2H had r^2 values ranging from 0.81 for Nuttall oak to 0.99 for sycamore and yellow-poplar (Table 4). Standard errors of estimate, expressed as a percentage of mean volume, ranged from 9 percent for sycamore to 15 percent for green ash. Combining the three oak equations showed no significant differences in slopes or intercepts. The combined equation was $V=0.044865+0.003277\ D^2H$, with $S_{y.x}=0.023$, and $(S_{y.x}/\overline{V})100=8$ percent. The only combination of other species' volume regressions without significant differences in slope and/or intercept was sweetgum and sycamore, where $V=0.113702+0.002583\ D^2H$, $S_{y.x}=0.053$, and $(S_{y.x}/\overline{V})100=10$ percent.

Regression equations for predicting whole tree green weights accounted for only 48 percent of the variation for Nuttall oak, but 83 to 98 percent for other species. However, standard errors of estimate were fairly large, varying from 13 to 31 percent of mean values. D^2 gave the best fit for sweetgum, green ash, and yellow-poplar; the second-best fit for sycamore, Nuttall oak and water oak; and the third-best fit for cherrybark oak. Height functions were never comparable to diameter functions as independent variables.

For whole-tree dry weight regression equations, D^2 provided the best fit for sweetgum, sycamore, green ash, and cherrybark oak, and the second best fit for the other three species. Best r^2 values ranged from 0.89 (green ash) to 0.97 (sycamore) except for Nuttall oak (0.58). Standard errors of estimate varied from 7 percent (cherrybark oak) to 31 percent (Nuttall oak). Total dry weight equations were based on the 10 trees analyzed for MC; total green weight equations were based on all trees. Regression coefficients were significant at the 0.01 level of probability for all species except Nuttall oak where significance level was 0.05.

SGs (Table 5) generally were slightly higher than published values (2). The reason for this is unknown.

For the pulping tests, all seven species had slightly lower pulp densities and yields, and less strength, than a currently used commercial chip mixture derived from larger hardwood trees grown on similar sites (Table 6). As softness and cleanness are important factors in facial tissue and dirt a major problem (bark is considered dirt as it won't cook properly and won't bleach out) none of the pulps could be considered as a practical partial mix with the present pulping operation. Disregarding dirt, the sycamore and sweetgum pulping characteristics were generally comparable to the currently used pulp, while the other species were not.

Trees measured in this study were considerably below currently accepted merchantable pulpwood size.

TABLE 5. — *SG (green volume basis) of stem wood and stem bark of sample trees.*

Species	No. in sample	Wood SG		Bark SG	
		$\overline{X}$	Range	$\overline{X}$	Range
Sweetgum	10	0.50	0.46-0.55	0.36	0.30-0.45
American sycamore	10	0.50	0.47-0.52	0.46	0.40-0.54
Green ash	10	0.50	0.43-0.57	0.36	0.28-0.42
Cherrybark oak	10	0.65	0.62-0.68	0.50	0.42-0.60
Nuttall oak	10	0.60	0.58-0.64	0.50	0.34-0.58
Water oak	10	0.65	0.60-0.71	0.52	0.45-0.61
Yellow-poplar	10	0.46	0.41-0.49	0.40	0.36-0.46

TABLE 6. — *Pulping tests (all data at a permanganate number of 12 and/or 500 ml CSF[1]).*

Species	Breaking length (m)	Burst factor	Tear factor	Total yield (% OD/OD wood)	Pulp density (g OD/cm^3)	Brightness (% refl/MgO)
Southern red oak[2]	8800	49.5	90	50.0	0.596	24.2
American sycamore	8600	48.0	88	43.8	0.564	23.6
Sweetgum	7400	43.5	82	43.0	0.588	22.3
Nuttall oak	6600	37.0	70	44.7	0.564	21.8
Yellow-poplar	6900	33.0	62	45.9	0.564	24.5
Water oak	5900	29.0	56	45.7	0.521	23.9
Green ash	5900	29.0	55	41.0	0.564	29.5
Cherrybark oak	5300	28.0	50	45.0	0.481	23.9

[1]From technical report by G. Scharzenberger (3).
[2]Predominant species in current production.

But whole-tree harvesting of small trees and chipping for fuel or fiber, including bark, may become feasible in the future.

Assuming that other trees of the same species will grow at similar rates when planted in solid blocks as in 1-row plots, and assuming that individual tree growth for 5 years will be the same regardless of survival, yields per acre with 10- by 10-foot spacing can be estimated. For Nuttall oak, cherrybark oak, and sweetgum, species that average about 15, 20, and 25 pounds per tree (aboveground parts), 5-year yields with 70 percent survival would be 2.29, 3.05, and 3.81 tons per acre. With 85 percent survival, yields would be 2.78, 3.70, and 4.63 tons per acre. If sycamore averages 50 pounds per tree in 5 years, 70 and 85 percent survival would result in 7.62 and 9.26 tons per acre.

In comparison, the silage concept—growing planted hardwoods in short rotations (up to 5 yr.) at close spacings (less than 20 to 25 ft.^{2} per tree) with complete tree cropping—has produced 2 to 4 tons of dry material per acre per year, with bark volume estimated at 10 to 20 percent of the stem and 25 percent of the limbs (4). At this time, however, bark creates a bleachable grade pulp utilization problem for trees of small size regardless of spacing and yield.

Literature Cited

1. BROWN, H. P., A. J. PANSHIN, and C. C. FORSAITH. 1952. Textbook of Wood Technology, Vol. II. McGraw-Hill Book Company, Inc., New York, N.Y. 783 pp.
2. JETT, J. B., and B. J. ZOBEL. 1975. Wood and pulping properties of young hardwoods. Tappi 58(1):92-96.
3. SCHARZENBERGER, G. 1977. Suitability of seven fast-growing hardwood species for the manufacture of facial tissue. Georgia-Pacific Corp. Tech. Rep., Toledo, Oreg. 90 pp.
4. ZOBEL, B. J., and R. C. KELLISON. 1972. Short-rotation forestry in the Southeast. Tappi 55(8):1205-1208.