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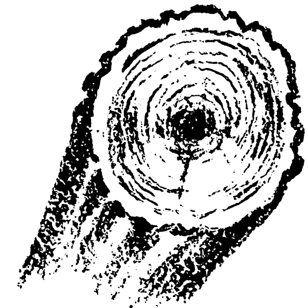

SUGAR MAPLE BARK THICKNESS AND VOLUME

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Estimating Sugar Maple Bark Thickness and Volume

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Estimating bark thickness is a requirement for tree quality assessment. Knowing the volume or weight of bark within the tree, log, or cordwood pile is important because bark cannot be combined with wood for many products. Bark is also becoming a usable material, and thus the demand for accurate methods to estimate its volume is increasing. Meyer (1946) developed mathematical equations for estimating bark thickness and volume:

$$(1) \quad B = D/2\ (1\text{-}k)$$

$$(2) \quad Vb = V\ (1\text{-}k^2)\ ,$$

where B is bark thickness, V_b is bark volume, D is usually d.b.h.o.b., but could be d.o.b. at any point on the tree, V is total stem volume including bark, and k is the regression coefficient for the relationship of d.i.b. (d) to d.o.b. (D). [1] Meyer plotted d as a function of D and obtained a constant ratio with a straight line passing through the origin of coordinates. Thus, the constant k is determined by the equation

$$(3) \quad k = \frac{\Sigma d}{\Sigma D} = \frac{\Sigma D - \Sigma 2B}{\Sigma D}\ .$$

We tested Meyer's equations to see how accurately they estimate bark thickness and volume for sugar maple (*Acer saccharum* Marsh.). In addition, we developed and tested the accuracy of equations that relate bark thickness and volume to average tree diameter outside bark, d.b.h.o.b., and total merchantable volume. Information is also presented on variation in bark thickness and k up the stem, and weight and volume of bark as a percentage of total merchantable stem weight and volume.

PROCEDURE

Forty-five trees in each of two sample areas, located approximately 200 miles apart, were felled and bucked into 8-foot

[1] *The d.i.b. and d.o.b. measurements are usually taken at d.b.h. A Swedish bark gauge is used to measure double bark thickness, which is subtracted from d.o.b. to obtain d.i.b.*

logs. [2] Tree age ranged from 92 to 289 years, averaging 192 years; d.b.h. ranged from 11 to 26 inches, averaging 18 inches; and tree growth rate ranged from 6 to 23 rings per inch of diameter, averaging 13 rings per inch.

We measured d.i.b., d.o.b., and bark thickness on cross-sectional discs sawed from the butt end of each log. Bark thickness values were determined by averaging four measurements taken at 90 degree intervals. Bark thickness, d.i.b., and d.o.b. were recorded at 8-foot intervals up the stem, and log bark volumes were totaled to get bark volume per tree.

The relationship of d.i.b. to d.o.b. was then plotted. The Y-axis intercept was not equal to zero, but was close enough to assume $k = d/D$, as reported by Meyer. Values of k were calculated for each 8-foot interval up the stem using the d/D ratios obtained from each cross-sectional disc. An average k value was then calculated and used in Equations 1 and 2 to estimate average bark thickness and bark volume for each tree, which were compared to measured values. The average k value is different from that used by Meyer, because he did not take into account variation of d/D up the stem; he measured this ratio only at d.b.h. We also used a different value for D in Equation 1. Meyer used d.b.h.o.b. for D, but we calculated an average d.o.b. per tree.

$$(4) \quad D = \left(\frac{4V}{\pi L}\right)^{1/2},$$

where V is total merchantable volume including bark and L is merchantable length. Because V was obtained for each tree by summing the log volumes, D is a good representative average diameter.

In addtion, because published data [3] show that bark thickness of various hardwoods and softwoods is related to tree size, age, site, and height, we related measured bark thickness and volume of the 90 trees to tree stem characteristics. All possible combinations of the following six independent variables were tried: stem length, average tree diameter (see Equation 4 for definition), d.b.h., tree age, merchantable stem volume, and (stem volume/stem length)$^{1/2}$. The R^2 values and residuals obtained for the regression runs were used to evaluate the accuracy of the developed equations.

To further test the accuracy of Meyer's equations and those we developed, a field test was made. Bark thickness and volume data were collected for 42 new trees located where Sample 1 trees were cut. A Swedish bark gauge was used to obtain bark thickness at 1 foot, 8 feet, and 16 feet above stump (fig. 1). Diameter outside bark measurements were also taken at these tree heights. We then estimated average bark thickness and bark volume for these trees using first our equations, then Meyer's Equations 1 and 2 (using the k value of Sample 1.) These estimates were then compared to the measured values.

We also investigated the rate of change of k and bark thickness with increased height above stump to see if equations could be developed to estimate bark thickness at any tree height. (Meyer's

2 The top log was not always 8 feet because total merchantable stem, based on a 6-inch d.i.b. minimum top or where the tree separated into two or more distinct branches, was utilized.

3 (Hale 1955, Klepac 1958, Krier and River 1968, Miller 1961, Minor 1953, Myers 1964, Spada 1960).

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Figure 1.—Collection of field test data. Bark thickness was obtained at various tree heights by using a Swedish bark gauge.

Equation 1 and those we developed give average bark thickness.) In addition, we calculated the average weight and volume of bark for sugar maple.

ESTIMATING BARK THICKNESS AND VOLUME

Meyer method.—The mean k values for Samples 1 and 2 were 0.929 and 0.934, respectively. These two k values, when used in Equations 1 and 2, where D and V were mean average tree diameter and merchantable stem volume for the 90 trees, give only slight differences for bark thickness and volume estimates. Thus, the average k value for the 90 trees, 0.932, was used in Equations 1 and 2 to estimate an average bark thickness and bark volume for each of the 90 trees. Estimated bark thickness was closely correlated with measured bark thickness (r=0.73), and estimated bark volume was closely correlated with measured volume (r=0.95).

Our method. — The equations we developed, using all combinations of six tree stem characteristics as independent variables, also gave good estimates of average bark thickness and bark volume. Average tree diameter can be used to estimate bark thickness — R^2 was almost as high as that obtained using all six independent variables combined. Average tree diameter and tree age combined do give a R^2 value equal to that obtained using all variables. Tree volume, d.b.h., and age were also significantly related to bark thickness (table 1). Bark volume was closely related to total merchantable stem volume (R^2 = 0.91); adding variables did not improve the relationship. Average tree diameter and d.b.h. were also related to bark volume (table 1).

Table 1.—*Some tree stem characteristics that are significantly correlated with bark thickness and volume*

Dependent variable	Increases with	R^2 Sample 1	R^2 Sample 2	R^2 All 90 trees	Equation (All 90 trees)
Average bark thickness	a. Average tree diameter	0.65	0.46	0.51	$Y = 0.1986+0.0206\ (X)$
	b. D.b.h.	.55	.44	.49	$Y = 0.2232+0.0153\ (X)$
	c. Total merchantable volume	.57	.48	.44	$Y = 0.3759+0.0022\ (X)$
	d. Tree age	.28	.36	.29	$Y = 0.3094+0.0010\ (X)$
	e. Average tree diameter (X_1) plus tree age (X_2)	.66	.50	.57	$Y = 0.1555+0.0170\ (X_1) + 0.0005\ (X_2)$
Bark volume	f. Average tree diameter	.81	.69	.75	$Y = -5.5267+0.8767\ (X)$
	g. D.b.h.	.79	.72	.74	$Y = -4.6542+0.6601\ (X)$
	h. Total merchantable volume	.92	.92	.91	$Y = 1.0614+0.1104\ (X)$

Field testing both methods. — Meyer's equations and those we developed (a and h from table 1) gave almost identical accuracy when they were used to estimate average bark thickness and bark volume for each of the 42 new trees – r = 0.80 for bark thickness, and r = 0.93 for bark volume. These results indicate that both methods are acceptable.

BARK THICKNESS VARIATION

Bark thickness at a specific tree height is often needed when appraising timber. However, we were unable to develop accurate equations that predict bark thickness (or k, which can be used to calculate bark thickness) at a specific tree height. We found, on the average, that k decreases with increased height above stump (fig. 2), and that bark thickness decreases with height in the first 30 percent of merchantable stem length and then remains almost constant (fig. 3). If the trees are grouped

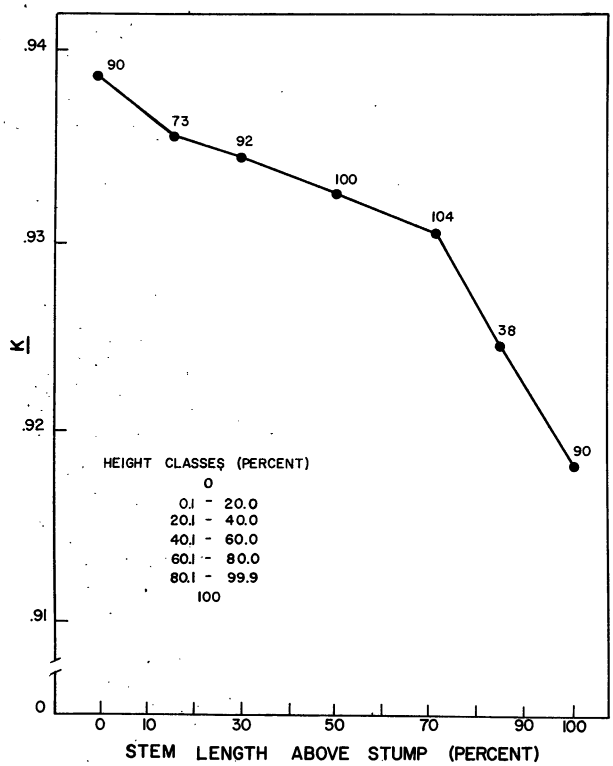

Figure 2.—Relation between K and height above stump. Figures at each point show number of observations.

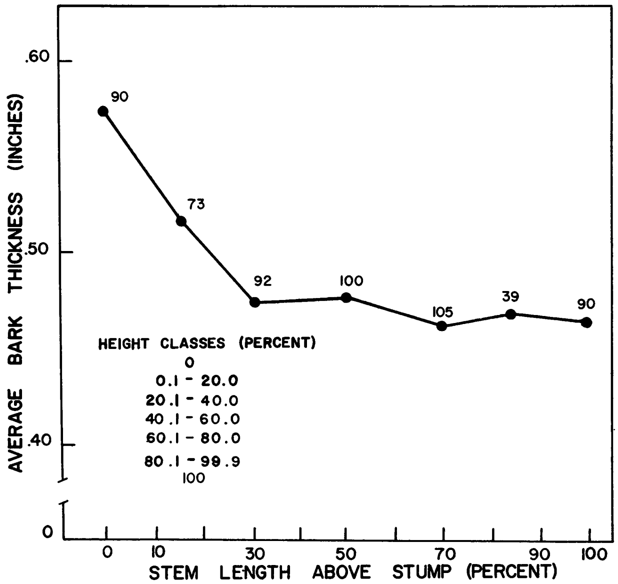

Figure 3.—Relation between bark thickness and height above stump. Figures at each point show number of observations.

by age class, bark thickness decreases with increased height above stump for the younger trees, but remains almost constant for the oldest trees (fig. 4). However, if regression analysis is used to relate bark thickness or k to height above stump, the variation about the regression line is tremendous (R^2 values range from 0.001 to 0.31). Therefore, general trends can be shown for change in bark thickness or k by height above stump, but the variation is too great to establish usable equations.

Our difficulty in predicting bark thickness at specific tree heights may have been due to differences in bark structure among trees. Sajdak (1968) defined four bark types for sugar maple — platy, shell, corrugated, and ropy. We found bark structure

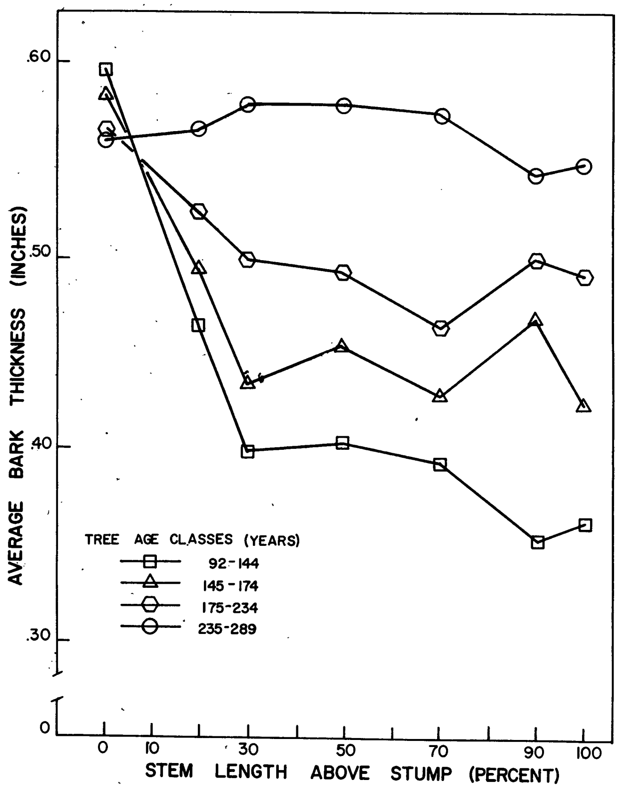

Figure 4.—Relation between bark thickness and height above stump by tree age classes. Percent stem length classes are the same as those given for Figures 1 and 2.

differences during our field test (fig. 5). Sugar maple trees may have to be grouped by bark types to improve bark thickness estimates at different tree heights.

BARK VOLUME AND WEIGHT

For the 90 trees sampled, the average amount of bark per tree was 7.38 cubic feet, or 13 percent of the merchantable stem volume including bark. This percentage is less than a reported value of 18 percent for old growth sugar maple (Gevorkiantz and Olsen 1951). We cannot explain the difference, however, because the method for calculating the 18 percent was not given.

The specific gravities (based on green volume and ovendry weight) of sugar maple wood and bark have been determined previously (Lamb and Marden 1968, 1969). Using these specific gravities and our calculated bark and wood volumes, we found that the weight of sugar maple

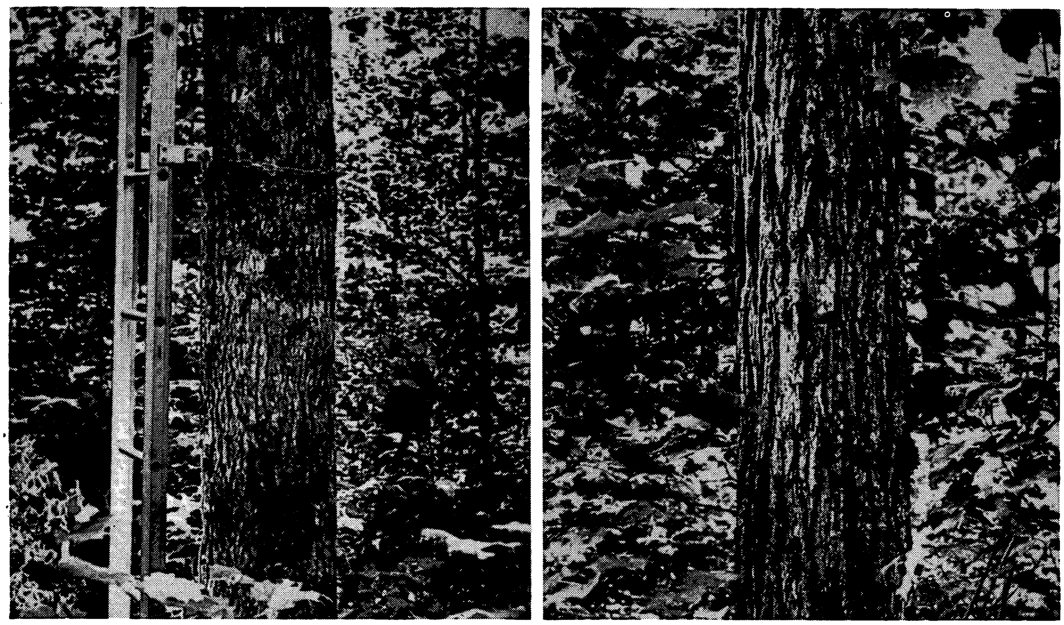

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Figure 5.—Sugar maple bark structure varies greatly. These two trees were only 5 yards apart and had about the same diameter.

bark is 12 percent of the merchantable stem weight. Hardy and Weiland (1964) gave an average bark weight percentage of 15.5 for northeastern sugar maple. Their value, however, is based on the weight of the wood rather than wood plus bark, and they used green weight for both bark and wood. We get a bark weight percentage of 14 when total merchantable weight excludes bark.

CONCLUSIONS

We found Meyer's equations (modified by use of different k and D values) to be accurate for estimating average bark thickness and bark volume for sugar maple trees. Our equations, based on direct relationships between bark thickness, bark volume, and tree stem characteristics, also gave accurate estimates. Both methods should be helpful in appraising timber and estimating the amounts of wood and bark in standing timber.

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