A Guide to SUGARBUSH STOCKING

Based on the Crown Diameter/D.b.h. Relationship of Open-Grown Sugar Maples

by H. Clay Smith and Carter B. Gibbs

U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-171
1970

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

The Authors

H. CLAY SMITH, silviculturist, received a bachelor's degree from West Virginia University in 1961 and a master's degree from Purdue University in 1962. He joined the Northeastern Forest Experiment Station in 1962 and did research on the silviculture of Appalachian hardwoods in West Virginia before joining the Station's sugar maple sap production project at Burlington, Vermont, in 1967.

CARTER B. GIBBS, silviculturist, earned a bachelor's degree in 1950 and a master's degree in 1956 from the University of New Hampshire. He received a Ph.D. degree in 1969 from the New York University College of Forestry at Syracuse. He joined the Forest Service in 1957 and has done research on the silviculture of southern pines and Appalachian hardwoods. In 1965 he joined the sugar maple sap production project at Burlington, Vermont, and now is project leader at the Northeastern Forest Experiment Station's spruce-fir project in Orono, Maine.

MANUSCRIPT RECEIVED FOR PUBLICATION 3 MARCH 1970.

HOW MANY TREES?

SUGARBUSH MANAGERS have long needed a guide for determining the stocking of their sugar maple stands. The question is: for desirable sugar maple sap production, how many trees per acre are needed?

To provide information about stocking, the USDA Forest Service's sugar maple sap production project at Burlington, Vermont, has made a regionwide study of the relationships between crown diameter and d.b.h. (diameter breast high) of open-grown sugar maple trees (*Acer saccharum* Marsh.).

We found a strong relationship between crown diameter and d.b.h., and converted these data into stocking guides for various stand-size classes. The stocking guide are based on the assumption that trees with full crowns produce the best sap yields.

BACKGROUND

More than 20 years ago Cope (*1946*) pointed out the lack of published information about the management of woodlands for the production of maple syrup. This is still true today. Research information about the management of sugar maple trees for the production of sap is still limited.

One of the first topics mentioned in any discussion of sugarbush management is the number of trees per acre to leave after thinning. The spacing suggested for a sugarbush varies from 25 to 50 trees per acre, though some estimates exceed 100 trees per acre, depending on tree size (*Morrow 1955; Rudolph 1968*).

It is generally believed that the ideal sugarbush tree is one that has a deep, wide, fully developed crown, exposed as much as possible to sunlight (*Jones et al. 1903*). In essence, this is a description of an open-growth tree. Therefore we needed to know how large sugar maple trees grow, and then to relate the size of the tree crown to changes in tree diameter at d.b.h. for open-grown trees. A high correlation has been reported between crown width

and tree diameter for several species growing in the Central States (*Gingrich 1964*), but little information about sugar maple is available.

THE STUDY

For sampling purposes, we divided the sugar maple region into the following subregions according to climatic and geographic differences that could affect tree growth and development:

Subregion	*Area*
New England	Maine, New Hampshire, Vermont, and northeastern New York.
Mid-Atlantic	Southern New York, northern Pennsylvania, and northeastern Ohio.
Southern	Southern Pennsylvania, western Maryland, and eastern West Virginia.
Central	Southern Michigan, Indiana, and Illinois.
North Central	Iowa, Minnesota, and Wisconsin.

We selected 301 trees at random in several areas of commercial sugar production (fig. 1). The trees were single-stemmed and

Figure 1.—Location of sampling areas in the sugar maple survey.

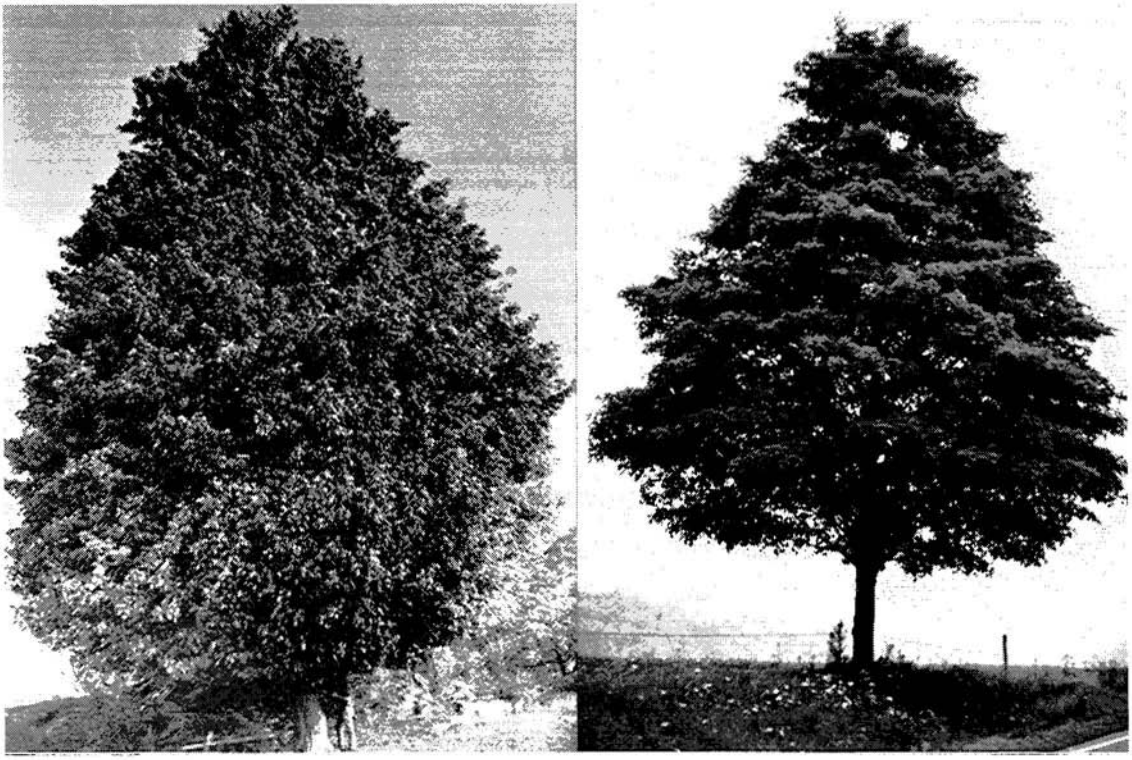

Figure 2. —Typical open-grown sugar maple trees.

open-grown, with no evidence of suppression or disease that might have impaired crown development (fig. 2).

Crown diameters were determined by using a perpendicular projection of the crown edge to the ground surface. The diameter of each tree crown was measured to the nearest 1.0 foot in north-south and east-west directions, and the two measurements were averaged.

Tree diameters were measured to the nearest 0.1 inch 4½ feet above the ground on the uphill side of the tree.

RESULTS

The results of the regression analysis indicated that there is a strong correlation between tree diameter and average crown diameter.

Analysis of the data from the five subregions showed no material differences among subregions in the crown diameter/stem diameter relationship of open-grown trees. Thus only one equation was derived for the whole sugar maple region.

The regression equation and coefficient of determination (R^2) are as follows:

Equation	R^2
$Y = 12.08 + 1.32X$	0.84

where: Y = average crown diameter, and X = diameter at breast height. This equation was used to determine a guide to stocking natural and planted sugarbushes.

TREES PER ACRE

To determine the number of sugarbush trees per acre, we first computed the estimated crown diameter for trees of each d.b.h. class, using the regression equation. Then the area of the crown for trees of each d.b.h. class was determined, and this was converted to the number of trees per acre.

Natural stands.—The best stocking for natural stands of sugar maples growing in a forest condition was summarized by average stand-diameter class (table 1). Based on these data, stands with an average d.b.h. of 10 inches should have a minimum of 79 evenly distributed trees per acre. Stands that average 20 inches d.b.h. should have a minimum of 34 trees per acre.

Plantations.— The number of trees per acre was also computed for sugar maple plantations (table 1). There should be a minimum of 68 trees per acre in a sugar maple plantation having trees with an average diameter of 10 inches at breast height. A minimum of 29 trees per acre is recommended for sugar maple plantations with trees averaging 20 inches d.b.h.

An ideal plantation would have fewer trees per acre than a sugarbush developed from a natural forest stand. More trees are recommended for a natural stand because the trees are established at random. The area of a hexagon (distance between opposite sides equal to crown diameter) was used to compute number of trees per acre in natural stands. The position of trees in a plantation is fixed by planting in a grid system, so the number of trees per acre in plantations was computed by using the area of a square (length of sides equal to crown diameter).

Table 1.—Average crown diameter and minimum number of sugar maple trees per acre, by average stand-diameter class, for natural sugarbush stands and plantations

Average stand d.b.h. class	Average crown diameter	Trees per acre	
		Natural Stands	Plantations
Inches	*Feet*	*Number*	*Number*
4	17.4	167	145
6	20.0	126	109
8	22.6	98	85
10	25.3	79	68
12	27.9	64	56
14	30.6	54	47
16	33.2	46	40
18	35.8	39	34
20	38.5	34	29
22	41.1	30	26
24	43.8	26	23
26	46.4	23	20
28	49.0	21	18
30	51.7	19	16

SPACING AND BASAL AREA

The tree-spacing guide (table 2) can be used to determine the ideal distance between trees. First, determine the average number of trees per acre for the sugarbush stand, using table 1. For example, a natural sugarbush containing trees that average 14 inches d.b.h. should have a minimum of 54 trees per acre. Then, referring to table 2, note that the distance between the trunks of selected trees in a natural sugarbush with 54 trees per acre should be about 31 feet. However, these spacing values are ideal distances and may be difficult to attain under field conditions.

With any spacing guide, the question arises about what to do when the trees in the stand are not all the same size. For example, what should the spacing be between a 20-inch tree and a 12-inch tree in a natural sugar maple stand? To find the spacing distance, first average the d.b.h.'s of the two trees and then determine the

Table 2.—Spacing guide for number of trees per acre in natural and planted stands of sugar maple

Trees per acre		Spacing between trees	Trees per acre		Spacing between trees
Natural stands	Planted stands		Natural stands	Planted stands	
Number	*Number*	*Feet*	*Number*	*Number*	*Feet*
257	222	14	41	36	35
224	194	15	39	34	36
196	170	16	37	32	37
174	151	17	35	30	38
155	134	18	33	29	39
139	121	19	31	27	40
126	109	20	30	26	41
114	99	21	28	25	42
104	90	22	27	24	43
95	82	23	26	22	44
87	76	24	25	22	45
80	70	25	24	21	46
74	64	26	23	20	47
69	60	27	22	19	48
64	56	28	21	18	49
60	52	29	20	17	50
56	48	30	19	17	51
52	45	31	19	16	52
49	43	32	18	16	53
46	40	33	17	15	54
44	38	34	17	14	55

crown diameter and spacing for the average d.b.h. The average d.b.h. in this case is 16 inches, and the crown diameter is 33.2 feet (table 1). A natural stand containing trees 16 inches d.b.h. with a crown diameter of 33.2 feet should have 46 trees per acre (table 1). Thus there should be 33 feet between the two trees, because 46 trees per acre is equivalent to a 33-foot spacing (table 2).

An estimate of the minimum residual basal area per acre, based on the number of trees per acre, was computed for both natural stands and plantations (table 3). For example, natural sugar maple stands that have 79 trees per acre and trees that average 10 inches in diameter should be thinned to a residual basal area of approximately 43 square feet per acre. A similar stand of 10-inch

Table 3.—Recommended residual basal areas per acre for natural and planted sugar maple stands

Average stand d.b.h. class	Residual basal area	
	Natural stands	Plantations
Inches	*Square feet*	*Square feet*
4	15	13
6	25	21
8	34	30
10	43	37
12	50	44
14	58	50
16	64	56
18	69	60
20	74	63
22	79	69
24	82	72
26	85	74
28	89	77
30	93	79

trees in a plantation with 68 trees per acre should be thinned to a basal area of about 37 square feet per acre.

CONCLUSION

This sugarbush stocking guide was developed from a survey of the crown diameter/d.b.h. relationship of open-grown trees. It can be applied to sugar maple trees in undeveloped forest-grown stands, in overcrowded producing sugarbushes, and in plantations. The guide gives the minimum number of trees per acre and minimum residual basal areas for the various d.b.h. classes.

This information can be used as a basis for the improvement of both natural and planted sugarbuses throughout the regions of commercial maple syrup production.

LITERATURE CITED

Cope, J. A.
1946. THE SILVICULTURE OF THE SUGARBUSH J. Forestry 44: 642-649.

Gingrich, S. F.
1964. CRITERIA FOR MEASURING STOCKING IN FOREST STANDS. Soc. Amer. Foresters Proc. (Denver, Colo.): 198-201, illus.

Jones, C. H., A. W. Edson, and J. W. Morse.
1903. THE MAPLE SAP FLOW. Vt. Agr. Exp. Sta. Bull. 103, 184 pp., illus.

Morrow, R. R.
1955. INFLUENCE OF TREE CROWNS ON MAPLE SAP PRODUCTION. N. Y. Agr. Exp. Sta. Bull. 916, 30 pp., illus.

Rudolph, V. J.
1968. SUGARBUSH MANAGEMENT. Nat. Maple Syrup Dig. 7: 18-19.

■

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.