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SILVICAL *Characteristics* OF . . .

SUGAR MAPLE

(*Acer saccharum*)

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U.S. DEPARTMENT OF AGRICULTURE

THE SILVICAL REPORTS

During 1907 and the following several years the U. S. Forest Service issued a series of silvical leaflets which covered the broad characteristics of a considerable number of major timber species. Since then much new knowledge has accumulated--some of it published in a variety of sources. There is also a considerable store of unpublished silvical information in the files of the forest experiment stations, the forest schools, and some other agencies. To compile this information systematically and make it available to foresters generally, the Lake States Forest Experiment Station is preparing reports on 15 individual species. Similar reports are being prepared by the other Federal forest experiment stations. When completed, these individual species reports will provide the basis for a comprehensive manual of silvics for the important trees of the United States, to be published by the U. S. Forest Service.

This report is one of the series being prepared by the Lake States Station. A preliminary draft was reviewed by several members of our own Station staff and by a number of well qualified staff members of other forest experiment stations, colleges, and universities; Federal, State, and Provincial forestry organizations; and forest industry. Their comments helped the author to make this report more complete, more accurate, and more up to date. Especially helpful reviews were submitted by Professors Grant Cottam and J. T. Curtis, Department of Botany, University of Wisconsin; Professor R. C. Hosie, Faculty of Forestry, University of Toronto; Professor Howard B. Kriebel, Ohio Agricultural Experiment Station; Professor I.C.M. Place, Department of Forestry and Wildlife Management; and staff members of the Lake States Station.

Every effort has been made to ensure the accuracy and completeness of the information concerning the silvical characteristics of each species consistent with a brief treatment of the subject. We shall appreciate it, however, if any errors or omissions of important information are brought to our attention.

M. B Dickerman

M. B. Dickerman, Director

Cover: Forest-grown sugar maple of desirable form, Upper Peninsula of Michigan. Drawing represents leaves and seed.

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SILVICAL CHARACTERISTICS OF SUGAR MAPLE

(*Acer saccharum* Marsh.)

By

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Sugar maple is one of the largest and most important of the hardwoods occurring in the eastern half of the United States and Canada. Sugar maple, as its name indicates, is the commercial source of maple sugar and syrup (36).[2/] In the lumber trade it is commonly called hard maple or rock maple (6, 74). In some localities the tree is occasionally called sugar tree or black maple, although the latter is recognized as a separate species, *Acer nigrum* (36).

DISTRIBUTION

The botanical range of sugar maple extends from Newfoundland, Nova Scotia, and Quebec, west to Ontario, southeastern Manitoba, and western Minnesota, south to central Iowa, eastern Kansas and Oklahoma, and northeastern Texas, east to Louisiana and northern Georgia, and north to central Virginia and New Jersey. It occurs locally also in southeastern North Dakota, northeastern South Dakota, and central Oklahoma (36) (fig. 1). It is not found in the South Atlantic or Gulf Coastal Plains, which is the natural range of the closely associated species Florida maple, *Acer barbatum* (36, 56).

The commercial range[3/] is confined to the northern portion of the botanical range, where the species occurs on the more fertile, well-drained but moist soils varying in elevation with the climatic conditions (6, 59). Most of the commercially important stands occur in the Lake States, Ohio, Pennsylvania, New York, New England and in the

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1/ Maintained by the Forest Service, U. S. Department of Agriculture, at St. Paul 1, Minn., in cooperation with the University of Minnesota.

2/ Underlined numbers in parentheses refer to literature cited, page 21.

3/ Commercial range is defined as that portion of the botanical range in which the species grows to commercial size and is a major or important component of the type.

SUGAR MAPLE (*Acer saccharum*)

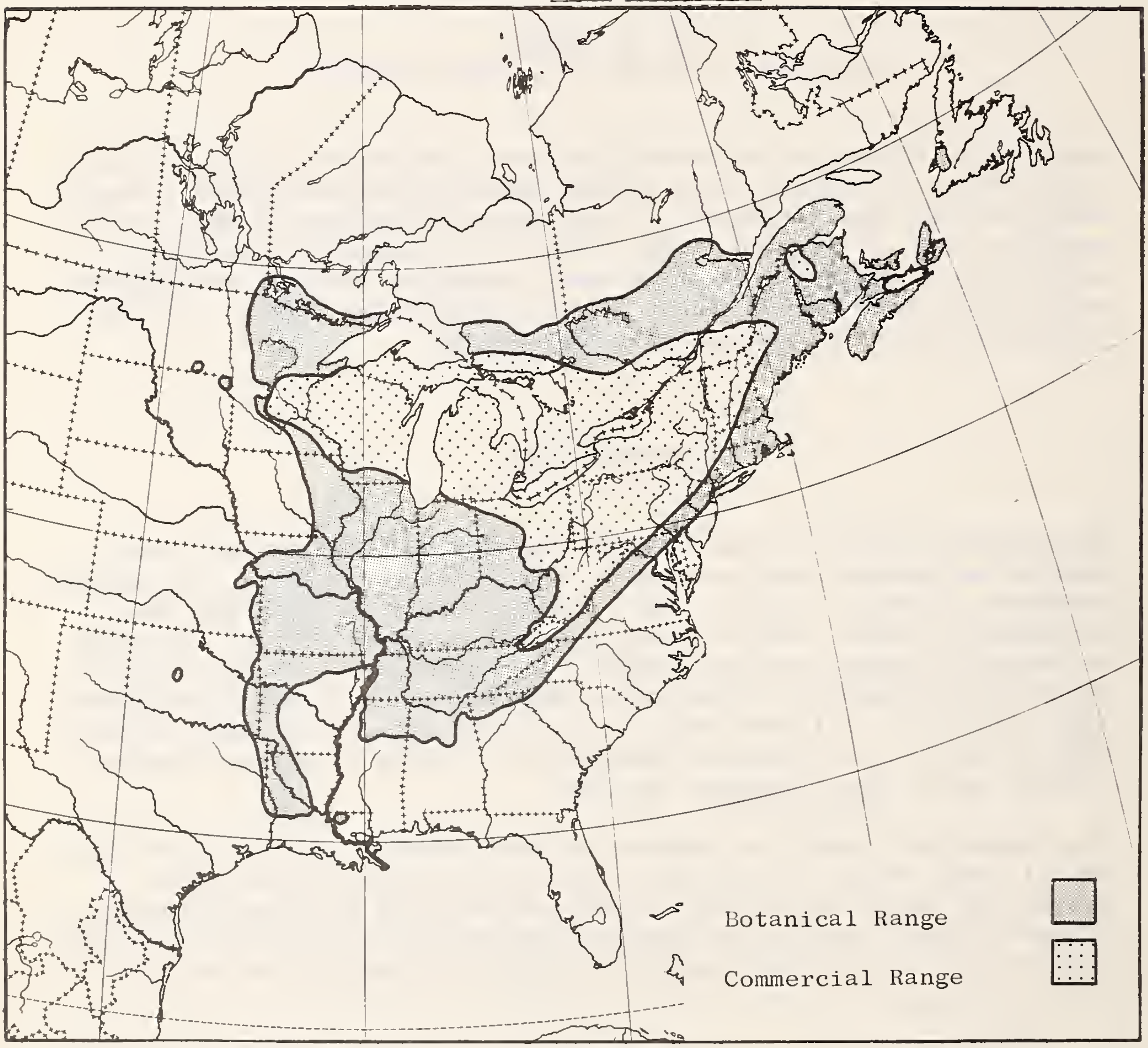

Figure 1.--Botanical and commercial range of sugar maple.

southern Appalachians and Canada (6, 59, 81) (fig. 1). Michigan has been the largest producer of sugar maple lumber of any single State for the past several years (6, 61).

HABITAT CONDITIONS

Sugar maple occurs over a very wide range of conditions covering most of the eastern half of the United States and adjacent Canada. Within its commercial range, however, altitudinal and soil requirements tend to restrict its occurrence so that general climatic conditions tend to be similar wherever the species is found (11).

Climatic Factors

Within the botanical range of sugar maple the average January temperatures range from 0° to 50° F. and the average July temperatures from 60° to 80°. Average annual maximum temperatures range from 90° to 100°, and the highest temperatures ever observed are about 15° higher. Average annual minimum temperatures vary from -40° to 20°, and the lowest temperatures ever observed are about 20° lower. Average annual precipitation ranges from 20 to 50 inches over most of the range but reaches 80 inches in some southern Appalachian localities. The average warm-season (April to September, inclusive) precipitation varies from 15 to 40 inches. The average annual snowfall ranges from 1 to 150 inches. The average date of the last killing frost in the spring ranges from March 20 to June 15, and the first killing frost in the fall from September 1 to November 10. On the average the frost-free period ranges from 80 to 260 days (7, 37, 70, 71). The northern limit of sugar maple closely parallels the 35° mean annual isotherm (70).

Some of these extremes occur in restricted localities within the general range limits of the species and may not necessarily coincide with the actual species location at the extremities of the range. Regional climatic means for the sugar maple and northern hardwood types, within the commercial range, as reported by Westveld (81), are as follows:

	Lake States	New York-Penna.	New England	Southern Appalachians
Mean annual temperature range-Degrees F.	35-46	43-54	40-50 1/	50-62
Average annual precipitation-Inches	30+	30-53	35-40	45-55
Mean July temperature-Degrees F.	59-70	65-75	65-75	69-77
Mean January temperature-Degrees F.	6-12	20-33	15-20	30-40
Frost-free period - Months	3-4	5	3½-4	4-6

1/ From "Climates of the States" (71).

Edaphic Factors

Sugar maple is found mostly on podzol, brown podzolic, and gray-brown podzolic soils although many of the soils are not highly podzolized (21). Loamy sands, sandy loams, loams, and occasionally silt loam soils support the better stands of sugar maple with the best development occurring on the loam soils (13, 21, 30, 31, 52, 79, 80).

Yield and quality of sugar maple stands increase as soil fertility and moisture conditions improve. The species thrives only on fertile, moist, and well-drained soils on nearly all soil types where these conditions exist. It does grow on poor, dry, shallow soils but is never thrifty there and is rarely, if ever, found in swamps (11, 21, 25, 29, 80).

Sugar maple can be found on soils ranging from strongly acid (pH 3.7) to slightly alkaline (pH 7.3) but most commonly occurs on soils having a reaction of pH 5.5 to 7.3 (21, 82).

The leaf litter of sugar maple has a nutrient element content, based on percentage of the dry weight, of about 1.81 percent calcium, 0.24 percent magnesium, 0.75 percent potassium, 0.11 percent phosphorus, 0.67 percent nitrogen, and 11.85 percent ash. The acidity of the leaves has been found to have a pH ranging from 4.0 to 4.9. The calcium content of the leaves is relatively uniform in trees growing on a surface soil having a pH range of 4.5 to 7.0, but drops rapidly as the soils become more acid. (40)

The narrow range of height differences on various soil types suggests that sugar maple has more exacting site requirements than many of its conifer associates. Westveld found that a range in site index from 70 to 90 feet at maturity covered most of the sites; and within these site indexes 92 percent of all the sample plots fell in the 80- and 90-foot classes (80). Roe (52), grouping soil types into soil moisture and soil texture groups, also found a narrow range in site index classes.

Physiographic Factors

In northern New England and New York State, sugar maple occurs at elevations up to 2,500 feet. In the Lake States it is found up to 1,600 feet and infrequently at slightly higher elevations. In the southern Appalachians it occurs in a zone from 3,000 to 5,500 feet extending to higher elevations on the southern slopes than on the northern slopes. At the lower elevations it grows most commonly on the cooler north slopes. In these regions sugar maple prefers the loamy soils of excellent fertility and good drainage. In the Central Forest Region it is common on flats in old pastures. In the southern region, it commonly occurs in the moist flats and ravines and along streams at elevations of 2,000 to 4,000 feet. In the more northerly portions of its range, sugar maple needs a favorable climate as well as good forest soils. Here it normally is found on the warmer ridges and upper slopes. (1, 11, 81)

Biotic Factors

Sugar maple is an integral member of 6 forest cover types and is associated with 17 other types in eastern North America (59, 81). The major cover types are shown below (59):

S.A.F. type no.	Cover type	Forest region
25	Sugar maple - beech - yellow birch	Northern Forest
26	Sugar maple - basswood	Northern Forest
27	Sugar maple	Northern Forest and northern part of Central Forest
28	Black cherry - sugar maple	Northern Forest
31	Red spruce - sugar maple - beech	Northern Forest
60	Beech - sugar maple	Northern Forest and northern part of Central Forest

These types are generally classed as climax with sugar maple tending to become climax over the other species. Commonly associated species, varying with the geographic region and soil type, include red maple (*Acer rubrum*), hemlock (*Tsuga canadensis*), northern red oak (*Quercus rubra*), white oak (*Q. alba*), white ash (*Fraxinus americana*), green ash (*F. pennsylvanica*), eastern white pine (*Pinus strobus*), balsam fir (*Abies balsamea*), American beech (*Fagus grandifolia*), paper birch (*Betula papyrifera*), sweet birch (*B. lenta*), yellow birch (*B. alleghaniensis*), American basswood (*Tilia americana*), black cherry (*Prunus serotina*), American elm (*Ulmus americana*), eastern hophornbeam (*Ostrya virginiana*), red spruce (*Picea rubens*), white spruce (*P. glauca*), mockernut hickory (*Carya tomentosa*), yellow-poplar (*Liriodendron tulipifera*), cucumbertree (*Magnolia acuminata*), and black walnut (*Juglans nigra*). (59, 82)

The ground flora associates of sugar maple vary considerably because of its large botanical range and the differences in the soil types on which it occurs. Some of the more common shrubs associated with the species within its commercial range include beaked hazel (*Corylus cornuta*), Atlantic leatherwood (*Dirca palustris*), scarlet elder (*Sambucus pubens*), American elder (*S. canadensis*), pagoda dogwood (*Cornus alternifolia*), dwarf bushhoneysuckle (*Diervilla lonicera*), Canada yew (*Taxus canadensis*), red raspberry (*Rubus idaeus*), and blackberries (*R. occidentalis* and *R. canadensis*). (82)

Typical herb associates in the nonwoody ground cover include wild leek (*Allium tricoccum*), yellow beadlily (*Clintonia borealis*), Virginia spring beauty (*Claytonia virginica*), violets (*Viola* spp.), bunchberry dogwood (*Cornus canadensis*), American wood anemone (*Anemone quinquefolia*), common miterwort (*Mitella diphylla*), hairy solomonseal (*Polygonatum pubescens*), bloodroot (*Sanguinaria canadensis*), big merrybells (*Uvularia grandiflora*), wakerobin (*Trillium* spp.), Alaska goldthread (*Coptis trifolia*), rosy twistedstalk (*Streptopus roseus*), Canada beadruby (*Maianthemum canadense*), and Indianpipe (*Monotropa uniflora*). Some of the more common ferns include ladyfern (*Athyrium* spp.), American maidenhair fern (*Adiantum pedatum*), and toothed woodfern (*Dryopteris spinulosa*). Clubmoss (*Lycopodium* spp.) is usually present in all stands. (82)

A large variety of animals and birds is commonly found in stands containing sugar maple, but most of them are not specifically associated with sugar maple. Those that affect its development, primarily through injury to the tree, are discussed in the appropriate sections.

LIFE HISTORY

Seeding Habits

Flowering and Fruiting

The first indication of a break in dormancy in sugar maple is the swelling of the leaf and flower buds, with emergence occurring at about the same time. The flowers are usually in full bloom within a week after emerging and the tree is in full leaf 3 to 4 weeks after the leaf buds begin to swell.[4/] In northern Michigan a 7-year record shows that the buds begin swelling about May 5, ranging from April 26 to May 12. In a 1-year study in Indiana, bud swelling began on April 14 (22).

Sugar maple normally produces both perfect and unisexual flowers although it is not constant in producing female flowers. The ratio of male to female flowers apparently is not less than 10 to 1 and is probably closer to 50 to 1. There is a noticeable localization of the female flowers on certain portions of the tree. In the vicinity of Philadelphia most of the trees produce only male flowers, or male flowers with a few female ones. Most are bee-pollinated. (83)

The fruit, a double samara, usually with but one of the pair viable (5, 72), ripens in about 12 weeks. The samaras begin falling about 2 weeks after they ripen or about the time height growth ceases.[4/] Some seed of sugar maple is eaten by squirrels (*Sciurus* spp.) as well as by birds, but this type of loss is considered negligible.

Seed Production and Dissemination

Observations indicate that light seed crops are produced by trees 8 inches in diameter, which vary in age from 40 to 60 years, and moderate seed crops by 10- to 14-inch trees ranging in age from 70 to 100 years. Mature dominant trees in a stand produce a great quantity of viable seed. In northern Michigan a series of traps gave 8,560,000 sugar maple seeds per acre under a virgin stand and 4,302,000 per acre in a selectively cut stand in an excellent seed year (77). In southern Wisconsin during an 8-year period, annual seedfall in one stand varied

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4/ Unpublished data, Lake States Forest Experiment Station.

from 127,500 to 5,270,000 per acre.[5] Some seed is produced every year, with good seed crops occurring at intervals of 2 to 5 years depending on climatic conditions (21, 23). The large papery wings of the samaras enable the seeds to be carried long distances by the wind. The seed of sugar maple is relatively large, averaging 6,100 per pound when commercially cleaned. (72)

Vegetative Reproduction

Sugar maple reproduces vegetatively by means of stump sprouts and to some extent by root suckers. Prolific, vigorous sprouts from dormant buds occur near the ground line with the smaller stumps producing a larger number of sprouts and more vigorous ones than the larger stumps (10, 21, 33).

Cuttings of sugar maple can be rooted but are somewhat difficult to keep alive after they strike roots. The rooting response varies with the time of year when the cuttings are obtained, specificity and concentration of growth substances, and the length of time of treatment (58). Use of cuttings to propagate trees with figured wood, such as curly grain and bird's-eye, have been unsuccessful (3).

A preliminary test has shown that budding of sugar maple on red maple has some promise as a direct method of improving stands of low unit value and extending the species to sites it normally would not occupy

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5/ Personal communication from Professors J. T. Curtis and Grant Cottam, Department of Botany, University of Wisconsin, Madison, 1956.

Figure 2.--Dense sugar maple reproduction 2 years after light partial cutting.

(46). Horticultural varieties (cultivars) are being successfully grafted and budded by commercial nurserymen.[6/]

Seedling Development

Establishment and Early Growth

Sugar maple reproduction is seldom difficult to obtain following partial cutting or clear cutting because of the large amount of seed and the prolific sprouting habit (fig. 2 on preceding page). In virgin and second-growth stands, thousands of seedlings and advance reproduction are usually present (8, 21, 75). However, unless released, mortality is high and is greater in new seedlings than in seedling sprouts or established seedlings (30). A study in southern Wisconsin showed that only 50 percent of the new seedlings survived the first year.[7/]

Clear cutting or heavy partial cutting tends to result in even-aged stands of sprout or seedling-sprout and seedling origin (fig. 3). The

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6/ Personal communication from E. J. Schreiner, Northeastern Forest Experiment Station, 1956.

7/ Personal communication from Professors J. T. Curtis and Grant Cottam, Department of Botany, University of Wisconsin, Madison, 1956.

Figure 3.--Reproduction of seedling and sprout origin 22 years after heavy partial cutting.

percentage of sprout and seedling sprouts increases with the intensity of the cut (8, 86).

Planting or other special regenerative measures for sugar maple are rarely needed on sites where the tree occurs naturally. It is seldom planted, except as a shade tree or for ornamental purposes. (75, 87) The seed will stay viable at least 1 year if stored in open or sealed containers at a temperature of 36° to 40° F. In the nursery, a germination of about 15 percent is all that normally can be expected, and the seedlings will require some shade while becoming established. Temperatures of 50° to 86° are favorable for germination. One study in central Wisconsin on the use of nursery fertilizers resulted in a germination of 70 to 80 percent, with seedlings 3 to 4 inches high and stems 1/16 inch in diameter by June 10. Four years later, frost caused the loss of about 20 percent of the seedlings.[8/]

Field plantings usually have a low survival, particularly on exposed areas (82). Planted sugar maple does not compete well with sod, and demands a good soil and an overstory nurse crop (65, 67). At this early age the species is susceptible to frost, deer, and hare damage to such an extent that its prospects for planting purposes are poor (18, 79).[8/] Ninth-year survival and height growth in a Wisconsin study were only 16 percent and 1.7 feet respectively.[8/] In Wisconsin, the most favorable planting sites are those with a minimum depth to the water table of 3.5 feet, a silt and clay particle content of at least 35 percent, not less than 3.0 percent of organic matter in the top 7 inches of the soil, and a soil reaction of between pH 5.5 and 7.3 (82).

Factors Limiting Seedling Development

In many areas sugar maple grows in farm woodlots and pastures grazed by domestic livestock. Although not a preferred browse, the number of stems of all size classes are generally fewer on grazed than on ungrazed farm woodlands (62). Exclusion of stock from farmwoods devoted to the production of maple sirup to eliminate browsing and soil trampling is one of the most important silvicultural practices in production of a sugar bush (14).

8/ Stoeckeler, J. H., and Heinselman, M. L. 1950. Experimental plantings and exploratory plots on the Nicolet, Chequamegon, and Hiawatha (Upper Michigan) National Forests. Unpublished progress report, Lake States Forest Expt. Sta.

Sugar maple is frequently browsed by white-tailed deer (Odocoileus virginianus), the extent of injury varying with the deer population. It can withstand heavy browsing for many years without mortality. It does, however, with repeated heavy browsing, become stunted and malformed (68). Swift (69) observed that where the deer population is high, as in northeast Wisconsin, deer browsing has been so severe in places that if maple did not reproduce in such abundance it would be questionable if it could survive. On the other hand, an instance has been observed where browsing of other species, particularly yellow birch, northern white-cedar, and hemlock, has produced changes in the composition of forest favoring sugar maple (23). Although the species does not rank high on the palatability list for deer, high populations will usually result in some injury to reproduction.

Moose (Alces alces) browse sugar maple in limited areas. It does not rank high on the palatability list as a winter browse, although it is a preferred summer food. In a study on Isle Royale, sugar maple was found to form 8 percent of the available food and made up 3.8 percent of the moose diet (34).

The snowshoe hare (Lepus americanus) and the cottontail rabbit (Silvilagus floridanus) sometimes nip off the tops of seedlings and injure or girdle the stems. This type of injury to sugar maple is generally common when the hare or rabbit populations reach high peaks. Generally, hare damage is considered relatively unimportant (21, 68).

Sometimes much reproduction is injured during logging.

Sapling Stage to Maturity

Growth Rates

Height and radial growth begin at about the same time as the buds leaf out. Height growth is completed in about 15 weeks and radial growth in 14 to 17 weeks, varying with the season and locality (22, 44).[9/] In some areas height growth is about 85 percent complete within 6 weeks and cambial growth is about 80 percent complete in 8 weeks (44).

The root system of sugar maple is deep and branching on the better soils (11). Feeder rootlets occur within 1 and 2 inches of the soil surface and extend deeper than 20 inches in most soils. Root growth is generally independent of the growth of the aerial portions of the

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9/ Unpublished data, Lake States Forest Experiment Station.

tree, and occurs throughout the year in northern regions where snow cover prevents the ground from freezing and moisture is adequate. However, the period of maximum development occurs at about the same time as in the stem cambium, shoots, and leaves, with over half of the yearly root growth occurring during the period of shoot growth and maximum leaf development (44).

The leaves begin to turn color near the end of the radial growth period, with maximum coloration occurring about 3 weeks later. During this period the tree forms a conspicuous part of the landscape with leaves of yellow, orange, or red. Leaf fall begins about 1 week after radial growth stops and is completed in about 3 to 4 weeks.[9]

Growth and form are greatly influenced by the origin of the trees. Those of sprout origin grow more rapidly at the start than those from seed. On heavy soils in central New England, trees from seed averaged 4 to 5 feet at the end of 5 years (12, 13). Trees from seed or seedling sprouts are usually sound, straight, and well-formed, and make good crop trees expressing dominance at an early age (13, 66). Sprouts from the smaller stumps, especially from stumps under 2 inches in diameter are less likely to develop decay than those from larger stumps or than multiple stem sprouts (8, 12, 13, 33). Heartwood, which is more susceptible to decay than sapwood, does not develop to any great extent until about the 40th year (10). Growth is relatively rapid up to this time and makes possible the rapid healing over of exposed wood (13).

In second-growth stands diameter growth varies with the degree of cutting or release. In a study in northern Michigan, diameter growth of trees 9.6 inches and larger on 5 units averaged from 0.63 to 0.85 inch over a 5-year period in partially cut sugar maple in contrast to an average of 0.48 inch on an uncut area (39). For the first 30 to 40 years, sugar maple grows in height at the rate of about 1 foot a year. A tree 6 to 8 inches in diameter and averaging 35 to 40 feet in height usually is about 30 years old (11).

The trees in mature stands normally grow at a slower rate than trees in the younger stands. In northeastern Wisconsin, one study found that the sugar maple in virgin stands grew 1 inch in diameter in 10 years (89). Following commercial clear cutting, however, sugar maple trees 5 to 12 inches in diameter made an average diameter growth of 5.1 inches in 24 years in contrast to 1.9 inches in the same period before logging. As a general rule, the rate of diameter growth is influenced by the density and quality of the residual stand, the amount of growth increasing with the intensity of the cut (89).

9/ Unpublished data, Lake States Forest Experiment Station.

Mature trees and stands of sugar maple reach ages of 300 to 400 years, heights of 70 to 110 feet, and diameters of 20 to 36 inches at breast height varying with the site quality (21, 25, 59, 80). The largest reported sugar maple tree, located near Bethany, W. Va., has a diameter of 5.57 feet at a point 4½ feet above the ground, and is 110 feet tall with a crown spread of 75 feet (1).

Height growth usually ceases or becomes negligible at about 140 to 150 years of age (80). Any height growth on trees over 18 to 20 inches in diameter does not add to the merchantable height as the crowns of trees that size and over have usually developed large branches which fix the merchantable limit (20). Diameter growth, however, does continue but usually at a slower rate than during the earlier stages.

Reaction to Competition

Sugar maple is very tolerant of shade (2, 24) and is able to withstand several years of complete suppression and still show a strong response to release (19, 41, 66).

In sapling stands one study showed that unreleased, good-vigor, dominant trees averaged 0.90 inch in diameter growth during a 7-year period, and heavily released trees 1.81 inches; unreleased, good-vigor, codominant trees averaged 0.66 inch and heavily released trees 1.48 inches. Pole-size stands also respond well to release. (19)

In young sugar maple stands subjected to suppression from scattered "wolf" trees or pin cherry the need for release is seldom justifiable, as sugar maple tends to overcome suppression (38, 45). If the trees are released too much, sugar maple, in addition to a response in diameter growth, develops epicormic sprouts from dormant buds within a few years. Generally these sprouts, in young fast-growing stands, attain a diameter of less than 0.1 inch and a length of 2 to 8 inches and then within about 8 years die and drop off as the stand closes in (66). Frequently, the opening up of stands will stimulate the growth of branches stunted by suppression rather than the development of new epicormic shoots (21). However, suppressed trees often develop abundant epicormic sprouts [redacted] release.[9]
before

Older trees give repeated responses to release at short intervals (87). In a light selection cutting in northern Michigan, diameter growth was accelerated 15 percent. Trees of small diameter responded about the same as the large ones. The actual rate of diameter growth, however, both before and after cutting gradually increased in trees from 10 to 18 inches diameter breast high, a point 4½ feet above the ground level, but in trees above this size the rate was about constant. The ratio

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9/ Unpublished data, Lake States Forest Experiment Station.

of diameter growth at any given level in the stem to the growth at d.b.h. was equal to the ratio of the diameter at that point to d.b.h. so that the form of the tree did not change (84).

Limiting Factors

Nonliving agents.--Sugar maple is relatively windfirm (21, 89) and can usually withstand winds up to tornado force without being windthrown, especially if growing on the deeper soils. In northern Michigan uprooting was the least important of recognized causes of loss in mature stands except in the heavy cuttings (21).

Glaze storms of severe intensity and duration injure sugar maples. Much damage occurred in New York State in 1942, varying from the loss of a few branches on a tree to complete stripping of the branches and breaking of the main stem either in or below the crown. The injured trees showed a slight tendency to sprout and renew growth. They had a pronounced tendency, especially the smaller trees, to develop saprot where 85 percent or more of the crown was broken away (60). Ice damage in stands under 40 years of age was found to be less than in older stands because heartwood had not yet formed in the trees and they were relatively resistant to such injury (9).

Mature sugar maple trees are relatively frost-hardy and are not commonly injured by late spring frosts. High temperatures are infrequent in sugar maple stands and seldom have a direct effect on the tree, as this species usually grows in a dense stand and is nearly always found on moist soils (fig. 4).

These moist soils, usually prevented from excessive drying by the heavy shade, also make sugar maple stands reasonably safe from fire. However, slash fires spreading from adjacent areas sometimes do heavy damage to residual trees and cause serious butt-rot (21, 87).

Increment borer holes made in sugar maple cause cambial dieback and provide entrance points for Nectria canker. One study, including trees from several areas, showed that decay occurred in 8 to 57 percent of the wounds, although all holes were closed at the end of 10 years. In the Southeast, Nectria canker had formed at all holes and delayed the closure. The discoloration of the wood around the holes extended from 1 to 2 linear feet from the wound and often for greater distances within the 10-year period. Plugging the holes or slanting them when they were made had no effect on the amount of discoloration or decay (27).

The wood surrounding the holes made in tapping for maple sap dries up at the end of the season. Usually an area slightly larger than the size of the hole is stained and may show some decay. These holes do

Figure 4.--Mature sugar maple stand 2 years after moderate selection cutting.

not produce sap again until a new layer of sapwood, 1 inch or more in thickness, has grown over the dead wood (50, 51).

Wildlife.--Serious injury is sometimes inflicted on occasional sugar maples by the porcupine (*Erethizon dorsatum*), which feeds on the bark and cambium of trees. The tree may be girdled to such an extent that its quality is lowered, or it may be killed (63).

Red squirrels (*Tamiasciurus hudsonicus*) and gray squirrels (*Sciurus carolinensis*) occasionally gnaw off the tips of branches or eat the bark and flowers. In western Michigan squirrels have girdled and killed back stems and branches on trees as large as 6 to 8 inches d.b.h.[10/] In central Minnesota during the winter gray squirrels girdle trees above 6 inches d.b.h., especially in the upper third of the crown

10/ Personal communication from J. L. Arend, Lower Peninsula Research Center, E. Lansing, Mich., 1956.

(32). They usually feed on sugar maple during the late winter or early spring when the sap is flowing (21, 78, 63).

Diseases.--Most of the diseases causing decadence or death of sugar maple may be grouped into three classes: (1) Those that cause wood rots, (2) those causing bark lesions or cankers, and (3) those that cause wilts. The decay fungi causing heartrot are the most damaging, usually entering through some type of wound or branch stub. Heartwood seldom develops in a sugar maple tree until it is 35 to 40 years of age so that the species is fairly resistant to this kind of decay up to that age (21, 33). Decay of heartwood and presence of cankers increases the susceptibility of the tree to breakage from high winds (21). Wilts cause mortality and dieback in sugar maple used as shade and ornamental trees, but generally are not important in forest stands.

Some common fungi causing heartrots in sugar maple are: *Armillaria mellea*, primarily a root-rotting fungus; *Fomes connatus*; *F. igniarius*, *Hydnum erinaceus*, and *H. septentrionale* causing soft, spongy, white heartrot; *Polyporus glomeratus*, causing white to light-brown spongy heartrot; and *Ustulina vulgaris* causing butt rot (21).

The canker, *Eutypella parasitica* (fig. 5), is the most common in sugar maple, sometimes killing the tree outright. *Nectria galligena* causing target-like cankers occasionally is found in this species, while *Schizoxylon microsporum* and *Hypoxylon blakei* rarely are found. *Phytophthora cactorum*, causing bleeding canker, is found primarily on shade and ornamental trees.[11] (21)

[11] Personal communication from R. L. Anderson, Lake States Forest Experiment Station, 1956.

Figure 5.--Canker on sugar maple probably caused by *Eutypella* spp.

The principal maple wilts are Verticillium albo-atrum and Ceratocystis virescens, causing sap stain. The latter is most common in the southeastern United States and has caused considerable mortality in trees larger than 8 inches. (26)

Insects.--Sugar maple is not highly susceptible to insect injury and serious outbreaks seldom occur. Defoliators are usually the most common insects attacking sugar maple, and these include the linden looper (Erannis tiliaria), which sometimes defoliates rather extensive areas; forest tent caterpillar (Malacosoma disstria), which has caused considerable damage in sugar orchards in the East both by top killing and by reducing the quality and quantity of sap; fall cankerworm (Alsophila pometaria) and spring cankerworm (Paleacrita vernata), which has partially defoliated stands in Upper Michigan; green-striped mapleworm (Anisota rubicunda); Bruce's spanworm (Operophtera bruceata); maple leaf cutter (Paraclemensia acerifoliella); the maple trumpet skeletonizer (Epinotia aceriella); and the saddled prominent (Heterocampa guttivitta).

Borers include the carpenterworm (Prionoxystus robiniae); the sugar maple borer (Glycobius speciosus), considered to be the most serious insect enemy of sugar maple (4); the maple callus borer (Conopia acerni); and occasionally horntails (Xiphydria abdominalis and X. maculata). (15)

Sucking insects include the woolly alder aphid (Prociphilus tessellatus) and the aphids (Neoprociphilus aceris and Periphyllus lyropictus), which cause injury to the leaves resulting in lessened growth. (15)

Of the scale insects, the maple phenacoccus (Phenacoccus acericola) is the most important. The maple leaf scale (Pulvinaria acericola) and the gloomy scale (Chrysomphalus tenebricosus) frequently attack sugar maple. (15)

Logging Damage.--Logging injuries to the stems of residual trees and reproduction frequently result in the entrance of decay and later serious loss of volume. In a study in Upper Michigan it was found that at least 30 percent of the logging scars on the main trunks of residual trees resulted in serious defects within 15 to 20 years (85). Larger limbs broken in logging also usually result in serious defects. Hesterberg's (28) study in Upper Michigan showed that after a 20-year period about 8-percent cull resulted from decay and stain that had entered through scars on limbs 4 inches and larger. Smaller limb breakage exposing only sapwood, however, generally results in a negligible loss of volume (10).

Defect.--The amount of defect in sugar maple trees in virgin and unmanaged stands is usually very high, commonly averaging 35 to 50 percent cull (21, 87). There is little correlation between diameter and cull percent in these stands because of the great variation in age. All diameter classes tend to show about the same proportion of defect or possibly a percentage increase of defect in the smaller diameters (45, 88).

Types of defects have been grouped to provide a practical tool for estimating the proportion of defect in a standing tree (88). Some defects are more prevalent in certain regions than in others. In the northwestern part of the botanical range of sugar maple, frost crack is more common and severe than in the other portions of the range.

Frequently the heartwood and sapwood of sugar maples are disfigured by deep-olive or greenish-black discolorations generally known as mineral stain or mineral streak. This defect degrades the lumber, as these areas have a tendency to crack open during seasoning. Nothing definite is known regarding its cause although some believe mineral streak may be initiated by generally obscure injuries, which in some way interfere with normal physiological processes of the surrounding cells. (57)

The defect or peculiar grain of sugar maple known as "bird's-eye" enhances the value of the wood. Numerous but unsuccessful attempts have been made to determine the cause of this phenomenon, which can be detected in the rough outer bark in standing trees as well as in the outer wood (3, 48). The only characteristic common to all trees with this grain has been the very slow growth in early life regardless of how vigorous the later growth may have been (3, 47, 48, 76).

SPECIAL FEATURES

The wood of sugar maple is used principally for lumber, veneer, railroad ties, bowling pins, distillation wood, and pulpwood. A large proportion of the lumber is manufactured into flooring, furniture, boxes and crates, shoe lasts, handles, woodenware and novelties, spools and bobbins, and motor vehicle parts (11, 35, 74). It is the outstanding wood for flooring under heavy use, as it resists abrasion especially well (11). The wood is heavy, strong, stiff, hard, and resistant to shock, and has large shrinkage. It is generally straight grained and has a fine uniform texture; the sapwood is white or has a slight reddish-brown tinge and the heartwood is usually a light reddish-brown but may be darker (74). The wood is without a characteristic odor or taste. It takes stain satisfactorily and is capable of a high polish; it ranks high in nail-holding ability and intermediate in ease of gluing.

Sugar maple is a principal wood in hardwood distillation for the production of charcoal, acetic acid, acetone, and methyl (wood) alcohol. Veneer cut from this species is used to a considerable extent for fruit and vegetable packages and in the manufacture of plywood (11). The curly grain and bird's-eye figure in the wood of some trees make them especially valuable in the plywood and lumber industry, where they bring premium prices (3, 48). The paper pulp made from sugar maple goes largely into book and similar grades of paper (11).

The sugar maple tree is the principal source of maple sugar. The trees are tapped early in the spring for the first flow of sap, which usually has the highest sugar content. The sap is collected in buckets and boiled or evaporated to a sirup. Further concentration by evaporation produces the maple sugar. It usually requires at least 32 gallons of sap to make a gallon of sirup or 8 pounds of sugar (11).

This species is widely planted as a shade tree in the eastern part of the United States as it is fairly hardy and long-lived, although susceptible to injury by gas and smoke (25).

Sugar maple is very resistant to chemical herbicides and is killed only after repeated applications. As a foliage spray, 2,4-D and 2,4,5-T, give a satisfactory kill when properly used at the recommended rate and season of year (53). Ammonium sulfamate as a foliage spray gives similar results. Ninety percent of sprouts less than a year old can be killed with a single application while 8-year-old sprouts require at least 2 applications (64). Stem application of sodium arsenite has been found to kill large cull sugar maple with relatively small dosages. One study, using 2 cubic centimeters per hole, spaced 8 inches apart, resulted in 80-percent crown damage on all trees within 3 years. Similar effects can be obtained with ammonium sulfamate solutions by using 16 cubic centimeters per hole. (55)

RACES, HYBRIDS, AND OTHER GENETIC FEATURES

Botanists recognize some 3 to 5 varieties or forms (forma) of sugar maple, differing in morphological characteristics. At least one of these (var. *Schneckii* Rehd.) is confined to a definite geographic range (from southern Indiana and Illinois into the southern Appalachians and westward into Missouri). However, it does not come true from seed.[12/]

Furthermore, three presently recognized species, Florida maple (*Acer barbatum*), chalk maple (*A. leucoderme*), and black maple (*A. nigrum*) are closely related to *A. saccharum* and possibly should be regarded as varieties. Some authorities suggest that these species may be gradations because of geographic range (17).

12/ Personal communication from J. W. Wright, Northeastern Forest Experiment Station, 1956.

Provenance tests of sugar maple in Ohio show distinct variation patterns; differences exist in drought endurance and resistance to leaf injury from high insolation. There were also clinal differences in phenological behavior.[13] It is suggested that there may be at least three races or ecotypes.

Hybrids have been reported between sugar maple and the following species: *Acer nigrum* and *A. rubrum* (49, 16). Hybrid seedlings have been obtained by pollinating sugar maple with pollen from a maple (presumably *Acer macrophyllum*) growing in the Columbia River Valley (43).

Possibilities that tree-breeding will improve yield and quality of sap appear promising because of consistent differences in the sap of individual trees under uniform environmental conditions (42).[14] However, an early attempt to cross-pollinate bird's-eye maples has been unsuccessful (54).

13/ Kriebel, H. B. 1956. Patterns of genetic variation in sugar maple. Unpublished Ph.D. thesis, Yale Univ.

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SILVICAL REPORTS PUBLISHED OR IN PREPARATION

This is the fifth of the silvical reports being prepared by the Lake States Forest Experiment Station. Already published are:

Station Paper 44 - Red pine

Station Paper 45 - Black spruce

Station Paper 47 - Rock elm

Station Paper 49 - Quaking aspen

Ensuing reports will cover the following species:

Bigtooth aspen	Jack pine
Basswood	Balsam poplar
American elm	White spruce
Slippery elm	Tamarack
Black maple	Northern white-cedar

SOME RECENT STATION PAPERS

Publications of the Lake States Forest Experiment Station.
L. P. Olsen and H. A. Woodworth.
Station Paper 39, 130 pp. 1956.

Guide for Selecting Superior Forest Trees and Stands in the Lake States.
Paul O. Rudolf.
Station Paper 40, 32 pp., illus. 1956.

Chemical Control of Brush and Trees in the Lake States.
Paul O. Rudolf and Richard F. Watt.
Station Paper 41, 58 pp., illus. 1956.

The Forest Insect and Disease Situation, Lake States, 1956.
L. C. Beckwith and R. L. Anderson.
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Wood Pallets in the Minneapolis-St. Paul Area: An Outlet for Low-Grade Hardwoods.
John R. Warner and D. R. Cowan.
Station Paper 43, 34 pp., illus. 1956.

Silvical Characteristics of Red Pine.
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The Market for Domestic Charcoal in Wisconsin.
John R. Warner and William B. Lord.
Station Paper 46, 15 pp., illus. 1957.

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Natural Regeneration on a 2-Acre Mixed-Oak Clear Cutting Five Years After Logging.
Harold F. Scholz and A. J. DeVriend.
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Silvical Characteristics of Quaking Aspen.
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