Acer saccharum Marsh. Sugar Maple

Aceraceae Maple family

Richard M. Godman, Harry W. Yawney, and Carl H. Tubbs

Sugar maple *(Acer saccharum),* sometimes called hard maple or rock maple, is one of the largest and more important of the hardwoods. It grows on approximately 12.5 million hectares (31 million acres) or 9 percent of the hardwood land and has a net volume of about 130 million m^3 (26 billion fbm) or 6 percent of the hardwood sawtimber volume in the United States. The greatest commercial volumes are presently in Michigan, New York, Maine, Wisconsin, and Pennsylvania (53). In most regions, both the sawtimber and growing stock volumes are increasing, with increased production of saw logs, pulpwood, and more recently, firewood.

Habitat

Native Range

The northern limit of sugar maple (figs. 1, 2) nearly parallels the 35th mean annual isotherm extending eastward from the extreme southeast corner of Manitoba, through central Ontario, the southern third of Quebec and all of New Brunswick and Nova Scotia. Within the United States the species is found throughout New England, New York, Pennsylvania, and the middle Atlantic States, extending southwestward through central New Jersey to the Appalachian Mountains, then southward through the western edge of North Carolina to the southern border of Tennessee. The western limit extends through Missouri into a small area of Kansas, the eastern one-third of Iowa, and the eastern two-thirds of Minnesota. A few outlier communites are found in northern Kansas, Georgia, and the Carolinas.

Climate

Sugar maple is restricted to regions with cool, moist climates. In northern areas, January temperatures average about -18" C (0° F) and July temperatures about 16" C (60" F). In the southern portions of the range, January temperatures average about 10" C (50" F) and July temperatures approach 27" C (80" F), although moisture and aspect influence these extremes. In the sugar maple region, typical ranges in temperatures are from 40" C (40" F) in the north to 38° C (100° F) in the southwestern areas. Occasional extremes may be more than 11" C (20" F) lower or higher than these.

Precipitation averages range from about 510 mm (20 in) annually near the western edge of the range to 2030 mm (80 in) in the southern Appalachians. Much of the northeastern region receives about 1270 mm (50 in) per year where substantial commercial volumes of sugar maple are located. In general, the growing season precipitation is well distributed and averages 380 mm (15 in) in the western areas and 1020 mm (40 in) in the East. Snowfall often exceeds 2540 mm (100 in) in the northern portion of the range.

In the broad geographic area covered by sugar maple, the growing season ranges from 80 to 260 days. The last killing frost usually occurs from March 20 to June 15 and the first killing frost occurs between September 1 and November 10. In mountainous areas of the Northeast, climatic factors largely determine the upper elevation limits of the species *(97).*

Soils and Topography

Sugar maple grows on a wide variety of sites ranging from a site index of about 12 m (40 ft) to nearly *24* m (80 ft) at age *50 (12,17,21,25,46,91).* Typical good quality second-growth stands usually fall between site index 17 and 20 m (55 and 65 ft) for sugar maple at base age 50 years. Height growth is slower after age 50 in the eastern regions. Except on the best sites, the depth of the soil and type of parent material has a marked influence on site index (69).

Sugar maple grows on sands, loamy sands, sandy loams, loams, and silt loams but it does best on well-drained loams *(30).* It does not grow well on dry, shallow soils and is rarely, if ever, found in swamps *(30).* Sugar maple is soil-site specific in southerly regions but abundant on a wide variety of soils in the northern Lake States. It is mostly found on Spodosols, Alfisols, and Mollisols among the soil orders. In New Hampshire, sugar maple is associated with sites that have abundant organic matter *(69),* and in West Virginia it is most abundant on areas with high oak site indices *(107).*

Sugar maple grows on soils ranging from strongly acid (pH 3.7) to slightly alkaline (pH 7.3), but it most commonly grows on soils with a pH of from 5.5 to 7.3 *(30).* The heavy leaf litter typical of sugar maple

---

The authors are Principal Silviculturist (deceased), North Central Forest Experiment Station, St. Paul, MN, and Research Foresters, Northeastern Forest Experiment Station, Radnor, PA.

tends to modify the pH and nutrient status of the soil. The leaves contain 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, based on dry weight. The pH of leaves ranges from 4.0 to 4.9. The calcium content remains relatively uniform in trees growing with a pH range of 4.5 to 7.0 but drops as the soils become more acid (5).

In the Lake States, sugar maple is found at elevations up to 490 m (1,600 ft)—most commonly on ridges between poorly drained areas and on soil with at least 1 to 1.5 m (3 to 5 ft) to the water table. In northern New England and New York State it grows at elevations up to 760 m (2,500 ft). In the Green

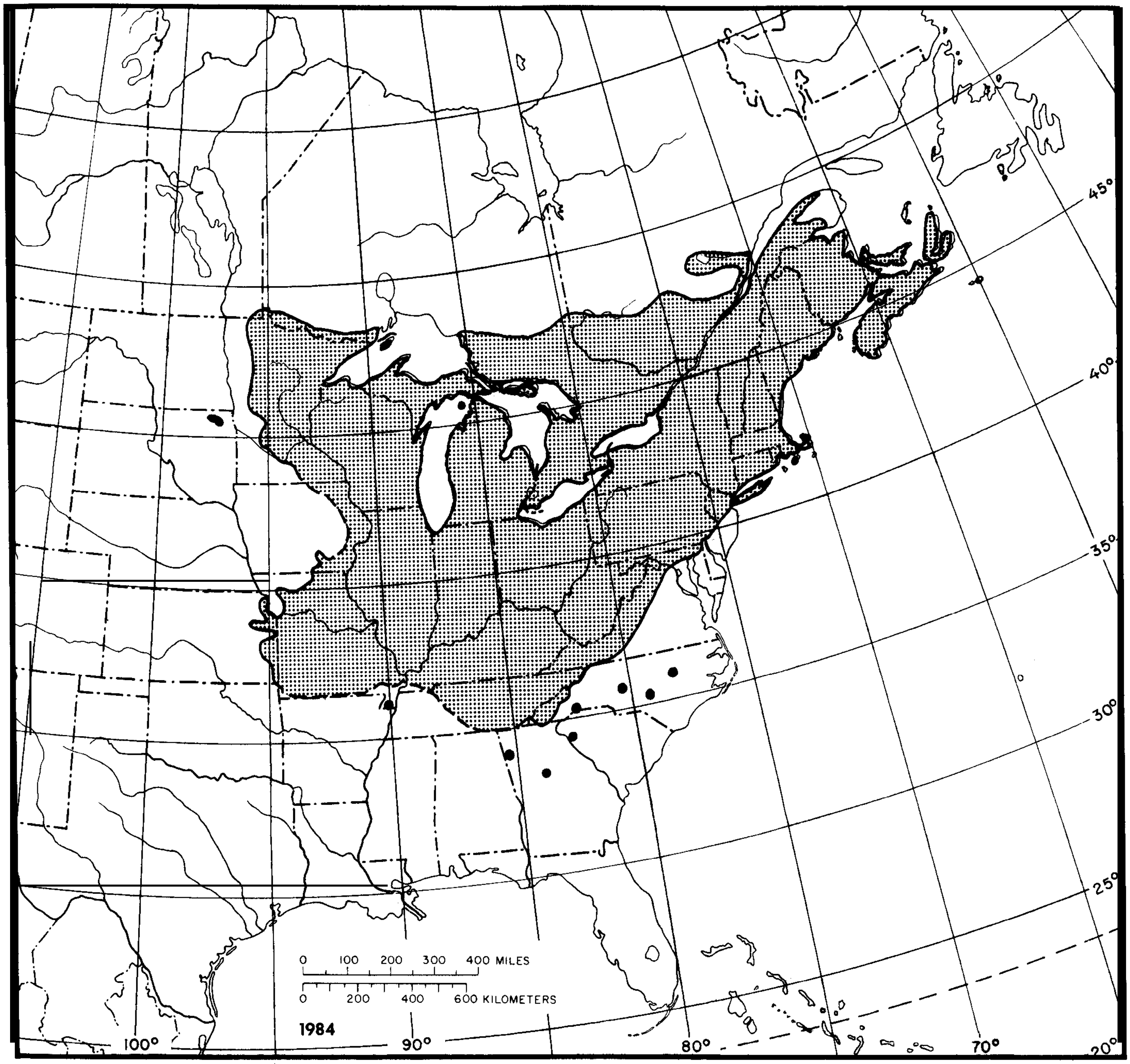

Figure *l-The native range of* sugar *maple.*

Mountains of Vermont and the White Mountains of New Hampshire, especially, the upper limit lies in a sharp horizontal band with a narrow transitional zone into the Boreal forest types. In the southern Appalachians the upper elevation ranges from 910 m (3,000 ft) to 1680 m (5,500 ft), with the lower levels generally restricted to the cooler north slopes. In the southern and southwestern parts of its range, sugar maple more typically grows on moist flats and along ravines at intermediate elevations in the rolling topography.

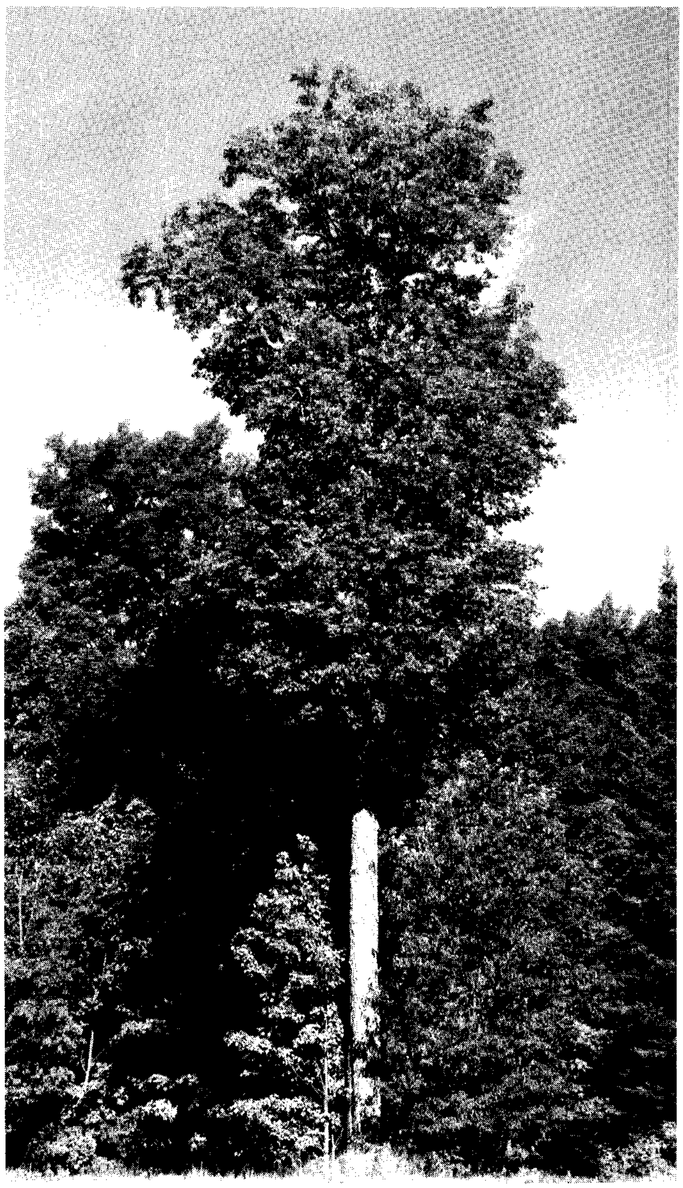

Figure *Z-Sugar* **maple.**

Associated Forest Cover

In eastern North America sugar maple is a major component in 7 Society of American Foresters forest cover types, a common associate in 17, and an infrequent species in 10 *(20).*

Sugar maple is a major component in the following types:

27	Sugar Maple
26	Sugar Maple-Basswood
25	Sugar Maple-Beech-Yellow Birch
60	Beech-Sugar Maple
28	Black Cherry-Maple
31	Red Spruce-Sugar Maple-Beech
16	Aspen (Canadian subtype)

Sugar maple is a common associate in the following types:

17	Pin Cherry
107	White Spruce
32	Red Spruce
30	Red Spruce–Yellow Birch
35	Paper Birch-Red Spruce-Balsam Fir
21	Eastern White Pine
22	White Pine-Hemlock
23	Eastern Hemlock
20	White Pine-Northern Red Oak-Red Maple
24	Hemlock-Yellow Birch
108	Red Maple
19	Gray Birch-Red Maple
55	Northern Red Oak
57	Yellow-Poplar
58	Yellow-Poplar-Eastern Hemlock
59	Yellow-Poplar-White Oak-Northern Red Oak
64	Sassafras-Persimmon

It occurs as an infrequent species in Jack Pine (Type 1), Balsam Fir (Type 5), Aspen (Type 16), Red Spruce-Balsam Fir (Type 33), Red Spruce-Fraser Fir (Type 34), Chestnut Oak (Type 44), Pitch Pine (Type 45), White Pine-Chestnut Oak (Type 51), White Oak-Black Oak-Northern Red Oak (Type 52), and River Birch-Sycamore (Type 61).

Large numbers of shrubs are found with sugar maple because of its varied altitudinal distribution. The most common within the commercial range are beaked hazel *(Corylus cornuta),* Atlantic leatherwood *(Dirca palustris)*, redberry elder *(Sambucus pubens)*, American elder *(S. canadensis),* alternate-leaf dogwood *(Cornus alternifolia),* dwarf bush-honeysuckle *(Diervilla lonicera),* Canada yew *(Taxus canadensis),* red raspberry *(Rubus idaeus),* and blackberries *(Rubus* spp.). Common flowering plants include springbeauty *(Claytonia caroliniana),* large-flowered trillium *(Trillium grandiflorum)*, anemone *(Anemone* spp.), marsh blue violet *(Viola cucullata)*, downy yellow violet *(V. pubescens),* Solomons-seal *(Polygonatum pubescens),* false Solomons-seal *(Smilacina stellata),* sweet cicely *(Osmorhiza* spp.), adderstongue *(Ophioglossom vulgatum),* jack-in-the-pulpit *(Arisaema atrorubens),* clubmosses *(Lycopodium* spp.), and largeleaf aster *(Aster macrophyllus).*

Life History

Reproduction and Early Growth

Flowering and Fruiting-Sugar maple trees seldom flower until they are at least 22 years old; flowering is heavier at later ages. The flower buds usually begin to swell at or slightly before the leaf buds show activity and reach full bloom 1 to 2 weeks before leaves emerge. Flowers appear between late March and mid-May, depending on the geographic location *(85).*

Flowering in sugar maple is polygamous, occurring over the entire crown. The long-pedicelled, apetalous yellow flowers, about 6.4 cm (2.5 in) long, seem to be perfect, but usually only one sex is functional within each flower. Both sexes are typically produced in the upper part of the crown but only males form in the lower part (26). In some trees, certain major limbs produce only male and others only female flowers. The flowers of sugar maple were thought to be bee-pollinated *(30,64),* but a recent study showed that pollination occurs freely in sugar maple without the aid of insects (28).

The fruit, a double samara, ripens in about 16 weeks. Usually only one of the paired samaras is filled with a single seed, typically averaging 7 to 9 mm (0.3 to 0.4 in) in length, but occasionally both samaras will contain seed or both will be empty. Some trees produce triple samaras and others produce samaras with double wings. Samaras collected from trees having the birds-eye wood grain characteristic showed a consistency of overlapping of the wings, a strong union between samaras, and lighter colored wings after drying but these characteristics have not been confirmed as being an attribute associated with birds-eye (32).

Seeds are mature when the samaras turn yellowish green and have a moisture content less than 145 percent (11,124). The samaras begin falling about 2 weeks after they ripen, usually just before the leaves fall.

Seed Production and Dissemination-The fruit of sugar maple is intermediate in size among species within the genus. Samaras average about 15,400/kg (7,000/lb), but range from 7,060 to 20,070/kg (3,200 to 9,100/lb) *(85).* The large papery wings, typically 20 to 27 mm (0.8 to 1.1 in) in length and 7 to 11 mm (0.3 to 0.4 in) wide, permit the samara to be carried at least 100 m (330 ft) by the wind. During a good seed year in northern Michigan, 173,000 samaras per hectare (70,000/acre) fell in the center of a 4-ha (lo-acre) clearcut *(31).* Samaras containing seed can be readily separated from empty samaras by immersion in N-pentane. Immersion up to 1 hour may delay germination but has no effect on seed viability *(124).*

Light fruit crops are produced by 40- to 60-year-old trees with 20 cm (8 in) d.b.h., and moderate crops by 70- to loo-year-old trees with 25- to 36-cm (10- to 14-m) d.b.h. Saw-log-size trees produce vast numbers of samaras. During an excellent fruiting year in northern Michigan, a series of traps caught 22 million/ha (8.56 million/acre) sugar maple samaras in a virgin stand and 11 million/ha (4.3 million/acre) in a selectively cut stand *(30).*

Based on 32 years of observation in north-central Wisconsin, good or better fruit crops occurred about 44 percent of the years, the lowest percentage among the major hardwood species of the area (37,401. Good or better fruit crops occurred as often as 4 successive years, but successive poor crops did not extend longer than 2 years. The period between good or better crops ranges from 1 to 4 years in north-central Wisconsin, from 2 to 5 years in other portions of the United States, and from 3 to 7 years in Canada *(30,47,115).*

To germinate, sugar maple seeds require moist stratification at temperatures slightly above freezing for 35 to 90 days. Each sugar maple seed seems to have its own stratification-period threshold, short of which the epigeal germination process ceases *(126).* Both moisture content and temperature affect how long seeds can be stored. Under proper conditions seeds have been stored for at least 5 years without loss of viability *(10).* In natural stands, few if any seeds remain viable on the forest floor beyond the first year (73).

Sugar maple seed has an extremely high germination capacity, with averages of 95 percent or more *(126).* The optimum temperature for germination is about 1" C (34" F), the lowest of any known forest species *(39,108).* Germination drops rapidly as temperatures increase, and little if any germination occurs above 10" C (50" F). Rapid warming of the surface soil in the spring of 1978 in northern Wisconsin, for example, prevented germination from the bumper seed crop of 1977, except in a few remaining snowbanks along the roads (38). Under natural conditions the cotyledon leaves are out and growing before the snow is gone in the northern regions. This unique characteristic of germination at low temperatures probably accounts for the abundance of sugar maple regeneration under most stand conditions in the north. Another major characteristic of the germinating sugar maple seed is its vigorous development of a strong radicle that has the strength and length to penetrate heavy leaf litter and reach mineral soil during the moist period.

Seedling Development-Seedlings of sugar maple are very shade tolerant and can survive long periods of suppression. In a study of seedling height for 5 years after germination under low lath shade in central Ontario, the tallest seedlings were found under about 65 percent shade, averaging about 127 cm (50 in) tall *(34,71)*. Heights were greater than 102 cm (40 in) from about 35 to 90 percent of full sunlight, with average heights decreasing at more open and heavier shading. A significant finding in this study was that supplemental watering was necessary for survival at more than 55 percent of full sunlight. Dry weight and root development were little affected by the level of light. A Vermont study of shade levels showed no significant difference in seedlings grown under 0, 30, and 60 percent shade but found a marked decrease in development under 90 percent shade. Seedlings grown under the different shade treatments showed no difference, however, in either height or diameter growth 4 years after field planting (125).

Sugar maple roots release an exudate that can inhibit the growth of yellow birch when the root growth periods coincide, thus gaining a growth advantage over one of its associated species *(110)*. Other tree species may be similarly affected. Aster and goldenrod exert an allelopathic effect on sugar maple by reducing germination and early growth of seedlings (24).

The growth of understory seedlings begins before the overstory leafs out, generally about mid-May in Upper Michigan. About 90 percent of the seasonal height growth occurs within 18 days under dense stands and 24 days in the open (50). The major growth of other species studied extended about three times longer.

Seedling numbers greater than 370,500/ha (150,000/acre) are common, although as many as 50 percent of the new seedlings may not survive the first year. Seedlings in the understory of young, dense stands may not survive for more than 5 years but many of the seedlings under stands averaging 25 cm (10 in) d.b.h. or more will persist, although they will have little annual height growth until released. In a study of reproduction in old growth stands cut to various basal area densities, number of seedlings per hectare did not differ significantly at either 2 or 5 years after cutting. After 10 years, seedlings under the lightest overstories (6.9 m^2/ha or 30 ft^2/acre) grew most rapidly although seedlings were abundant under all overstory densities *(109)*.

In the drier Lake States region, natural seedlings must have overstory shade for survival until they reach 0.6 to 1.2 m (2 to 4 ft) in height, at which time their root systems have developed from the litter-mineral soil interface into mineral soil. The entire overstory can then be removed with high seedling survival and full stocking (42). Removing the overstory before seedlings are established usually results in semipermanent wildlife openings in the Lake States ***(112)***. In partially cut stands, the tallest seedlings usually develop and constitute the trees of the new stand as the overstory is gradually removed *(78)*.

Planting or other special regenerative measures are rarely needed for sugar maple in New England or the Lake States where the tree grows naturally. In other regions, sugar maple is less aggressive and planting is a desirable practice. Nursery stock used in planting is usually fall sown at a depth of about 6 mm (0.25 in) and covered with about 6 mm (0.25 in) of sawdust. The nursery bed is covered by about 50 percent lath shade. Sowing density should yield about 130 to 160 seedlings per square meter (12 to 15 seedlings/ft^2) and seedlings should be vertically root pruned before lifting, usually as 2-O stock *(101,121,124)*. On more difficult sites 3-O stock is preferred with tops averaging about 25 cm (10 in) or about twice the height of 2-O seedlings *(101)*.

Open field plantings with sugar maple have a high survival rate, but seedlings grow poorly because of their inability to compete for moisture and nutrients with herbaceous vegetation. Generally, open field plantings require good stock and several years of site maintenance to assure success ***(114,127)***. Time of planting is important. Survival and growth can be vastly improved by planting very early in the spring compared to planting late in the spring. The increase is attributed to the greater root regeneration capabilities during that time ***(118)***. Fall plantings have been highly successful in Vermont *(127)*. Sugar maple must be planted at relatively close spacings in order to correct the forking problems that result from the frequent loss of the terminal bud in this opposite-branched species *(78,89)*.

Vegetative Reproduction-Sugar maple reproduces by stump sprouts and will occasionally layer (22). Root suckering is rare. Seedlings broken during logging readily sprout from dormant buds on the lower bole and quickly regain the height of undamaged seedlings (52). Initial deformities, primarily crook, and stem losses from deer browsing are rapidly overgrown and corrected without development of internal rot *(51).*

In older stands, the percentage of stumps sprouting decreases with increase in tree size, stand density, and years since cutting. Two years after a cutting in northern Michigan, the most sprouting occurred on 15-cm (6-in) trees and the least sprouting on 76-cm (30-in) trees. The percent of stumps sprouting averaged 94 and 38, respectively. Five years after cutting, the percent of sprouting dropped to about 58 and 6, respectively. The number of sprouts per stump also declined with years since cutting *(30).* Sugar maple is a prolific sprouter in the North, but it sprouts less than other hardwood species in the southern part of its range *(9,86,88,99).*

Cuttings of sugar maple can be rooted but may later fail due to poor overwintering survival. Cuttings can be successfully over-wintered by forcing the cutting to break bud and produce a flush of new growth immediately after it roots with the use of gibberellic acid *(128).* Rooting response varies greatly between clones-differences range from 0 to 100 percent, and rooting response tends to be consistent from year to year. Timing the collection of cuttings is critical; those taken in mid-June generally give the best results. A rooting medium consisting of a 1 to 1 mixture of perlite and sphagnum moss, with intermittent misting, has worked well with sugar maple cuttings. The reliability of cuttings to propagate trees with figured wood, such as curly grain and birds-eye, has not been verified *(30).*

Sugar maple trees with desirable genetic characteristics can be reproduced by grafting. Success with this method can be highly variable depending to a large degree on grafting techniques, that is, when and under what conditions the scions were collected and handled, treatment of the rootstock, and experience of the grafters *(129).* Of the various methods available, bud grafting is used most commonly and with a high degree of success by commercial nurserymen (64).

Air-layering, a method of propagation that stimulates root development on branches still attached to the parent tree, is another method that has been successfully used *(16).* A major disadvantage of this procedure is that branches on some trees selected for propagation may not be readily accessible.

Sapling and Pole Stages to Maturity

Growth and Yield-Early growth of sugar maple is slow, partly because it regenerates under heavy shade. In natural stands, the younger seedlings are sensitive to surface moisture conditions because they have a shallow, fibrous root system that lies between the litter-mineral soil interface of typical podzols. With a gradual increase in light, the root systems penetrate deeper into the mineral soil and height growth increases.

Growth during the pole stage is slower than for most associated hardwood species. Height and radial growth begins at about the same time as the buds leaf out. Height growth is completed in about 15 weeks and radial growth in from 14 to 17 weeks, depending on the season and locality *(30).* In some areas, height growth is about 85 percent complete within 5 weeks and cambial growth is about 80 percent complete in 8 weeks *(30).*

In the Lake States, older sugar maple trees (fig. 3) in a mature stand grew 2.5 cm (1 in) d.b.h. in 10 years *(30).* Maximum diameter growth rates of individual trees in mature stands in the Upper Peninsula of Michigan were about 7.6 cm (3 in) per decade for 46-cm (18-in) trees, 8.9 cm (3.5 in) for 30-cm (12-in) trees, and 10.2 cm (4 in) for 15-cm (6-in) trees *(15).* Growth in second-growth stands, however, generally exceeds 5.1 cm (2 in) in 10 years for sawlog-size trees *(18)* and a maximum rate in excess of 10.2 cm (4 in) has been reported *(106).* For the first 30 to 40 years, sugar maples average about 30 cm (12 in) a year in height growth.

Mature trees and stands of sugar maple reach 300 to 400 years of age, 27 to 37 m (90 to 120 ft) in height, and 76- to 91-cm (30- to 36-in) in d.b.h. *(30).* Following repeated cutting under the uneven-aged system, age and diameter show strong linear relation with the older ages, seldom exceeding 250 years (68,111). Height growth usually ceases or becomes negligible at about 140 to 150 years *(30).* Diameter growth continues at a decreasing rate with age and size. The largest reported sugar maple tree, growing near Kitzmiller, MD, has a d.b.h. of 209 cm (82.1 in), is 23.8 m (78 ft) tall, and has a crown spread of 20.1 m (66 ft) *(1).*

Yields of mixed hardwood stands, but predominantly sugar maple, range up to a maximum of 216 m^3/ha (14,000 gross board feet/acre) *(30,70).*

Yields for northern hardwood stands in the Lake States are available from estimates of average stand age and average stand diameter (table 1). Both parameters are based on overstory trees. Basal-area stocking of stands commonly ranges from 27.6 to 36.8 m^2/ha (120 to 160 $ft^2/acre$). A few older stands exceed 45.9 m^2/ha (200 $ft^2/acre$). Even-age and uneven-age silvicultural systems are available for managing stands in which sugar maple is a principal component and a desired species. Periodic annual growth averaging about 4.2 m^3/ha (350 fbm/acre) and annual

Figure ***34 mature*** sugar ***maple stand in Nicolet National Forest,*** *WI.*

basal-area growth of up to 0.7 m^2/ha (3 ft^2/acre) is typical of young stands on good sites in the Lake States but varies with total basal-area stocking, distribution of trees by size class, and site ***(18).*** Improvement in grade and tree size should be the guiding principle in stand management because this factor contributes more to value increase than diameter growth under most conditions *(41,75,105).*

Rooting Habit-The root system of sugar maple has strong, oblique laterals with extensive branching. Roots on the upper side of the laterals grow upward into the humus layers and those on the lower side grow downward. Most of the fine feeder roots

Table l-Yields from average, well-stocked stands of northern hardwoods in the Lake States dominated by sugar maple (adapted from *29*)

Stand age (yr)[1]	Average d.b.h.	Basal area	Volume	
			Total[2]	Saw log[3]
	cm	*m²/ha*	*m³/ha*	*m³/ha*
Good site				
40	19	19.7	92.4	13.3
80	29	26.4	193.9	85.4
120	38	31.5	265.3	150.5
160	47	35.6	317.1	197.4
200	56	38.6	350.0	228.2
Medium site				
40	14	18.8	51.8	4.2
80	24	25.0	135.1	49.0
120	31	29.4	202.3	100.8
160	38	32.8	250.6	144.2
200	44	35.6	283.5	176.4
Poor site				
40	10	16.3	25.2	1.4
80	19	22.0	72.1	16.8
120	25	25.9	127.4	53.2
160	30	28.7	175.0	86.1
200	35	30.8	211.4	116.2
	in	*ft²/acre*	*ft³/acre*	*fbm/acre*
Good site				
40	7.4	86	1,320	950
80	11.6	115	2,770	6,100
120	15.1	137	3,790	10,750
160	18.6	155	4,530	14,100
200	22.1	168	5,000	16,300
Medium site				
40	5.6	82	740	300
80	9.5	109	1,930	3,500
120	12.2	128	2,890	7,200
160	14.8	143	3,580	10,300
200	17.4	155	4,050	12,600
Poor site				
40	4.1	71	360	100
80	7.6	96	1,030	1,200
120	10.0	113	1,820	3,800
160	11.9	125	2,500	6,150
200	13.8	134	3,020	8,300

'Age determined from overstory trees.
'Cubic volumes determined from sound trees 13 cm (5 in) and larger in d.b.h. to a top diameter inside bark of 10 cm (4 in), exclusive of bark.
[3]The Scribner log rule was used for trees 23 cm (9 in) and larger in d.b.h. to a variable top diameter, with a minimum of 20 cm (8 in) inside bark. Deductions were made for cull.

remain within the general area of origin ***(23,103).*** Intraspecific root grafting is common.

Although some root growth may continue throughout the year if the soil does not freeze, the bulk of the new root regeneration depends on growth factors exported from physiologically nondormant buds. In northern races of sugar maple, about 2,500 hours of continuous chilling are required to break bud dormancy (64).

Sugar maple roots are extremely sensitive to flooding during the growing season. The roots of maple form both endotrophic and ectotrophic mycorrhizae.

Reaction to Competition-Sugar maple is rated as very tolerant of shade, exceeded among hardwoods only by a few smaller, shorter lived species. In large trees, only American beech *(Fagus grandifolia)* equals it in tolerance under forest conditions *(30).* Maximum photosynthetic activity generally occurs under about 25 percent of full sunlight. The species can survive for long periods under heavy shade and still show a strong response to release *(30).*

Release is seldom justifiable for young sugar maple stands subjected to suppression from scattered dominant trees or pin cherry *(Prunus pensylvanica)* because the sugar maple will overcome suppression under those conditions *(30).* Release is needed, however, when sugar maple competes with striped maple *(Acer pensylvanicum),* black cherry *(Prunus serotina),* yellow-poplar *(Liriodendron tulipifera),* and the oaks *(Quercus* spp.), because growth is retarded and survival is reduced by such competition *(107).*

One sapling stand study showed that unreleased, dominant trees of good vigor averaged 23 mm (0.9 in) in diameter growth and heavily released trees averaged 46 mm (1.8 in) in diameter growth per year during a 7-year period; unreleased, codominant trees of good vigor averaged 18 mm (0.7 in) in diameter growth and heavily released trees 38 mm (1.5 in). Pole-size trees also respond well to release (31,102).

If released too much, sugar maple readily develops epicormic sprouts from dormant buds *(14,31,33,* 36,781. Gradual release and good crown development provide adequate control over epicormic sprouting and also enhance natural pruning of epicormic branches on the lower bole. Consequently, proper thinning at scheduled intervals is necessary to encourage quality improvement as well as diameter growth.

Damaging Agents-Early studies in old-growth sugar maple indicated that after two or possibly three cyclic cuts had been made, few damaging agents would affect trees or stands. Current work in second-growth, however, shows some major agents, particularly in even-aged stands (77,122).

At least two species of bud miners, *Proteoteras moffatiana* and *Obrussa ochrefasciella,* overwinter in the terminal bud of sugar maple and kill it. This causes repeated forking, which reduces merchantable log length and adds to the risk of crown loss from splitting. Other bud-damaging insects that may also cause forks are *Choristoneura rosaceana, Cenopis pettitana, Phyllobius oblongus,* and *Platycerus virescens (65,66,77,98,123).*

Forking at the terminal bud occurs in trees of all ages but is especially pronounced in overstory trees. Side crowding and overhead shading help correct lower forking (32). But early or heavy thinning sets the fork and causes shorter merchantable lengths. As fork members increase in size and weight, fork breakage also increases.

Except for bud losses, sugar maple is not highly susceptible to insect injury and serious outbreaks are not common (62). The most common insects to attack sugar maple are defoliators and these include the gypsy moth *(Lymantria dispar),* forest tent caterpillar *(Malacosoma disstria),* linden looper *(Erannis tiliaria),* fall cankerworm *(Alsophila pometaria),* spring cankerworm *(Paleacrita vernata),* green-striped mapleworm *(Anisota rubicunda),* Bruce spanworm *(Operophtera bruceata),* maple leaf-cutter *(Paraclemensia acerifoliella),* maple trumpet skeletonizer *(Epinotia aceriella),* and saddled prominent *(Heterocampa guttivitta).*

One insect of the genus *Phytobia* occasionally causes pith flecks that seriously degrade veneer logs. This insect tunnels the full length of the cambium layer and exits near the root collar *(117).*

Borers that attack sugar maple include the carpenterworm *(Prionoxystus robiniae),* sugar maple borer *(Glycobius speciosus),* maple callus borer *(Synanthedon acerni),* and occasionally horntails *(Xiphydria abdominalis* and *X. maculata) (95).*

Sucking insects that affect sugar maple include the woolly alder aphid *(Prociphilus tesselatus)* and other aphid species *(Neoprociphilus aceris* and *Periphyllus lyropictus)* which injure leaves and reduce growth.

Of the scale insects, the maple phenacoccus *(Phenacoccus acericola),* is the most important to sugar maple. The maple leaf scale *(Pulvinaria acericola)* and the gloomy scale *(Melanaspis tenebricosa)* also frequently attack sugar maple.

Many sugar maple trees died in a small area of Wisconsin and Michigan in 1957 *(113).* Certain insects-the leaf rollers *(Sparganothis acerivorana* and *Acleris chalybeana)* and the maple webworm *(Tetralopha asperatella)*—combined with disease and climatic factors were thought to be the cause of this mortality *(44,48,61,120).* The decline has abated but appears to have recurred with less severity on a portion of the same area in the late 1970's.

Diseases of sugar maple generally deform, discolor, or decrease volume but seldom kill the tree *(80).* The two most important diseases in managed second-growth are probably Eutypella *(Eutypella parasitica)* and Nectria *(Nectria galligena)* cankers. In the Lake States these cankers each affect from about 1 to 4 percent of the trees (77) but in Ontario they occur more frequently (60,87). Nectria canker is more prevalent following shelterwood cuttings, probably because conditions favorable for infection are established (2). Two other cankers (*Schizoxylon microsporum* and *Hypoxylon lilakei*) occur rarely on sugar maple. In a few instances cankers may kill a tree but generally only predispose it to breakage.

Some common fungi-causing heart rots in sugar maple are *Armillaria mellea*, primarily a root-rotting fungus; *Hydnum septentrionale*, which causes a soft, spongy, white heart rot; *Inonotus glomeratus*, which causes white to light brown spongy heart rot; and *Ustulina vulgaris*, which causes a butt rot (30).

The amount of defect in sugar maple trees in virgin and unmanaged stands is usually high-commonly from 35 to 50 percent (30). Defect resulting from logging damage usually is minor in small wounds for as long as 10 years, but 20-cm (8-in) scars all were infected within 20 years and value losses were significant (47,811.

Logging injuries to the stems of residual trees and to reproduction frequently result in the entrance of decay and eventually serious volume loss (6,79). In a study in Upper Michigan at least 30 percent of the logging scars on the main stem of older trees resulted in serious defects within 15 to 20 years (30). Larger limbs broken in logging also usually result in serious defects (93,94). In Upper Michigan after a 20-year period about 8 percent cull resulted from decay and stain that had entered through scars on limbs 10 cm (4 in) and larger (30). Smaller limb breakage exposing only sapwood, however, generally results in little volume loss (4,30).

Two wilts occasionally attack and kill sugar maple. Sapstreak, caused by *Ceratocystis coerulenscens*, enters through root injuries from logging and has been reported in several localities (56,57,80). Verticillium wilt, caused by *Verticillium albo-atrum*, is usually found only in shade trees. This wilt also invades the trees through the roots.

When stored for more than a year, a saprophytic fungus, *Cryptostroma corticale*, sometimes develops on the bark of sugar maple. The spores from this fungus are released during processing and have caused bronchial asthma and severe allergenic lung disorders to millworkers (83,84).

Physical and climatic injuries often occur on sugar maple. Much damage from glaze storms occurred in New York in 1942. The injured trees showed a slight tendency to sprout and renew growth. Many of the smaller trees that had 85 percent or more of their crown broken away developed saprot (30).

Winter sunscald frequently occurs in even-aged sugar maple stands. Trees are damaged from late winter heating of the bole above the snowline on bright sunny days followed by rapid freezing that ruptures the cells. Most injury occurs when the stems are 2.5 to 7.6 cm (1 to 3 in) in d.b.h., and certain topographic positions are affected more than others (55). Healing in dense stands is slow, if at all, and later stages often appear to be a simple frost crack. Various fungi may be present but may or may not prevent closure (59). Part of the lack of closure may be due to shrinkage and swelling of the bole associated with changes in air temperature (35).

In some areas the lower portion of sugar maple boles contains many vertical cracks from 2.5 to 7.6 cm (1 to 3 in) long. Although these cracks have been termed annual maple cankers, the causal agent does not seem to be a fungus. These cankers slowly disappear and new ones recur at short intervals (32). In Pennsylvania they were most common on slowly permeable soils (116) but no specific cause has been identified (3,58).

Sugar maple can be severely damaged from deicing road salt (96). In an industrial area the number of overstory sugar maples was markedly reduced from exposure to sulfur oxides, nitrogen oxides, chlorides, and fluorides. Sugar maple remained an abundant species in the understory because of a lower exposure level (72).

Numerous animals feed on or injure sugar maple without serious effect except in local and limited situations. Deer browsing is probably the most common wildlife factor. Winter browsing in the Lake States causes little damage or reduced growth (51,100). In the central Adirondacks, however, continual browsing of sugar maple allows American beech, which the deer avoid, to dominate northern hardwood understories (54).

Red, grey, and flying squirrels sometimes gnaw or feed on the seed, buds, foliage, and twigs of sugar maple. In rare instances, they have girdled and killed larger branches and tree tops (30,100). Porcupines may feed on the bark and kill the top by girdling the upper stem (8,30).

Sapsuckers frequently peck and cause degrade in some sugar maple trees but rarely, if ever, kill the tree (19,82,90,92). On heavily pecked trees in the spring a fungus develops on the sap and causes the bark to turn black (82). Such trees probably should be retained in the stand to prevent other trees from being attacked.

Special Uses

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 and boiled or evaporated to a syrup. Further concentration by evaporation produces the maple sugar. Sugar maple sap averages about 2.5 percent sugar; about 129 liters (34 gal) of sap are required to make 3.8 liters (1 gal) of syrup or 3.6 kg (8 lb) of sugar. Guides have been printed for developing a sugar bush from natural stands (67).

Breeding experiments have determined that sugar content is high for certain families and that sugar content in individual trees is consistent over a period of years (64,104). A sugar content of 7.4 percent has been attained by crossing two selected parents of slightly lower content (64). The sugar content is also correlated with the volume yield of sap *(7,74)*.

Genetics

Sugar maple is a genetically variable tree. Some botanists recognize from three to six varieties or forma that differ in morphological characteristics, but others consider them to be subspecies. Extensive research indicates a "flow of characteristics" over the wide geographic distribution and variation in habitat conditions *(30,64)*. Kriebel indicated that sugar maples could be grouped into three major geographic races or ecotypes, each containing a parallel clinal variation (30). Provenance tests in his study indicate differences in drought endurance, resistance to leaf injury from high insolation, and phenological behavior.

Most of the genetic work in sugar maple is currently confined to improving maple syrup (27) and developing ornamental trees *(49,62,119)*. Nurserymen rely mostly on budding and some grafting for vegetative propagation. Birds-eye grain trees have been grafted since the early 1960's but results are not available for propagation of this characteristic (63). The USDA Forest Service, in recent work, has selected 228 superior sugar maple trees and established three plantations with 126 families (43).

Hyrbids have been reported between sugar maple and black and red maples (30). Hybrid seedlings have been obtained by pollinating sugar maple with another maple (presumably *Acer macrophyllum)* (30).

Literature Cited

1. American Forestry Association. 1982. National register of big trees. American Forests 88(4):36.
2. Anderson, Robert L., and Daniel J. Mosher. 1978. How to identify and control Nectria canker. USDA Forest Service, Northeastern Area State and Private Forestry, Broomall, PA. 4 p.
3. Barnard, Joseph E., and Wilbur W. Ward. 1965. Low temperatures and bole canker of sugar maple. Forest Science 11(1):59–65.
4. Basham, J. T., and H. W. Anderson. 1977. Defect development in second-growth sugar maple in Ontario. I. Microfloral infection relationships associated with dead branches. Canadian Journal of Botany 55(8):934–976.
5. Beals, E. W., and J. B. Cope. 1965. Vegetation and soils in an eastern Indiana woods. Ecology 45(4):777–792.
6. Biltonen, Frank E., William A. Hillstrom, Helmuth M. Steinhilb, and Richard M. Godman. 1976. Mechanized thinning of northern hardwood pole stands: methods and economics. USDA Forest Service, Research Paper NC-137. North Central Forest Experiment Station, St. Paul, MN. 17 p.
7. Blum, Barton M. 1974. Relation of sap yields to physical characteristics of sugar maple trees. Forest Science 19(3):175–179.
8. Brander, Robert B. 1973. Life history notes on the porcupine in a hardwood-hemlock forest in Upper Michigan. Michigan Academician 5(4):425–433.
9. Braun, E. Lucy. 1950. Deciduous forests of eastern North America. Hafner Publishing Co., New York. 596 p.
10. Carl, Clayton M., Jr. 1976. Effect of separation in N–pentane on storability of sugar maple seeds. USDA Forest Service, Research Note NE-218. Northeastern Forest Experiment Station, Upper Darby, PA. 3 p.
11. Carl, Clayton M., Jr., and Albert G. Snow. 1971. Maturation of sugar maple seed. USDA Forest Service, Research Paper NE-217. Northeastern Forest Experiment Station, Upper Darby, PA. 9 p.
12. Carmean, Willard H. 1978. Site index curves for northern hardwoods in northern Wisconsin and Upper Michigan. USDA Forest Service, Research Paper NC-160. North Central Forest Experiment Station, St. Paul, MN. 16 p.
13. Carmean, Willard H. 1979. Site index comparisons among northern hardwoods in northern Wisconsin and Upper Michigan. USDA Forest Service, Research Paper NC-169. North Central Forest Experiment Station, St. Paul, MN. 17 p.
14. Church, Thomas W., Jr., and R. M. Godman. 1966. The formation and development of dormant buds in sugar maple. Forest Science 12(3):301–306.
15. Crow, Thomas R., Rodney D. Jacobs, Robert R. Oberg, and Carl H. Tubbs. 1981. Stocking and structure for maximum growth in sugar maple selection stands. USDA Forest Service, Research Paper NC-199. North Central Forest Experiment Station, St. Paul, MN. 16 p.
16. Cunningham, Frank E., and Richard J. Peterson. 1965. Air-layering sugar maple. USDA Forest Service, Research Paper NE-42. Northeastern Forest Experiment Station, Upper Darby, PA. 16 p.
17. Curtis, Robert O., and Boyd W. Post. 1962. Site index curves for even-aged northern hardwoods in the Green Mountains of Vermont. Vermont Agriculture Experiment Station, Bulletin 629. Burlington. 11 p.
18. Erdmann, Gayne G., and Robert R. Oberg. 1973. Fifteen-year results from six cutting methods in second-growth northern hardwoods. USDA Forest Service, Research Paper NC-100. North Central Forest Experiment Station, St. Paul, MN. 12 p.

19. Erdmann, Gayne G., and Robert R. Oberg. 1974. Sapsucker feeding damages crown-released yellow birch trees. Journal of Forestry 72 (12):760–763.
20. Eyre, F. H., ed. 1980. Forest cover types of United States and Canada. Society of American Foresters, Washington, DC. 148 p.
21. Farrington, R. A., and M. Howard, Jr. 1958. Soil productivity for hardwood forests of Vermont. *In* Proceedings, First North American Forest Soils Conference. p. 102–109. Michigan State University Agriculture Experiment Station, East Lansing, MI.
22. Fayle, D. C. F. 1964. Layering habit of the sugar maple. Forest Chronicle 40(1):116–121.
23. Fayle, D. C. F. 1965. Rooting habit of sugar maple and yellow birch. Canada Department of Forestry, Publication 1120. Ottawa, ON. 31 p.
24. Fisher, R. F., R. A. Woods, and H. R. Glavic. 1978. Allelopathic effects of goldenrod and aster on young sugar maple. Canadian Journal of Forest Research 8(1):1–9.
25. Frothingham, E. H. 1915. The northern hardwood forest: its composition, growth and management. U.S. Department of Agriculture, Bulletin 285. Washington, DC. 79 p.
26. Gabriel, W. J. 1962. Inbreeding experiments in sugar maple (*Acer saccharum* Marsh.)-early results. *In* Proceedings, Ninth Northeastern Forest Tree Improvement Conference. p. 8-12.
27. Gabriel, W. J. 1975. Phenotypic selection of sugar maples for superior sap volume production. *In* Proceedings, Twenty-first Northeastern Forest Tree Improvement Conference. p. 91-96.
28. Gabriel, W. J. 1981. Personal communication.
29. Gevorkiantz, S. R., and William A. Duerr. 1937. A yield table for northern hardwoods in the Lake States. Journal of Forestry 35:340–343.
30. Godman, R. M. 1965. Sugar maple (*Acer saccharum* Marsh.). *In* Silvics of forest trees of the United States. p. 66-73. H. A. Fowells, comp. U.S. Department of Agriculture, Agriculture Handbook 271. Washington, DC.
31. Godman, Richard M. 1969. Culture of young stands. *In* Proceedings, Sugar Maple Conference, August 1969, Houghton, MI. p. 82-87. Michigan Technological University and USDA Forest Service.
32. Godman, Richard M. 1981. Unpublished data.
33. Godman, Richard M., and David J. Books. 1971. Influence of stand density on stem quality in pole-size northern hardwoods. USDA Forest Service, Research Paper NC-54. North Central Forest Experiment Station, St. Paul, MN. 7 p.
34. Godman, R. M., and G. A. Mattson. Undated. Relative tolerance of hardwood and associated conifer seedlings. USDA Forest Service, Hardwood Management Note. North Central Forest Experiment Station, St. Paul, MN. 2 p.
35. Godman, R. M., and G. A. Mattson. 1970. Periodic growth of hardwood influenced by cold weather. Journal of Forestry 68:86–87.
36. Godman, R. M., and G. A. Mattson. 1970. The sprouting potential of dormant buds on the bole of pole-size sugar maple. USDA Forest Service, Research Note NC-88. North Central Forest Experiment Station, St. Paul, MN. 4 p.
37. Godman, Richard M., and Gilbert A. Mattson. 1976. Seed crops and regeneration problems of 19 species in northeastern Wisconsin. USDA Forest Service, Research Paper NC-123. North Central Forest Experiment Station, St. Paul, MN. 5 p.
38. Godman, R. M., and G. A. Mattson. 1980. Low temperatures optimum for field germination of northern red oak. Tree Planters' Notes 31(2):32–34.
39. Godman, Richard M., and G. A. Mattson. 1981. Optimum germination temperatures for hardwoods. USDA Forest Service, Hardwood Management Note. North Central Forest Experiment Station, St. Paul, MN. 2 p.
40. Godman, R. M., and G. A. Mattson. 1981. Thirty-two years of forest tree seed crop records in northeast Wisconsin. Data on file at Rhinelander, WI.
41. Godman, Richard M., and Joseph J. Mendel. 1978. Economic values for growth and grade changes of sugar maple in the Lake States. USDA Forest Service, Research Paper NC-155. North Central Forest Experiment Station, St. Paul, MN. 16 p.
42. Godman, Richard M., and Carl H. Tubbs. 1973. Establishing even-age northern hardwood regeneration by the shelterwood method-a preliminary guide. USDA Forest Service, Research Paper NC-99. North Central Forest Experiment Station, St. Paul, MN. 9 p.
43. Gould, Norman E. 1979. Reforestation and timber stand improvement report for Fiscal Year 1978 and 1979. WO-2490 Records and Report. USDA Forest Service, Washington, DC. 57 p.
44. Griffin, H. D. 1965. Maple dieback in Ontario. Forestry Chronicle 41(3):295–300.
45. Grisez, Ted J. 1975. Flowering and seed production in seven hardwood species. USDA Forest Service, Research Paper NE-315. Northeastern Forest Experiment Station, Upper Darby, PA. 8 p.
46. Hawes, F. F., and B. A. Chandler. 1914. The management of second growth hardwoods in Vermont. Vermont Agriculture Experiment Station, Bulletin 176. University of Vermont, Burlington. 88 p.
47. Hesterberg, G. A. 1957. Deterioration of sugar maple following logging damage. USDA Forest Service, Station Paper 51. Lake States Forest Experiment Station, St. Paul, MN. 58 p.
48. Hibben, C. R. 1962. Investigations of sugar maple decline in New York woodlands. Thesis (Ph.D.), Cornell University, Ithaca, NY. 307 p.
49. Howe, G. E. 1968. Early results of a sugar maple provenance study. *In* Proceedings, Sixteenth Northeastern Forest Tree Improvement Conference. p. 27-28.
50. Jacobs, Rodney D. 1965. Seasonal height growth patterns of sugar maple, yellow birch, and red maple seedlings in Upper Michigan. USDA Forest Service, Research Note LS-57. Lake States Forest Experiment Station, St. Paul, MN. 4 p.
51. Jacobs, Rodney D. 1969. Growth and development of deer browsed sugar maple seedlings. Journal of Forestry 67(12):870–874.
52. Jacobs, Rodney D., 1974. Damage to northern hardwood reproduction during removal of shelterwood overstory. Journal of Forestry 72(10):654–656.

53. Kallio, Edwin, and Carl H. Tubbs. 1980. Sugar maple: an American wood. USDA Forest Service, FS-246. Washington, DC. 5 p.
54. Kelty, Matthew J., and Ralph D. Nyland. 1981. Regenerating Adirondack northern hardwoods by shelterwood cutting and control of deer density. Journal of Forestry 79(1):22–26.
55. Kessler, Kenneth J., Jr. 1969. A basal stem canker of sugar maple. USDA Forest Service, Research Note NC-76. North Central Forest Experiment Station, St. Paul, MN. 2 p.
56. Kessler, Kenneth J., Jr. 1972. Sapstreak disease of sugar maple. USDA Forest Service, Forest Pest Leaflet 128. Washington, DC. 4 p.
57. Kessler, Kenneth J., Jr. 1972. Sapstreak disease of sugar maple found in Wisconsin for the first time. USDA Forest Service, Research Note NC-140. North Central Forest Experiment Station, St. Paul, MN. 2 p.
58. Kessler, Kenneth J., Jr. 1974. Annual canker of sugar maple in northeastern Minnesota. Plant Disease Reporter 58(11):1042–1043.
59. Kessler, Kenneth J., Jr., and John H. Ohman. 1967. Sunscald canker of sugar maple. Phytopathology 57(8):817.
60. Kliejunas, John T., and James E. Kuntz. 1974. Eutypella canker, characteristics and control. Forestry Chronicle 50(3):106–108.
61. Knight, Fred B. 1969. Insect enemies. *In* Proceedings, Sugar Maple Conference, August 1969, Houghton, MI. p. 32-36. Michigan Technological University and USDA Forest Service.
62. Kriebel, Howard B. 1976. Twenty-year survival and growth of sugar maple in Ohio seed source tests. Ohio Agriculture Research and Development Center, Research Circular 206. University of Ohio, Wooster.
63. Kriebel, H. B. 1981. Personal communication.
64. Kriebel, H. B., and W. J. Gabriel. 1969. Genetics of sugar maple. USDA Forest Service, Research Paper WO-7. Washington, DC. 17 p.
65. Kulman, H. M. 1965. Effects of disbudding on the shoot mortality, growth and bud production in red and sugar maple. Journal of Economic Entomology 58:23–26.
66. Kulman, H. M. 1967. Biology of the hard maple bud miner, *Obrussa ochrefasciella,* and notes on its damage (Lepidoptera:Nepticulidae). Annals of the Entomological Society of America 60:387–391.
67. Lancaster, Kenneth F., Russell S. Walters, Frederick M. Laing, and Raymond T. Foulds. 1974. A silvicultural guide for developing a sugarbush. USDA Forest Service, Research Paper NE-286. Northeastern Forest Experiment Station, Upper Darby, PA. 11 p.
68. Leak, W. B. 1975. Age distribution in virgin red spruce and northern hardwoods. Ecology 56(6):1451–1454.
69. Leak, W. B. 1978. Relationship of species and site index to habitat in the White Mountains of New Hampshire. USDA Forest Service, Research Paper NE-397. Northeastern Forest Experiment Station, Broomall, PA. 9 p.
70. Leak, William B., Dale S. Solomon, and Stanley M. Filip. 1969. A silvicultural guide for northern hardwoods in the Northeast. USDA Forest Service, Research Paper NE-143. Northeastern Forest Experiment Station, Upper Darby, PA. 34 p.
71. Logan, K. T. 1965. Growth of tree seedlings as affected by light intensity. I. White birch, yellow birch, sugar maple, and silver maple. Canadian Forestry Service, Department of Forests, Publication 1121. Ottawa, ON. 16 p.
72. McClenahen, James R. 1978. Community changes in a deciduous forest exposed to air pollution. Canadian Journal of Forest Research 8(4):432–438.
73. Marquis, David A. 1975. Seed storage and germination under northern hardwood forests. Canadian Journal of Forest Research 5:478–484.
74. Marvin, J. W., Mariafranca Morselli, and F. M. Laing. 1967. A correlation between sugar concentration and volume yields in sugar maple-an 18-year study. Forest Science 13(4):346–351.
75. Meteer, James W. 1969. Hardwood tree evaluation. *In* Proceedings, Sugar Maple Conference, August 1969, Houghton, MI. p. 104-111. Michigan Technological University and USDA Forest Service.
76. Metzger, Frederick T. 1977. Sugar maple and yellow birch seedling growth after simulated browsing. USDA Forest Service, Research Paper NC-140. North Central Forest Experiment Station, St. Paul, MN. 6 p.
77. Miller, William E., Kenneth J. Kessler, Jr., John H. Ohman, and John T. Eschle. 1978. Timber quality of northern hardwood regrowth in the Lake States. Forest Science 24(2):247–259.
78. North Central Forest Experiment Station. 1981. Data on file.
79. Nyland, Ralph D., and William J. Gabriel. 1971. Logging damage to partially cut hardwood stand in New York State. AFRI Research Report 5. State University of New York, Syracuse. 38 p.
80. Ohman, John H. 1969. Disease. *In* Proceedings, Sugar Maple Conference, August 1969, Houghton, MI. p. 37-51. Michigan Technological University and USDA Forest Service.
81. Ohman, John H. 1970. Value loss from skidding wounds in sugar maple and yellow birch. Journal of Forestry 68(4):226–230.
82. Ohman, John H., and Kenneth J. Kessler, Jr. 1964. Black bark as an indicator of bird peck defect in sugar maple. USDA Forest Service, Research Paper LS-14. Lake States Forest Experiment Station, St. Paul, MN. 8 p.
83. Ohman, John H., and Kenneth J. Kessler, Jr. 1969. How to prevent maple bark diseases. USDA Forest Service, Leaflet 9. North Central Forest Experiment Station, St. Paul, MN. 4 p.
84. Ohman, John H., Kenneth J. Kessler, Jr., and G. C. Meyer. 1969. Control of *Cryptostroma corticale* on stored sugar maple pulpwood. Phytopathology 59(6):871–873.
85. Olson, David F., Jr., and W. J. Gabriel. 1974. *Acer* L. Maple. *In* Seeds of woody plants in the United States. p. 187-194. C. S. Schopmeyer, tech. coord. U.S. Department of Agriculture, Agriculture Handbook 450. Washington, DC.
86. Perala, Donald A. 1974. Growth and survival of northern hardwood sprouts after burning. USDA Forest Service, Research Note NC-176. North Central Forest Experiment Station, St. Paul, MN. 4 p.
87. Pomerleau, R. 1946. Occurrence and importance of canker and rots in deciduous forests in Quebec. Phytopathology 36:408.

88. Powell, Douglas S., and E. H. Tryon. 1979. Sprouting ability of advance growth in undisturbed stands. Canadian Journal of Forest Research 9(1):116–120.

89. Rudolph, V. J., A. K. Quinkert, and J. N. Bright. 1964. Analysis of growth and stem quality in mixed hardwood plantings. Michigan Agricultural Experiment Station, East Lansing. Quarterly Bulletin 47(1):94–112.

90. Rushmore, Francis M. 1969. Sapsucker damage varies with tree species and seasons. USDA Forest Service, Research Paper NE-136. Northeastern Forest Experiment Station, Upper Darby, PA. 19 p.

91. Shetron, S. G. 1972. Site index curves for sugar maple in northern Lower Michigan. Michigan Technological University, Research Note 6. Houghton. 8 p.

92. Shigo, Alex L. 1963. Ring shake associated with sapsucker injury. USDA Forest Service, Research Paper NE-8, Northeastern Forest Experiment Station, Upper Darby, PA. 10 p.

93. Shigo, Alex L. 1965. Organism interactions in decay and discoloration in beech, birch, and maple. USDA Forest Service, Research Paper NE43. Northeastern Forest Experiment Station, Upper Darby, PA 24 p.

94. Shigo, Alex L., and Edwin vH. Larson. 1969. A photoguide to the patterns of discoloration and decay in living northern hardwood trees. USDA Forest Service, Research Paper NE-127. Northeastern Forest Experiment Station, Upper Darby, PA. 100 p.

95. Shigo, Alex L., William B. Leak, and Stanley M. Filip. 1973. Sugar maple borer injury in four hardwood stands in New Hampshire. Canadian Journal of Forest Research 3(4):512–515.

96. Shortle, W. C., J. B. Kotheimer, and A. E. Rich. 1972. Effect of salt injury on shoot growth of sugar maple, *Acer saccharum*. Plant Disease Reporter 56(11):1004–1007.

97. Siccama, Thomas G. 1974. Vegetation, soil and climate on the Green Mountains of Vermont. Ecological Monographs 44(3):325–349.

98. Simmons, Gary A., and Fred B. Knight. 1973. Deformity of sugar maple caused by bud feeding insects. Canadian Entomologist 105:1559–1566.

99. Solomon, Dale S., and Barton M. Blum. 1967. Stump sprouting of four northern hardwoods. USDA Forest Service, Research Paper NE-59. Northeastern Forest Experiment Station, Upper Darby, PA. 13 p.

100. Stearns, Forest W. 1969. Wildlife pressures. In Proceedings, Sugar Maple Conference, August 1969, Houghton, MI. p. 51-59. Michigan Technological University and USDA Forest Service.

101. Stoeckeler, J. H., and G. W. Jones. 1957. Forest nursery practice in the Lake States. U.S. Department of Agriculture, Agriculture Handbook 110. Washington, DC. 124 p.

102. Stone, Douglas M. 1977. Fertilizing and thinning northern hardwoods in the Lake States. USDA Forest Service, Research Paper NC-141. North Central Forest Experiment Station, St. Paul, MN. 7 p.

103. Stone, Douglas M. 1977. Leaf dispersal in a pole-size maple stand. Canadian Journal of Forest Research 7(1):189–192.

104. Taylor, F. H. 1956. Variation in sugar content of maple sap. Vermont Agriculture Experiment Station, Bulletin 587. University of Vermont, Burlington. 39 p.

105. Trimble, George R., Jr. 1965. Improvement in butt-log grade with increase in tree size, for six hardwood species. USDA Forest Service, Research Paper NE-31. Northeastern Forest Experiment Station, Upper Darby, PA. 15 p.

106. Trimble, George R., Jr. 1967. Diameter increase in second-growth Appalachian hardwood stands-a comparison of species. USDA Forest Service, Research Note NE-75. Northeastern Forest Experiment Station, Upper Darby, PA. 5 p.

107. Trimble, George R., Jr. 1973. The regeneration of central Appalachian hardwoods with emphasis on the effects of site quality and harvesting practice. USDA Forest Service, Research Paper NE-282. Northeastern Forest Experiment Station, Upper Darby, PA. 14 p.

108. Tubbs, Carl H. 1965. Influence of temperature and early spring conditions on sugar maple and yellow birch germination in Upper Michigan. USDA Forest Service, Research Note LS-72. Lake States Forest Experiment Station, St. Paul, MN. 2 p.

109. Tubbs, Carl H. 1968. The influence of residual stand densities on regeneration in sugar maple stands. USDA Forest Service, Research Note NC-47. North Central Forest Experiment Station, St. Paul, MN. 4 p.

110. Tubbs, Carl H. 1973. Allelopathic relationships between yellow birch and sugar maple seedlings. Forest Science 19(2):139–145.

111. Tubbs, Carl H. 1977. Age and structure of a northern hardwood selection forest, 1929-1976. Journal of Forestry 75(1):22–24.

112. Tubbs, Carl H., and Louis J. Verme. 1972. How to create wildlife openings in northern hardwoods. USDA Forest Service, North Central Forest Experiment Station, St. Paul, MN. 5 p.

113. U.S. Department of Agriculture, Forest Service. 1964. The causes of maple blight in the Lake States. USDA Forest Service, Research Paper LS-10. Lake States Forest Experiment Station, St. Paul, MN. 15 p.

114. Von Althen, F. W. 1977. Planting sugar maple; fourth-year results of an experiment on two sites with eight soil amendments and three weed control treatments. Canadian Forestry Service, Department of Fisheries and Environment, Report O-X-257. Sault Ste. Marie, ON. 10 p.

115. Wang, B. S. P. 1974. Tree-seed storage. Canadian Forestry Service, Department of Environment, Publication 1335. Ottawa, ON. 32 p.

116. Ward, James C., and Richard M. Marden. 1965. Sugar maple veneer logs should be graded for pith flakes. USDA Forest Service, Research Note LS41. Lake States Forest Experiment Station, St. Paul, MN. 4 p.

117. Ward, W. W., J. V. Berglund, and F. Y. Borden. 1966. Soil-site characteristics and occurrence of sugar maple canker in Pennsylvania. Ecology 47(4):541–548.

118. Webb, D. Paul. 1976. Root growth in *Acer saccharum* Marsh. seedlings: effects of light intensity and photoperiod on root elongation rates. Botanical Gazette 137(3):211–217.

119. Wendel, G. W., and W. J. Gabriel. 1976. Sugar maple provenance study: West Virginia outplanting 6-year results. *In* Proceedings, Twenty-second Northeastern Forest Tree Improvement Conference, 1974. p. 163-171.

120. Westing, A. H. 1966. Sugar maple decline: an evaluation. Economic Botany 20(2):196–212.

121. Williams, Robert D., and Sidney H. Hanks. 1976. Hardwood nurseryman's guide. U.S. Department of Agriculture, Agriculture Handbook 473. Washington, DC. 78 p.

122. Winget, Carl H. 1969. Apparent defect in second-growth tolerant hardwood stands in Quebec. Forestry Chronicle 45(3):180–183.

123. Witter, J. A., and R. D. Fields. 1977. *Phyllobius oblongus* and *Sciaphillus asperatus* associated with sugar maple reproduction in northern Michigan. Environmental Entomology 6(1):150–154.

124. Yawney, Harry W. 1969. Artificial regeneration. *In* Proceedings, Sugar Maple Conference, August 1969, Houghton, MI. p. 65-74. Michigan Technological University and USDA Forest Service.

125. Yawney, Harry W. 1976. The effects of four levels of shade in sugar maple seedling development. (Abstract) *In* Proceedings, Fourth North American Forest Biology Workshop. p. 189-190. State University of New York, College of Environmental Science and Forestry, Syracuse.

126. Yawney, Harry W., and Clayton M. Carl, Jr. 1968. Sugar maple seed research. *In* Proceedings, Twentieth Anniversary Nurserymen's Conference, September 1968, Delaware, OH. p. 115-123. USDA Forest Service, Northeastern Area State and Private Forestry, Upper Darby, PA.

127. Yawney, Harry W., and Clayton M. Carl, Jr. 1970. A sugar maple planting study in Vermont. USDA Forest Service, Research Paper NE-175. Northeastern Forest Experiment Station, Upper Darby, PA. 14 p.

128. Yawney, Harry W., and J. R. Donnelly. 1981. Clonal propagation of sugar maple by rooting cuttings. *In* Proceedings, Twenty-seventh Northeastern Forest Tree Improvement Conference, 1979. p. 72-81.

129. Yawney, Harry W., and J. R. Donnelly. 1982. The vegetative propagation of sugar maple. *In* Summary of Sugar Maple Research at the George D. Aiken Laboratory. Chapter 9, p. 61-70. USDA Forest Service, General Technical Report NE-72. Northeastern Forest Experiment Station, Broomall, PA.