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Sugar Maple Research:

Sap Production, Processing, and Marketing of Maple Syrup



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Introduction

Prefaces such as this often say something to the effect that we have recently generated a large mass of new and practical information and that there is a lot more coming. In a somewhat restrained sense this is true for the sugar maple sap and syrup industry because a combination of new technology and disruptive economic events have combined to vastly alter traditional methods.

For example, the advent of inexpensive plastic tubing and fittings has greatly reduced the labor involved in sap collection and has, simultaneously, permitted the use of vacuum pumps to increase the amount of sap extracted and lengthen the period of sap collection. The end of the era of cheap fossil fuels created an immediate need for more energy-efficient methods of reducing maple sap to syrup. Improvements are being made in conventional evaporators, and with entirely new methods of removing water from sap.

In addition, the vastly increased cost of energy has made the maple industry more acutely aware than ever of the need for higher sugar concentrations in maple sap. Some trees consistently produce sap much higher in sugar concentration than average. Hence considerable effort is being expended to achieve higher sap-sugar yields by silvicultural manipulation and genetic selection. Progress has been made recently in these areas.

The strong demand for maple syrup and the development of new markets, far from the point of production, created a need for information about maple syrup consumers. Surveys in cities throughout North America have provided information about consumers—their buying and use habits, attitudes about syrup and packaging, flavor preferences, and reactions to pricing policies.

The evolution of research effort into something of practical value is one of the most satisfying aspects of our work. We desire, all of us, to become applied scientists—immediately if possible. Yet we tend, collectively, to forget how long and hard the work must be before application is achieved. We also tend to forget, or overlook, the element of chance that is nearly always involved in research achievements; plastic tubing for example. Once plastic tubing was available it was predictable and inevitable that it would be used in sap collection with the help of some applied research.

It should be evident, therefore, that the advances of the last couple of decades, which are bringing new methods and understanding to the maple industry, are well rooted in the previous work of many individuals and organizations, some far afield. It is, of course, our obligation to share that understanding. The following papers attempt to consolidate the body of knowledge we possess about maple sap collection, processing, and marketing, and to stimulate the search for more.

Abstract

This report summarizes sugar maple research at the Northeastern Forest Experiment Station's George D. Aiken Sugar Maple Laboratory in Burlington, Vermont, covering: (1) sap extraction and collection, including information on the sap flow mechanism, tapping and plastic tubing pipeline systems, and management of the sugarbush; (2) genetic improvement of the sugar maple tree for sap-sugar production; (3) propagation and planting, including the rooting of sugar maple cuttings; (4) economics of maple sap and syrup production (which examines sap collecting systems, evaporator designs, and alternate methods of processing sap into syrup); and (5) the marketing structure of the maple syrup industry.

Note

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Section I

Sugar Maple Sap Extraction and Collection

Chapter 1

Release of Sap Sugar and Control of Sap Pressure

by
Robert A. Gregory

Wood Structure

To understand what controls sap sweetness and what causes sap to flow from a taphole, a knowledge of the structure of sugar maple wood and the individual wood elements is essential.

Most of the wood in healthy, uninjured maple stems is sapwood, consisting of living and dead cells functioning in various ways (Gregory 1978).

The sapwood is largely saturated with water containing low concentrations of many organic and inorganic substances. In plant tissues, water can move practically anywhere and in any direction; but in tree species such as maple, rapid long-distance transport from root tips to leaves is confined to long, wide contiguous vessels, scattered in the fibrous ground tissues of the wood or xylem (Fig. 1-1). When functional, the vessels are dead. In sugar maple they may be up to 60 cm long and 0.12 mm wide, and normally conduct water for many years. Sap flows from severed vessels bordering a taphole.

Most of the sapwood in sugar maple is a fibrous groundmass (Fig. 1-1) consisting almost entirely of narrow, thick-walled, axially elongate, fusiform elements. Most of these fibers are dead, their lumens empty, and they function primarily in mechanical support. A few fibers in stem wood, mostly next to vessels, are living.

Vascular rays are a prominent feature of sugar maple wood (Fig. 1-1). They are the horizontal conduits for translocatable substances, and they extend from the living bark (phloem) through the wood. They also function as storage sites for reserve materials, mostly starch in maple stems. Under certain conditions it is converted to sucrose, the principal sugar in maple sap. Rays vary in size, each consisting of many radially elongate living cells.

Elements of the phloem and xylem are produced by the vascular cambium, a tissue surrounding the stem, positioned between the phloem and xylem, and generally considered to be one cell wide. There are two cell types in the cambium, which are referred to as "initials": fusiform initials, and ray cell initials. The former give rise to the axial elements of wood (e.g., vessel segments and fibers); the latter produce cells that compose the rays.

Ray cell initials may occupy from less than 10 to more than 30 percent of the surface area of the cambium in sugar maple. Thus the amount of ray tissue per unit of xylem, or the relative amount of ray tissue, can vary within a tree, and between trees (Gregory 1977, Morselli et al. 1978, Wallner and Gregory 1980), and the amount of this storage tissue appears to be related to the amount of sucrose in xylem sap (Morselli et al. 1978, Wallner and Gregory 1980). We know that the relative amount of ray tissue is amenable to silvicultural manipulation (Gregory 1977). Increasing the rate of wood production (cambial activity) increases the ratio of ray cell initials to fusiform initials so that the wood produced subsequently contains more ray tissue, which means more space for starch storage. Cambial activity can be increased by releasing trees from competing vegetation (thinning), by fertilization, or by a combination of

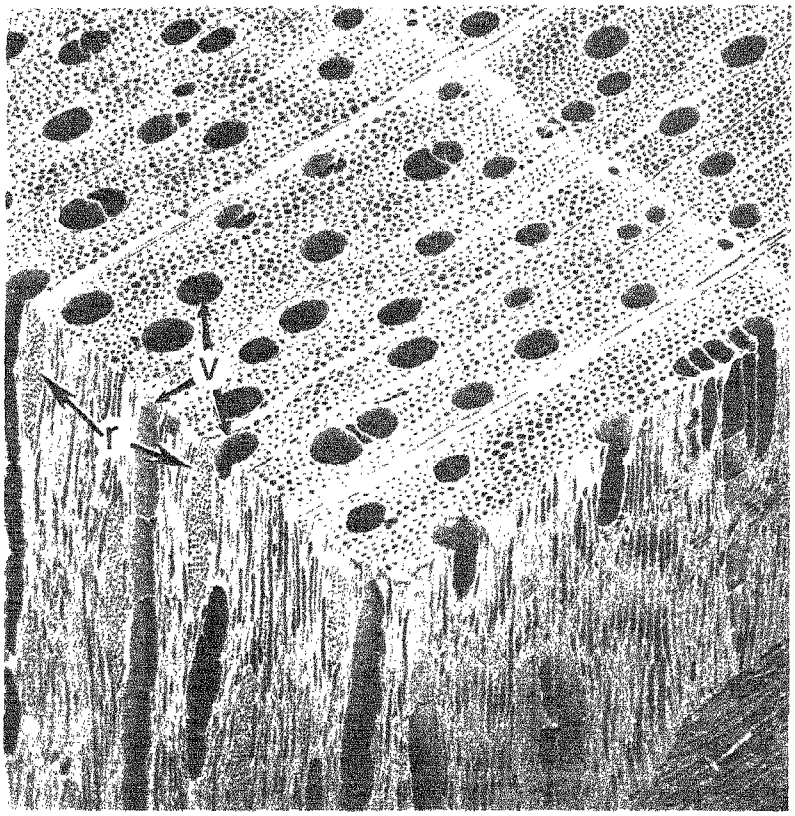


Figure 1-1.—Scanning electron micrograph of sugar maple wood. The vessels (v) and vascular rays (r) are embedded in a ground system consisting mostly of empty, nonliving fibers. (Courtesy Dr. W. A. Cote, N. C. Brown Center for Ultrastructure Studies, College of Environmental Science and Forestry, State Univ. of New York, Syracuse).

these silvicultural techniques. Possibly, some trees are inherently capable of producing more ray tissue than others. Thus it may be possible to manipulate starch storage genetically.

Contact cells are elements in axial and ray tissues of sapwood. They are living cells that border vessels, and can be recognized by large paired pitted areas between the two cell types (Figs. 1-2 and 1-3). The pit pairs are separated by a membrane that is part of the outer wall of each cell (Fig. 1-3), and is porous to sap and most sap solutes. It has been reported (Sauter et al. 1973) that contact cells are involved in loading vessel sap with sucrose, as will be described shortly.

Microscopic examination of fresh sections of maple sapwood shows that the lumens of the nonliving fibers contain gas bubbles, which can be seen throughout the fibrous groundsystem (Wiegand 1906, O'Malley 1979). The gas is probably CO_2, a product of respiratory activity. The rest of the nonliving tissues, including the spaces between structural fibrils of the cell walls (cell wall capillaries), are filled with xylem sap. The abundance of trapped gas bubbles in maple wood appears to be important in the mechanism regulating sap pressure. As far as we know, they are not common in north temperate woody plants, at least not to the extent that they have been observed in maple.

Sap Sugar

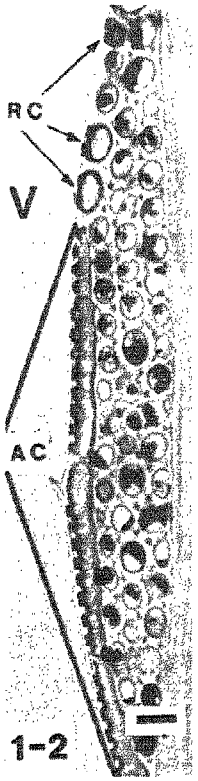
Sucrose, the principal sugar in maple sap, appears in xylem water of sugar maple from late fall through early spring (Sauter et al. 1973), a period that coincides with the dissolution of stored starch in the vascular rays. Sauter (1966) found the following seasonal changes in starch content of vascular rays in aboveground organs of young *Populus* trees in Germany:

1. A maximum content in early autumn, shortly after leaf abscission;
2. A period of increasing dissolution of starch in late fall and winter;
3. A minimum content in winter;
4. Resynthesis of starch at the end of dormancy;
5. A maximum in early spring;
6. Dissolution of starch during the period of bud swelling and unfolding of leaves;
7. A minimum of starch after the unfolding of leaves at the beginning of the vegetation period;
8. A period of starch deposition during the growing season.

The trend in sugar maple shoots seems similar (Marvin et al. 1971) with resynthesis as in (4) above beginning in early April, and reaching a maximum, as in (5) above, in mid-April in Vermont. Sauter found that changes in starch content in *Populus* can be induced by temperature change. Starch synthesis occurred between 5° and 10°C; breakdown occurred above and below this range. Cultured tis-

sue of sugar maple showed a significant reduction in starch at 4° and 6°C (Marvin et al. 1971). The dissolution of starch, therefore, can and does occur at relatively low temperatures. It has been observed, for example, that late winter sap-sugar concentrations are higher than those in late fall (Koelling 1968). It has also been observed (Taylor 1956) that sap-sugar concentrations decrease toward the end of the sap season, a period that coincides with the resynthesis of starch at the end of dormancy as noted in (4) and (5) above.

The movement of sucrose from storage tissues into the xylem sap has been thought to depend on the unique physiological activity of contact cells. Sauter et al. (1973) reported that increased enzyme activity in contact cells was restricted to the time when sucrose appeared in the vessels, and that secretion of sucrose depended on the metabolic energy generated by these enzymes. Subsequently, however, Sauter (1980) acknowledged that the enzyme-inhibiting effect of p-chloromercuribenzoate, used earlier (Sauter et al. 1973) to test the effect of contact cell enzyme inhibition on sucrose accumulation in vessels, could have reduced membrane permeability as well as enzyme activity, thus limiting sucrose release into vessels by the former effect rather than the latter. Passive leakage of sucrose into vessels could result from the damaging effects of repeated freezing and thawing on the cell membranes, because passive leakage seems more probable during cold winter periods when enzyme activity is limited (Sauter 1980). Although little is known about the exact mechanism of sucrose release from the contact cell protoplast into the vessels, it is possible to speculate about what controls sap-sugar concentrations.



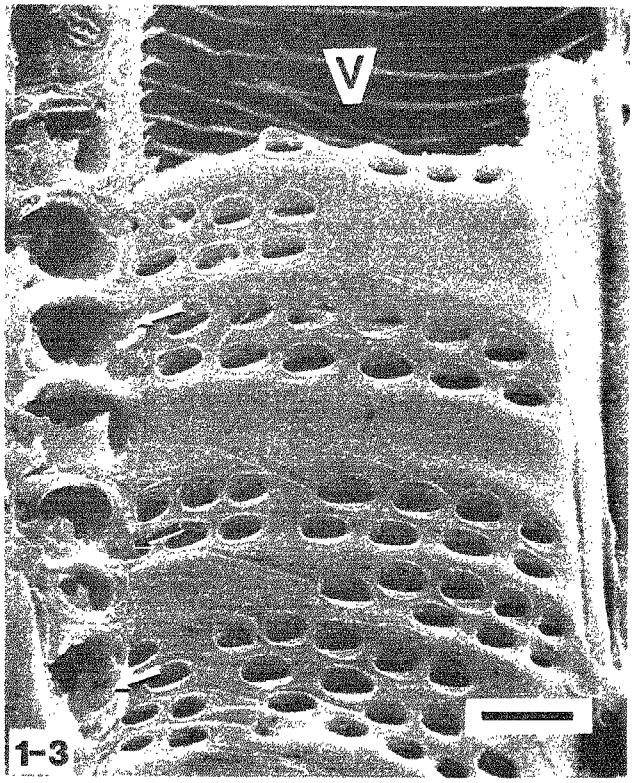


Figure 1-2.—Tangential view of axial contact cells (AC) and ray contact cells (RC) bordering a vessel (V). The black bar is 10 μm long.

Figure 1-3.—Details of pitting between ray contact cells (left) and a vessel segment (V). The large contact pits of the vessel can be seen in the outer vessel wall where the bordering ray has been broken and torn away. They are separated from the shallower paired pits of the ray cells by the pit membranes (arrows). The black bar is 10 μm long. (Courtesy Mr. Barry S. Faigel).

For example, it is logical that the amount of starch storage space should affect sap-sugar concentrations as noted above. However, it seems obvious that other factors are also involved (Wallner and Gregory 1980). It has been observed that sap sugar concentration is low after growing seasons when conditions for photosynthate production were poor; for example, after defoliation (Jones et al. 1903). It is also conceivable that a vigorous, fast-growing tree might use so much currently produced photosynthate that stored starch would be limited to considerably less than the storage capacity of the rays, in which case a large storage volume might not promote relatively sweet sap. The number of contact cells bordering the vessels could also be a factor, and one that would relate to the amount of ray tissue: the more ray tissues, the more ray-to-vessel contact—hence more sucrose permeation area per unit of vessel wall.

Certainly, the enzyme systems are implicated, and their respiratory activity, upon which the release of sucrose may depend, seems temperature-dependent. Sauter et al. (1973) observed that the amount of sucrose released into vessels increased with rising temperature, reaching a maximum at 22°C, and declining thereafter.

Finally, all types of variations in the enzyme systems, either inherent or environmentally induced, could affect the rate of starch dissolution and sucrose secretion. A better understanding of the sucrose release mechanism in maple xylem may be gained from studies of other systems. For example, xylem contact cells seem similar to specialized cells that have a significant role in loading and unloading sucrose during long-distance phloem translocation.

Sap Pressure

That sap flows from severed wood elements of sugar maple because the pressure in the wood exceeds that of the atmosphere has been known for more than 100 years (Clark 1875). A pressure gradient from the stem to the atmosphere permits sap to flow. Lowering atmospheric pressure with a vacuum pump steepens the gradient, or creates a gradient when one would not otherwise exist—the advantage of tubing and vacuum pumps in sap collection.

Pressures at the base of maple stems seldom exceed one to two atmospheres above ambient pressure during periods of sap flow. Therefore, pressures in the upper crown of mature trees must rarely, if ever, exceed ambient pressure, because the hydrostatic gradient of nonflowing xylem water in dormant trees is about 0.1 atmosphere per meter of height, or greater if any water is lost by evaporation or transpiration. Thus, if the pressure at the base of a tree is two atmospheres, that at 10 m would be one atmosphere at most along the same track, approximately equal to ambient pressure. At heights above 10 m, the sap would be in tension.

What controls sap pressure? Presumably, if we knew this we could more accurately predict the time and rate of sap flow, improve the methods of sap collection, and perhaps manipulate the pressure mechanism.

Jones and his colleagues (1903) found that stem pressure is likely to rise above and fall below that of the atmosphere when air temperatures fluctuate around 0°C. Usually, as daytime temperatures rise above freezing, stem pressures exceed atmospheric; they drop below atmospheric on cold nights.

Wiegand (1906) was one of the first to speculate about the mechanism controlling sap flow. He noted that the high pressures in maple differed from those in birch and grape species; the former depend on temperature, the latter on root phenomena. Wiegand discounted the expansion of gas, water, wood, or combinations of these as causes for pressures exhibited in maple in favor of some sort of system directly associated with living cells of the xylem. He noted, significantly, that "except when the temperature is rising past the vicinity of 0°C, the pressure is very moderate or slight."

Stevens and Eggert (1945) made two additional observations: (1) that a water supply to stems was essential for normal sap flow; and (2) that a cooling period, later referred to as the "conditioning period" by Marvin (1958), was necessary for the uptake of water.

Marvin and Erickson (1956) noted that variations in sap flow were most closely related to the severity and duration of freezing, and that twig temperatures correlated best with sap flow. They also observed that temperatures prevailing on the day of the flow appeared to have a "triggering" effect: "flows characteristically begin after a rapid temperature rise above freezing."

Recently, Sauter (1974) revised the idea that the gas in fibrous ground tissue was directly involved in creating the high sap pressures in maple. He reasoned that because the solubility of CO_2 in water changes tremendously with temperature, marked changes in sap pressure could result. According to Sauter, "warming the CO_2-saturated water will always lead to a considerable increase in pressure (because less CO_2 can be kept in solution), and cooling will cause a decrease in pressure." In other words, Sauter speculated that pressure created by insoluble CO_2 in the fibrous tissue compresses the vessels of the water-conducting system, and when these vessels are severed, as in a taphole, sap will flow from them. Cooling allows CO_2 to be reabsorbed, pressures drop below atmospheric, sap flow ceases, and the water-conducting system is recharged with water pulled in through the roots. There is some doubt, however, that the forces are great enough to compress the vessels (O'Malley 1979), for Marvin (1949) found that diameter changes in sugar maple wood were minute. Nonetheless, it is also possible that the insoluble CO_2 could cause increased pressure by displacement of water rather than by vessel compression.

Most recently there have been major contributions to our understanding of the conditioning and triggering responses by Dr. John A. Milburn and his students.[1] Milburn began experimenting with *Acer saccharum* in the United States and continued this work with his students after returning to the University of Glasgow. They conducted extensive experiments on the mechanism of sap flow and pressurization in sycamore maple (*Acer pseudoplatanus*) culminating in a Ph.D. dissertation (O'Malley 1979) and several manuscripts by Milburn and O'Malley that are presently (1981) in advanced stages of preparation. They found that sap uptake during the conditioning period was biphasic (Fig. 1-4). The first phase (Fig. 1-4, a-b), before freezing, is believed to result from contraction of gas and liquid and dissolution of gases. The reverse of this process, upon warming, could account for a slight in-

[1] Personal communications with Professor John A. Milburn, present address: Dept. of Botany, The University of New England, Armidale, N.S.W., Australia.

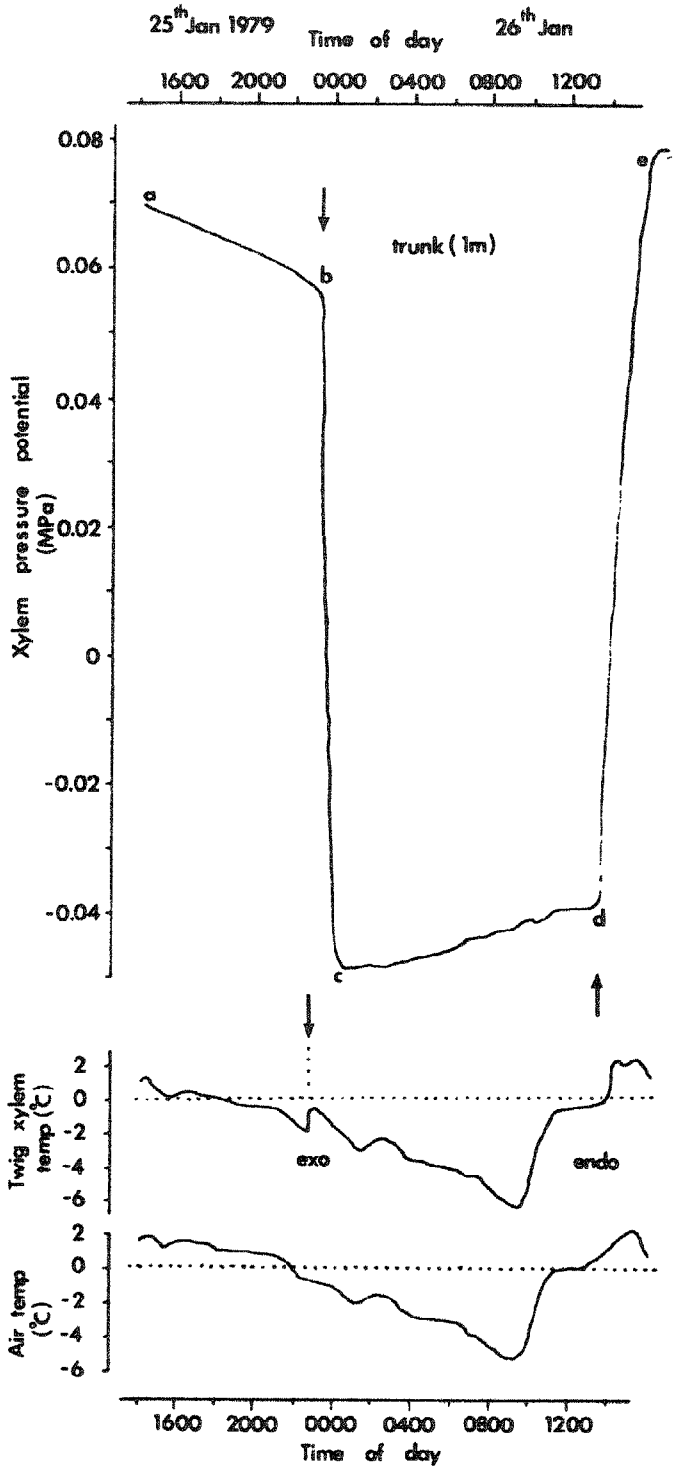


Figure 1-4.—A record of sap pressure in an *Acer pseudoplatanus* tree growing near Glasgow, Scotland. See text for detail. (Courtesy Prof. J. A. Milburn and Dr. P. E. R. O'Malley. Redrawn from O'Malley 1979).

crease in pressure caused by displacement of water by gas, as suggested above. This would account for sap flow in the absence of freezing. The second phase (Fig. 1-4, b-c) which is associated with freezing, is much more dramatic, and was previously unreported. A sudden large drop in pressure, from above to below atmospheric, is coincident with sap freezing, as noted by the exotherm in the temperature record. The resulting tension was maintained, almost unchanged, until twig thawing (endotherm), which triggered an increase in pressure greater than that present before freezing. O'Malley observed this sequence of events repeatedly in dormant mature trees, and in excised branches under simulated conditions in the laboratory. There can be little doubt that recharging of xylem water results from sap freezing, and that subsequent high pressures, sufficient to induce sap flow, occur upon thawing.

Milburn and O'Malley suggest the following mechanism to account for these occurrences (Fig. 1-5). The gas-filled fibers are an essential component. Initial cooling before freezing causes gas contraction and dissolution into the sap of the fiber wall capillaries, developing gas tension within the fiber lumen. A slight absorption of sap occurs, wetting the inner wall surface, causing high humidity of the entrapped gas. When freezing occurs, free water crystallizes on the inner wall surface but not within the wall capillaries because here the freezing point is lowered by surface adsorption effects. Because the loss of heat to the surrounding air causes a radially oriented temperature gradient, freezing is expected to occur first on the cooler outer wall. Further growth of ice depends on the temperature gradient between the surrounding air and xylem sap which, in turn, thermodynamically induces movement of water toward the freezing sites. Thus, according to Milburn and O'Malley, stem tension and the uptake of water are induced, basically, by the removal of heat to the atmosphere. Supercooled sap releases latent heat, stem temperature rises,

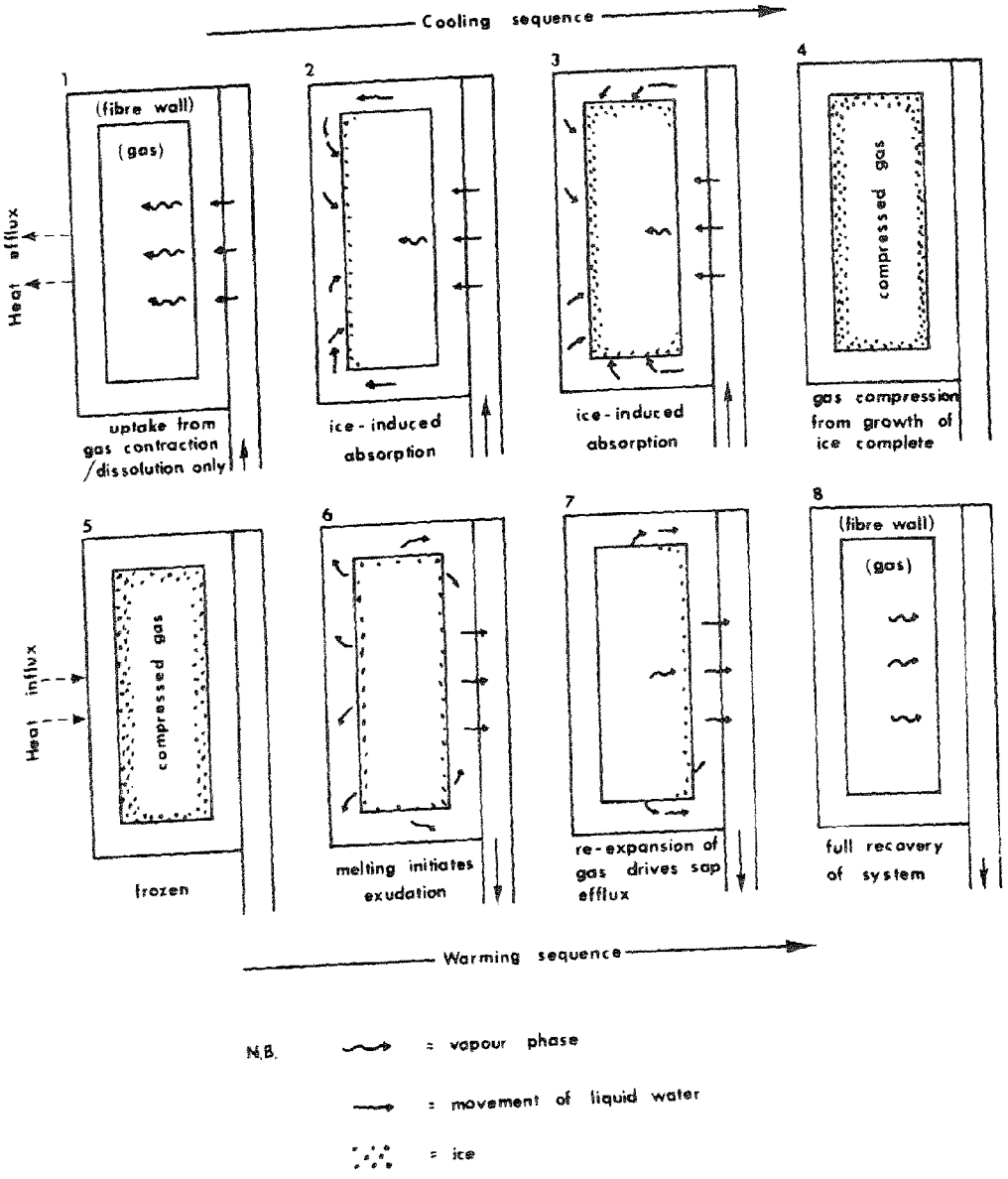


Figure 1-5.—Depiction of the hypothetical freezing-thawing processes in a maple fiber. See text for detail. (Courtesy Prof. J. A. Milburn and Dr. P. E. R. O'Malley. Redrawn from O'Malley 1979).

and a temperature differential, governing the rate of ice growth, is established between the stem and the atmosphere. The ice, when it has formed completely around the inner fiber wall, compresses the gas within the fiber lumen (Fig. 1-5,4). Absorption of water from deeper unfrozen tissues, and ultimately from the soil, continues until ice growth stops; that is, until a temperature gradient between stem and atmosphere no longer exists. Thawing reverses the process, triggering an abrupt increase in pressure from reexpansion of the compressed gas in the recharged reservoir of the sap wood. Movement of water in a basal direction will also occur from gravitational effects, resulting in considerable hydrostatic pressure toward the base of the tree. Apparently, the relatively high concentration of sucrose prevents leakage, or reverse osmosis, from the roots.

It is the volume of water pulled into the sapwood during the conditioning period that determines how much will be available for exudation. O'Malley (1979) lists several factors that may affect this process, including "severity and duration of freezing, availability of gas sites, relative tree crown size, exposure, resistance to sap movement within the stem, permeability of roots". In addition, the amount of soil water and its state (frozen or unfrozen) appears to be important, judging by the poor sap season at the end of the "snowless" 1979-80 winter in the northeastern U.S.

The mechanism, as envisioned by Milburn and O'Malley, is purely mechanical; living cells are not directly involved. It seems clear, however, that considerable gas, presumably from respiratory activity of living cells, must be present in the fibers for the expansion of sap and growth of ice to occur. Indeed, Milburn and O'Malley found that the response to freezing was a function of the percentage water content of the wood, with sap tension decreasing as water content increased. At 55 to 60 percent water content there was a reversal of the freeze response; freezing induced an increase rather than a decrease in pressure at these and higher values, most likely because there were not enough gas pockets for the compression or dissolution needed to cushion the expansion of water upon freezing.

Milburn and O'Malley recognize that high sap-sucrose content could be linked indirectly with the potential for high sap pressure. Such a relationship has been reported (Marvin et al. 1967). If the loading of sucrose depends on metabolic activity, then a consequence of contact cells loading sucrose at a greater rate would be more CO_2 from this activity, and hence the likelihood of increased freeze absorption. Yet, during the growing season, when contact cells are presumably quiescent, and there is little or no sucrose in the sap (Sauter et al. 1973), the gas bubbles in the fibrous tissues seem as abundant as ever on microscopic observation. Also, Milburn and O'Malley found that stem segments excised during the growth season responded to freezing and thawing precisely as those from dormant trees. Possibly, relatively high concentrations of sucrose might be effective in reducing leakage, or reverse osmosis, of water from roots; thus accounting for the relationship between sap pressure and sap-sugar concentration. Nonetheless, two important questions remain. Where does the gas in the sapwood fibers of maple species come from? Why is it so abundant?

Practical Implications

Our knowledge of the loading of sucrose and pressurization of xylem sap has practical significance.

Increasing the cambial activity of mature trees by thinning, fertilization, or both appears promising as a means of increasing starch storage and, hence, sap-sugar concentration. The application of this technique is being tested.

Another possibility that is being examined is that some trees are genetically capable of producing more ray tissue than others. A rapid field technique for observing relative ray abundance has been developed and is being employed to locate trees that may be genetically superior in this respect.

It seems obvious that the volume of sap contained in a tree—which is a function of stem and branch diameters, and crown size—would govern rate and quantity of sap flow. Again, maintaining fast growth and a large crown would be favorable. The loss or destruction of conducting sapwood by disease, wounding, or any other factor would be detrimental.

Availability of soil water is important. Anything that impedes water uptake is detrimental to sap yield. Examples are soil compaction and damage to roots by livestock, soil freezing, or soil water depletion. A lack of soil water during the conditioning period reduces subsequent sap yield. Alternatively, one would expect water uptake during the conditioning period to be enhanced by unusually low temperatures of long duration, provided that soil water was available.

Forecasting sap sweetness and yield may be possible to some extent. For example, reduction of photosynthetic capacity by insect defoliation or drought suggests that sap-sugar concentration will be considerably lower than average the following sap season.

Finally, as the sap season progresses and air temperatures rise, starch should be assimilated with a concomitant decline in sap-sucrose concentration. Existing evidence indicates that sap from midseason, or slightly earlier, is the sweetest and, therefore, the most valuable.

Acknowledgment

I wish to thank Professors Martin H. Zimmermann and John A. Milburn for their review and helpful criticism of the manuscript.

Chapter 2

Sugar Maple Tapholes

by
Russell S. Walters
and
Harry W. Yawney

The sap, or "sweet water," of the maple tree will flow from a taphole when the internal pressure of the tree is greater than the atmospheric pressure (Fig. 2-1). The amount of sap that can be collected is extremely variable. Robbins (1960), in a review of past literature, cites a range in average annual yield per taphole from 4-1/2 to 15 gallons of sap. He also reports a figure of his own—19 gallons per taphole annually over a 5-year period.

Some of this variation is due to differences in the sap production potential of the individual tree, but a good share is attributable to characteristics of the taphole, such as its diameter and depth.

Because maple sap may flow in the fall when weather conditions are right, some producers have advocated fall sap collection. This was suggested as a way of increasing the overall production of sap from a sugarbush. However, tapholes drilled in the fall were found to produce only about half as much sap as those drilled in the spring (Koelling 1968). Also, sugar concentrations from fall tapping were only about two-thirds of those expected from a spring tapping. In addition, trees that had been tapped in the fall produced only about two-thirds of a normal spring yield when retapped the following spring. Fall tapping for sugar production is therefore not recommended; the limited amount of sugar collected in the fall does not appear to justify the damage done to the tree by drilling the extra taphole (Walters and Smith 1972a). Collecting sap in the fall with a vacuum pump was no more successful than collecting it with buckets; therefore, fall vacuum pumping is also not recommended (Smith and Snow 1971, Smith and Snow 1972b).



Figure 2-1.—Tapholes are drilled into sugar maple trees usually in the early spring, to take spouts like this one.

Taphole Drilling

Tapholes should be drilled as close to the beginning of the spring sap flow season as possible. This is difficult to judge. Early warm weather does not always occur every year on the same date, nor at the same time in all parts of the maple region. If trees are tapped too late, early sap flows may be missed; if they are tapped too early, the taphole may "dry out" before the season ends. If the tree is tapped when it is frozen, it may be seriously damaged because the bark is apt to split when the spout is driven in (Walters 1978a).

Tapholes are drilled either by hand with a carpenter's brace or with a portable power drill (gasoline or electric) (Fig. 2-2). They should be drilled with a slight upward pitch, about 10°, to facilitate sap drainage. If the holes are pitched downward, ice crystals forming in the taphole may loosen the spout, allowing sap to leak out around it. Loosening of the spout also allows air to leak into a vacuum system, reducing its effectiveness (Walters and Shigo 1978b).

Taphole Diameter

Jones et al. (1903) reported that larger diameter tapholes yield greater amounts of sap—about 11 percent more for a 1/8-inch increase in diameter. Robbins (1965), however, found no significant differences in the sap yield among 7/16-, 11/16-, and 15/16-inch tapholes, but a significantly lower yield from a 3/8-inch taphole than from 7/16-inch and larger tapholes.

While drill bits of many different sizes were used to make tapholes in the past, the industry now uses a standard 7/16-inch-diameter bit for tapping, and spouts are designed for this size hole. It seems logical that the larger the taphole diameter, the greater the sap yield, as more sap-bearing vessels would be severed. But, it is also logical that larger diameter tapholes take longer to heal and close over. The 7/16-inch diameter was chosen as a compromise; it is big enough to produce a good amount of sap, but small enough to heal quickly.

Taphole Depth

Taphole depth is not as standardized as taphole diameter, and it should not be. A commonly recommended depth is 3 inches (Willits 1958). This is thought to be the optimum depth for maximizing quantity and sweetness of sap. Deeper tapholes will not yield much additional sap, and sap from deeper in the tree may have a lower sugar content (Gibbs 1969a). A maximum depth of 2-1/2 inches is better to reduce internal damage in the tree. But even 2-1/2 to 3 inches is too deep for many trees that have been heavily tapped or damaged in other ways. New tapholes should not be so deep as to break into compartmented discolored or decayed wood. If dark wood shavings come out of the hole when it is being drilled, it is too deep. Experience in tapping will help establish the best depth. When in doubt, make the tap-

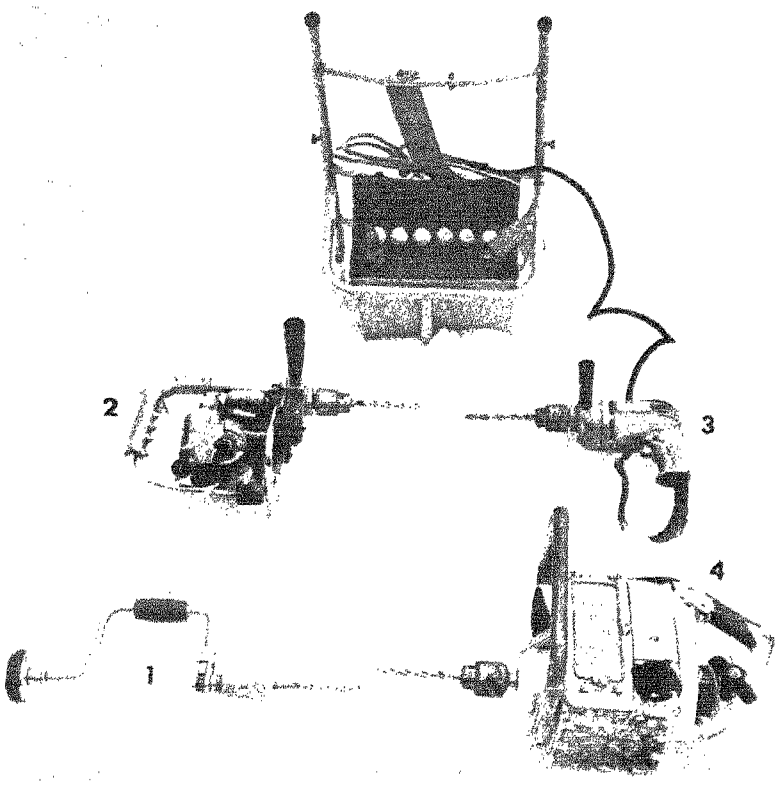


Figure 2-2.—Four types of tappers used to drill tapholes in sugar maple trees: (1) a hand auger; (2) a small gasoline-powered drill; (3) a battery-powered electric drill; and (4) a gasoline-powered chain-saw drill.

hole shallower, rather than deeper (Walters and Shigo 1978b).

If taphole depth is measured from the outside at the bark surface, the effective depth into the sap-producing wood will vary with bark thickness (Blum and Koelling 1967). The thickness of bark of the sugar maple was found to be positively correlated with the diameter of the tree at breast height (dbh), and ranged from 1/4 to 1 inch (Smith 1968, Smith 1969a). Using a metal collar on the drill bit is a common method for controlling taphole depth, but doesn't allow for easy adjustment for differing bark thicknesses. A method using easily removed washers on the drill bit with the collar was developed to help adjust to bark thicknesses (Koelling and Blum 1967).

Taphole Location

Tapholes for sap collection by buckets should be about 2 or 3 feet aboveground or snow level to facilitate handling of the buckets (Willits 1958). For sap collection by plastic pipeline, the taphole may be higher or lower, to fit into the configuration of the pipeline (Smith and Snow 1972a).

The location of tapholes in relation to cardinal direction, height aboveground, and position relative to root and crown features has been of much interest to sugar producers. The compass location of the taphole is not important (Robbins 1965). Although the warm (southerly) side is often favored, this is not justified. It is more important to not concentrate taphole damage on any one side of the tree, but take advantage of good sugar-producing wood on all sides (Walters and Shigo 1978b). Tapping trees under large branches, or over large roots, has not been found to increase sap yields (Moore et al. 1951, Robbins 1965). Tapping at different heights has had some effect: Jones et al. (1903) found that a taphole 4 feet aboveground outyielded tapholes at groundline and at 14 feet aboveground. Robbins (1965) also collected significantly less sap from a taphole 1 foot aboveground than from tapholes at 2 or 3 feet. The taphole 1 foot aboveground was also occasionally covered by snow.

Trees may be tapped year after year for many decades if the tapping is done properly. Improper tapping can seriously damage trees and reduce future sap yields (Fig. 2-3). A safe tapping pattern is to drill holes no closer than 6 inches, circumferentially, to an old taphole until after it has closed over. After new tree growth has closed over a taphole, it is safe to drill closer than 6 inches (Smith 1971a, Smith and Walters 1972). New and old tapholes should be staggered up and down the tree; they should not be in the same horizontal or vertical planes (Walters and Shigo 1978b).

Taphole Number

A sugar maple tree less than 10 inches in diameter, or 31 inches in circumference, at the tapping zone should not be tapped. Willits (1958) provides an often-used guide for the number of taps per tree. Another more conservative guide is suggested by Winch and Morrow (1962). These are:

Tree diameter in inches (Willits 1958)	*Tree diameter in inches* (Winch and Morrow 1962)	*Number of tapholes*
less than 10	less than 10	0
10 to 14	10 to 17	1
15 to 19	17 to 24	2
20 to 24	24 to 30	3
25 and over	30 and over	4

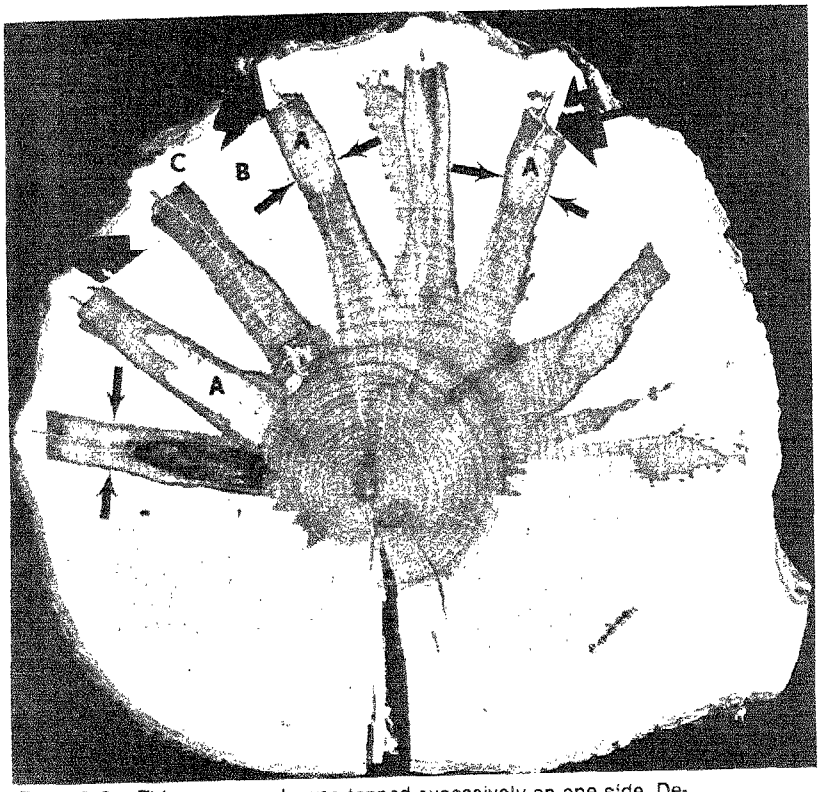


Figure 2-3.—This sugar maple was tapped excessively on one side. Decayed wood (A) was associated with some of the tapholes. Slightly discolored wood (B) formed between the tapholes. The arrows indicate the radial compartmentalization of the tapholes. The large arrows indicate the barrier zone. The clear wood (C) continued to develop after the tree was tapped. The boundaries of tapholes are often bright green in sugar maple.

If a tree has been extensively damaged or appears to be in unhealthy condition, the number of tapholes should be reduced. Poor tree vigor is indicated when tapholes do not heal and close within 2 or 3 years.

Spout Design

Robbins (1965) studied the effect of spout design on sap yield, and found no significant differences in yields among four common commercial types (Grimm, L'Hoir, Soule, and Warner). Other than this, few comparisons have been made. Metal spouts have remained basically unchanged for many years. Recently, plastic spouts have been designed specifically for use with tubing.

Almost all commercial spouts, including tubing spouts, have one common characteristic: A sizeable portion of the spout is inside the taphole when the spout is in use. The discovery by Gibbs (1969a) that the sweetest sap from a sugar maple taphole comes from the young xylem tissue near the bark suggested the need for a new design. In an attempt to extract this sweeter sap from near the bark, plastic spouts were modified by cutting a 1/2-inch-long slot in the top and bottom of the part that is inserted into the taphole. A comparison of these spouts with unmodified spouts did not show any differences in either sugar content or volume of sap collected (Rye and Walters 1977).

Taphole Damage

Tapholes are wounds. Damage occurs both inside and outside the tree adjacent to the taphole. Internally, wood is discolored in a streak about 1/2 inch wide which may extend up to 18 inches or more above and below the taphole. External damage results in the death of cambial tissues around the taphole. The wound injures the wood and exposes it to wood-destroying and other microorganisms. Most sugar maples can react effectively to some wounding without developing internal problems, but tapholes may be the source of internal problems that lead to extreme decay—even to death of trees. Trees may be tapped every year for many years if the tapping is done properly. Improper tapping (Fig. 2-4) can seriously damage trees and reduce future sap crops (Walters and Shigo 1978b).

Wound Reaction

When a taphole is drilled, the tree reacts to the wound by altering the normal internal processes of the living cells adjacent to the taphole. Substances used normally for the

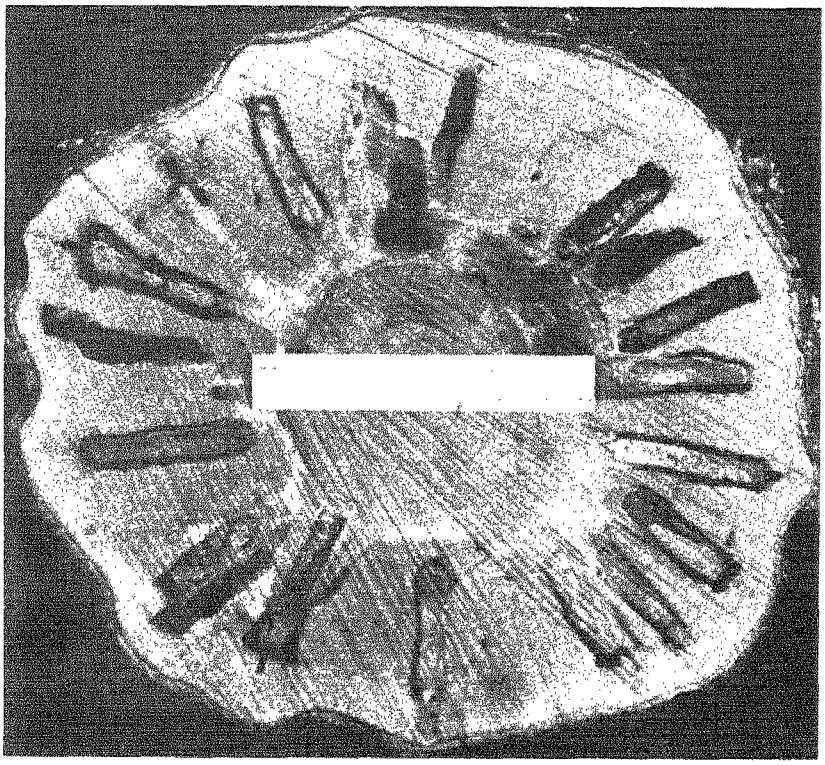


Figure 2-4.—This sugar maple was tapped heavily, and decay has developed adjacent to many of the tapholes. Although the decayed wood is compartmented, decayed zones in one part of the tree can greatly weaken the stem. Such trees are likely to fall during storms, or when heavily laden with snow.

maintenance of the tree are shunted to materials that have protective functions. This results in discoloration of the wood surrounding the taphole (Shortle et al. 1971, Tattar and Rich 1973). Very shortly after wounding, amorphous deposits, called amber plugs, form to block the vessels (Laing 1953, Rier and Shigo 1972). Sap will continue to flow from broken vessels until the plugs form.

Wounds in a tree do not heal in the sense that injured and infected tissues are replaced, repaired, or restored to their previously healthy state. Plant pathologists have come to recognize that the changes in cellular chemistry associated with wounding wall-off, confine, or compartmentalize the injured area. This is similar to isolating damage in a battleship by closing hatches and sealing off the damaged compartments. In a tree, the extent and effectiveness of compartmentalization, vertically, laterally, and radially toward the center of the tree, will depend upon such factors as the general health and vigor and genetic makeup of the tree (Shigo et al. 1977). The size of the compartment associated with the taphole is indicated by the length and width of the stain column. Generally, extension of the compartment outward toward the bark of the tree is confined to the last growth ring in which the injury occurred. New wood that forms the year after injury is not affected. Details on compartmentalization have been reported by Shigo and Hillis (1973), Shigo (1976b), and Shigo and Marx (1977).

Infection by microorganisms occurs soon after tapping, but the protective chemicals produced by the cells surrounding the taphole inhibit infection by the decay-causing Hymenomycete fungi. However, other microorganisms such as nondecaying fungi and some bacteria can grow in the presence of those protective chemicals. These are referred to as pioneer microorganisms. Their action eventually alters the protective chemical system so that open wounds become susceptible to invasion by wood-decaying fungi (Shigo 1976a, Tattar et al. 1971). For this reason, it is important to use tapping methods and sugarbush management practices that will minimize taphole damage and speed taphole healing.

Cambial Dieback Around Tapholes

The cambial tissue surrounding the taphole often dies, resulting in elliptical wounds much larger than the original taphole (Fig. 2-5). After measuring dead tissue adjacent to 40 tapholes, Gibbs and Smith (1973) found it to average about 1 inch wide and about 3-1/2 inches long. These enlarged wounds take longer to close, and are therefore susceptible to invasion by decay-causing fungi for a longer time. In addition, the wider the wound, the greater the width of unproductive dead, discolored wood inside the tree. When tapholes close over rapidly, new layers of wood form, and the same area of the tree bole may be retapped sooner than if the taphole remains open.

Paraformaldehyde in Tapholes

Sap flow from sugar maple tapholes sometimes slows down and stops prematurely before the end of the sap flow season, limiting sap production. Microorganisms have been suspected as a major cause. Evidence was provided by Sheneman et al. (1959) who reported a highly significant correlation between microbial counts in tapholes and sap yields.

The actual mechanism of taphole sap flow stoppage by microorganisms is not fully clear. Shene-

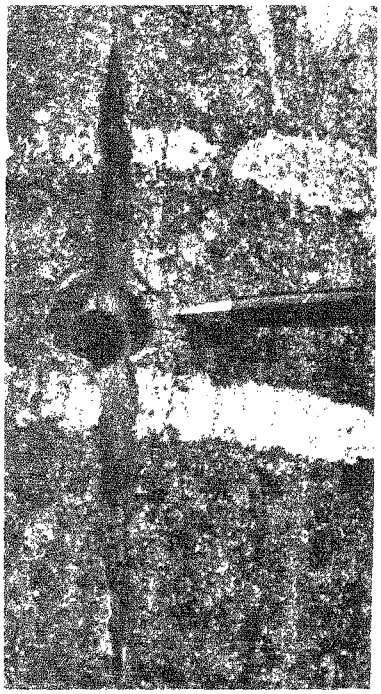


Figure 2-5.—A seriously damaged taphole. The bark split above and below the taphole. The dead cambium can be seen through the taphole and split in the bark.



Figure 2-6.—Paraformaldehyde pills are sometimes used in sugar maple tapholes to increase and prolong the sap yield. The pill is usually placed at the innermost end of the taphole.

man et al. (1959) suggested that microorganisms, which include the yeasts and molds as well as bacteria, created a physical blockage. Ching and Mericle (1960) concluded, however, that although blockage of the vessels in the taphole may be a factor, the major cause of sap flow stoppage may be invasion of living tissues by bacteria entering through pits along the cell walls. The presence of these bacteria in the living cells of the maple tissue may alter the physiological function of the cells so that normal sap flow is not possible.

Some years ago, the idea developed to control taphole-invading microorganisms with a growth inhibitor, or sanitizer. Many different compounds were tried. Because so many unrelated microorganisms were involved, the material had to have a very broad range of antimicrobial activity. Also, it could not affect the flavor or color of the syrup produced, and it had to volatilize or be destroyed during the sap boiling process. Paraformaldehyde was selected as the most promising for commercial use. Thus, 250 mg pills of paraformaldehyde became the standard maple-taphole sanitizer treatment (Fig. 2-6) (Costilow et al. 1962, Sheneman and Costilow 1959, Sheneman et al. 1959, Naghski and Willits 1955). Comparisons of sap volumes collected from paraformaldehyde-treated tapholes with those from untreated tapholes showed that the treated tapholes averaged 62 percent more sap over a 3-year period. The difference varied from year to year, but was greatest in a warmer sap season when conditions were more favorable to microbial growth.

Although paraformaldehyde increased sap yields, there was always the possibility of negative side effects. McArthur and Blackwood (1966) warned that continued use of paraformaldehyde (or any other chemical) in maple tapholes might damage the trees by poisoning. Later, Shigo and Laing (1970) suggested that paraformaldehyde caused considerable internal injury and questioned its long-term effects.

Two studies (Walters and Shigo 1978a, Walters and Shigo 1979) were subsequently done to determine the long-term effects of paraformaldehyde in tapholes. One study, started in 1970, used sugar maple trees in six different areas in Vermont. The second study, started in 1973, used sugar maple trees in Vermont, New York, Michigan, Maine, and Pennsylvania. The study technique compared a taphole treated with 250 mg paraformaldehyde with an untreated taphole on the same tree. Some of the study trees were dissected after 2 months and others at intervals over the next 5 years. The length of the stain column and decayed wood and the microorganisms associated with each taphole were recorded. These studies showed more decay (higher incidence and greater total length of column) associated with the paraformaldehyde-treated tapholes than with the untreated tapholes (Fig. 2-7).

Paraformaldehyde apparently interferes with the tree's wound-defense mechanism. Because the chemical kills wood cells so quickly, the protective chemicals that are antagonistic to the wood-decaying fungi may not form. Also, the development of plugs in the vessels is delayed, retarding compartmentalization of the taphole. Thus, paraformaldehyde increases susceptibility to rot.

Spout Effects

Sap collection spouts have a tapered end that, when properly driven into the taphole, forms a water- and airtight seal. Sometimes inserting the spouts will split the bark and xylem above and below the taphole.

Gibbs and Smith (1973) compared cambial dieback areas adjacent to tapholes using galvanized metal and plastic spouts. They found no differences in dieback areas attributable to the type of spout used. However, tapping and driving spouts into sugar maples

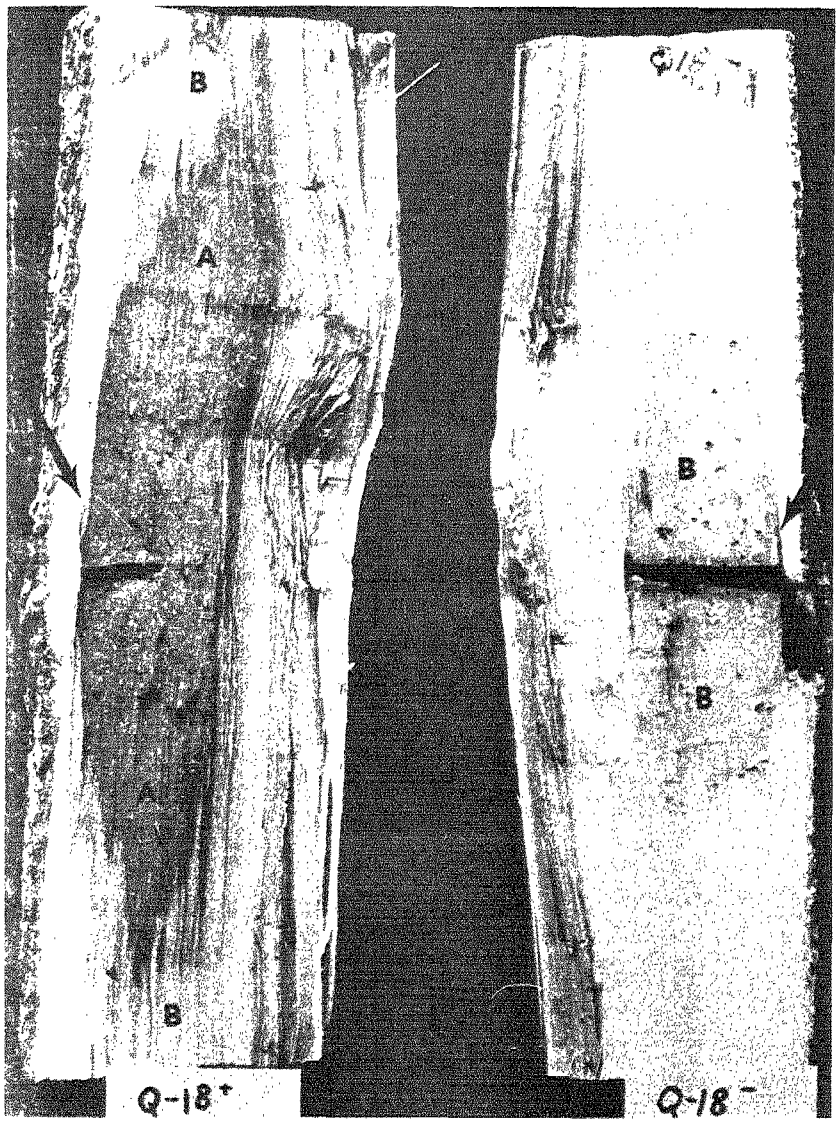


Figure 2-7.—Decayed and discolored wood is associated with the paraformaldehyde-treated taphole on the left; only discolored wood is associated with the untreated taphole from the same tree on the right. The arrows indicate the barrier zone between tissues formed before and after wounding. Decayed wood (A) is surrounded by discolored wood (B).

that were frozen did have an effect on taphole closure. Walters (1978a) reported that after 3 years, only 25 percent of the tapholes drilled into frozen trees were completely closed, compared to 80 percent healing of tapholes drilled into the same trees when they were unfrozen.

Tapping Equipment

In the past, tapholes were drilled with a brace and bit. Now, many producers use either battery- or gasoline-powered drills. Chainsaw engines have been fitted with drill chucks that revolve at extremely high speed (Fig. 2-8). Concern developed that such high-speed drilling might burn or scorch the taphole and reduce sap yield. Comparison of drill speeds from 120 rpm (hand auger) to 6600 rpm (chainsaw) indicates that sap yields were not affected. Further, no taphole scorching with any of the equipment was observed (Smith and Lamore 1971, Smith and Kelser 1971).

We also investigated the possibility that heavy, high-speed drills, such as a gasoline-powered chainsaw with a drill chuck, would contribute to greater cambial damage. We were concerned that vibration or the weight of the machine as the bit is being withdrawn from the taphole might cause the rapidly revolving drill bit to hit the bark at the edge of the taphole and rupture the cambium cells. However, we found no differences in taphole closure rate between holes drilled with a hand auger and those drilled with a chainsaw drill (Walters 1978a).

Care should be taken to insure that only very sharp drill bits are used to bore tapholes. A sharp bit will cut a clean-edged hole through the bark, reducing the probability of cambial dieback. A sharp bit will also slice the vessels intersected by the taphole cleanly, facilitating the flow of sap. In contrast, a dull bit will make a ragged hole; the vessels will be crushed and torn (Fig. 2-9). Ragged tapholes may restrict sap flow and facilitate infection by microorganisms (Walters and Shigo 1978b).



Figure 2-8.—Fast, gasoline-powered drills such as this did not affect the sap yield or closure rate of the tapholes drilled.

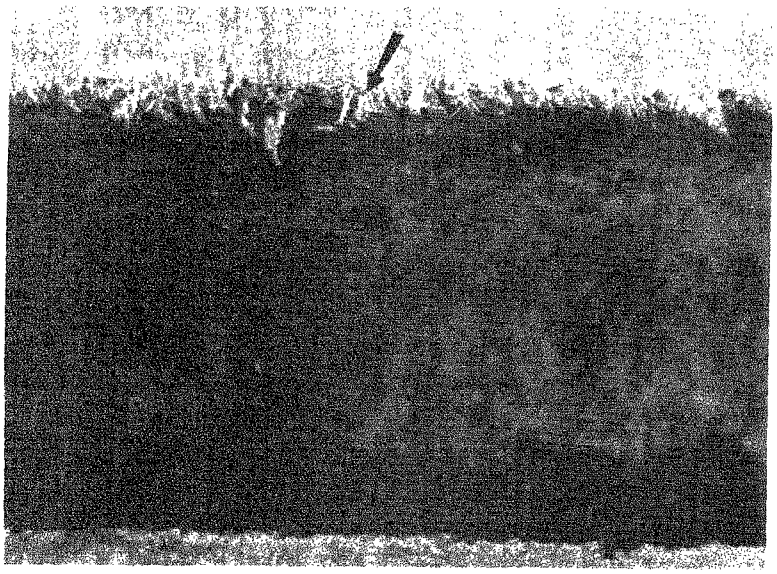


Figure 2-9.—This taphole was drilled with a dull bit. The arrow indicates where the vessels were crushed and torn, leaving a tangle of fibrous materials.

Promoting Taphole Closure

Taphole closure follows the same pattern as the healing of a pruning wound. Each year, a layer of callus tissue develops from live cambial tissue on each side of the taphole. With each successive layer, the callus converges toward the center of the taphole. The most important factors affecting tree-wound closure are tree vigor and wound size (Neely 1970). Thus, to promote taphole closure, the trees should be healthy and vigorous, and the taphole wound should be as small as possible.

Attempts to promote callus growth around tapholes with plant growth regulators have not been successful. Gibbs and Smith (1973) used traumatic acid; 2,4-dichlorophenoxy acetic acid; indo-3-acetic acid; and 2,4,5-trichlorophenoxy acetic acid, each at several rates.

Minimizing Taphole Damage

Decay begets decay

Before drilling, it is important to consider the condition of the tree and where on the bole the taphole is to be made. New tapholes should be located so as not to penetrate the discolored wood or stain column of an old compartment. Tapping into an old compartment will increase its size to include the wood surrounding the new taphole. This is to be avoided, especially if rot is associated with the old compartment. When a taphole penetrates decayed wood, rot will develop rapidly in the newly injured tissues (Fig. 2-10). This means that great care should be taken when tapping trees that have obvious columns of decayed wood. If tapholes are drilled in such trees, the holes should be shallow, and should not break the barrier wall surrounding the compartment of decayed wood. Even though each taphole becomes compartmentalized, there is a point at which stain columns will begin to coalesce when they approach each other internally. It is useless to tap discolored or decayed wood; such wood does not

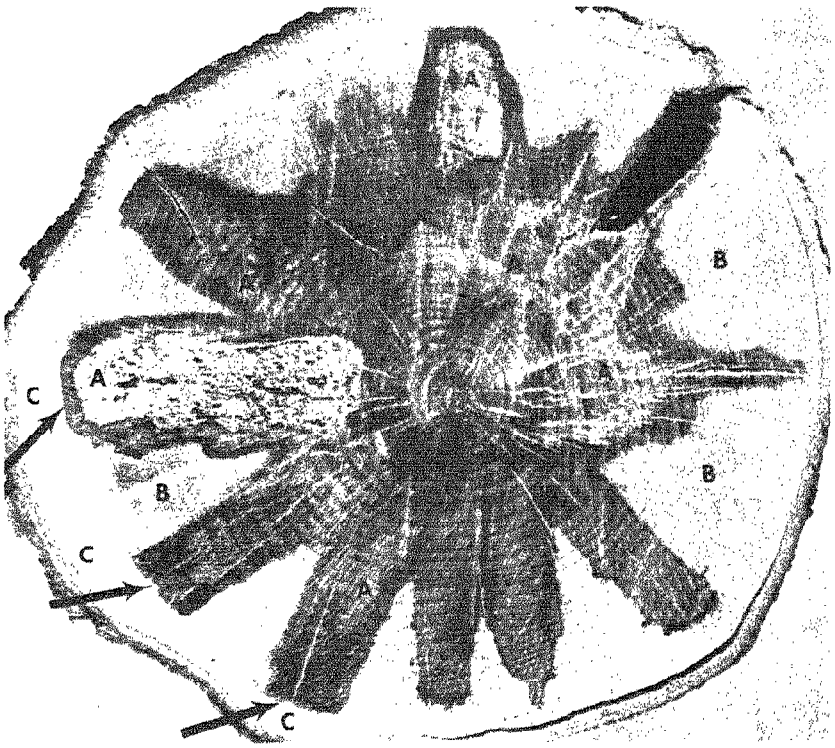


Figure 2-10.—This small sugar maple was tapped extensively. Decayed wood (A) is associated with many tapholes. Discolored wood was associated with all tapholes. When a new taphole penetrates decayed wood, the decay will develop rapidly in the newly injured tissues.

produce sap and may even yield ill-flavored water which will give the syrup produced an unwanted flavor (Walters and Shigo 1978b).

Hope for Injured Trees

A tree with many external wounds can survive for years as a productive sap producer. The effects of these wounds are minimal because compartmentation within the tree walls off its injuries. However, the tree may need some help. Of course, sugar maple trees, like all other organisms, get old and die and there is a time when little can be done to help them.

A tree with serious injuries may need a rest. This may mean fewer and shallower tapholes, or perhaps no tapholes for several years—a small price to pay to save a tree. A tree with a large central column of discolored and decayed wood surrounded by a narrow band of healthy whitewood can be tapped, but the taps should be shallow, as the compartment wall surrounding the injured tissue must not be broken.

Trouble Indicators

Sugar maple is one of the northern hardwoods that is most resistant to discoloration and decay, yet there are many defective sugar maples. Besides tapholes, there are a number of other causes of injury resulting in discoloration and decay. These include sugar maple borers, squirrels, porcupines, sapsuckers, human activity, and natural causes. Some of the more important decay-causing fungi in sugar maple are *Oxyporus populinus* (Schum. ex. Fr.) Donk, *Phellinus igniarus* (L. ex. Fr.) Quel., and *Inonotus glomeratus* (Pk.) Murr. There are many external signs that suggest when a sugar maple is in trouble. Lack of a healthy, vigorous appearance, small, sparse, yellowish leaves, reduced twig elongation, and dead twigs are some signs of trouble. Trees with many large basal wounds, badly trampled roots, large dead branch stubs, and broken limbs will usually have a large column of discolored or rotten wood. Other obvious signs of trouble are fungus fruit bodies, sugar maple borer wounds, and sapsucker damage (Shigo and Larson 1969, Walters and Shigo 1978b).

Chapter 3

Sugar Maple Sap Collection

by
Russell S. Walters



Figure 3-1.—The bucket (*left*) is the traditional sap collecting utensil and still widely used. The plastic bag (*right*) has replaced the bucket to some extent.

Sap Collection

Historically, collecting maple sap after it leaves the taphole has been one of the most difficult and costly steps in sugar making. It has been stated that when buckets are used, more than 40 percent of the labor in sugar making goes into sap collection (Jones 1962, Willits and Sipple 1961). Buckets are the traditional collection utensils, and are still widely used. Plastic bags have replaced buckets to some extent (Fig. 3-1). The most recent and innovative sap collection system is the plastic pipeline.

Bucket Collection

Buckets have been used for collecting sap since the very beginning of sugaring in this country—the only real changes being from wooden to metal and plastic buckets and the increased use of bucket covers. These changes added immeasurably to sap quality, and to the quality of the final product. Wooden buckets were hard to keep clean and free of sap contaminants. Covers help keep debris, rain, and snow out of the sap (Sproston and Lane 1953).

The most commonly used metal buckets are zinc coated and hold 15 quarts (Willits 1958). Minute amounts of zinc dissolve in the sap and help reduce microbial growth (Frank et al. 1959). Lead-coated metal or lead-soldered buckets and buckets painted with lead paint should not be used for sap collection because lead may dissolve in the sap and exceed safe levels in the resulting syrup. Aluminum buckets are popular in Canada and are considered very satisfactory (Willits 1958).

Plastic Bags

Plastic bags have been used to some extent in place of buckets. The bags keep the sap cleaner because they have narrow, covered openings, and because plastic ba are transparent, the sterilizing eff of ultraviolet light from the sun im proves sap quality. Under some c ditions, it will make sap practicall sterile (Naghski and Willits 1953, Winch and Morrow 1962, Sprostor and Lane 1953). Plastic bags are very light in weight, and because they store flat, occupy little room (Winch and Morrow 1962).

However, they also have disadvantages: they have narrow necks that prevent easy ice removal; they may be difficult to empty; seams may split, especially when a full bag freezes; their capacity is often too small to hold a full day's sap flow; chafing against rough-barked trees in a high wind may damage the bags; and squirrels are apt to puncture them to get at the sap (Winch and Morrow 1962).

Sap Gathering

Gathering sap, whether from buckets or plastic bags, is very laborious. Most often, a gathering tank on a sled or wagon is drawn through the sugarbush (Fig. 3-2). Each bucket is emptied into a gathering pail, and the pail is carried to the tank. Buckets may be emptied by taking them off the spout, or they may be rotated about the spout and emptied. Sap loss from spilling and missed buckets may be considerable. A system is needed to prevent missing a bucket or losing time checking an already emptied bucket. Some producers color-code their trees to identify the roadway from which the tree is to be serviced.

Another method requires boring two holes on opposite sides of each bucket and painting a stripe on one side. Each time a bucket is emptied, it is turned and hung from the hole on the opposite side. Whether the stripe is exposed or hidden readily indicates whether or not the bucket has been emptied (Willits 1958).

Pumps are sometimes used to reduce the hand labor involved in emptying buckets. A suction pump and hose are mounted on the gathering tank. The other end of the hose is taken to each bucket and the sap is pumped from them into the tank. This method eliminates handling the buckets, but requires a very open sugarbush with a good road system (Arnold 1957). It is especially useful in roadside operations.

Dumping stations can eliminate the movable sap-gathering tank. Dumping stations are simply large buckets or milk cans strategically located in the sugarbush so that buckets can be conveniently emptied into them. Sap flows by gravity through a plastic tubing network connecting the several dumping stations in the sugarbush to the sugarhouse or sap-storage tank (Barraclough 1947). Although this system is an improvement over previous systems, sap can probably be collected more efficiently by a complete tubing system in any sugarbush where dumping stations will work.

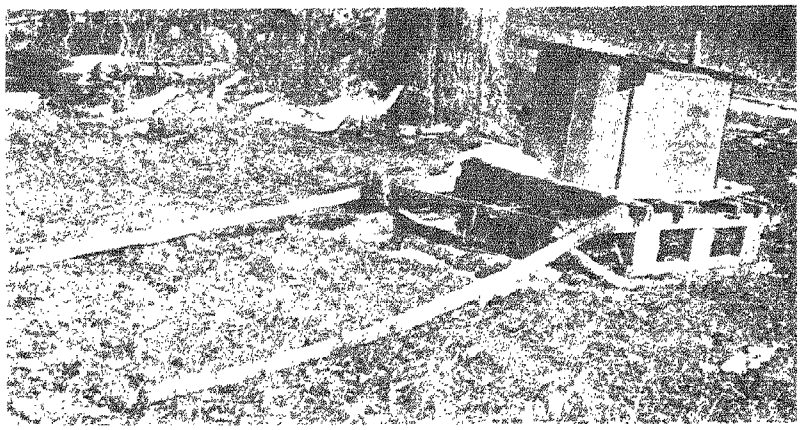


Figure 3-2.—Sap-gathering tank mounted on a horse-drawn sled.

Plastic Pipelines

Pipelines have been recognized for many years as a way to improve the efficiency of maple sap collection. The first improvement over the old bucket-and-wagon method was the dumping station system. A later refinement was the complete pipeline from spout to storage tank. An early version of this system was installed about 1930, using galvanized steel tubing supported by wires and stakes. The metal tubing leaked and was difficult to install, and never attained wide usage. Plastic pipelines (Fig. 3-3), which solved many of the problems, were developed in the 1950s (Griggs 1955, Willits and Sipple 1961).

Jones (1962) lists the advantages of the plastic pipeline as:

1. Permits a better distribution of labor during sugaring.
2. Effects a great reduction in the amount of labor necessary during sap collection.
3. Achieves more sanitary collection and transportation of sap.
4. Eliminates the costly building and upkeep of roads in the sugarbush.
5. Makes higher yields during sugaring possible by reducing infection in the taphole by airborne microorganisms.

Plastic pipelines were not immediately accepted. Some producers obtained excellent results; others could not make the system work satisfactorily and returned to using buckets. Early systems were installed like a high-pressure water line because sap sometimes issues from the tree under high pressure and could be forced through the pipeline (Griggs 1955, Willits and Sipple 1961). But sap can also flow from tapholes at a very low pressure, so tubing did not always perform as well as expected.

When first introduced, the tubing went directly from spout to spout, from tree to tree, then to a

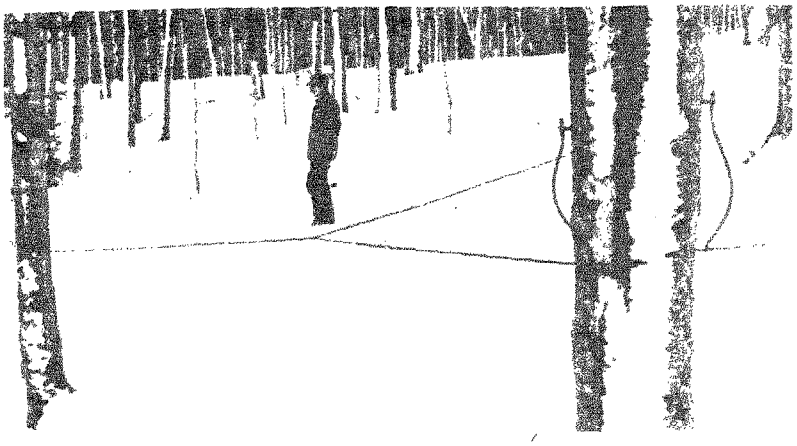


Figure 3-3.—Plastic pipeline systems for collecting maple sap were developed in the 1950s.



Figure 3-4.—The dropline carries sap away from the taphole, and prevents sap loss through reabsorption.

larger main line, and then to the storage tank. But during periods of weeping flows and when only a few trees are flowing, considerable quantities of sap may be absorbed by trees that are not flowing (Marvin and Greene 1959). Also, one taphole may be dripping sap while another taphole on the same tree may be reabsorbing it. Laing et al. (1964) reported that adding a dropline (Fig. 3-4) from each spout to the tubing system eliminated the reabsorption problem.

The value of the dropline was established, but other questions persisted. Should tubing be suspended (aerial) or laid on the ground? Should the system be vented or not? An aerial system is more difficult to install than a groundline, but it thaws earlier and freezes later, allowing a longer flow period, and it can traverse irregularities in topography smoothly. Groundlines may be more labor-efficient during installation where the topography is favorable, but they must be pulled from snow covering them in order to thaw, and they require much more care to avoid hollows and hummocks (Laing et al. 1964). Gas exuding from the tree along with sap forms so-called gas or vapor locks, often cited as a cause of sap flow restriction. Venting was recommended as a solution to this problem (Willits and Sipple 1961). Each of these ideas had its advocates, and the design of plastic pipelines became very confused.

Aerial or Groundline

It is difficult to compare aerial and groundline systems without also considering the question of venting. In general, sap yields from groundline systems were not significantly different from those of aerial systems (Fig. 3-5) (Laing et al. 1964, Smith 1969b, Smith and Gibbs 1971a, Smith and Walters 1971). However, unvented aerial systems seem to function better than similar unvented groundline systems (Koelling et al. 1968a).

The more important differences between the aerial and ground systems are in installation and maintenance. The suspended system is above the snow, and less likely to be blocked by ice. The groundline (Fig. 3-6) will absorb enough heat to bury itself in the snow and will need to be pulled up to the surface again almost daily. Installing a groundline is more than just laying tubing on the snow or ground. Depressions and hummocks must be avoided, as they create low points that can impede sap flow. Further, droplines must be long enough to reach the ground after the snow has melted, otherwise they can also create bumps in the line that will hinder sap flow. A uniform grade can be achieved in a properly installed taut aerial system if the trees are not too far apart. Excessive sag is difficult to avoid on very long expanses (over 30 feet) without intermediate supports, especially in warm weather. Groundlines require much more tubing than aerial systems (Laing 1971, Smith and Snow 1972a).



Figure 3-5.—Comparisons show that sap yields with a groundline did not differ significantly from yields obtained with aerial lines.

Venting Versus Non-Venting

Unvented or closed systems produce as much sap as vented or open systems, or more (Laing et al. 1964; Blum 1967, 1968). The unvented aerial system has an even greater advantage over the unvented ground system: Blum (1967) observed 43 percent greater yield from the closed system (Fig. 3-7). This increase was attributed to natural vacuum produced by sap flowing downhill in the closed system, creating an effect like a siphon which extracted additional sap from the tapholes.

Briefly, results of tubing experiments by Koelling et al. (1968a), Gibbs (1968), Gibbs (1969b), Smith (1969b), Smith and Gibbs (1971a), and Smith and Walters (1971), can be summarized as follows:

1. Natural vacuum, which will increase sap yield, can be developed in carefully graded unvented lines on sloping land.
2. Natural vacuum develops to a lesser degree in unvented groundlines than in unvented aerial systems.
3. With vented spouts, the method of tubing installation—aerial or groundline—makes little difference in total sap yield.

Recommended Tubing Systems

The closed dropline aerial system (Fig. 3-8) appears to be the most productive of the various installations tested. In this system, the lateral 5/16-inch tubing is usually hung 2 to 4 feet above the ground or snow level. Droplines 18 to 24 inches long are used to connect the spouts to the lateral line. The longer droplines are especially helpful on trees that have more than one taphole because they provide greater flexibility in locating new tapholes when reinstalling the tubing line. Lateral lines, in turn, are connected by manifolds or 4-way "Ys" into larger (1/2-inch or more) conduits or main lines to form an overall network for an entire sugarbush. Recommended installation methods and techniques have been published (Laing 1971, Smith and Snow 1972a, Lancaster and Walters 1973, Lancaster and Walters 1974).

Some of the advantages of the closed dropline aerial system are (Smith and Snow 1972a):

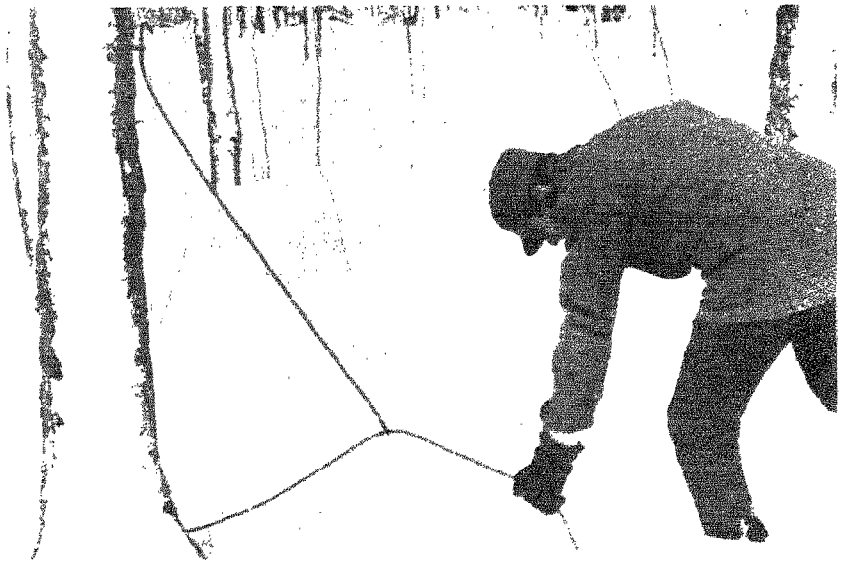


Figure 3-6.—Groundlines must be pulled out of the snow to the surface almost daily.

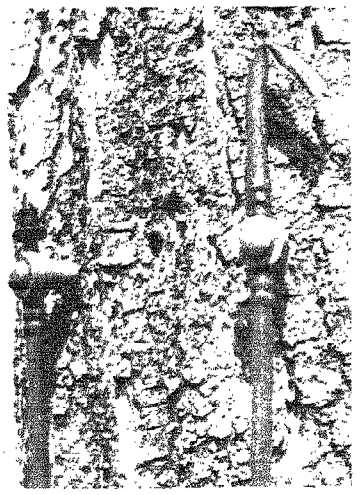


Figure 3-7.—The closed aerial system yielded 43 percent more sap than the companion open system.

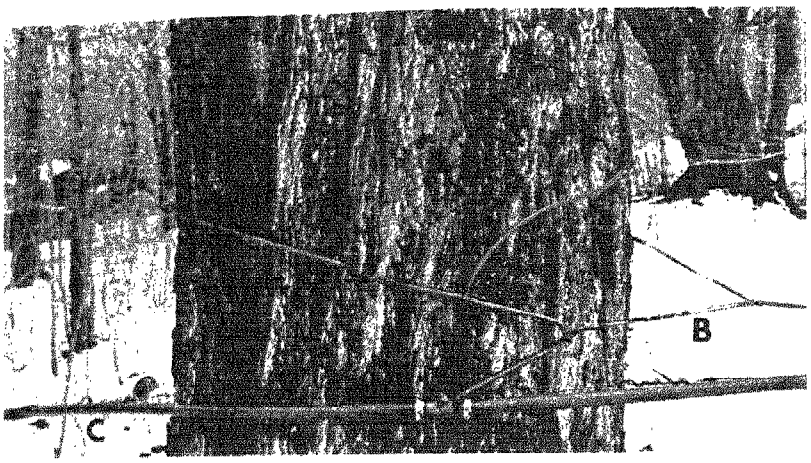


Figure 3-8.—The closed aerial dropline (*A*) system is recommended. Small lateral lines (*B*) that connect from tree to tree are joined to the larger conduit pipe (*C*) by a manifold (*D*).

1. Freezing problems are minimal because most of the lines are above the snow and thaw very quickly. Frozen tubing under the snow thaws very slowly.

2. The slope of the tubing line is easy to control.

3. A minimum amount of tubing is used per taphole.

4. Problem areas are easier to locate and correct.

5. Tubing can be used on nearly flat areas because the slope of the line can be regulated to a degree by the height of tapping.

Disadvantages of the system are:

1. It is harder to install than groundlines. To install the tubing properly, it must be stretched; but even after stretching, new tubing may develop sags. And, if tubing is stretched too tightly, it may separate from the fittings.

2. If the distance between the trees is great—say, 30 feet or more—the tubing may have to have intermediate supports to minimize sagging.

3. In some instances, freezing rain, ice, or wet snow can collect on the lines and damage them.

Commercial tubing produced specifically for the maple syrup industry has an inside diameter of 5/16 inch. This small diameter limits the number of taps the tubing can accommodate before it must be connected to a larger pipe, and this number will vary with the steepness of the slope in the sugarbush. Smith and Snow (1972a) recommended 20 to 50 taps per line on a 5-percent slope. Morrow (1972) suggested up to 80 taps on a 10-percent slope, and over 100 taps on slopes steeper than 10 percent. In actual practice, however, more than 80 taps are seldom put on a line because the line gets so long that it becomes difficult to handle (Walters 1975).

The lateral lines connecting the trees are, in turn, connected to larger main lines, 1/2 inch or more in diameter. As the system increases in size, it is necessary to use larger and larger main lines. The size of the main line is determined by the number of taps connected to it and its slope (Table 3-1) (Smith 1971b, Walters and Smith 1972b). For example, on a 6-percent slope a 1/2-inch main line can carry the sap from about 300 taps. Because of the steeper pitch, the same main line can have up to 900 taps on a 40-percent slope. A 3/4-inch main line has about double the capacity of a 1/2-inch line.

Vacuum Pumping

One of the early objectives of vacuum pumping was to help move sap through the lines. For example, Morrow (1963) stated that vacuum pumps aid in removing sap from the lines during slow runs, break air locks, and help clear the lines before night freezing, especially on level or undulating grades.

The discovery by Blum (1967) that natural vacuum resulted in increased sap yields led to the use of

Table 3-1.—Approximate maximum number of tapholes that can be used for collecting sap by gravity flow using various diameters of plastic tubing on a designated slope

Slope percent	Plastic tubing diameter, in inches					
	1/2	3/4	1	1 1/4	1 1/2	2
40	888	1,866	3,504	7,200	10,800	20,900
30	756	1,590	3,000	6,240	9,240	17,880
25	684	1,440	2,700	5,640	8,400	16,080
20	606	1,284	2,430	5,040	7,440	14,280
15	516	1,098	2,100	4,320	6,360	12,240
10	414	888	1,680	3,480	5,052	9,720
6	312	672	1,260	2,640	3,840	7,440

vacuum pumps for drawing additional sap from trees. It was shown that vacuum pumping may extract as much as 4 times as much sap as can be collected by gravity (Blum and Koelling 1968a, Smith and Gibbs 1970c). Morrow and Gibbs (1969) then found that vacuum pumping more than doubled sap yields from tubing installations on nearly level ground. A further benefit is that paraformaldehyde pills are not needed to maintain sap flow. Sap yields from pumped systems were not influenced by the use of the pill in the taphole (Smith and Gibbs 1970a, Smith and Gibbs 1970b).

The higher the vacuum in a tubing system, the greater the volume of sap. Walters and Smith (1975) reported that sap volumes collected at vacuum levels of 10 and 15 inches of mercury were significantly greater than those collected at a 5-inch vacuum. Although the 15-inch vacuum yielded more sap than the 10-inch level, the difference was not significant. Although, in theory, maximum yields will be obtained at the highest possible vacuum levels, there are practical limits to the levels that producers can or should obtain—limits imposed by the cost/benefit ratio of the vacuum pump to be used. An efficient vacuum system (Fig. 3-9) should maintain a vacuum level of at least 10 inches of mercury at the taphole. To be meaningful, the vacuum must be measured at the taphole or at the end of the tubing system away from the vacuum pump, and not at the pump itself (Smith and Rye 1970).

The actual vacuum level at the taphole may be considerably less than the level at the pump, especially if the distance from the sugarbush to the pump is 400 yards or more. This vacuum loss is due to friction and leaks in the pipe system. A vacuum-transfer system was found to yield 27 percent more sap than a vacuum system without the transfer tank (Walters 1978b). The vacuum-transfer system uses two tanks—one at the vacuum pump, and the other in the sugarbush (Fig. 3-10). Conduit lines from this tank branch out to the different sections of the sugarbush. Two pipelines connect the transfer tank to the vacuum tank: one pipe at the bottom of the tank carries sap, while another pipe at the top of the tank evacuates gases, creating a vacuum.



Figure 3-9.—An efficient vacuum system should maintain a vacuum level of 10 inches of mercury at the taphole. This gauge was connected to the spout in the taphole farthest from the vacuum pump.

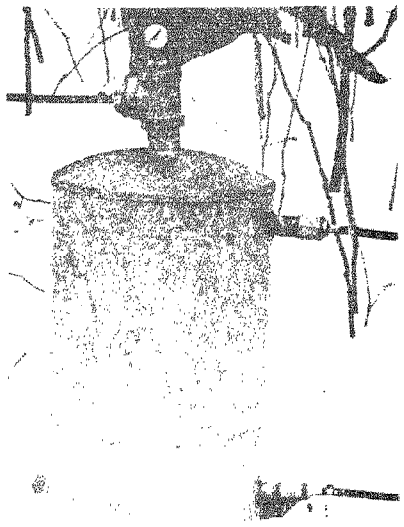


Figure 3-10.—The vacuum transfer is in the sugarbush. Sap flows from the tree on the left into the tank. The upper pipe on the right removes air from the tank, creating a vacuum; sap flows out through the lower pipe.

Pump Installation

Vacuum for a tubing network may be obtained from any of several types of pumping units. The wet and dry pumps are the two most common types. The major distinction between them is whether sap actually passes through the pump.

A wet pump is a small centrifugal pump that forces sap through a well jet containing a Venturi tube which creates vacuum in the pipeline. The centrifugal pump recirculates sap from a small reservoir replenished by sap from the field line attached to the Venturi tube. As additional sap is collected, the excess flows from the reservoir to a separate storage tank. This type of pump is very efficient, and will maintain a high vacuum level for a long period. One drawback is that during periods of low flow, sap in the reservoir may heat up from being recirculated through the pump. This may alter the chemical composition of the sap and reduce the quality of the syrup (Koelling 1970, Laing and Arnold 1971, Walters 1975).

Dry pumps (Fig. 3-11) are compressor-type pumps similar to those used in milking machines. The pump creates a vacuum in a separate tank to which the field tubing system is connected. As sap flows into the vacuum tank, it must be emptied periodically. One method is to release the vacuum and allow the sap to drain out (Staats 1972). Another method uses a water pump connected to the bottom of the tank and controlled by a float switch (Koelling 1970, Laing and Arnold 1971, Walters 1975).

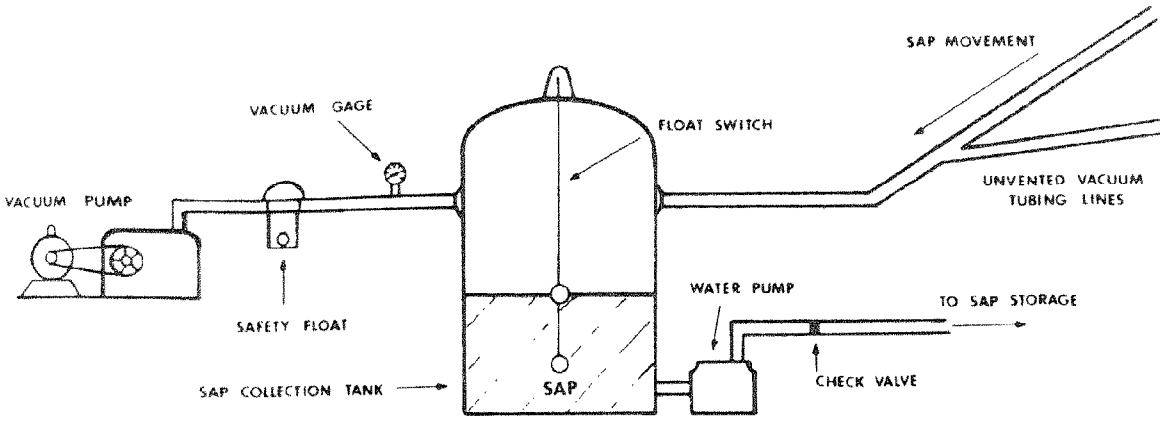


Figure 3-11.—Schematic of a dry-pump vacuum tank. The float switch inside the tank automatically controls the water pump that removes the sap.

Why Vacuum Increases Sap Yield

Vacuum pumps, when used in airtight, leak-free tubing systems, can more than double sap yields over buckets. Vacuum pumping accomplishes two things that account for this increase in production: it produces sap on days when sap would ordinarily not be running and it increases the rate of sap flow during normal flow periods.

It is well understood by sugarmakers that sap flow coincides with a rise in tree pressure which is triggered by a change in temperature from below freezing to slightly above freezing. And, when tree pressure is greater than atmospheric pressure, sap will flow. Vacuum pumping, by pulling air from the tubing system, has the effect of lowering the atmospheric pressure within the tubing—thus creating a pressure differential. Applied vacuum will work only when the differential between internal tree pressure and outside atmospheric pressure is within about 3/4 of an atmosphere.

Effect of Vacuum on the Tree

Maple sap is a complex solution of sucrose, other sugars, minerals, and organic compounds. A large proportion—about 96 percent of the dissolved solids—is sucrose (Willits 1958). For the most part, these solutes come from the living cells into the sap in the vessels. Because of the complexity of the constituents in maple sap and the mechanism by which sap enters the vessels, concern developed that vacuum might possibly increase the amount of water in the sap and dilute it. Various sap constituents might respond selectively to vacuum at the taphole, and sap composition might be altered. Possibly, vacuum could even cause the extraction of substances that do not normally appear in sap flowing from the taphole. Laing et al. (1971) considered these possibilities and concluded that, under normal conditions of gravity flow, only a small part of the available sap reaches the taphole, and vacuum as high as 25 inches simply removes more unaltered sap.

It seems unlikely that vacuum sap collection has any great effect on the structure or vigor of maple trees. Vacuum applied to tapholes did not affect the movement of dyed sap nor affect pressure readings from other tapholes 6 inches away horizontally in the same tree (Blum and Koelling 1968b). This implies that the vacuum's influence is vertical, through the vessel system, and thus does not affect any parts of the tree other than those that would normally be affected by any taphole. Vacuum applied to maple tapholes did not change the pattern or length of discolored wood columns: the columns adjacent to vacuum-pumped tapholes were neither longer nor shorter than those adjacent to other tapholes.[1] Trees from which sap has been collected under vacuum for 10 years or more do not show signs of reduced vigor (Laing 1971).

Syrup Quality

Maple sap is fragile and perishable. It can easily become contaminated and soured, resulting in dark syrup with an undesirable flavor (Naghski et al. 1957). Thus to minimize degrade, sap-collecting equipment must be kept clean. Buckets should be emptied after runs that are too short to produce enough sap to warrant collection, even though this is a time-consuming and expensive chore. If the buckets are not emptied, the sap can sour and reduce the quality of the sap

[1] Unpublished data, USDA Forest Service, Northeastern Forest Experiment Station, Burlington, Vermont.

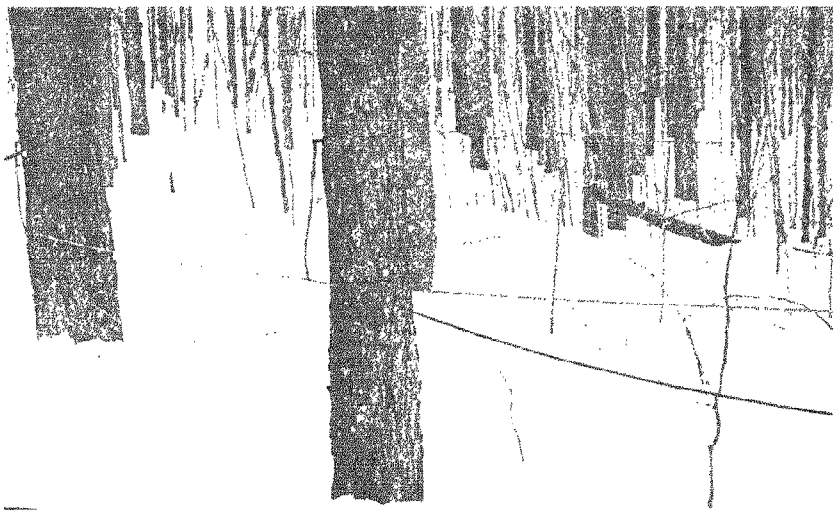


Figure 3-12.—Syrup made from the improperly installed tubing (sagging between trees) was usually darker in color than the syrup from the properly installed tubing, which doesn't sag between the trees and has a smooth configuration that facilitates sap flow downhill.

from the next sap run. Similarly, sap that remains in sags and low spots in a poorly installed tubing network may affect sap and syrup quality from later flows. Walters and Yawney (1978) found that syrup made from sap collected by properly installed plastic pipelines was consistently light-colored and of high quality during the entire season, whereas syrup made from sap collected by an improperly or carelessly installed pipeline varied greatly in color and quality from day to day (Fig. 3-12).

Equipment Sanitation

An extremely important and difficult problem for the sugarmaker is how to clean the equipment used. Sap as it comes from the taphole is sterile. However, during the tapping, handling, and installation of collection equipment (either buckets or tubing), a considerable number of microorganisms can be introduced (Willits et al. 1959). Proper cleaning of equipment will reduce this source of contamination.

Buckets are not difficult to clean, although the process is time-consuming. Because they are open and large, they are easy to clean with a brush and cleaning solution. An adequate washing solution is 1 gallon of laundry bleach (containing 5.25 percent sodium hypochlorite) mixed with 19 gallons of water (Foulds 1973). This should be followed by a rinse (Willits 1958, Wasserman 1963). If a detergent is used, several rinses are recommended.

Tubing is another story. Its small diameter makes it difficult to clean and rinse.

A recent step forward is the development of the "spool-type" tubing washer (Staats 1973), which works on the principle of Archimedes screw. The washer is easily assembled to fit an available tank, from parts that are easily and cheaply acquired, if not already on hand. The tubing, with or without the droplines attached but with all fittings uncapped, is rolled onto the spool. The spool, revolves slowly, partially submerged in the cleaning solution. The open fittings allow the solution to enter and flow through the tubing as the spool turns. After several hours, the spool is elevated and rotated so that the tubing drains.

Another method of cleaning the tubing uses a pump to force cleaning solution from a tank through a manifold connecting several rolls of tubing (Willits et al. 1959). The droplines are removed and tees capped.

Addition of a water-softening compound to the previously mentioned cleaning solution helps to make it more effective[1]. Use any commercially available water softener powder and follow the directions on the package.

Many tubing users prefer to leave their pipeline systems hanging in the sugarbush and clean them in place. The spouts are pulled from the tapholes and capped (plugs and caps are available from equipment suppliers). The pipeline system is filled with a cleaning solution, either by pumping from the bottom or by gravity from the top. Air is bled from the line at each spout so the cleaning solution reaches all parts of the lines. If slime molds and other deposits have built up inside the tubing, the cleaning solution should remain in the system for about a week before it is drained. The filling procedure is repeated with clear water to rinse out the system. The plugs are replaced to keep the interior of the pipeline clean. Droplines should not be left hanging where they may be susceptible to damage; they should be fastened to the lateral lines (Fig. 3-13) with either tape or a commercially available clip.

Coding the Tubing System

If the tubing is to be taken down for cleaning, it should first be marked or coded so that it can be reinstalled in the same position the following year. The coding system should be as simple as possible. It may use a color or number code painted on the first tree and the corresponding roll of tubing of each lateral line. A sketch map may prove helpful to record the locations of the lateral lines.

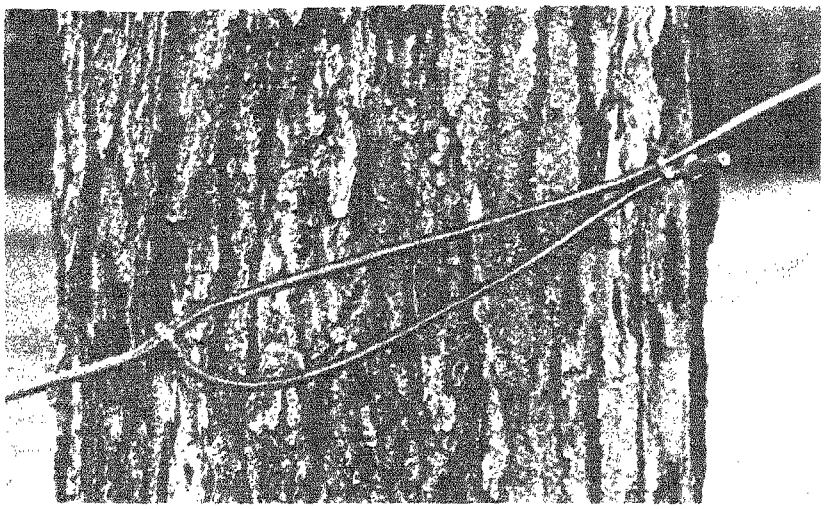


Figure 3–13.—Spouts should be plugged and the dropline secured to the lateral line after the sap-flow season if the tubing is to be left in the sugarbush all year.

Rules of Thumb for Estimating Supplies for the Installation of Tubing System

First, determine the number of taps the sugarbush will support. With this information, you can determine the numbers of:

1. Spouts.
2. Droplines (number of drops × length of drop = feet of tubing).
3. "Ts" (one for each taphole, plus 25 percent).
4. Connectors (two dozen per 1,000 taps).
5. Feet of 5/16-inch tubing (15 × number of taps).
6. 4-way "Ys" or manifolds (one per 100 taps).
7. Clamps (two per "Y" or manifold, plus 50 percent).
8. Clips (four per "Y" or manifold, plus 50 percent).
9. Storage tank capacity = 1 to 2 gallons per tap.

Chapter 4

Sugarbush Management

by Russell S. Walters



Figure 4-1.—Many of the sugarbushes in use today were developed from natural forest stands that occupied portions of the farm.

Most of the sugarbushes being tapped today developed from natural forest stands (Fig. 4-1). Differences in past cutting practices and land use have resulted in wide variation in the age, density, form and composition of these maple stands. Their development has been hit-or-miss, mostly from second- and third-growth stands of northern hardwoods. Many bushes are also being developed in young stands of sugar maple that were naturally seeded on abandoned agricultural lands (Gibbs and Smith 1970).

Another type of sugarbush or group of trees being tapped for sap might be referred to as nonforest sugarbushes (Fig. 4-2). They are often part of the pasture land on small dairy farms, are usually grazed, and look like orchards. Their environmental conditions, as well as tree development and growth, are quite different from those found in a forest. Other types of nonforest bushes include roadside and fenceline trees.



Figure 4-2.—Some sugarbushes are very sparse, and grow on parts of the pasture land on small dairy farms.

Planted sugarbushes are rare because of the many problems encountered in seed production and nursery rearing and the poor survival of planted trees. The development of superior genotypes and successful artificial regeneration practices will make the planting of sugar-producing orchards possible.

Because the structure of existing sugarbushes varies greatly, management needs for improving and developing them differ too. Some of the older sugarbushes need regeneration to provide replacement trees. Other sugarbushes need to be thinned or have their understories cleaned out. All-aged stands are often recommended because, once established, they provide a continuous supply of tappable trees. Even-aged stands, however, are considered easier to develop and easier to operate because of their openness. The few publications pertaining to sugarbush management vary in content, but they do provide some helpful guidelines (Coons 1975, Foulds et al. 1956, Lancaster et al. 1974, Morrow 1975, Rudolph 1968, Smith and Gibbs 1970d).

Sugar maple (*Acer saccharum* Marsh.) is the species most tapped for sap production. Black maple (*Acer nigrum* Michx. f.) is so similar to sugar maple that most foresters

consider it a variety of the species and treat it equally (Slabaugh 1958). However, sugar and black maple are not the only species tapped. Red maple (*Acer rubrum* L.) and silver maple (*Acer saccharinum* L.) are also used (Coons 1975). A major drawback of these "soft" maples is that the buds of red and silver maple develop much earlier in the spring than sugar maple, and their sap becomes "buddy" and unusable before the end of the sugar maple sap flow season. This is not a serious problem where buckets are used for sap collection; the buckets can be removed from the soft maples early. But with a tubing collection system, the sap is not so easily separated. Larsson and Jaciw (1967) compared sap and syrup from sugar maple with that of red, silver, Manitoba (*Acer negundo* L.) and Norway maple (*Acer platanoides* L.) and concluded that these four species could be regarded as potential syrup producers. Where they occur, they can be retained and tapped, but sugar maple should always be favored over them.

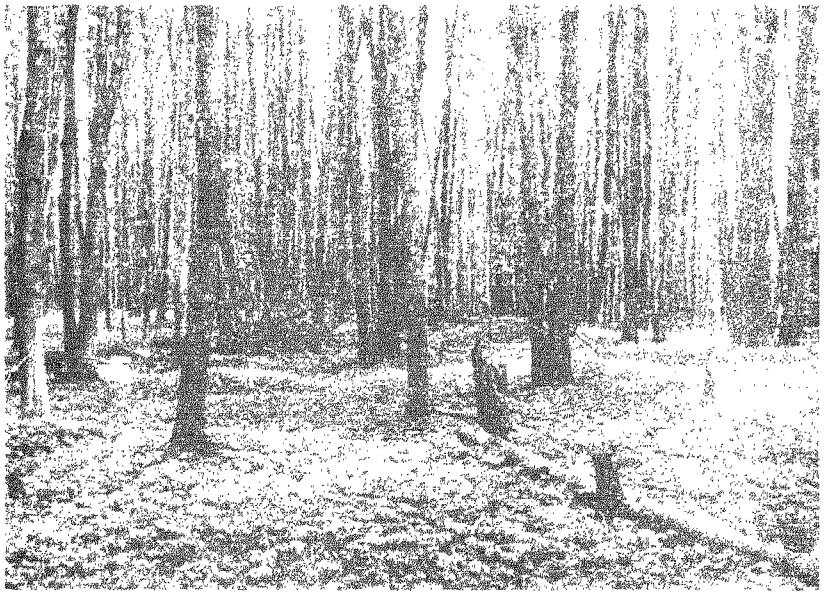


Figure 4-3.—Dense reproduction of seedlings under even-aged pole stand of sugar maple, 45 to 50 years old.

Silvical Highlights of Sugar Maple

Regenerating sugar maple is usually not difficult. The species produces a large quantity of seed and is a prolific sprouter. Second-growth stands will normally have thousands of seedlings and plenty of advance reproduction (Fig. 4-3). Mortality of new seedlings without release is high; half of the new seedlings in southern Wisconsin did not survive their first year (Godman 1957).

Being very tolerant of shade, sugar maple responds strongly to release, even after several years of complete supression (Fig. 4-4). Study of a sapling stand 2 to 4 inches in dbh showed that, during a 7-year period, unreleased, vigorous, dominant trees averaged 0.90-inch diameter growth; similar but heavily released trees averaged 0.66-inch diameter growth; and heavily released codominant trees averaged 1.48-inch growth. Trees in pole-sized stands 6 to 8 inch dbh also responded well to release (Godman 1957).



Figure 4-4.—Sugar maple seedlings will often respond vigorously to even a moderate release.

Sugar maple is found on a wide variety of soil types and under many different conditions. It thrives best in fertile, moist, well-drained, loamy soils, but it will also grow in poor, dry, shallow soils. In general, the yield and quality of sugar maple stands increase as soil fertility and moisture conditions improve (Godman 1957). It can be found in soils ranging from strongly acid (pH 3.7) to slightly alkaline (pH 7.3), although most commonly it occurs in neutral or slightly acid soils (Godman 1957). Soil moisture is often a limiting factor in sugar maple establishment, growth, and development (Post 1968).

Objective of Sugarbush Management

Simply stated, sugarbush management encompasses any activity that results in the production of maple sap that can be collected for making syrup and sugar. Tapping trees and gathering sap would be minimal management. A more agressive objective might be to obtain the highest possible yield of sugar-rich sap per acre, and improve the operational efficiency of the sugarbush.

The sugar content of sap has a direct effect on the processing costs of making maple syrup. The "Rule of 86"[1] tells us that 43 gallons of sap with 2 percent sugar are required for 1 gallon of syrup, whereas only about 22 gallons of 4-percent sap are needed (Jones 1946). The sweeter the sap, the less time and fuel are required to make a gallon of syrup.

A tree's sap and sugar production is determined by its environment and by its genetic makeup. Environmental conditions help determine a tree's size, and allow it to develop certain physical characteristics. These are subject to silvicultural manipulation; thus sap and sugar production can be influenced to some degree. Some trees are naturally sweeter than others because of their particular genetic heritage. Sap sweetness may range from 1 to 5 percent or more among a group of forest-grown maple trees. Taylor (1956) found that sweetness of the sap from a particular tree may vary considerably from year to year, but that individual trees retain their same relative ranking in sap-sugar content if their environmental conditions do not change. Thus, it is possible and important that stand improvement operations favor the naturally sweet trees.

Managing a sugarbush provides the opportunity to increase its yield and favor the development of the sweetest trees. Careful thinning, crop-tree selection, provision for regeneration, and protection from grazing will all help to sustain a sugarbush and improve it for the production of maple products.

Tree Characteristics

To manage a sugarbush effectively, it is essential to know the characteristics of a tree that will produce large volumes of sugar-rich sap. It is generally believed that the ideal sugarbush tree is a vigorous, fast-growing tree that has a deep, wide, fully developed crown exposed to full sunlight (Fig. 4-5). The larger the crown, the greater the leaf surface area, and hence, the greater the capacity for photosynthesis—the process that converts carbon dioxide (CO_2) with the aid of the sun's energy into carbohydrate reserves from which sap sugars are derived. It should be the purpose of any silvicultural treatment to en-

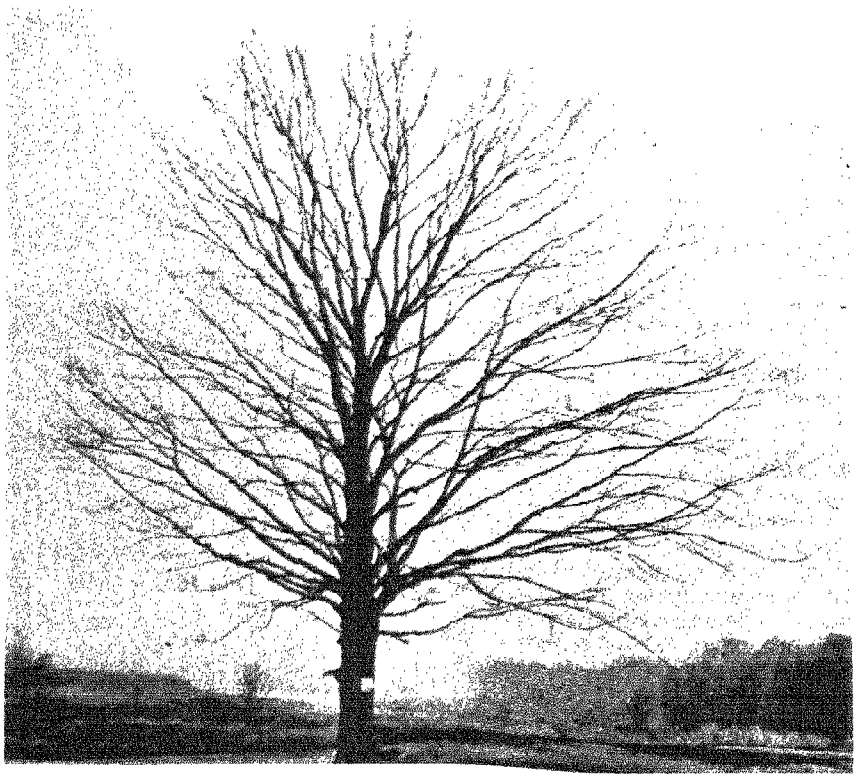


Figure 4-5.—For high sugar production, the ideal sugar tree has a wide, deep, fully exposed crown.

[1] The "Rule of 86" states that 86 divided by the Brix (percentage of solids) value of the sap equals the number of gallons of sap required for 1 gallon of syrup.

courage crown development in trees.

Sap production of individual trees has been shown to increase with increases in live crown ratio (length of crown divided by tree height), width of the crown, and growth rate (Moore et al. 1951). Trees with crown ratios averaging 50 to 75 percent of their total height yielded about 25 percent more sap than similar size trees with a crown ratio of less than 50 percent. Width of crown had a more dynamic effect: Trees with crowns more than 30 feet wide (crowns typical of trees in an open stand) produced over 100 percent more sap than similar trees having the same stem diameter, but with crowns less than 20 feet wide (a crown size typical of forest-grown trees). Growth rate, which is related to crown size, is strongly correlated with sap yield. Trees with a growth rate of 5 to 10 rings per inch yielded about 30 percent more sap than trees growing more slowly, at the rate of 15 to 20 rings per inch.

Stevenson and Bartoo (1940) reported on extensive sweetness studies in Pennsylvania, and found that the sugar content of forest-grown trees averaged about 2.25 percent, in contrast to 3.34 percent for open-grown trees. Morrow (1955) reported a positive correlation between live-crown ratio, crown diameter, and sugar content. Measurements on three sugarbushes (one with a closed canopy, one under both open and closed conditions, and one open), showed that crown diameter and live-crown ratio contributed 21 percent, 8 percent and 38 percent of the variation in sugar content. Toma (1961), in another comprehensive study of tree characteristics and sap and sugar yield, found that the combined effect of stem diameter, height, crown diameter, and live-crown ratio accounted for 19 percent of the variation in sap yield and 32 percent of the variation in sugar yield. These findings seem to be further substantiated by Marvin and others (1967), who found that sap volume and sweetness increased with tree size over an 18-year period. Blum (1971, 1972, 1973), on the other hand, found that although tree and crown characteristics were positively correlated with sap volume and total sugar production, the correlation of size with sweetness was not significant. It seems likely that other variables, so far not accounted for, are also involved in sap sweetness.

Stand Density

The objective of sugarbush management is to produce the highest possible yield of sugar-rich sap per acre. This is accomplished by manipulating stand density and stocking to encourage the development of healthy, vigorous trees with deep, wide crowns. There is wide variation in recommendations among the publications pertaining to sugarbush management—from 25 to 50 trees per acre up to more than 100 trees per acre (Morrow 1955, Rudolph 1968, Morrow 1975).

On the assumption that a large crown size is desirable, sugarbush stocking guides provide space for maximum crown expansion (Foulds et al. 1956, Smith and Gibbs 1970d, Smith and Gibbs 1971b). These are based on the relationship of maximum crown size (of open-grown trees) to tree diameter at breast height (dbh), and number of trees per acre (Fig. 4-6).

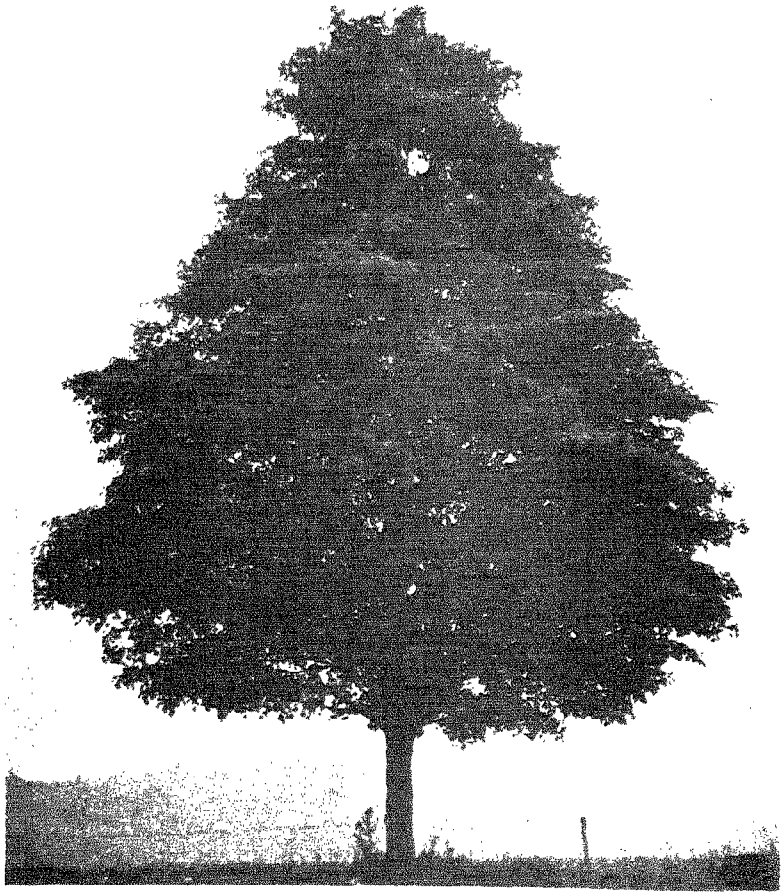


Figure 4-6.—An open-grown sugar maple that has never had competition from neighboring trees will develop a maximum crown spread.

DIAGNOSTIC TALLY SHEET FOR SUGARBUSH STANDS

[For the determination of the number of trees per acre, average stand diameter, stocking, and spacing for sugarbush management]

Dbh (inches)	Number of trees tallied														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	458	917	1375	1834	2292	2750	3209	3667	4125	4584	5042	5501	5959	6417	6876
4	115	229	344	458	573	688	802	917	1031	1146	1260	1375	1490	1604	1719
6	51	102	153	204	255	306	357	407	458	509	560	611	662	713	764
8	29	57	86	115	143	172	201	229	258	287	316	344	372	401	430
10	18	37	55	73	92	110	128	147	165	183	202	220	238	257	275
12	13	25	38	51	64	76	89	102	115	127	140	153	165	178	191
14	9	19	28	37	47	56	66	75	84	94	103	112			
16	7	14	21	29	36	43	50	57	64	72	79	86			
18	6	11	17	23	28	34	40	45	51	57	62	68			
20	5	9	14	18	23	27	32	37	41						
22	4	8	11	15	19	23	27	30	34						
24	3	6	10	13	16	19	22	25	29						
26	2	5	8	11	14	16	19	22	26						
28	2	5	7	9	12	14	16	19	21						
30	2	4	6	8	10	12	14	16	18						

Number of plots

Tally Legend

/

O

X

No. of trees/acre

Total Number of Trees Per Acre.—Add the last figures checked on each line and divide by the number of point samples tallied.

BA Per Acre.—Add the total number of entries in each nine class, multiply by 10 and divide by the number of point samples tallied. (BA factor = 10)

STAND DESCRIPTION:

Number of trees per acre_____ BA per acre _____ Average stand dbh _____

Trees per acre at C level_____ BA at C level_____
(or level selected for management) (or selected level)

STAND PRESCRIPTION:

Mark for cutting or girdling _____ trees = _____ BA (Total minus C or selected level)

Average crop tree spacing _____ feet

TAP HOLE COMPUTATION SHEET

CUMULATIVE TALLY - NUMBER OF TAP HOLES PER ACRE (BA FACTOR 10)

D.B.H.	Number of trees															TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
10	18	37	55	73	92	110	128	146	165	183	201	220	238	256	275	
12	13	25	38	51	64	76	89	102	114	127	140	152	165	178	191	
14	9	19	28	38	47	56	66	75	85	94	103	113	122	132	141	
16	14	29	43	58	72	86	101	115	130	144	158	173	187	202	216	
18	11	23	34	46	57	68	80	91	103	114	125	137	148	160	171	
20	14	28	41	55	69	83	97	110	124	138	152	166	179	193	207	
22	11	23	34	46	57	68	80	91	103	114	125	137	148	160	171	
24	10	19	29	38	48	58	67	77	86	96	106	115	125	134	144	
26	11	22	32	43	54	65	76	86	97	108	119	130	140	151	162	
TOTAL																

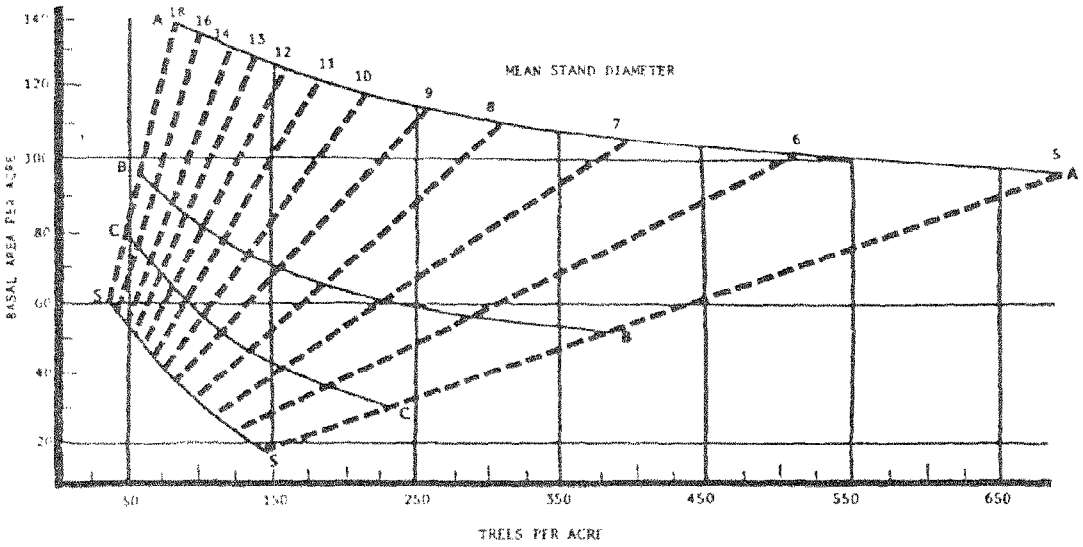
Total number of tap holes per acre - Add the last figure in each diameter class and divide by the number of point samples taken.

(Total)_____ ÷ Point Samples_____ = Tap holes per acre

(Tap holes per acre)_____ X (acres) _____ = _____ Total per woodland

Figure 4-7.—Diagnostic tally sheet for sugarbush stands.

Figure 4-8.—Stocking chart for even-aged northern hardwoods, based on number of trees in the main canopy, average diameter, and basal area per acre. For timber objectives, stands above the A line are overstocked. Stands between A and B lines are adequately stocked. Stands between B and C lines should be adequately stocked within 10 years. Stands below the C line are definitely understocked. For sugarbush management, maple stands at the S line are at minimum stocking levels.



Much of the existing knowledge on sugarbush development has been summarized and developed into a guide that includes techniques of stand analysis and treatment prescription (Lancaster et al. 1974). In fact, the method suggested uses the same stand-examination methods and prescription-writing procedures used in timber management (Leak et al. 1969).

The "Diagnostic Tally Sheet for Sugarbush Stands" (Fig. 4-7) provides the means of gathering the data necessary for making sound management decisions (Lancaster et al. 1974). The tally is used to determine the number of trees and their basal area per acre, and the necessary ingredients of the "Stocking Chart" (Fig. 4-8) for even-aged northern hardwoods. The chart provides the means of comparing existing stand stocking with the suggested stocking levels for increased sap yield. For example, in Figure 4-8, the B level represents a minimum stocking for timber objectives. The C level is considered understocked for quality timber production; but in pole and larger stands not previously thinned, it is the level of management prescribed for improving sap production. The S level, which was developed from the relationship between crown diameter and dbh of open-grown sugar maple (Smith and Gibbs 1970d), is a minimum stocking for maximum crown development with full utilization of crown space. However, this ideal crown development is attainable only if management is started early in the life of the stand—at the sapling or small pole size stage—and carried to stand maturity. Table 4-1 shows a comparison of the number of trees and the average spacing at the B, C, and S levels.

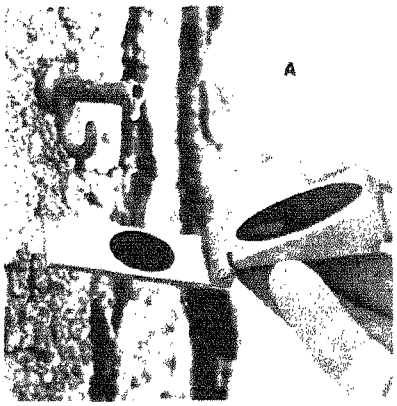
Stand Prescription

Saplings (2 to 4 inches dbh). Thinning should start early in the life of the stand when trees average 2 to 4 inches in diameter, and should be repeated at 5- to 10-year intervals. Early thinning encourages the development of large side branches, and favors rapid diameter growth. It is at this young age that deep crowns can be maintained or developed most successfully. The crop-tree selection method is used in thinning these young stands, releasing 100 to 125 crop trees per acre.

Poletimber (6 to 10 inches dbh and larger stands). To achieve good spacing between crowns, a residual stocking at the C level is recommended for stands not previously thinned. For stands previously thinned, a residual stocking below

Table 4-1.—Number of sugar maple trees per acre and spacing by average stand-diameter class for sugarbush stands at the S level, C level, and B level of stocking.

Average stand dbh class	S Level		C Level		B Level	
	Trees per acre	Tree spacing	Trees per acre	Tree spacing	Trees per acre	Tree spacing
Inches	*No.*	*Feet*	*No.*	*Feet*	*No.*	*Feet*
6	126	19	160	16	299	12
8	98	21	140	17	190	15
10	79	23	105	20	129	18
12	64	26	86	23	99	21
14	54	28	76	24	86	23
16	46	31	70	25	76	24



the C level, about halfway between C and S lines, is suggested.

Thinning Sugarbushes

Sugarbush management is a two-part effort. Before the thinning cuts are made, it is necessary to select the crop trees to be retained. These should be vigorous, well formed, free of defect, and have sweeter than average sap. Sap sweetness can be measured with a refractometer (Fig. 4-9) (Lancaster et al. 1978).

Trees that are tapped in the spring for sap collection can be tested easily: a few drops of sap from the spout are placed in a refractometer and the scale is read. In sapling stands, the method of tapping and obtaining sap for test readings will need to be modified because of the size of the trees. For these trees small, shallow tapholes may be used (Fig. 4-9B). The necessary sap may be collected from a toothpick or hypodermic needle (Lancaster et al. 1974), or from a beverage straw (Lancaster et al. 1978) placed in the hole. (The beverage straw technique (Fig. 4-9C) has worked very well for us). Because individual trees retain their relative sweetness in comparison to their neighbors, it is possible to choose the sweetest trees in the fall as well as in the spring, even though fall sugar readings will generally be lower than spring ones (Koelling et al. 1968b, Gibbs 1969c).

Understory Removal

The presence of a coniferous understory in a sugarbush was found to affect sap production and growth of the sugar maple trees (Fig. 4-10) (Walters 1978c). In this study we compared sap yields from half of a sugarbush where the understory was completely removed with yields from the other half, where the understory was left intact. The data after 5 years began to show greater and more consistent sap volumes from the half with the

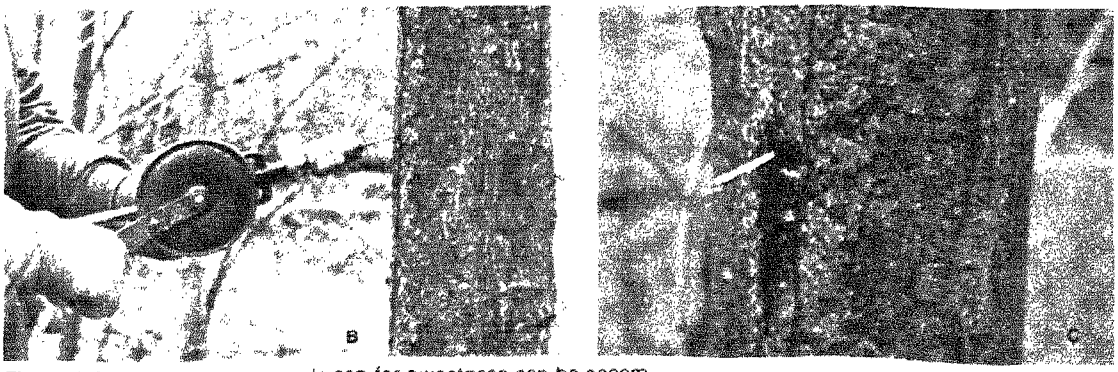


Figure 4-9.—Testing sugar maple sap for sweetness can be accomplished by collecting a drop of sap for the sugar refractometer (A). For a tree too small to tap (B), drill a 1/2-inch-deep hole the diameter of a beverage straw, and insert a short length of beverage straw in the hole (C).



Figure 4-10.—A portion of a sugarbush area after the conifers (stumps) were removed. Sugar production from the residual maple trees increased after removal of the understory.



Figure 4-11.—Fertilizer applied to this sugarbush failed to increase either sap volume or sap-sugar yield during four consecutive sap seasons following application.

understory removed. This was attributed to increased availability of soil moisture and nutrients. In addition, the shade from a heavy conifer understory can affect air temperatures within the sugarbush and thereby affect sap yields. Another advantage of removing the understory is improved accessibility and better working conditions in the sugarbush.

Sugarbush Fertilization

Maple syrup is a special crop, but the objective of fertilization is the same as for any other forest product—to increase production. The objectives of sugarbush fertilization are to increase sap flow and sap-sugar content (Yawney and Walters 1973).

Sap-sugar content varies considerably among sugarbushes and among trees in the same sugarbush. Genetic factors contribute significantly to this variation. It must be assumed that some of this variation, particularly among sugarbushes, is due to differences in environmental factors—especially site productivity. A further assumption is that improving site productivity by fertilization would enhance sap-sugar production.

Very few studies deal specifically with fertilization of sugar maple trees to alter sap production. These were summarized by Yawney and Walters (1973), who found them inconsistent and yet intriguing. Some of them seem to indicate that fertilization may indeed have promise.

Increased syrup yields from fertilization have been reported. Kriebel (1961) applied 600 pounds per acre of N as ammonium nitrate, and observed a 10-percent increase in sap sugar over a 3-year period. LaValley (1969) made five annual applications of N, P and K at 18, 6, and 11 pounds per acre respectively. After the second year he observed an 18-percent-a-year increase over the control, and by the fifth year, the sap-sugar concentration of the fertilized trees averaged 12 per-

cent higher than the controls and they yielded 10 percent more sap.

Watterston and others (1963) investigated the effects of N, P, and K fertilizers on sugar production. These fertilizers, applied singly and in combination, affected total sugar yield either through total sap volume or sap-sugar concentration. The combination fertilizer depressed total sugar yield the first season after treatment, and increased the yield in the second season. The N and K fertilizers resulted in little change in the control trees, while P alone produced a significant decrease in sugar concentration.

In Vermont, Smith and Walters[2] studied the effects of fertilization on sap production. N, P, and K broadcast at rates of up to 160, 70, and 66 pounds per acre respectively, with and without 10 tons per acre of hydrated lime, failed to increase either sap volume or sap sugar during 4 consecutive seasons after fertilization (Fig. 4-11).

Vascular rays are the principal storage areas for starch, from which the sucrose of sugar maple is derived. There is evidence that some sugar maple trees have more sugar in their sap than others because they have more ray volume per unit of wood (Morselli et al. 1978, Wallner and Gregory 1980). Stimulating cambial activity in maple trees and increasing the rate of growth produces wood with a higher proportion of ray volume. This presents an attractive possibility for increasing maple sugar production, because the proportion of ray volume in wood can be manipulated silviculturally by fertilization and/or thinning. Furthermore, the production of such wood seems to continue for several years, even after substantial decline in cambial activity (Gregory 1977).

[2] Smith, H. Clay, and Russell S. Walters, unpublished office report, Northeastern Forest Experiment Station, Burlington, Vermont, 1973.

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Section II Chapter 5

Genetic Improvement in Sap-Sugar Production

Genetic Improvement in Sap-Sugar Production

by
William J. Gabriel

The knowledge that trees differ in the sugar content of their sap is not new, although it has only recently been properly documented. Sugar producers know that certain trees in their stands are sweeter than others. In an intensive study of a relatively small area in Vermont, Taylor (1956) found that individual trees and stands differed by as much as 100 percent in sap sweetness. And an extensive survey throughout the important syrup-producing states in the Northeast found that the sugar content of sap from 21,080 trees ranged from 0.7 percent to 10.8 percent (Gabriel 1972a).

This variation makes it possible to improve sugarbush production in two ways: existing sugarbushes can be thinned by removing the trees that produce less sugar (as shown in tests of the sap from individual trees), and the productiveness of sugar maple trees can be improved over a long term by selective breeding.

Not all of the factors that influence sap sweetness are known. Within any sugaring season, the sap of a single tree may vary widely in sugar content, but individual trees that are superior maintain their superiority from year to year (Fig. 5-1).

As was mentioned in Chapter 4, researchers generally agree that certain crown characteristics are correlated with sap volume and sweetness. Crown characteristics are determined primarily by the environment of the tree, and that can be manipulated by thinning and other silvicultural techniques; but trees that owe their superiority to environmental factors are not useful for selective breeding because acquired characteristics are not transmitted from parent to progeny. There are

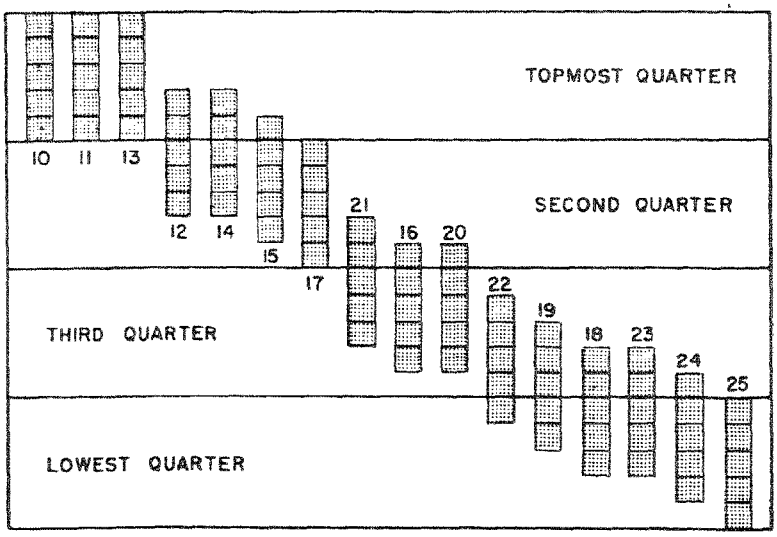


Figure 5-1.—Individual trees perform consistently from year to year. Each vertical bar represents the 5-year record for one tree. Each square within a bar shows the rank of the same tree for one season (Taylor 1956).

presently no external morphological characteristics, such as bark configuration or color, leaf shape or size, or tree form, that distinguish trees with superior sugar production. The internal characteristic of proportion of ray volume to xylem has been reported to be related to sap-sugar production (Morselli et al. 1978).

No significant differences in sugar content have been associated with the age of the tree, but difficulty in obtaining sap samples from trees less than 3 cm in diameter above the root collar makes these comparisons undependable. Larger open-grown saplings 7 to 10 years old produce reliable quantities of sap as high in sugar content as sap from mature trees (Kriebel 1960).

Sugar content of sap is easily measured with a refractometer (Fig. 4-9A) but the volume of sap produced by a tree is more difficult to measure. It would be helpful in selecting superior trees for breeding if sweeter sap was correlated with high volume production, but they were found to be highly correlated in some years and poorly correlated in others (Marvin et al. 1967). Over an 18-year period, a significant correlation was found between the two variables.

Selective breeding to improve the flavor of maple syrup has also been considered, but flavor is related primarily to the heat used to evaporate the sap to syrup, so genetic improvement of flavor is unlikely.

Selecting Superior Trees

Genetic improvement by selective breeding depends upon selection of parent trees that owe their superiority to heredity rather than to environment. It is important to use selection procedures and criteria that will distinguish these trees.

Research in Ohio has led to the recommendation that selection candidates be tested for sugar content for 3 years before their final selection (Kriebel and Gabriel 1969). Tests should be made in the early or middle part of the sap season, when sugar concentrations tend to be higher. Sugar percentages generally drop in the latter part of the season; small differences between trees make comparisons difficult and may mask genetic variation.

Single-tree selection has been recommended because earlier research showed that variation in sugar content was greater between individual trees than between sugarbushes or geographic origins (Kriebel and Gabriel 1969). But recent results from a rangewide sugar maple provenance study have shown that differences between geographic origins tested in West Virginia were significant. Two provenances from Minnesota consistently outperformed the average for the outplanting—one provenance by 25 percent in 1977 and by 37 percent in 1978, the second by 21 percent in 1977 and 14.5 percent in 1978. Further investigation of variation within these provenances is in progress.

Parent stock has been selected throughout the important syrup-producing states in the Northeast, using procedures that require a selection candidate to produce sap at least 30 percent sweeter than the average of several surrounding standard trees (Fig. 5-2), and to ex-



Figure 5-2.—The sap sugar produced by the selected tree (indicated by the arrow) ranged from 46 to 68 percent above the average of the adjacent standard trees over a 4-year period.



Figure 5-3.—A general view of the clonal bank in Vermont, which serves as a source of parental stock in a selective breeding program to improve sap-sugar production in sugar maple. Photo at right shows the oldest ramets in the planting which are 8 years of age.

ceed the sweetest standard tree by a minimum of 0.5 percent (Gabriel 1964). Trees were scored on their similarity to the standard trees in diameter, height, crown shape, and other characteristics. From these scores, in combination with the highest degree of superiority in sap sugar, 53 final selections were made (Gabriel 1972a). All selections have been vegetatively propagated through scionwood grafting and are currently growing in a clonal bank in Vermont where they are serving as parental stock in the ongoing breeding program (Fig. 5-3).

Evaluation of the Genotype

A sugar maple tree selected for superiority in sap-sugar production over other trees is referred to as a superior phenotype. Its superiority is a product of the interaction between genes inherited by the tree (genotype) and the environment in which it grows. Since it is impossible to measure the influence of genes on sap sweetness directly, genotypes are evaluated indirectly by progeny testing, where the performances of their offspring, grown under similar conditions, are compared in a replicated experiment.

One progeny test of sugar maples selected for sap-sugar concentration was conducted in Ohio. It included 12 families that represented controlled pollinations between high, low, and intermediate trees and families from open pollinations (Kriebel and Gabriel 1969). After 3 years of sap testing, analysis of data showed that differences observed between families were highly significant. Further analysis indicated that additive gene effects were an important component of the calculated variance. Analysis of data collected from open-pollinated progenies showed no significant differences in sap sugar.

Trees selected for high sugar content by the Vermont Agricultural Experiment Station and the former Hopkins Forest Unit of the Northeastern Forest Experiment Station were progeny-tested in replicated plantings in Massachusetts and Vermont. Significant differences were found between families at each location, although from year to year the same families were not always in the highest rankings (Gabriel 1972b). Sap-sugar content was generally lower in the Vermont plantation, but no significant interaction between family and plantation location was detected. Correlation analysis has shown no relationship between average performances of parents and their respective progenies.

Replicated test plantings have recently been established in Michigan, Ohio, Pennsylvania, and Vermont. Results of this experiment, expected over the next 5-year period, will guide roguing of a clonal bank composed of ramets derived from the ortets (phenotypes) represented in the progeny test. Similarly, progeny-test plantations could be rogued in anticipation of their use as seedling seed orchards.

Breeding and Recurrent Selection

A selective breeding program, emphasizing recurrent selection for general combining ability, is currently in progress in Vermont. Seed was collected from open-pollinated, selected phenotypes *in situ*. The resulting seedlings were outplanted in four progeny-test plantations, each representing a different set of grow-

ing conditions. Differences between half-sib family averages will be analyzed, and the general combining ability of the selected parents will be estimated. Those parents with the best general combining ability will be intercrossed to form the population for a second selection cycle.

Intercrossing in the Vermont program will be carried out in the clonal bank which is made up of five pairs of ramets of each ortet, each pair being randomly located on the planting. Prior to intercrossing, all clones with poor general combining ability will be rogued from the planting. Cross-pollination between the remaining trees of good general combining ability will be allowed to occur naturally. Flowering of clones within the bank is considered satisfactory. At the end of the last 4-year flowering cycle of sugar maple, in 1976, 90 percent of the clones and 48 percent of the ramets bloomed. An isolation strip of about 1/4 mile around the bank will be established in which all other sugar maples will be removed to guard against possible contamination by foreign pollen.

In 1976, an estimated 7,900 filled fruits were collected from the Vermont clonal bank. Pollination occurred at random among the trees in the unrogued planting, with possible contamination by four nearby flowering maples outside the planting. The latter have since been removed. The ensuing seedlings, kept separate according to family, have been planted and will be compared for sugar concentration. Since heritability estimates for the trait of sap sweetness are relatively high, 0.70 in Vermont and 0.60 in Ohio, a modified, simple recurrent selection procedure should give substantial genetic gains with a minimum of expense.

A breeding program in Ohio also makes use of random crossing between superior progenies or individuals in test plantations. Through asexual propagation of selections, flowering of ramets has produced one crop of 12,000 seedlings for distribution to landowners. These trees are now being outplanted at 30 x 30-foot spacing.

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Section III Chapter 6

The Propagation and Planting of Sugar Maples

Seed Collection and Handling

by
Clayton M. Carl, Jr.

To propagate sugar maple from seeds successfully, a grower needs information on seed development and on the proper methods of collecting and handling the seeds.

It is important to use seed that is high in germinability, and, if possible, from a known source. Desirable seeds come from vigorous, superior phenotypes, either sweeter than average (for the grower who wants to plant a sugar orchard) (Kriebel and Gabriel 1969) or from well-formed trees (for the timber producer). A combination of these two characteristics would be even more desirable.

Fruit Development

Sugar maples generally begin bearing light fruit crops when they are 8 inches in diameter, and about 25 to 30 years old (Godman 1957, Limstrom 1965). A few trees in one of our plantations began bearing fruit when they were 20 years old, and our records show scions from mature trees bearing fruit 2 years after being grafted to 1-year-old root stock.

Sugar maple trees are usually monoecious in their flowering habits. The flowers bloom in the spring, usually in late April or early May. They are borne in inflorescences at or near the ends of the branches, and are pollinated by insects. Although good sugar maple flower and fruit crops may occasionally occur in 2 successive years (Godman and Matson 1976), they are usually intermittent, varying from 2 to 7 years apart (Godman 1957, U.S. Department of Agriculture, Forest Service 1974, Eyre and Zillgit 1953).

The fruits are pairs of fused samaras which ripen in the autumn. Each samara (often incorrectly called a seed) may or may not contain a seed. (Unless otherwise specified, all references to seeds in this chapter mean the seeds enclosed in their fruit coats. All references to samaras mean as they are collected, both those containing a seed, filled samaras, and those without a seed, empty samaras). The samara pairs eventually separate and the single samaras are normally dispersed by the wind.

Sugar maple fruits mature in the fall and must be collected at the proper time to ensure maximum seed germination. The actual date of maturation varies from year to year for an individual tree, and maturation dates differ among trees within a stand in the same year (Carl and Snow 1971).

Mature sugar maple seeds have a very high germination capacity. In our experience, nearly all of the mature seeds will germinate. Seeds generally will have reached their maximum germination potential when the majority of the samaras on the tree have changed from bright green to a yellowish green. When the samaras have turned completely brown, they will soon be shed. A more accurate method of determining when sugar maple seeds are ripe is to determine the moisture content of the samaras. Carl and Snow (1971) reported that when the moisture content of the samaras was below 145 percent, germination for 17 out of 19 individual collections was over 90 percent. The other two collections were from a tree on which the samaras were heavily infested with aphids, and this may have caused a decrease in seed germination.

Apparently, sugar maple seeds

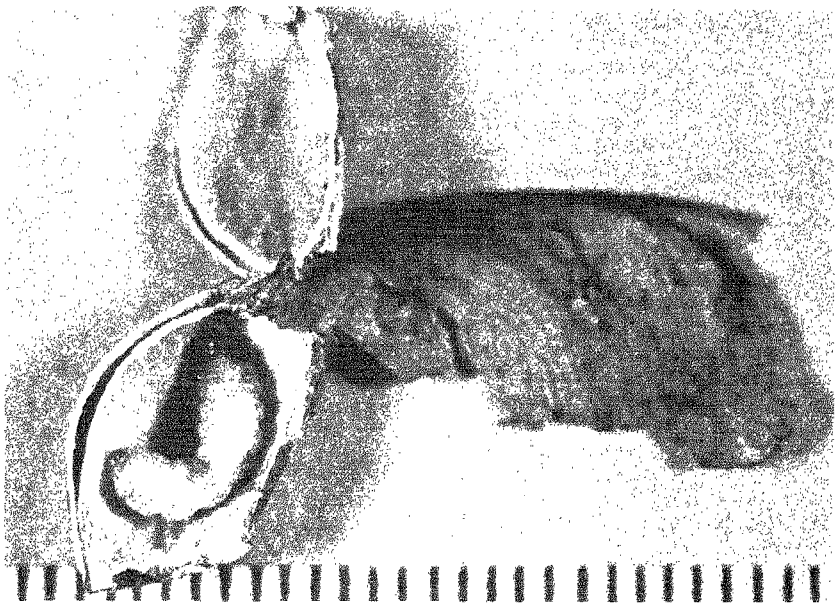


Figure 6-1.—Unidentified maggot which destroys sugar maple seeds.

have few natural insect enemies. There was the one aphid infestation mentioned above, and there is a maggot, as yet unidentified, that attacks the seeds (Fig. 6-1). Although individual trees may, at times, be heavily infested with these maggots, we consider this insect relatively unimportant at present.

Samara Collection and Separation

In the future, high-quality sugar maple seeds may be collected from superior seed sources grown in seed orchards. At present, however, seeds are usually collected locally from selected trees during good seed years. If possible, the samaras should be collected from trees that exhibit desirable characteristics, although there is no guarantee that these characteristics will be transmitted to the offspring. Seeds from local sources are usually better adapted to local planting sites than seeds from foreign sources. If local seeds are not available, and no information is available on provenance performance, seeds from areas that have a climate similar to that of the proposed planting site should be used.

Limstrom (1965) gives some general advice about seed sources, and recommends selecting maple trees within the seed-collection zone where the planting is planned. He states that transfers from the adjacent southern zone are permissible—with reservations—to take advantage of exceptional trees. Before collecting any seeds, the collector should secure the landowner's permission to do so.

The samara-collection period for sugar maple—that period when seeds will have a germination rate of over 90 percent—varies from tree to tree, and from year to year. In the study by Carl and Snow (1971), samaras were collected at weekly intervals from late August until the samaras were shed during 2 separate years. During the first year of the study, there was a period of 5 or 6 weeks for each tree when the seeds germinated over 90 percent. This period began about September 1 for one tree, but it was 3 weeks later before seeds from the last tree had a germination rate of over 90 percent. However, there were only 2 weeks when seeds from all the trees had a germination rate of better than 90 percent. In the second year of the study, there was only a 2-week period for each tree when its seeds had germination rates of 90 percent or better, and there was no week when the seeds from all three trees had germination rates of at least 90 percent. Because of the differences in times of maturation, collection time has to be determined for each tree.

Developing samaras turn from bright green to yellowish green, and finally brown. If the samaras have not been picked before they turn brown, they should be picked immediately, as they will soon be shed.

Mature samaras can be stripped from the branches easily. There are several ways to collect the seeds: They can be picked up from the ground; ladders and raised platforms can be used to make the seed-bearing branches accessible (Fig. 6-2); or seeds from particularly desirable trees may be gathered by climbing the tree. Pruning poles are sometimes used to clip off the ends of seed-bearing branches high up

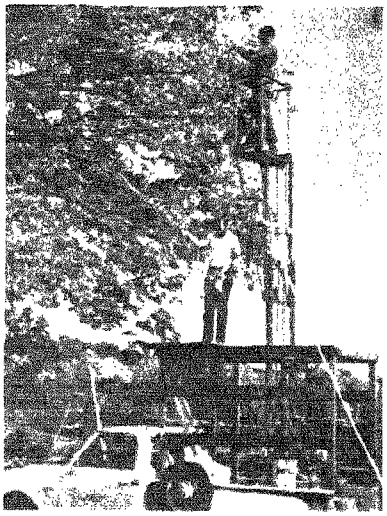


Figure 6-2.—Ladders and raised platforms can be used to pick samaras from large open-grown sugar maple trees.

on the tree, but this damages the tree and exposes the branches to possible fungal infection and decay. Another method that has been employed with fair success is to spread drop cloths on the ground under the tree, and shake its branches. Samaras can also be collected from felled trees, but if this is done, the seeds should be mature when the trees are cut down.

Freshly collected samaras should be cared for soon after collection. If this is not possible, they should be kept cool to protect the viability of the seeds. Samara pairs generally break apart when picked. Usually only 50 percent of the samaras contain seeds, but they can vary from 20 to 74 percent among trees (Carl and Yawney 1966). We recommend that the empty samaras be removed and discarded. This reduces handling and storage space requirements considerably. Sowing time in the nursery is also reduced, and seedling density—an important factor affecting seedling development (Shipman 1964, Stoeckeler 1950, 1967, and Sluder 1964)—can be controlled more precisely.

The moisture content of freshly collected samaras can range from about 35 percent to over 140 percent (dry weight basis), depending on their stage of development. Carl and Yawney (1969) reported that individual sugar maple samaras with a moisture content greater than 50 percent can be quickly and efficiently separated with pentane; the empty samaras float, and the filled samaras sink (Fig. 6-3). This technique has proven to be 95 to 100 percent effective. If the filled samaras are to be sown within 3 or 4 months after separation, they should be put in cold storage. If it will be much longer before they are sown, they should be prepared for long-term storage.

Storage

Since good seed years do not occur every year, some provision must be made to store seeds to sustain a continuing planting program. Storage temperature and seed moisture content are both critical factors affecting the length of time seeds can be stored and still retain their viability.

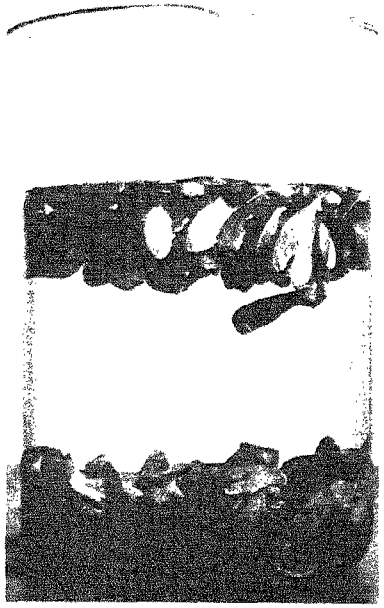


Figure 6-3.—Pentane is 95 to 100 percent effective for separating filled (sinkers) from empty (floaters) sugar maple samaras.

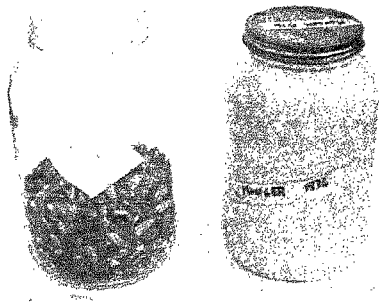


Figure 6-4.—These 1-gallon food jars hold about 10,000 samaras each and make excellent sealed containers for storage.

If the samaras are to be stored, even for only a few months, they should be dried. Our procedure is to air dry the collections slowly in an unheated building. Soon after collection, if they are not to be separated, or immediately after separation in pentane, the samaras should be spread on wire-screen trays to dry. The maximum depth should be 1 inch and the samaras should be stirred daily to prevent heat buildup and consequent loss of seed viability.

For long-term storage, the moisture content of the samaras should be reduced to about 10 percent. If the moisture content of the samaras has not been reduced to 10 percent after 6 to 8 weeks of drying on the wire screens, it will be necessary to transfer them to a heated room (18 to 21°C) to complete drying. It might be all right to dry the samaras in a shorter time in a heated room rather than an unheated building, but we do not know what effect rapid drying has on the seeds.

The dry samaras can be stored for long periods by putting them in sealed containers to maintain stable moisture conditions (Fig. 6-4). In

Table 6-1.—Effects of seedlot, moisture content, temperature, and time on percent viability of sugar maple seed stored in sealed containers (Yawney and Carl 1974)

Seed moisture content (percent)	Storage temperature (°C)	Seedlot 1 months in storage					Seedlot 2 months in storage					Seedlot 3 months in storage				
		6	18	30	42	54	6	18	30	42	54	6	18	30	42	54
35	18	0[a]	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	7	83	0	2	0	0	86	0	2	0	0	99	0	1	0	0
	2	95[b]	8	1	0	0	94	19	0	0	0	95	4	0	0	0
	−10	95	93	87	1	0	98	68	36	8	2	96	99	86	1	0
25	18	44	0	2	0	0	0	0	0	0	0	2	0	0	0	0
	7	95	65	3	0	0	98	23	0	0	0	100	51	0	0	0
	2	95	85	50	7	0	97	89	9	0	0	100	99	69	1	14
	−10	97	95	96	46	7	98	98	98	3	9	93	99	96	3	14
17	18	62	0	0	0	0	15	1	0	0	0	40	0	1	0	0
	7	95	86	0	0	0	96	62	0	0	0	100	94	5	0	0
	2	97	93	82	58	60	99	94	73	4	0	100	98	98	83	14
	−10	97	96	93	92	86	97	98	97	92	95	98	99	100	97	98
10	18	90	55	1	1	0	94	68	0	0	0	100	95	9	0	0
	7	89	91	91	93	85	93	95	95	92	92	100	100	100	98	96
	2	93	93	89	91	94	97	95	96	93	96	100	100	99	100	99
	−10	95	95	97	89	94	98	96	96	97	94	99	98	99	99	99

[a] Viability percentages are averages of 3 samples.
[b] Percentages within the shaded area are not significantly different from each other.

Table 6-2. Effect of separation in pentane and length of time in storage on the percent germination of sugar maple seeds (Carl 1975)

Year of collection	Treatment	Months in storage										
		0	6	12	18	24	36	42	48	54	60	66
1967[a]	Pentane	98.2	97.2	—	94.8	—	—	95.6	—	96.8	—	98.4
	Control	98.2	91.5	—	94.4	—	—	87.6	—	93.8	—	93.1
1968[b]	Pentane	94.9	—	92.4	—	90.7	86.2	—	88.2	—	90.3	—
	Control	94.9	—	92.0	—	87.3	86.6	—	90.4	—	91.1	—
1970[b]	Pentane	99.0	—	97.1	—	97.8	97.7	—	—	—	—	—
	Control	99.0	—	96.9	—	97.8	98.6	—	—	—	—	—

[a] Single tree.
[b] Average of 4 trees.

one storage study (Yawney and Carl 1969), it was found that unseparated samaras from three different trees could be stored for 4-1/2 years without any significant loss of viability when they were stored at 10 percent moisture content at +2°C or at −10°C (Table 6-1). In a subsequent experiment, Carl (1976) separated samaras in pentane, dried them to about 10 percent moisture content, and stored them at −10°C. He found that the seeds could be successfully stored for 5-1/2 years without losing their viability, and without any apparent damage from separation in pentane (Table 6-2).

Seed Testing and Nursery Germination

Information on the germination potential of a seedlot is vital to any seed handling program. This information will serve as a guide to estimating how much seed is needed to produce a given number of seedlings, and how many seeds to sow per square foot to give the desired seedbed density. The seeds should be tested just before sowing.

A sample of seeds may be sent to the National Tree Seed Laboratory[1] for germination tests. There is a set fee for these tests. In addition, some states maintain tree seed testing facilities. If time and facilities are available, you may do your own testing. The procedures are relatively simple, but require from 50 to 90 days, depending on the method used. The Association of Official Seed Analysts (AOSA) and the International Seed Testing Association (ISTA) rules for testing sugar maple seeds differ only slightly from each other. The AOSA says to place the seeds on top of a moist blotter, or in moist sand, and prechill for 60 days at 3 to 5°C, then change the seeds to a constant 15°C for 28 days, or alternating temperatures of 18° and 24°C for 14 days. The ISTA says to place the seeds on top of germination paper, or in moist sand, and prechill for 60 days at 1 to 5°C, then change the seeds to 20°C for 21 days. Both associations also give procedures for testing excised embryos, but if there are several seedlots, excising embryos can be very time consuming.

Janerette (1978) reported that she got 95 percent germination in 51 days. She soaked samaras in tap water for 24 hours, placed them on a moistened paper towel, and wrapped them in aluminum foil. The aluminum foil packets were then stratified at 3 to 4°C.

Carl and Yawney (1966) compared the effectiveness of sand, perlite, spagnum moss, and germination paper as stratification/germination media. All four media gave equally satisfying results, but the germination paper in plastic boxes (Fig. 6-5) was the most convenient, so we recommend it. The procedure is to soak the samaras in tap water, at room temperature, for 24 hours. Then drain off the water, place the samaras on germination paper in plastic boxes and stratify them at 2°C for 90 days. It has been our experience, and that of others (Webb and Dumbroff 1969, Janerette 1978), that germination begins after about 30 to 35 days of stratification. Although a few seeds may require the full 90 days of stratification, most of the germination is complete by the end of 65 to 70 days. When testing a seedlot for germinability, we usually use five samples of 50 samaras each. If the samaras have not been separated in pentane, 100 samaras are used per sample. After stratification is complete, the remaining samaras are opened to see if they actually contain seeds. The final germination percentages are based on the number of seeds in the sample, not samaras.

If the seeds have been stored for more than a year since the last germination test, or if something has happened that may affect their viability, a new germination test should be made. Germination and survival in a nursery will not always equal germination under ideal laboratory conditions. Insects, disease, and unfavorable weather conditions all have an adverse effect on nursery germination and survival despite the best efforts of the nurseryman.

In our experience, fall-sown sugar maple seeds do have nearly 100 percent germination (Carl and Yawney 1977). While this 100 percent figure may vary from year to year, and possibly from nursery to nursery, it will serve as a guide to determine sowing rates until a nurseryman gains experience with the species.

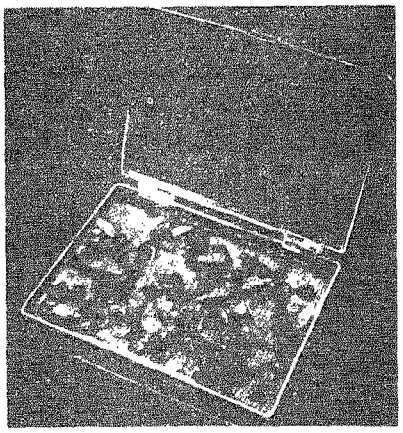


Figure 6-5.—Germination paper in plastic boxes used for testing sugar maple seed germinability.

[1] It would be advisable to contact the National Tree Seed Laboratory, Rt. 1, Box 182-B, Dry Branch, GA 31020, for information on fees, sample size, etc., before sending any seeds.

Chapter 7

Nursery Practices

by
Clayton M. Carl, Jr.

Requests for sugar maple seedlings, particularly from genetically superior stock, have increased during the past few years. As the demand for good sugar maple seedlings increases, the number of nurseries growing these maples will increase and there will be an increasing need for information on growing and handling sugar maple seedlings. For those who manage, or are anticipating managing, nurseries for the production of tree seedlings, publications by Stoeckeler and Jones (1957), Armson and Sadreika (1974), and Williams and Hanks (1976) are helpful.

Any successful nursery management program requires careful records of what is done to the soil and the seedlings, and the size and quality of the seedlings produced. This report summarizes information that will help growers produce plantable sugar maple seedlings.

Soil Management

The growing medium is basic to the production of any crop. In the nursery production of seedlings, the soil is that medium, and proper management of the soil is probably the most important step in any production program. To grow vigorous, healthy seedlings, the soil must provide nutrients, moisture, oxygen, and growing space. And to assure their availability, the nurseryman has to control texture, fertility, drainage, and acidity.

Generally, hardwood seedlings are considered more demanding than conifers in their soil requirements. Therefore, if one has a choice, the best nursery soil, in texture, drainage, fertility, and pH, should be used for sugar maple. If there is no choice, then efforts should be made to improve the soils with suitable amendments. Anyone selecting a new nursery site should consult the publication by Stoeckeler and Jones (1957), who cover this topic in some detail.

Soil texture. Soil texture refers to the relative proportions of sand, silt, and clay particles in the soil. This relationship is quite stable and not easily changed. For a sugar maple seedling nursery, as for other hardwoods, the best-textured soils are sandy loams and loams with less than 35 percent silt plus clay (Stoeckeler and Jones 1957, Williams and Hanks 1976). There should be adequate surface drainage, and the subsoil should have good drainage.

Small changes in soil texture can be made in the plow layer by adding sand to clay, or vice versa. But, it takes a tremendous amount of sand or clay to change the soil texture appreciably. Deep plowing is another possible way of influencing soil texture if there is a difference in texture between the plow layer and the subsurface soil. However, both the addition of sand or clay to the plow layer and deep plowing are quite costly and time-consuming, so if soil texture is a serious problem, the best solution might be to move to a more favorable location.

Organic matter. Organic content has an important influence on both chemical and physical properties of the soil. The amount of organic matter in the soil should be about 2 percent, more for heavier soils and slightly less for sandier soils. The addition of organic material such as sawdust or humus, or rotation with green manure crops, or both, is highly recommended. The addition of sludge as organic matter can be advantageous, but there is the possibility of contamination by heavy metals, depending on the source of the sludge.

It would probably be best to add organic matter frequently (after each rotation), and in smaller quantities that will decay rather rapidly. If large amounts of organic matter are added at one time, care should be taken to replace the nitrogen and phosphorus used by the soil micropopulation in its decomposition (Millar 1955).

Soil pH and fertility. Soil pH is a measure of the hydrogen-ion activity in the soil on a logarithmic scale of 1 to 14. The lower the pH number, the more acid the soil is; the higher the pH, the more alkaline the soil is. A pH of 7.0 is considered neutral. The recommended pH for a hardwood nursery soil is about 6.0, although Wilde (1946, 1958) recommends from 5.5 to 7.3, with the best being 5.8.

In nursery soils, pH may exert considerable influence on plant growth by regulating the solubility, and thus availability to the seedlings, of many essential elements (Allaway 1957). The soil pH can be changed by the addition of lime to raise the pH or sulfur to lower it. A number of factors, such as cation exchange capacity, organic matter content, and soil moisture content, influence the amount of lime or sulfur required to bring about a unit change in pH in a given soil.

The initial nutrient content of the soil is not a critical factor, since the fertility level can be restored from organic and inorganic fertilizer sources. If a soil was originally high in nutrients, it would be depleted by the removal of a seedling crop (both roots and tops) every few years. The proper fertilizer should be added at the right time, and in the right amount, to keep the nutrient supply at the optimum level. Wilde (1946, 1958) gives these recommended soil fertility standards for raising sugar maple seedlings:

pH 5.5–7.3
Total N (%) .20
Available P_2O_2 per acre (lb) 100–150
Available K_2O per acre (lb) 250–275
Base exchange capacity (meq/100 g) 10–14

Exchangeable Ca (meq/100 g)
5.0–8.5
Cations (meq/100 g) 2.0–2.5

Seedbed Preparation

Seedbed preparation for sugar maple is not essentially different from that for most other seedlings. The seedbeds should be prepared just before sowing the samaras; for sugar maple this is usually in the fall after they are collected. If crop rotation (alternating seedlings with a green-manure crop) is practiced, the green manure should be plowed under about 4 to 6 weeks before the beds are formed. If the green-manure crop was not fertilized sufficiently, enough fertilizer should be added at that time to hasten its decomposition.

One of the last tasks before the actual formation of the beds, is eradicating any harmful biotic elements—weeds, insects, fungi, etc.—that may be present. We have successfully used "Roundup"[1] experimentally for weed control. It can be applied 1 to 2 weeks before plowing, using the recommended rates and procedures. Since it does not control weed seeds, however, another, and perhaps better way would be to apply the "Roundup" several weeks before preparing the seedbeds, wait for the weed seeds present to germinate and grow, and then re-treat with "Roundup".

Fumigation would control most weed problems, as well as soil-borne insects, nematodes, fungi, and diseases. Williams and Hanks (1976) report that fumigation stimulates the growth of some species such as yellow poplar. But Martin et al. (1963) report evidence that fumigation inhibits phosphorus absorption, causing phosphorous deficiency, and Thiegs (1955) reports that it temporarily inhibits nitrifying bacteria. This may be due, at least in part, to the killing of beneficial mycorrhizae and bacteria. There are endomycorrhizae that penetrate the root cells of hardwoods and are necessary for good seedling growth (Clark 1964), and maples form endomycorrhizae (Marx 1977). By not fumigating, we do not destroy any beneficial mycorrhiza-forming fungi, or nitrogen-fixing and symbiotic bacteria that may be present. We feel that this justifies not fumigating unless absolutely necessary.

After the harmful biotic elements have been controlled, the area should be plowed (to a depth of 8 to 10 inches) and disked to promote good seedling root development. Soil samples should be taken to determine fertilizer and lime requirements. We know of no formal experiments that give specific nutrient requirements for sugar maple, but Wilde (1946, 1958) does make some recommendations. Since there is no nutrient level optimal for all soils, each soil will require individual attention and treatment and these recommendations may be of limited value. In a pot-culture experiment, Carl, Donnelly, and Post (1973) found no significant response to added nutrients. The seedlings were watered from a deep well simulating actual irrigation of nursery stock, but this water contained trace amounts of dissolved minerals which may partially explain the lack of seedling response to the added nutrients.

Nurserymen are divided as to when to add lime and fertilizer. Some believe lime should be added before the beds are formed, while others prefer to form the beds first, then lime and fertilize. In either case, it should be done after fumigation. We add lime and fertilizer after the beds are formed, and mix them into the upper 2 to 4 inches of soil. Part of our reason for doing this is that the material is there readily available for germinating tree seeds, and little is wasted on the paths where it would be used by weeds.

Only enough fertilizer to supply current seedling crop needs should be applied; excess fertilizer can be harmful to the seedlings. Experiments are presently being conducted with slow-release fertilizers to see how effective a single fertilizer application can be in providing nutrients for an extended time. Additional fertilizer can be applied to the seedlings at any time through the rotation, as the growth of the seedlings requires. While deficiency symptoms indicate a lack of a particular element, the seedlings have been stressed and growth reduced before the deficiencies are visible. And, although these deficiencies can be corrected if noticed soon enough, it is better to start with adequate nutrient levels and have an ongoing soil and tissue analysis program, with proper interpretation of the results. Nurserymen might do well to establish demonstration areas in their own nurseries to determine optimum growth rates of the seedlings grown under their specific environmental conditions.

Our seedbeds are raised, and usually made with a bed former. Various types or combinations of equipment are available for bed forming. For small areas, the beds can be formed by hand, by shoveling the soil from the paths into the beds. Raising the beds improves aeration and soil drainage. Our beds are about 42 inches wide, and are raised 4 to 6 inches above the general ground level. The paths between the beds are 18 to 24 inches wide.

Seed Sowing

The seed of the sugar maple is actually contained within a winged fruitcoat; the entire structure is called a samara. There is no mechanical equipment suitable for sowing samaras, and since there is no easy method of removing the fruitcoat or the wing, conventional sowing equipment cannot be used. The samaras can be hand sown, either broadcast or planted in rows. Sugar maple seeds have a dormant embryo; this dormancy can be overcome by stratification at a low temperature, so we recommend fall sowing in the nursery. Stratification

[1] Roundup™ is manufactured by the Monsanto Company, St. Louis, MO 63166. Casoron™ is manufactured by the Thomas-Hayward Chemical Company, Kansas City, KA 66110.

will occur naturally during the winter and germination in the spring. This method provides greater germination, survival, and first year's growth than spring sowing (Carl and Yawney 1977).

Broadcasting is a relatively quick way to sow the samaras, but it is difficult to control their density over a large area. The recommended density for sugar maple is about fifteen 1-year-old seedlings per square foot (Stoeckeler and Jones 1957, Williams and Hanks 1976). The number of samaras per pound depends on their size and whether they have been separated in pentane. The percentage of samaras containing seeds can easily be determined by a cut test. Carl and Yawney (1966) found from 20 to 74 percent. If the samaras have been separated in pentane (Carl and Yawney 1969), close to 100 percent will contain seeds. If the sugar maple seeds are ripe when picked and properly handled, their germination will be close to 100 percent. The resulting sugar maple seedlings usually have a very high survival rate, 95 to 100 percent.

One method to help obtain the desired density is to broadcast the calculated amount of samaras over small portions of the seedbed, such as 100 square feet at a time. The amount of samaras to sow in a given area can be computed by a formula similar to that given by the TVA (1954). The nurseryman must know the number of samaras per pound, the percentage of samaras containing seeds, the germination percentage of the seeds, and the expected survival of the germinated seeds. The formula then is

$$P = \frac{A \times D}{S \times F \times G \times Y}$$

where P = pounds

of samaras to sow; A is the area to be sown in square feet; D is the desired density per square foot; S is the number of samaras per pound; F is the percentage of samaras containing seeds, expressed as a decimal; G is the germination percentage of the seeds, expressed as a decimal; and Y is the percentage of germinated seeds that produce seedlings that survive at the end of the first year, expressed as a decimal.

As an example, suppose a nurseryman wants to sow several 100 square-foot plots using samaras from a lot that has not been separated in pentane. There are 6500 samaras per pound, 50 percent of the samaras contain seed, the germinative capacity is 98 percent, and the expected survival factor is 95 percent. The formula then becomes:

$$P = \frac{100 \times 15}{6500 \times .50 \times .98 \times .95}$$

$$= \frac{1500}{3025} = .5 \text{ pound per lot}$$

We use a planter (Fig. 7-1) which is a modification of one described for planting experimental seedlots of Douglas-fir *(Pseudotsuga menziesii)* (Schmidt 1968). Our planter sows the samaras in seven rows, with 6 inches between rows and 1-3/4 inches between samaras in a row. This sows the samaras at a density of about 15 per square foot. Since most of the samaras contain seeds (having been separated in n-pentane), and since sugar maple has a very high germinability, this results in a seedling density close to the recommended fifteen 1-year-old seedlings per square foot.

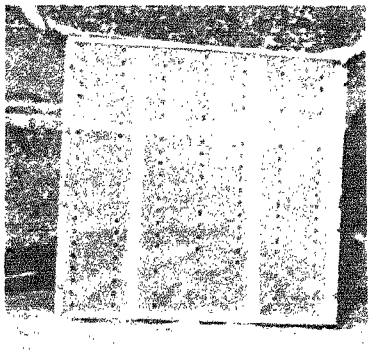


Figure 7-1.—Planter used for sowing experimental lots of sugar maple samaras.

After the samaras have been sown, we pull a small lawn roller over the beds to firm the samaras into the ground, and to level the seedbed. We cover the beds with about 1/2 inch of fresh softwood sawdust. In one experiment, we used partially decomposed sawdust to cover the seedbeds. In that experiment, 70 percent of the viable sugar maple seeds were destroyed by the maggot *Hylemya florilega* (Zetterstedt) (MacCollom and Yawney 1967). This was attributed to the insect laying its eggs in the partially decomposed sawdust and the emerging larvae feeding on the sugar maple seeds. We have also tried hardwood sawdust, but it formed a crust (Fig. 7-2) which prevented many of the germinated seeds from growing through.

Birds have never pilfered seeds we have sown, but rodents have caused serious losses of unprotected seeds. To protect the seeds, we place a 4 x 4 hardware cloth on top of the sawdust. This also helps to prevent the sawdust from being blown away.

Before we used the hardware cloth, we tried both leaves and saltmarsh hay to hold the sawdust in place, but neither prevented the loss of the sawdust and they did not protect the seeds from rodents.

In a sowing of sugar maple seeds at the Vermont State Nursery, nearly 95 percent of the seeds were lost to rodents. Since then, they have coated the samaras with anthroquinone; this has deterred rodent pilferage (personal communication with William Baron, Vermont State Nursery 1980).

Tending Seedbeds and Seedlings

Shade. In a study reported by Cunningham (1965), 0, 33, 67, and 87 percent shades were compared for their effect on survival and growth of sugar maple. Although there were no statistically significant differences in the average height of seedlings 2 years after seeding, only the 33 and 67 percent shade treatments had seedlings taller than 3 feet.

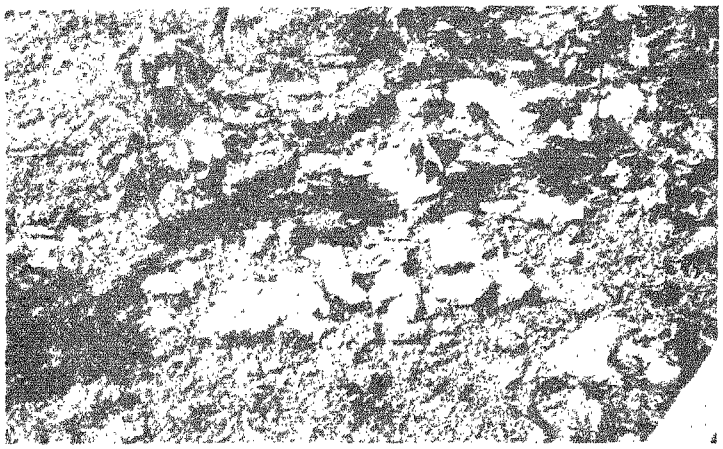


Figure 7-2.--Large plates of hardwood sawdust such as these prevented germinated sugar maple seeds from growing through.

Logan (1965) also grew seedlings under four levels of shade (87, 75, 55 and 0 percent). After 5 years, seedlings grown in full sunlight were significantly shorter than those in the other three treatments, but reduction in light had much less effect on root and shoot weights. Shade improves survival, probably by helping to prevent desiccation of freshly germinated seeds. Shade also helps to conserve water by retarding evaporation from the seedbed surface, and it may improve growth by increasing the availability of soil moisture.

Irrigation. In a study by Carl et al. (1973), watering significantly increased the shoot and root dry weights, and shoot height and diameter of seedlings. Height growth differences due to treatment were more apparent after the second and third growing seasons than after the first. However, too much moisture, particularly late in the summer, may result in succulent growth that can be killed by early frosts. High levels of soil moisture in a nursery may produce seedlings with low root/shoot ratios, which may reduce the survival of outplanted seedlings. Therefore, it is recommended that seedlings be given ample water early in the growing season for good growth, but that watering be reduced in late August and September to harden off the seedlings.

Disease, insects, and weeds. In our experience, sugar maple seedlings do not generally have serious disease problems. Hepting (1971) says that *Rhizoctonia solani* occasionally causes damage, and he cites a report of *Sclerotium bataticola* having killed seedlings in an Illinois nursery. U.S. Department of Agriculture Handbook No. 470 (1975) describes a number of hardwood nursery diseases, but none is specifically mentioned as attacking sugar maple. This may be because there has been very little experience raising sugar maple and little study of its diseases has been necessary.

It is better to prevent disease than to cure it. If good cultural procedures are followed, disease problems are minimized. Proper fertilization, watering, and cultivation help maintain seedlings in a vigorous, healthy state, able to withstand pathogens. Sprays and dusts are also helpful in preventing disease, but are usually not a cure. Also, rotating beds among different species helps to reduce disease problems.

Because of the increasingly stringent regulations covering the use of pesticides, it is difficult to make specific recommendations for the various diseases. Therefore, it is recommended that any specific pathogen be identified, and a program for control be planned by an expert. Such help can usually be secured from the pathology department of your state college or university, or your state department of agriculture.

Insects usually cause more damage to sugar maple seedlings than diseases, and a close watch should be kept to detect insect attacks early so control measures can be taken. Insects damage leaves, stems, and roots. Baker (1972) discusses a number of insects that attack sugar maple forest trees; many of these insects also attack seedlings. Several of the more common insects that damage hardwood seedlings are discussed by Williams and Hanks (1976). The most obvious damage is that done by the leaf feeders. However, no less serious, though not so apparent, is the damage done by sucking insects and root feeders.

Some of the more common leaf feeders are the larvae of the eastern tent caterpillar, the forest tent caterpillar, the gypsy moth, and the saddled prominent (Figs. 7-3A, 7-3B, 7-3C, and 7-3D). Insects that cause damage by sucking plant juices include aphids, scale insects, and leafhoppers. The latter have been a serious problem in our experimental nursery, causing considerable reduction in seedling growth. A striking example of the damage done to sugar maples by leafhoppers is reported in the American Nurseryman (1972), and in Agricultural Research (1972). Root feeders include wireworms, white grubs, and cutworms. Several species of cutworms also feed on aboveground portions of plants. Nematodes, although not insects, are root feeders, and are often included in discussions of insects. Before using any pesticide, it is best to get a positive identification of the pest in ques-

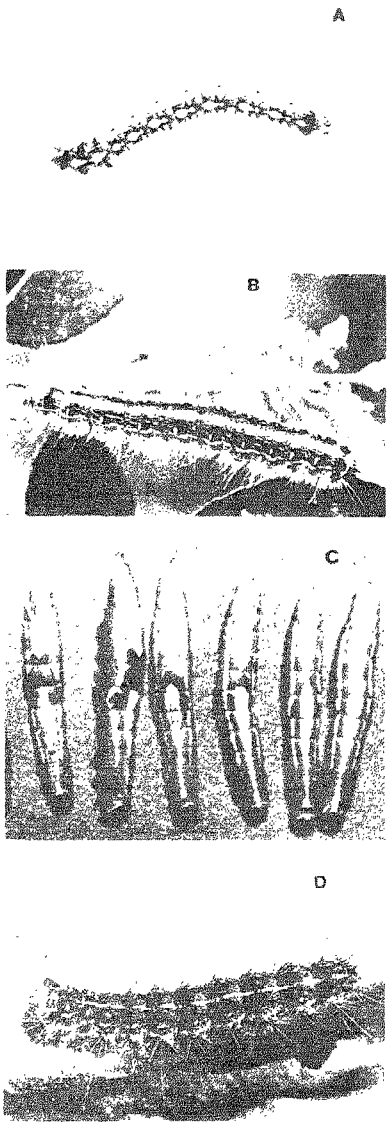


Figure 7-3.—Examples of caterpillars and larvae that feed on sugar maple seedlings: (A) forest tent caterpillar; (B) eastern tent caterpillar; (C) saddled prominent; and (D) gypsy moth.

tion, together with a prescription for control, from an expert.

Weeds are a serious problem in sugar maple seedbeds. They compete for space, nutrients, and moisture essential to the seedling crop. Fumigation will kill weeds and weed seeds that are in place, but does not offer complete control. Weed seeds that blow in from surrounding areas after fumigation find an ideal seedbed. Fumigation also destroys mycorrhizae which, for hardwoods, are slow to reinvade the seedbeds. So far, we have not found a pre-emergence herbicide that will kill the weed seeds but not the sugar maple seeds. Dimethyl tetrachloroterephthalate (DCPA) is an herbicide that was reported for nursery weed control for hard maple at the 1967 Northeastern Area Nurserymens' Conference. However, others in general conversation say that the application has to be precisely timed, or the germinating sugar maple seeds will also be killed.

We use "Roundup" in our experimental nursery to kill established weeds prior to seedbed preparation. But for the first growing season after seed germination, we resort to the expensive, laborious hand weeding of our experimental seedbeds. Mony (1954) and Baker (1962) report on mechanical cultivators that can be adapted for weeding larger nurseries. After the first year, we use "Casoron"[1] for the control of weeds in our seedbeds. Whenever any herbicide is used, however, the manufacturer's instructions should be scrupulously followed.

Mice have also caused damage by girdling the bark or cutting off small seedlings. Keeping grass mowed and the area free of weeds helps eliminate protective cover for the rodents. This helps reduce their numbers, and thus the amount of damage they do. Rodents can be trapped, but probably the best way to eliminate them is by the use of registered, prepared baits. We use zinc phosphide-treated oats placed in bait stations throughout the nursery area. Stoeckeler and Jones (1957) also recommend baiting a bordering zone 200 feet outside the nursery area. The bait should be placed where non-target animals will not have access to it.

Rabbits also cause damage at times by cutting off seedlings. They can usually be effectively excluded by fencing. This fence should be high enough to prevent the rabbits from entering during periods of deep snow or heavy snowdrifting. Rabbits that remain in the area or gain access to it after it is fenced have to be trapped or shot.

Pruning. Root/shoot ratios and the type of root system are important in the survival and growth of outplanted seedlings. It is generally recommended that high-quality seedlings selected for outplanting have a high root/shoot ratio (Carlson 1972, Hawley and Smith 1954). Pruning the root system tends to retard stem growth while stimulating the production of a heavier, more fibrous root system. This gives a higher root/shoot ratio, as recommended. In addition to improving seedling development, root pruning also makes the seedlings easier to handle. Verticle pruning reduces the number of interlaced roots, making the seedlings easier to lift with less root damage, and the more compact root system makes them easier to plant. Preliminary work at our nursery has shown that vertical pruning stimulates root proliferation of sugar maple, but further studies are needed.

Sugar maple has opposite branches, which frequently results in a forked seedling if the terminal bud dies. When this happens, some top pruning is necessary to help shape the seedling. More experimental work is needed to determine the effects of pruning branches on growth and development of sugar maple.

Handling Seedlings

To help reduce the damage to planted seedlings caused by deer browsing (See Chapter 8), we sug-

gest planting seedlings 6-foot or larger in reforestation projects or for orchard establishment. However, 6-foot seedlings cannot be lifted with conventional lifting equipment; they must be dug by hand or with some type of mechanical digger. We have used a plain front-end bucket loader on a tractor, but it damaged the seedlings considerably. We have also used a front-end loader equipped with tines, and this does a satisfactory job of lifting seedlings. Seedlings that have been transplanted usually have a more compact root system, and can be lifted fairly easily by hand. Although we have not yet tried one, a conventional tree digger would probably work very well for lifting the transplanted seedlings.

Sugar maple seedlings are usually lifted in the fall, after they have hardened off. They can then be fall planted, or heeled-in, or placed in cold storage for spring planting. If digging is delayed until spring, the seedlings may have broken dormancy before the seedbeds can be worked.

The survival and growth of any plantation will depend to a large extent on the quality of the planting stock. Although seedling grades have been established for some hardwoods (Limstrom 1963, von Althen 1972), there are no grades for sugar maple. If deer browsing is not a problem, a general rule might be to plant as large a seedling as practicable, keeping in mind that the seedlings should have high root/shoot ratios. Any seedlings that are obviously too small, diseased, or damaged should be discarded.

Seedlings that are acceptable for planting should be packaged immediately to prevent drying out of the tender root tips and damage from handling. If the stock is large and to be planted immediately, it can be placed in a stock tank with its roots covered with water and transported to the planting site in the tank. The stock should be held in cold storage and kept moist if it cannot be packaged within a day. While the large seedlings present some problems in packaging, the smaller seedlings can be packed by conventional methods such as the jellyroll or Olsen bale. The kraft bag can be used for smaller seedlings, and it is becoming more popular. These methods are fully described by Williams and Hanks (1976).

Sugar maple seedlings can be stored safely for extended periods if necessary. Perhaps the easiest method, and certainly the least expensive, is by heeling-in. Williams (1963) reported that fall-lifted hardwood stock that had been heeled-in survived overwintering and grew as well as spring-lifted stock. We have frequently used this method successfully. The hardened-off seedlings are lifted and the diseased and damaged seedlings are culled. Williams and Hanks (1976) recommend using only sandy soil for heeling-in, even if it must be hauled in. A trench is dug deep enough so the roots can be covered to 1 inch above the root collar without bending the roots. This trench can be dug by hand, if there aren't too many seedlings, or with a plow. The seedlings are culled and the good seedlings are then placed in the trench and covered with soil. Drench the seedlings after they have been heeled-in to wash the soil around the roots to eliminate air pockets. Additional trenches parallel to the first one can be dug as needed. The trenches should be far enough apart to avoid exposing the roots of the previous row, but close enough so space is not wasted. A mulch can be placed on top to protect the seedlings from alternate freezing and thawing and deep frost. However, we have not had to mulch the seedlings in northern Vermont, probably because of the deep snow cover. Seedlings overwintered in this manner are readily available for spring planting.

The seedlings can also be kept in cold storage at about 0.5°C (Webb and von Althen 1980). This is expensive but it does have some advantages over heeling-in: Heeled-in seedlings may break bud during a prolonged warm spell. Also, a cold room can be used to store a large quantity of lifted seedlings temporarily and they can be graded and counted after the ground freezes.

Chapter 8

Planting Sugar Maple

by Harry W. Yawney

Planting Sugar Maple

Interest in planting sugar maple has been rekindled in recent years and has been growing steadily. It comes, for the most part, from sugarmakers wanting to start new sugarbushes. The production of maple syrup, once thought to be a dying industry, has been made profitable by the development of innovative technology such as plastic pipeline, vacuum pumping, and new sap processing systems. And another factor stimulating interest in planting is the possibility of increased syrup production from genetically superior, high-yielding sugarbushes.

Sugar maple has been planted for over 200 years. In 1793, Rush mentioned in an essay on sugar making that appeared in the transactions of the American Philosophical Society, a Pennsylvania farmer who averaged a pound of sugar from 3 gallons of sap collected from trees he had planted 20 years before. (It is interesting to note that Rush indicated it took 5 to 6 gallons of sap from forest-grown trees to produce the same amount of sugar.) In his article, Rush also noted that Thomas Jefferson had planted maple trees on his Virginia farm for the express purpose of producing sugar. It seems that the merit of gathering sap from roadside trees was obvious to the colonists, and plantings during the colonial period undoubtedly account for the large, stately, evenly spaced sugar maples that still line both sides of many country lanes throughout New England.

A book by Jones published in 1832 provides some little-known facts about the sugar maple tree. The book is a compilation of published articles that contained much of what was then known about the maple sugaring process, including the advantages, both economic and "*medicinal*", of maple sugar over cane sugar. From several of these articles, it is clear that the Quakers in America at that time perceived in the sugar maple tree a means of destroying the slave trade. They believed that if the world markets could be supplied with a cheaper sugar than that produced on the slave plantations of the West Indies, there would be little incentive for slavery. Jones, an Englishman, was concerned about the troubled world conditions of his time, and hoped the information he compiled in his book would encourage the widespread planting of sugar maple throughout England. Jones reasoned that if a sufficient number of trees were planted, England could eventually produce enough domestic sugar to become free of her dependency on an uncertain foreign sugar supply. With his compilation of articles, Jones included instructions for ordering sugar maple seedlings from Northern America and instructions for planting (Fig. 8–1).

Although sugar maple and other hardwood species have been planted for many years, the small amount of information that has accumulated suggests that hardwood plantations are difficult to establish. Hardwood planting began as a conservation measure during the late 1800's, dating almost from the beginning of the conservation movement in this country. Planting to reclaim idle lands in North Carolina was begun in 1890 (Hassis 1930), and records of planting in Indiana date back to 1903 (DenUyl 1951). Hardwood planting began in New York in 1909 (Eliason and Littlefield 1967).[1] In Ontario, Canada, hardwood plantings were carried out around 1880 (von Althen 1977). Both state and federal agencies undertook large-scale hardwood plantings, and bulletins and leaflets with hardwood planting recommendations were printed for public use (Brown et al. 1914, Tillotson 1921, Kittredge 1929, Mattoon 1930, Hetzel 1939). Reforestation efforts with hardwood species reached a peak with the Civilian Conservation Corps in the 1930's. The number of hardwood plantings made is not known, but it must be assumed to be considerable. In the Tennessee Valley drainage alone, Allen (1953) reported that the number of hardwood seedlings of various species planted up to 1946 exceeded 72 million. These plantings, however, resulted in discouragingly few successes, and after 1950 reforestation projects using hardwood seedlings all but ceased as a forestry practice.

In West Virginia, Tryon (1956) asked the question: "Why have hardwood plantings failed so often in a region where high quality timber grows so well?" Winch (1937), in his analysis of hardwood planting in New York, provided some insight into the problems involved. He concluded that the most significant factors contributing to poor growth, and often complete failure, were (1) planting on sites not suitable for hardwoods, (2) competition from field vegetation, and (3) damage caused by animal feeding. Later studies reached similar conclusions (Wallihan 1949, Stoeckeler and Limstrom 1950, Allen 1953, Zarger 1956, von Althen 1964). Our experience in Vermont indicates that sugar maple, planted on a suitable site with weed control and protection from animal damage, should grow to a tappable size of 10 inches in 20 to 25 years.

[1] Eliason, E. J., and E. W. Littlefield. 1967. What about hardwood planting? New York State Conservation Dep. Unpublished office report.

INSTRUCTIONS FOR PLANTING.

It is necessary to pay particular attention to what is said in the extracts about the soil in which the Sugar Maple grows. Dr. RUSH says, "They grow chiefly in the richest soil, and frequently on stony ground: springs of the purest water abound in their neighbourhood."—Mr. MICHAUX says, "The trees grow on excellent land."—CAPTAIN CARVER says, "The hard Maple (meaning the Sugar Maple) likes best, hills and high places."—Mr. WELD says, "The Sugar Maple is never seen but upon good ground;" and he adds, "There are two kinds of this valuable tree in Canada, the one called the *Swamp Maple*, from its being generally found upon low-lands; the other the *Mountain or Curled Maple*, from growing on high dry ground, and from the grain of the wood being very beautifully variegated with little stripes and curls." From the tree growing as here mentioned, on good dry upland ground, and in stony places, it is commonly called, in America, the *Rock Maple*, hence it is not proper to plant it in low lands or damp soil, but in such lands as are above described.

And to give the trees proper *source of nutriment*, they should be planted at fifteen feet distance, which will give 225 feet square to each tree; that will admit of planting about 200 on one acre. Where there is abundance of ground, the distance may be twenty feet, or as the proprietor thinks proper; but more than fifteen feet is not absolutely necessary.

The ground should be opened several days before the trees are put in, and good earth brought *from* another place, and mixed with that dug out; the whole turned over and over for five or six days, and spread a little, that it may attract the nitre from the air.

If it should be rainy weather, a little hillock to be raised round the tree, and just touched with the spade, to prevent too much rain from entering the hole; but if dry weather, then the tree to be often watered with water that has been exposed to the sun at least 24 hours.

Before putting in the tree, all the points of the little twigs should be clipped, to refresh them.

As to the rest, the experienced gardener will know well how to succour the tree according to the weather.

The white or swamp Maple will also be furnished for those who wish to have that species to plant in wet grounds.

4 OC 58

Acer Saccharinum Plantation Office,

6, GREAT ST. HELEN'S, LONDON,

WHERE orders are received for furnishing young trees or saplings of the North American and Canadian Sugar Maple Tree, on the following

CONDITIONS:

The tree to be five feet high at the least.

The price six shillings the tree.

Two shillings a tree to be paid at the time of giving the order, the rest on the delivery of the trees.

The orders to be executed according to the priority of their dates.

The trees to be delivered at London, Bristol, or Liverpool, in November, December, January, February, or March, in every year.

NOTE.—*Orders to be given before the first of July.*

Figure 8-1.—These instructions for ordering and planting sugar maple seedlings appeared in the book by Jones which was published in England in 1832.

The Planting Site

Choosing the proper site is probably the most important consideration (von Althen 1977). Sugar maple grows on a variety of soil types, but thrives only where the soils are fertile, medium textured, and well drained (Godman 1965). Occasionally, sugar maple can be found on dry, shallow soils, but the trees are not thrifty and growth is slow (Hickok et al. 1931, Westveld 1933). Sugar maple does not grow well in heavy clay soils. Because sugar maple has rather specific site requirements, it is essential, as von Althen (1979) cautioned, to determine soil texture, depth of topsoil, drainage, and general fertility of the proposed site before any planting is done.

Good growth can be expected on soils classified as sandy loams and silt loams, but the best growth should occur on loam soils. Generally, soils for sugar maple plantings should have a silt plus clay content between 30 and 50 percent (Stoeckeler and Limstrom 1942).

Sugar maple can tolerate a wide range of soil acidity, but Wilde (1958) recommends a pH between 5.5 to 7.5 as optimum for planting sugar maple. The fertility requirements for sugar maple given in Table 8-1 can be used to evaluate the suitability of proposed planting

Table 8-1.—Characteristics of forest soils supporting productive stands of sugar maple. Data are for the upper 8 inches of the soil profile (From Wilde and Patzer 1940)

pH	5.79 ± .12
Base exchange capacity (meq/100 g)	13.76 ± .9
Total N (%)	0.185 ± .012
Approximate level of available N per acre (lb)	41
Available P_2O_5 per acre (lb)	136.7 ± 12.4
Available K_2O per acre (lb)	242.3 ± 17.5
Replaceable Ca (meq/100 g)	8.3 ± .9
Replaceable Mg (meq/100 g)	2.1 ± .3

sites. The data shown were developed in the Lake States by Wilde and Patzer (1940), based on an extensive sampling of productive natural sugar maple stands growing on loam or silt loam soils.

County soil survey reports prepared by the Soil Conservation Service can be extremely useful for selecting potential sugar maple planting areas. Mapping is normally done on the basis of soil series. Smaller mapping units are used on agricultural lands to indicate different phases of a soil series, delineated according to stoniness, steepness of slope, or some other dominant soil feature. The reports will indicate texture and depth of the topsoil and of the various horizons, moisture drainage characteristics, type of parent material, and general productivity. Selection of potential planting areas from the soil survey should be followed by an on-the-ground examination by a soil scientist to verify its suitability.

The soils best suited for growing sugar maple are also the best and most productive agricultural soils, so areas available for planting may be limited. But this is changing; in states such as Vermont much of what was agricultural land is now in transition from open to wooded, and fields and pastures that are becoming overgrown with brush and tree saplings may offer suitable planting sites.

Old fields generally are not thought to be good planting sites for hardwood trees. This is true of old fields where continued cropping and poor farming practices resulted in erosion of the topsoil and organic matter, and depleted the available nutrients and water supply by severly altering soil structure. Such an area would indeed be a poor choice for a sugar maple plantation. In Vermont, the recent trend away from what was once about 65 percent agriculture to a landscape now 75 percent forested is not due entirely to depleted soil conditions but to other economic factors governing the agribusiness. Many fields and pastures were little affected by past use; many were under good management while in agricultural use, and thus are good potential planting sites.

As these fields were abandoned, they were quickly invaded by aggressive brushy vegetation. The growth rate of this vegetation provides some indication of the productivity of these sites. Observations of hardwood plantations in Indiana by Carmean et al. (1976) suggest that shrub or tree cover that invades abandoned fields is beneficial to the site by improving soil conditions that favor planting hardwoods even on marginal farm land. They found that hardwood seedlings grew faster on old fields that are reverting to a forested condition because the soils were modifed physically, chemically, and biologically by a well-stocked stand of trees. Accordingly, the best soils for planting hardwoods are to be found under existing forests where the soil environment has remained relatively undisturbed.[2]

[2] Hannah, P. R. (Professor of Forestry, University of Vermont). Personal communication.

Either old fields that are reverting to forest conditions or sites tha have long supported forest stands are suited for planting sugar maple. However, as pointed out in the next section, good site preparation and weed control are essential to the success of sugar maple planting, and the choice of a planting site may be decided by the economics of clearing the site. Land most recently abandoned by agriculture wil be the easiest and least costly to prepare for planting.

Control of Competing Vegetation

It is essential to free seedlings from competing vegetation. This requires site preparation before planting to remove existing vegetation, and weed control for several years after planting (Fig. 8-2).

Vegetation influences seedling survival and growth in several ways. Most obvious is competition for light, moisture, and nutrients. Other effects include mechanical damage from snow acting on heavy, overtopping herbaceous cover, and damage by mice and rabbits, for which dense stands of weeds and grasses provide ideal habitats. An



Figure 8-2.—A suitable site, elimination of competing vegetation, and protection from animal damage is necessary for good growth. This sugar maple tree, planted in 1971, is about 4.5 inches in diameter.

effect that is not so obvious is allelopathy—the process whereby biochemical substances released into the environment from one plant may be toxic to a neighboring plant. While the concept of allelopathy is not new (Tukey 1969), only in recent years has evidence begun to trickle in to suggest that allelopathy and not the direct competition for moisture and nutrients may have been the major cause of past hardwood planting failures.

Several herbaceous species in an old-field plant community contain allelopathic compounds that inhibit nitrogen-fixing bacteria in the soil (Rice 1964). The implication of this where these and similar herbaceous plants are found is that in time the soil will be depleted of nitrogen, and the available phosphorus, potassium, and other nutrient elements may become limiting. Carmean et al. (1976) speculated that similar allelopathic influences may be the reason for the poor hardwood growth they observed in their old-field plantings in Indiana. Similarly, allelopathy may explain the poor results in one of our studies (Yawney and Carl 1970). Differences in growth between sugar maple seedlings planted in old field sod and those planted on plots with site preparation and weed control were striking. Our data showed that 4 years after planting, while survival was good, the seedlings in sod grew very little and were essentially the same size as when they were planted (Fig. 8-3). Growth of these seedlings did not appear to be influenced by any factor other than the presence of the old-field weeds and grasses. In contrast, on the plots where the weeds were essentially eliminated, there was a significant increase in growth even though these seedlings were heavily browsed by deer. The inhibitory effect of weeds and grasses on sugar maple seedling growth is demonstrated in a study by Zarger (1956) in Tennessee, who reported that 8 years after planting, many sugar maple seedlings were still hidden by the heavy growth of grasses and weeds.

The effectiveness of weed control during the first few years after planting will largely depend on the intensity of site preparation (von Althen 1977). In unused pastures, site preparation may involve no more than plowing and disking; where brushy vegetation and trees are present, heavy equipment may be necessary to prepare the planting site. On sites with steep topography or numerous large stumps, complete site preparation may not be possible, and herbicides may be the only means of controlling unwanted vegetation. Von Althen (1977) states that the method used will depend on soil condition, topography, accessibility, density, and composition of the existing cover, and the cost of the various methods under consideration. He adds: "Under no circumstances, however, should the success of a plantation be jeopardized for an initial saving in the cost of site preparation and weed control."

Plowing and disking the whole plantation area is probably the best method of site preparation. It not only eliminates all vegetation but also destroys the habitat and protective cover of mice and rabbits. When preparing the whole area is not feasible, von Althen (1976b and 1981) recommends cultivating or herbiciding strips 6 to 9 feet wide. For best results, he suggests that the soil be turned over by rototilling and plowing and disking several times before planting. If herbicides are to be used, the spraying should be done during the growing season before planting. Von Althen's recommendations include the herbicide "Roundup" to kill standing weeds and grasses.

Site preparation, regardless of method, provides only a temporary respite from weed competition. Reinvasion by weeds is rapid—often they fully occupy the prepared areas before the first growing season is well under way. Forest sites that have been cleared will quickly be revegetated by the rankest kind of growth. The sudden appearance of a variety of herbaceous species will be accompanied by vigorous sprouting if the stumps are not removed or sprayed with herbicides. Because post-planting weed control is absolutely necessary for the success of



Figure 8-3.—After four growing seasons, sugar maple seedlings planted without weed control had increased in height by only 4 inches.

hardwood planting (von Althen 1977), it is essential that the planting area be "set-up" during site preparation to permit access with spraying or mowing equipment.

We keep our plantation free of weeds by applying herbicides in a swath about 3-feet wide on either side of the row of trees (Fig. 8-4). Weeds and grasses between rows are controlled by mowing two or three times each year. The herbicide "Casoron" (G-4), applied in the granular form at the rate of 150 pounds per acre, has been used with success as a pre-emergence treatment. However, "Casoron" tends to lose its effectiveness in late summer, necessitating a follow-up treatment. We found "Roundup" highly effective for controlling weeds during the growing season. It is a systemic herbicide that enters through the leaves and is translocated to the roots, killing the entire plant. Because it will damage sugar maple, it must be applied carefully around small trees to keep the spray from hitting the leaves. "Roundup" is generally applied at the rate of 2 to 4 quarts per acre, depending on the height of the weeds to be sprayed. (Before applying any herbicide, check both state and federal regulations concerning its use and follow directions on the label).

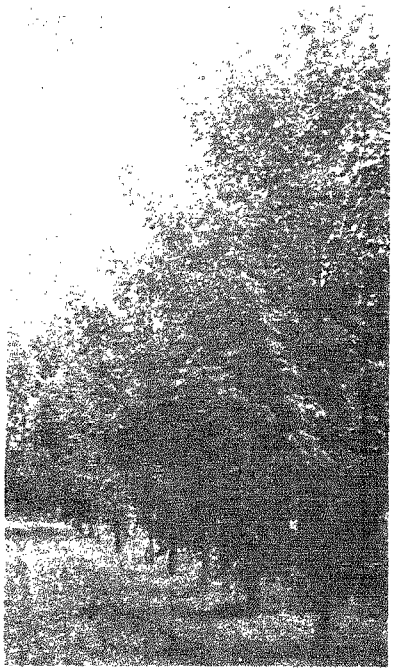


Figure 8-4.—Herbicides are used to kill weeds around the base of each tree. Weeds between rows are controlled by mowing two or three times each year.

Animal Damage

Protecting seedlings from animal damage is just as important as selecting the proper planting site and eliminating competing vegetation. The extent of animal damage that can occur is documented in Stoeckeler and Limstrom's (1950) survey of sugar maple and other hardwoods planted in the Lake States; they found that more than 80 percent of the seedlings were damaged by deer browsing. Wallihan (1949), in his analysis of northern hardwood plantations in New York, indicated that the risk of serious damage by heavy concentrations of mice and rabbits was so great that the feasibility of hardwood planting was questionable without some effective means of control.

Deer and rabbits damage seedlings mainly by browsing and clipping the terminal and lateral branches; mice damage them by girdling the stems near the ground. Seedlings may be killed outright or form multiple stems. When the terminal bud is destroyed, multiple stems develop; repeated browsing reduces the seedling to a bush with little probability of ever developing into a suitable tree (Fig. 8-5).

The extent of damage is related directly to the abundance of local populations, and is greatest during the winter months when other food is scarce (Pearce 1937). Aldous (1938), however, says that certain hardwoods, particularly maple, are choice browse for deer and likely to be among the chief items in their spring, summer, and fall diets. Our own observations (Yawney and Johnson 1974), indicate that sugar maple seedlings are browsed throughout the year except during periods of deep snow, but because our planting site was at a high elevation, the deer wintered at lower elevations. There is little doubt that sugar maple is subjected to year-round browsing by deer, and constant protection is needed.

Basal feeding by rodents can cause serious damage to sugar maple, particularly when rodent populations are high. Figure 8-6 shows a natural stand of young northern hardwood trees; although yellow birch and beech were present in abundance with some red maple, the damage was restricted to all the sugar maples.

Measures to control rodent damage might include trapping or poisoning, but neither of these methods appears to be practical. Spencer (1955) cited an example: In the Pacific Northwest rodents were



Figure 8-5.—Sugar maple seedlings browsed by deer produce multiple stems and have little probability of developing into suitable trees.

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Section II Chapter 5

Genetic Improvement in Sap-Sugar Production

Genetic Improvement in Sap-Sugar Production

by
William J. Gabriel

The knowledge that trees differ in the sugar content of their sap is not new, although it has only recently been properly documented. Sugar producers know that certain trees in their stands are sweeter than others. In an intensive study of a relatively small area in Vermont, Taylor (1956) found that individual trees and stands differed by as much as 100 percent in sap sweetness. And an extensive survey throughout the important syrup-producing states in the Northeast found that the sugar content of sap from 21,080 trees ranged from 0.7 percent to 10.8 percent (Gabriel 1972a).

This variation makes it possible to improve sugarbush production in two ways: existing sugarbushes can be thinned by removing the trees that produce less sugar (as shown in tests of the sap from individual trees), and the productiveness of sugar maple trees can be improved over a long term by selective breeding.

Not all of the factors that influence sap sweetness are known. Within any sugaring season, the sap of a single tree may vary widely in sugar content, but individual trees that are superior maintain their superiority from year to year (Fig. 5-1).

As was mentioned in Chapter 4, researchers generally agree that certain crown characteristics are correlated with sap volume and sweetness. Crown characteristics are determined primarily by the environment of the tree, and that can be manipulated by thinning and other silvicultural techniques; but trees that owe their superiority to environmental factors are not useful for selective breeding because acquired characteristics are not transmitted from parent to progeny. There are

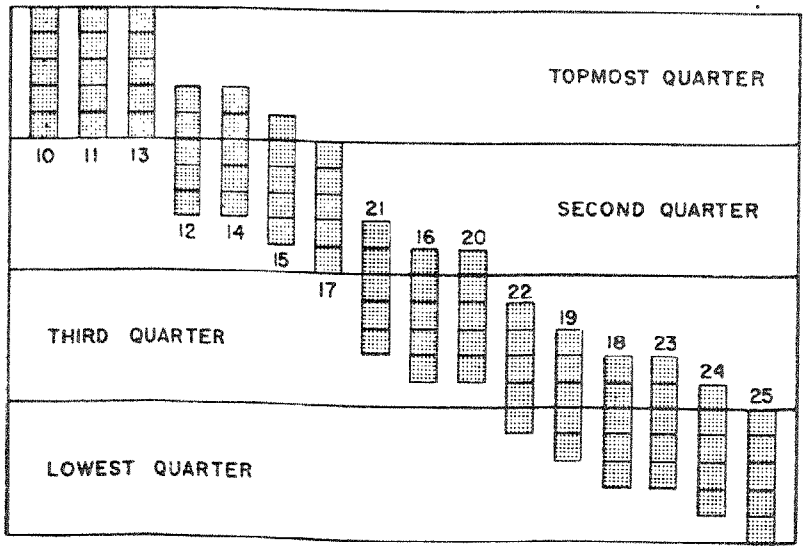


Figure 5-1.—Individual trees perform consistently from year to year. Each vertical bar represents the 5-year record for one tree. Each square within a bar shows the rank of the same tree for one season (Taylor 1956).

presently no external morphological characteristics, such as bark configuration or color, leaf shape or size, or tree form, that distinguish trees with superior sugar production. The internal characteristic of proportion of ray volume to xylem has been reported to be related to sap-sugar production (Morselli et al. 1978).

No significant differences in sugar content have been associated with the age of the tree, but difficulty in obtaining sap samples from trees less than 3 cm in diameter above the root collar makes these comparisons undependable. Larger open-grown saplings 7 to 10 years old produce reliable quantities of sap as high in sugar content as sap from mature trees (Kriebel 1960).

Sugar content of sap is easily measured with a refractometer (Fig. 4-9A) but the volume of sap produced by a tree is more difficult to measure. It would be helpful in selecting superior trees for breeding if sweeter sap was correlated with high volume production, but they were found to be highly correlated in some years and poorly correlated in others (Marvin et al. 1967). Over an 18-year period, a significant correlation was found between the two variables.

Selective breeding to improve the flavor of maple syrup has also been considered, but flavor is related primarily to the heat used to evaporate the sap to syrup, so genetic improvement of flavor is unlikely.

Selecting Superior Trees

Genetic improvement by selective breeding depends upon selection of parent trees that owe their superiority to heredity rather than to environment. It is important to use selection procedures and criteria that will distinguish these trees.

Research in Ohio has led to the recommendation that selection candidates be tested for sugar content for 3 years before their final selection (Kriebel and Gabriel 1969). Tests should be made in the early or middle part of the sap season, when sugar concentrations tend to be higher. Sugar percentages generally drop in the latter part of the season; small differences between trees make comparisons difficult and may mask genetic variation.

Single-tree selection has been recommended because earlier research showed that variation in sugar content was greater between individual trees than between sugarbushes or geographic origins (Kriebel and Gabriel 1969). But recent results from a rangewide sugar maple provenance study have shown that differences between geographic origins tested in West Virginia were significant. Two provenances from Minnesota consistently outperformed the average for the outplanting—one provenance by 25 percent in 1977 and by 37 percent in 1978, the second by 21 percent in 1977 and 14.5 percent in 1978. Further investigation of variation within these provenances is in progress.

Parent stock has been selected throughout the important syrup-producing states in the Northeast, using procedures that require a selection candidate to produce sap at least 30 percent sweeter than the average of several surrounding standard trees (Fig. 5-2), and to ex-



Figure 5-2.—The sap sugar produced by the selected tree (indicated by the arrow) ranged from 46 to 68 percent above the average of the adjacent standard trees over a 4-year period.



Figure 5-3.—A general view of the clonal bank in Vermont, which serves as a source of parental stock in a selective breeding program to improve sap-sugar production in sugar maple. Photo at right shows the oldest ramets in the planting which are 8 years of age.

ceed the sweetest standard tree by a minimum of 0.5 percent (Gabriel 1964). Trees were scored on their similarity to the standard trees in diameter, height, crown shape, and other characteristics. From these scores, in combination with the highest degree of superiority in sap sugar, 53 final selections were made (Gabriel 1972a). All selections have been vegetatively propagated through scionwood grafting and are currently growing in a clonal bank in Vermont where they are serving as parental stock in the ongoing breeding program (Fig. 5-3).

Evaluation of the Genotype

A sugar maple tree selected for superiority in sap-sugar production over other trees is referred to as a superior phenotype. Its superiority is a product of the interaction between genes inherited by the tree (genotype) and the environment in which it grows. Since it is impossible to measure the influence of genes on sap sweetness directly, genotypes are evaluated indirectly by progeny testing, where the performances of their offspring, grown under similar conditions, are compared in a replicated experiment.

One progeny test of sugar maples selected for sap-sugar concentration was conducted in Ohio. It included 12 families that represented controlled pollinations between high, low, and intermediate trees and families from open pollinations (Kriebel and Gabriel 1969). After 3 years of sap testing, analysis of data showed that differences observed between families were highly significant. Further analysis indicated that additive gene effects were an important component of the calculated variance. Analysis of data collected from open-pollinated progenies showed no significant differences in sap sugar.

Trees selected for high sugar content by the Vermont Agricultural Experiment Station and the former Hopkins Forest Unit of the Northeastern Forest Experiment Station were progeny-tested in replicated plantings in Massachusetts and Vermont. Significant differences were found between families at each location, although from year to year the same families were not always in the highest rankings (Gabriel 1972b). Sap-sugar content was generally lower in the Vermont plantation, but no significant interaction between family and plantation location was detected. Correlation analysis has shown no relationship between average performances of parents and their respective progenies.

Replicated test plantings have recently been established in Michigan, Ohio, Pennsylvania, and Vermont. Results of this experiment, expected over the next 5-year period, will guide roguing of a clonal bank composed of ramets derived from the ortets (phenotypes) represented in the progeny test. Similarly, progeny-test plantations could be rogued in anticipation of their use as seedling seed orchards.

Breeding and Recurrent Selection

A selective breeding program, emphasizing recurrent selection for general combining ability, is currently in progress in Vermont. Seed was collected from open-pollinated, selected phenotypes *in situ*. The resulting seedlings were outplanted in four progeny-test plantations, each representing a different set of grow-

ing conditions. Differences between half-sib family averages will be analyzed, and the general combining ability of the selected parents will be estimated. Those parents with the best general combining ability will be intercrossed to form the population for a second selection cycle.

Intercrossing in the Vermont program will be carried out in the clonal bank which is made up of five pairs of ramets of each ortet, each pair being randomly located on the planting. Prior to intercrossing, all clones with poor general combining ability will be rogued from the planting. Cross-pollination between the remaining trees of good general combining ability will be allowed to occur naturally. Flowering of clones within the bank is considered satisfactory. At the end of the last 4-year flowering cycle of sugar maple, in 1976, 90 percent of the clones and 48 percent of the ramets bloomed. An isolation strip of about 1/4 mile around the bank will be established in which all other sugar maples will be removed to guard against possible contamination by foreign pollen.

In 1976, an estimated 7,900 filled fruits were collected from the Vermont clonal bank. Pollination occurred at random among the trees in the unrogued planting, with possible contamination by four nearby flowering maples outside the planting. The latter have since been removed. The ensuing seedlings, kept separate according to family, have been planted and will be compared for sugar concentration. Since heritability estimates for the trait of sap sweetness are relatively high, 0.70 in Vermont and 0.60 in Ohio, a modified, simple recurrent selection procedure should give substantial genetic gains with a minimum of expense.

A breeding program in Ohio also makes use of random crossing between superior progenies or individuals in test plantations. Through asexual propagation of selections, flowering of ramets has produced one crop of 12,000 seedlings for distribution to landowners. These trees are now being outplanted at 30 x 30-foot spacing.

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Section III

The Propagation and Planting of Sugar Maples

Chapter 6

Seed Collection and Handling

by
Clayton M. Carl, Jr.

To propagate sugar maple from seeds successfully, a grower needs information on seed development and on the proper methods of collecting and handling the seeds.

It is important to use seed that is high in germinability, and, if possible, from a known source. Desirable seeds come from vigorous, superior phenotypes, either sweeter than average (for the grower who wants to plant a sugar orchard) (Knebel and Gabriel 1969) or from well-formed trees (for the timber producer). A combination of these two characteristics would be even more desirable.

Fruit Development

Sugar maples generally begin bearing light fruit crops when they are 8 inches in diameter, and about 25 to 30 years old (Godman 1957, Limstrom 1965). A few trees in one of our plantations began bearing fruit when they were 20 years old, and our records show scions from mature trees bearing fruit 2 years after being grafted to 1-year-old root stock.

Sugar maple trees are usually monoecious in their flowering habits. The flowers bloom in the spring, usually in late April or early May. They are borne in inflorescences at or near the ends of the branches, and are pollinated by insects. Although good sugar maple flower and fruit crops may occasionally occur in 2 successive years (Godman and Matson 1976), they are usually intermittent, varying from 2 to 7 years apart (Godman 1957, U.S. Department of Agriculture, Forest Service 1974, Eyre and Zillgit 1953).

The fruits are pairs of fused samaras which ripen in the autumn. Each samara (often incorrectly called a seed) may or may not contain a seed. (Unless otherwise specified, all references to seeds in this chapter mean the seeds enclosed in their fruit coats. All references to samaras mean as they are collected, both those containing a seed, filled samaras, and those without a seed, empty samaras). The samara pairs eventually separate and the single samaras are normally dispersed by the wind.

Sugar maple fruits mature in the fall and must be collected at the proper time to ensure maximum seed germination. The actual date of maturation varies from year to year for an individual tree, and maturation dates differ among trees within a stand in the same year (Carl and Snow 1971).

Mature sugar maple seeds have a very high germination capacity. In our experience, nearly all of the mature seeds will germinate. Seeds generally will have reached their maximum germination potential when the majority of the samaras on the tree have changed from bright green to a yellowish green. When the samaras have turned completely brown, they will soon be shed. A more accurate method of determining when sugar maple seeds are ripe is to determine the moisture content of the samaras. Carl and Snow (1971) reported that when the moisture content of the samaras was below 145 percent, germination for 17 out of 19 individual collections was over 90 percent. The other two collections were from a tree on which the samaras were heavily infested with aphids, and this may have caused a decrease in seed germination.

Apparently, sugar maple seeds

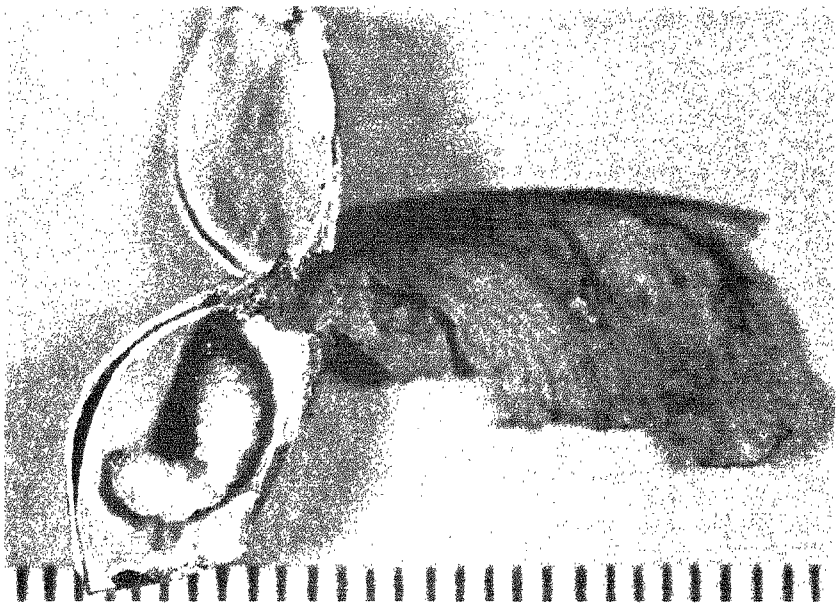


Figure 6-1.—Unidentified maggot which destroys sugar maple seeds.

have few natural insect enemies. There was the one aphid infestation mentioned above, and there is a maggot, as yet unidentified, that attacks the seeds (Fig. 6-1). Although individual trees may, at times, be heavily infested with these maggots, we consider this insect relatively unimportant at present.

Samara Collection and Separation

In the future, high-quality sugar maple seeds may be collected from superior seed sources grown in seed orchards. At present, however, seeds are usually collected locally from selected trees during good seed years. If possible, the samaras should be collected from trees that exhibit desirable characteristics, although there is no guarantee that these characteristics will be transmitted to the offspring. Seeds from local sources are usually better adapted to local planting sites than seeds from foreign sources. If local seeds are not available, and no information is available on provenance performance, seeds from areas that have a climate similar to that of the proposed planting site should be used.

Limstrom (1965) gives some general advice about seed sources, and recommends selecting maple trees within the seed-collection zone where the planting is planned. He states that transfers from the adjacent southern zone are permissible—with reservations—to take advantage of exceptional trees. Before collecting any seeds, the collector should secure the landowner's permission to do so.

The samara-collection period for sugar maple—that period when seeds will have a germination rate of over 90 percent—varies from tree to tree, and from year to year. In the study by Carl and Snow (1971), samaras were collected at weekly intervals from late August until the samaras were shed during 2 separate years. During the first year of the study, there was a period of 5 or 6 weeks for each tree when the seeds germinated over 90 percent. This period began about September 1 for one tree, but it was 3 weeks later before seeds from the last tree had a germination rate of over 90 percent. However, there were only 2 weeks when seeds from all the trees had a germination rate of better than 90 percent. In the second year of the study, there was only a 2-week period for each tree when its seeds had germination rates of 90 percent or better, and there was no week when the seeds from all three trees had germination rates of at least 90 percent. Because of the differences in times of maturation, collection time has to be determined for each tree.

Developing samaras turn from bright green to yellowish green, and finally brown. If the samaras have not been picked before they turn brown, they should be picked immediately, as they will soon be shed.

Mature samaras can be stripped from the branches easily. There are several ways to collect the seeds: They can be picked up from the ground; ladders and raised platforms can be used to make the seed-bearing branches accessible (Fig. 6-2); or seeds from particularly desirable trees may be gathered by climbing the tree. Pruning poles are sometimes used to clip off the ends of seed-bearing branches high up

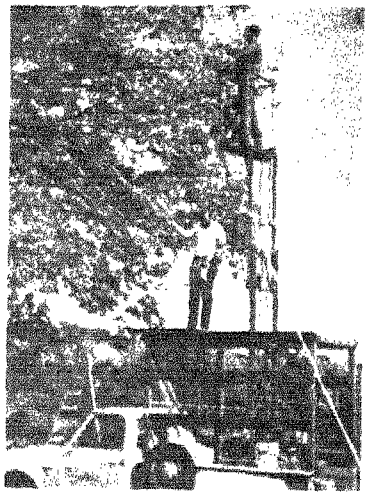


Figure 6-2.—Ladders and raised platforms can be used to pick samaras from large open grown sugar maple trees.

on the tree, but this damages the tree and exposes the branches to possible fungal infection and decay. Another method that has been employed with fair success is to spread drop cloths on the ground under the tree, and shake its branches. Samaras can also be collected from felled trees, but if this is done, the seeds should be mature when the trees are cut down.

Freshly collected samaras should be cared for soon after collection. If this is not possible, they should be kept cool to protect the viability of the seeds. Samara pairs generally break apart when picked. Usually only 50 percent of the samaras contain seeds, but they can vary from 20 to 74 percent among trees (Carl and Yawney 1966). We recommend that the empty samaras be removed and discarded. This reduces handling and storage space requirements considerably. Sowing time in the nursery is also reduced, and seedling density—an important factor affecting seedling development (Stupman 1964, Stoeckeler 1950, 1967, and Sluder 1964)—can be controlled more precisely.

The moisture content of freshly collected samaras can range from about 35 percent to over 140 percent (dry weight basis), depending on their stage of development. Carl and Yawney (1969) reported that individual sugar maple samaras with a moisture content greater than 50 percent can be quickly and efficiently separated with pentane; the empty samaras float, and the filled samaras sink (Fig. 6-3). This technique has proven to be 95 to 100 percent effective. If the filled samaras are to be sown within 3 or 4 months after separation, they should be put in cold storage. If it will be much longer before they are sown, they should be prepared for long-term storage.

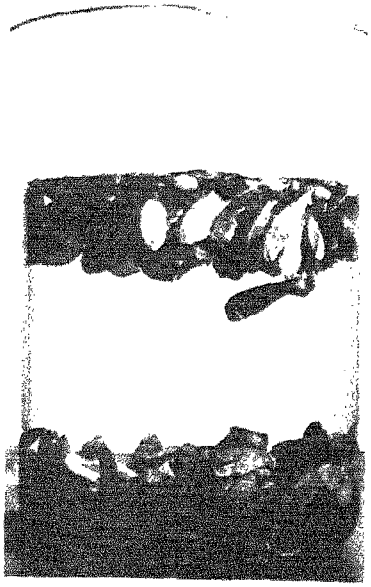


Figure 6-3.—Pentane is 95 to 100 percent effective for separating filled (sinkers) from empty (floaters) sugar maple samaras.

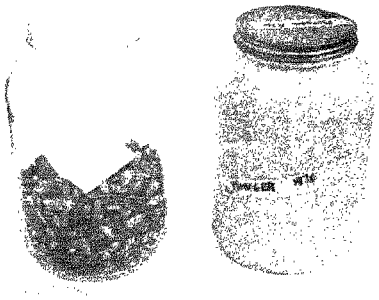


Figure 6-4.—These 1-gallon food jars hold about 10,000 samaras each and make excellent sealed containers for storage.

Storage

Since good seed years do not occur every year, some provision must be made to store seeds to sustain a continuing planting program. Storage temperature and seed moisture content are both critical factors affecting the length of time seeds can be stored and still retain their viability.

If the samaras are to be stored, even for only a few months, they should be dried. Our procedure is to air dry the collections slowly in an unheated building. Soon after collection, if they are not to be separated, or immediately after separation in pentane, the samaras should be spread on wire-screen trays to dry. The maximum depth should be 1 inch and the samaras should be stirred daily to prevent heat buildup and consequent loss of seed viability.

For long-term storage, the moisture content of the samaras should be reduced to about 10 percent. If the moisture content of the samaras has not been reduced to 10 percent after 6 to 8 weeks of drying on the wire screens, it will be necessary to transfer them to a heated room (18 to 21°C) to complete drying. It might be all right to dry the samaras in a shorter time in a heated room rather than an unheated building, but we do not know what effect rapid drying has on the seeds.

The dry samaras can be stored for long periods by putting them in sealed containers to maintain stable moisture conditions (Fig. 6-4). In

Table 6-1.—Effects of seedlot, moisture content, temperature, and time on percent viability of sugar maple seed stored in sealed containers (Yawney and Carl 1974)

Seed moisture content (percent)	Storage temperature (°C)	Seedlot 1 months in storage					Seedlot 2 months in storage					Seedlot 3 months in storage				
		6	18	30	42	54	6	18	30	42	54	6	18	30	42	54
35	18	0[a]	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	7	83	0	2	0	0	86	0	2	0	0	99	0	1	0	0
	2	95[b]	8	1	0	0	94	19	0	0	0	95	4	0	0	0
	−10	96	93	87	1	0	94	96	93	8	2	96	99	86	1	0
25	18	44	0	2	0	0	0	0	0	0	0	2	0	0	0	0
	7	95	65	3	0	0	92	23	0	0	0	100	51	0	0	0
	2	95	85	50	7	0	97	89	9	0	0	100	99	69	1	14
	−10	97	96	96	46	7	98	98	96	3	9	93	99	98	3	14
17	18	62	0	0	0	0	15	1	0	0	0	40	0	1	0	0
	7	95	86	0	0	0	96	62	0	0	0	100	94	5	0	0
	2	97	93	82	58	60	93	94	73	4	0	100	98	98	83	14
	−10	97	96	93	92	86	97	98	97	92	95	99	98	100	97	98
10	18	90	55	1	1	0	98	68	0	0	0	100	95	9	0	0
	7	89	91	91	93	85	93	96	95	92	92	100	100	100	96	96
	2	93	93	89	91	94	97	95	96	93	96	100	100	99	100	99
	−10	95	95	97	89	94	98	96	96	97	94	99	98	99	99	99

[a] Viability percentages are averages of 3 samples.
[b] Percentages within the shaded area are not significantly different from each other.

Table 6-2. Effect of separation in pentane and length of time in storage on the percent germination of sugar maple seeds (Carl 1975)

Year of collection	Treatment	Months in storage										
		0	6	12	18	24	36	42	48	54	60	66
1967[a]	Pentane	98.2	97.2	—	94.8	—	—	95.6	—	96.8	—	98.4
	Control	98.2	91.5	—	94.4	—	—	87.6	—	93.8	—	93.1
1968[b]	Pentane	94.9	—	92.4	—	90.7	86.2	—	88.2	—	90.3	—
	Control	94.9	—	92.0	—	87.3	86.6	—	90.4	—	91.1	—
1970[b]	Pentane	99.0	—	97.1	—	97.8	97.7	—	—	—	—	—
	Control	99.0	—	96.9	—	97.8	98.6	—	—	—	—	—

[a] Single tree.
[b] Average of 4 trees.

one storage study (Yawney and Carl 1969), it was found that unseparated samaras from three different trees could be stored for 4-1/2 years without any significant loss of viability when they were stored at 10 percent moisture content at +2°C or at −10°C (Table 6-1). In a subsequent experiment, Carl (1976) separated samaras in pentane, dried them to about 10 percent moisture content, and stored them at −10°C. He found that the seeds could be successfully stored for 5-1/2 years without losing their viability, and without any apparent damage from separation in pentane (Table 6-2).

Seed Testing and Nursery Germination

Information on the germination potential of a seedlot is vital to any seed handling program. This information will serve as a guide to estimating how much seed is needed to produce a given number of seedlings, and how many seeds to sow per square foot to give the desired seedbed density. The seeds should be tested just before sowing.

A sample of seeds may be sent to the National Tree Seed Laboratory[1] for germination tests. There is a set fee for these tests. In addition, some states maintain tree seed testing facilities. If time and facilities are available, you may do your own testing. The procedures are relatively simple, but require from 50 to 90 days, depending on the method used. The Association of Official Seed Analysts (AOSA) and the International Seed Testing Association (ISTA) rules for testing sugar maple seeds differ only slightly from each other. The AOSA says to place the seeds on top of a moist blotter, or in moist sand, and prechill for 60 days at 3 to 5°C, then change the seeds to a constant 15°C for 28 days, or alternating temperatures of 18° and 24°C for 14 days. The ISTA says to place the seeds on top of germination paper, or in moist sand, and prechill for 60 days at 1 to 5°C, then change the seeds to 20°C for 21 days. Both associations also give procedures for testing excised embryos, but if there are several seedlots, excising embryos can be very time consuming.

Janerette (1978) reported that she got 95 percent germination in 51 days. She soaked samaras in tap water for 24 hours, placed them on a moistened paper towel, and wrapped them in aluminum foil. The aluminum foil packets were then stratified at 3 to 4°C.

Carl and Yawney (1966) compared the effectiveness of sand, perlite, spagnum moss, and germination paper as stratification/germination media. All four media gave equally satisfying results, but the germination paper in plastic boxes (Fig. 6-5) was the most convenient, so we recommend it. The procedure is to soak the samaras in tap water, at room temperature, for 24 hours. Then drain off the water, place the samaras on germination paper in plastic boxes and stratify them at 2°C for 90 days. It has been our experience, and that of others (Webb and Dumbroff 1969, Janerette 1978), that germination begins after about 30 to 35 days of stratification. Although a few seeds may require the full 90 days of stratification, most of the germination is complete by the end of 65 to 70 days. When testing a seedlot for germinability, we usually use five samples of 50 samaras each. If the samaras have not been separated in pentane, 100 samaras are used per sample. After stratification is complete, the remaining samaras are opened to see if they actually contain seeds. The final germination percentages are based on the number of seeds in the sample, not samaras.

If the seeds have been stored for more than a year since the last germination test, or if something has happened that may affect their viability, a new germination test should be made. Germination and survival in a nursery will not always equal germination under ideal laboratory conditions. Insects, disease, and unfavorable weather conditions all have an adverse effect on nursery germination and survival despite the best efforts of the nurseryman.

In our experience, fall-sown sugar maple seeds do have nearly 100 percent germination (Carl and Yawney 1977). While this 100 percent figure may vary from year to year, and possibly from nursery to nursery, it will serve as a guide to determine sowing rates until a nurseryman gains experience with the species.

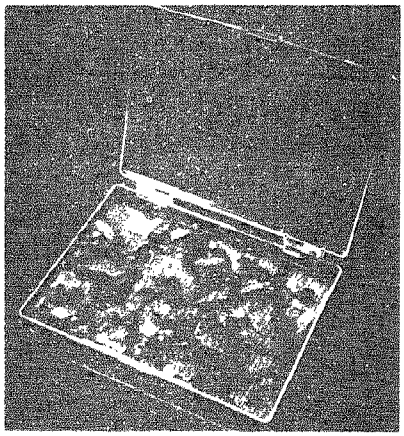


Figure 6-5.—Germination paper in plastic boxes used for testing sugar maple seed germinability.

[1] It would be advisable to contact the National Tree Seed Laboratory, Rt. 1, Box 182-B, Dry Branch, GA 31020, for information on fees, sample size, etc., before sending any seeds.

Chapter 7

Nursery Practices

by
Clayton M. Carl, Jr.

Requests for sugar maple seedlings, particularly from genetically superior stock, have increased during the past few years. As the demand for good sugar maple seedlings increases, the number of nurseries growing these maples will increase and there will be an increasing need for information on growing and handling sugar maple seedlings. For those who manage, or are anticipating managing, nurseries for the production of tree seedlings, publications by Stoeckeler and Jones (1957), Armson and Sadreika (1974), and Williams and Hanks (1976) are helpful.

Any successful nursery management program requires careful records of what is done to the soil and the seedlings, and the size and quality of the seedlings produced. This report summarizes information that will help growers produce plantable sugar maple seedlings.

Soil Management

The growing medium is basic to the production of any crop. In the nursery production of seedlings, the soil is that medium, and proper management of the soil is probably the most important step in any production program. To grow vigorous, healthy seedlings, the soil must provide nutrients, moisture, oxygen, and growing space. And to assure their availability, the nurseryman has to control texture, fertility, drainage, and acidity.

Generally, hardwood seedlings are considered more demanding than conifers in their soil requirements. Therefore, if one has a choice, the best nursery soil, in texture, drainage, fertility, and pH, should be used for sugar maple. If there is no choice, then efforts should be made to improve the soils with suitable amendments. Anyone selecting a new nursery site should consult the publication by Stoeckeler and Jones (1957), who cover this topic in some detail.

Soil texture. Soil texture refers to the relative proportions of sand, silt, and clay particles in the soil. This relationship is quite stable and not easily changed. For a sugar maple seedling nursery, as for other hardwoods, the best-textured soils are sandy loams and loams with less than 35 percent silt plus clay (Stoeckeler and Jones 1957, Williams and Hanks 1976). There should be adequate surface drainage, and the subsoil should have good drainage.

Small changes in soil texture can be made in the plow layer by adding sand to clay, or vice versa. But, it takes a tremendous amount of sand or clay to change the soil texture appreciably. Deep plowing is another possible way of influencing soil texture if there is a difference in texture between the plow layer and the subsurface soil. However, both the addition of sand or clay to the plow layer and deep plowing are quite costly and time-consuming, so if soil texture is a serious problem, the best solution might be to move to a more favorable location.

Organic matter. Organic content has an important influence on both chemical and physical properties of the soil. The amount of organic matter in the soil should be about 2 percent, more for heavier soils and slightly less for sandier soils. The addition of organic material such as sawdust or humus, or rotation with green manure crops, or both, is highly recommended. The addition of sludge as organic matter can be advantageous, but there is the possibility of contamination by heavy metals, depending on the source of the sludge.

It would probably be best to add organic matter frequently (after each rotation), and in smaller quantities that will decay rather rapidly. If large amounts of organic matter are added at one time, care should be taken to replace the nitrogen and phosphorus used by the soil micropopulation in its decomposition (Millar 1955).

Soil pH and fertility. Soil pH is a measure of the hydrogen-ion activity in the soil on a logarithmic scale of 1 to 14. The lower the pH number, the more acid the soil is; the higher the pH, the more alkaline the soil is. A pH of 7.0 is considered neutral. The recommended pH for a hardwood nursery soil is about 6.0, although Wilde (1946, 1958) recommends from 5.5 to 7.3, with the best being 5.8.

In nursery soils, pH may exert considerable influence on plant growth by regulating the solubility, and thus availability to the seedlings, of many essential elements (Allaway 1957). The soil pH can be changed by the addition of lime to raise the pH or sulfur to lower it. A number of factors, such as cation exchange capacity, organic matter content, and soil moisture content, influence the amount of lime or sulfur required to bring about a unit change in pH in a given soil.

The initial nutrient content of the soil is not a critical factor, since the fertility level can be restored from organic and inorganic fertilizer sources. If a soil was originally high in nutrients, it would be depleted by the removal of a seedling crop (both roots and tops) every few years. The proper fertilizer should be added at the right time, and in the right amount, to keep the nutrient supply at the optimum level. Wilde (1946, 1958) gives these recommended soil fertility standards for raising sugar maple seedlings:

pH 5.5–7.3
Total N (%) .20
Available P_2O_2 per acre (lb) 100–150
Available K_2O per acre (lb) 250–275
Base exchange capacity (meq/100 g) 10–14

Exchangeable Ca (meq/100 g)
5.0–8.5
Cations (meq/100 g) 2.0–2.5

Seedbed Preparation

Seedbed preparation for sugar maple is not essentially different from that for most other seedlings. The seedbeds should be prepared just before sowing the samaras; for sugar maple this is usually in the fall after they are collected. If crop rotation (alternating seedlings with a green-manure crop) is practiced, the green manure should be plowed under about 4 to 6 weeks before the beds are formed. If the green-manure crop was not fertilized sufficiently, enough fertilizer should be added at that time to hasten its decomposition.

One of the last tasks before the actual formation of the beds, is eradicating any harmful biotic elements—weeds, insects, fungi, etc.—that may be present. We have successfully used "Roundup"[1] experimentally for weed control. It can be applied 1 to 2 weeks before plowing, using the recommended rates and procedures. Since it does not control weed seeds, however, another, and perhaps better way would be to apply the "Roundup" several weeks before preparing the seedbeds, wait for the weed seeds present to germinate and grow, and then re-treat with "Roundup".

Fumigation would control most weed problems, as well as soil-borne insects, nematodes, fungi, and diseases. Williams and Hanks (1976) report that fumigation stimulates the growth of some species such as yellow poplar. But Martin et al. (1963) report evidence that fumigation inhibits phosphorus absorption, causing phosphorous deficiency, and Thiegs (1955) reports that it temporarily inhibits nitrifying bacteria. This may be due, at least in part, to the killing of beneficial mycorrhizae and bacteria. There are endomycorrhizae that penetrate the root cells of hardwoods and are necessary for good seedling growth (Clark 1964), and maples form endomycorrhizae (Marx 1977). By not fumigating, we do not destroy any beneficial mycorrhiza-forming fungi, or nitrogen-fixing and symbiotic bacteria that may be present. We feel that this justifies not fumigating unless absolutely necessary.

After the harmful biotic elements have been controlled, the area should be plowed (to a depth of 8 to 10 inches) and disked to promote good seedling root development. Soil samples should be taken to determine fertilizer and lime requirements. We know of no formal experiments that give specific nutrient requirements for sugar maple, but Wilde (1946, 1958) does make some recommendations. Since there is no nutrient level optimal for all soils, each soil will require individual attention and treatment and these recommendations may be of limited value. In a pot-culture experiment, Carl, Donnelly, and Post (1973) found no significant response to added nutrients. The seedlings were watered from a deep well simulating actual irrigation of nursery stock, but this water contained trace amounts of dissolved minerals which may partially explain the lack of seedling response to the added nutrients.

Nurserymen are divided as to when to add lime and fertilizer. Some believe lime should be added before the beds are formed, while others prefer to form the beds first, then lime and fertilize. In either case, it should be done after fumigation. We add lime and fertilizer after the beds are formed, and mix them into the upper 2 to 4 inches of soil. Part of our reason for doing this is that the material is there readily available for germinating tree seeds, and little is wasted on the paths where it would be used by weeds.

Only enough fertilizer to supply current seedling crop needs should be applied; excess fertilizer can be harmful to the seedlings. Experiments are presently being conducted with slow-release fertilizers to see how effective a single fertilizer application can be in providing nutrients for an extended time. Additional fertilizer can be applied to the seedlings at any time through the rotation, as the growth of the seedlings requires. While deficiency symptoms indicate a lack of a particular element, the seedlings have been stressed and growth reduced before the deficiencies are visible. And, although these deficiencies can be corrected if noticed soon enough, it is better to start with adequate nutrient levels and have an ongoing soil and tissue analysis program, with proper interpretation of the results. Nurserymen might do well to establish demonstration areas in their own nurseries to determine optimum growth rates of the seedlings grown under their specific environmental conditions.

Our seedbeds are raised, and usually made with a bed former. Various types or combinations of equipment are available for bed forming. For small areas, the beds can be formed by hand, by shoveling the soil from the paths into the beds. Raising the beds improves aeration and soil drainage. Our beds are about 42 inches wide, and are raised 4 to 6 inches above the general ground level. The paths between the beds are 18 to 24 inches wide.

Seed Sowing

The seed of the sugar maple is actually contained within a winged fruitcoat; the entire structure is called a samara. There is no mechanical equipment suitable for sowing samaras, and since there is no easy method of removing the fruitcoat or the wing, conventional sowing equipment cannot be used. The samaras can be hand sown, either broadcast or planted in rows. Sugar maple seeds have a dormant embryo; this dormancy can be overcome by stratification at a low temperature, so we recommend fall sowing in the nursery. Stratification

[1] Roundup™ is manufactured by the Monsanto Company, St. Louis, MO 63166. Casoron™ is manufactured by the Thomas-Hayward Chemical Company, Kansas City, KA 66110.

will occur naturally during the winter and germination in the spring. This method provides greater germination, survival, and first year's growth than spring sowing (Carl and Yawney 1977).

Broadcasting is a relatively quick way to sow the samaras, but it is difficult to control their density over a large area. The recommended density for sugar maple is about fifteen 1-year-old seedlings per square foot (Stoeckeler and Jones 1957, Williams and Hanks 1976). The number of samaras per pound depends on their size and whether they have been separated in pentane. The percentage of samaras containing seeds can easily be determined by a cut test. Carl and Yawney (1966) found from 20 to 74 percent. If the samaras have been separated in pentane (Carl and Yawney 1969), close to 100 percent will contain seeds. If the sugar maple seeds are ripe when picked and properly handled, their germination will be close to 100 percent. The resulting sugar maple seedlings usually have a very high survival rate, 95 to 100 percent.

One method to help obtain the desired density is to broadcast the calculated amount of samaras over small portions of the seedbed, such as 100 square feet at a time. The amount of samaras to sow in a given area can be computed by a formula similar to that given by the TVA (1954). The nurseryman must know the number of samaras per pound, the percentage of samaras containing seeds, the germination percentage of the seeds, and the expected survival of the germinated seeds. The formula then is

$$P = \frac{A \times D}{S \times F \times G \times Y}$$

where P = pounds of samaras to sow; A is the area to be sown in square feet; D is the desired density per square foot; S is the number of samaras per pound; F is the percentage of samaras containing seeds, expressed as a decimal; G is the germination percentage of the seeds, expressed as a decimal; and Y is the percentage of germinated seeds that produce seedlings that survive at the end of the first year, expressed as a decimal.

As an example, suppose a nurseryman wants to sow several 100 square-foot plots using samaras from a lot that has not been separated in pentane. There are 6500 samaras per pound, 50 percent of the samaras contain seed, the germinative capacity is 98 percent, and the expected survival factor is 95 percent. The formula then becomes:

$$P = \frac{100 \times 15}{6500 \times .50 \times .98 \times .95}$$

$$= \frac{1500}{3025} = .5 \text{ pound per lot}$$

We use a planter (Fig. 7-1) which is a modification of one described for planting experimental seedlots of Douglas-fir *(Pseudotsuga menziesii)* (Schmidt 1968). Our planter sows the samaras in seven rows, with 6 inches between rows and 1-3/4 inches between samaras in a row. This sows the samaras at a density of about 15 per square foot. Since most of the samaras contain seeds (having been separated in n-pentane), and since sugar maple has a very high germinability, this results in a seedling density close to the recommended fifteen 1-year-old seedlings per square foot.

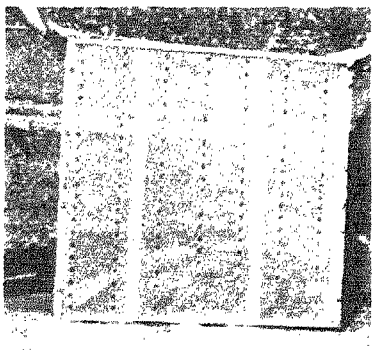


Figure 7-1.—Planter used for sowing experimental lots of sugar maple samaras.

After the samaras have been sown, we pull a small lawn roller over the beds to firm the samaras into the ground, and to level the seedbed. We cover the beds with about 1/2 inch of fresh softwood sawdust. In one experiment, we used partially decomposed sawdust to cover the seedbeds. In that experiment, 70 percent of the viable sugar maple seeds were destroyed by the maggot *Hylemya florilega* (Zetterstedt) (MacCollom and Yawney 1967). This was attributed to the insect laying its eggs in the partially decomposed sawdust and the emerging larvae feeding on the sugar maple seeds. We have also tried hardwood sawdust, but it formed a crust (Fig. 7-2) which prevented many of the germinated seeds from growing through.

Birds have never pilfered seeds we have sown, but rodents have caused serious losses of unprotected seeds. To protect the seeds, we place a 4 x 4 hardware cloth on top of the sawdust. This also helps to prevent the sawdust from being blown away.

Before we used the hardware cloth, we tried both leaves and salt-marsh hay to hold the sawdust in place, but neither prevented the loss of the sawdust and they did not protect the seeds from rodents.

In a sowing of sugar maple seeds at the Vermont State Nursery, nearly 95 percent of the seeds were lost to rodents. Since then, they have coated the samaras with anthroquinone; this has deterred rodent pilferage (personal communication with William Baron, Vermont State Nursery 1980).

Tending Seedbeds and Seedlings

Shade. In a study reported by Cunningham (1965), 0, 33, 67, and 87 percent shades were compared for their effect on survival and growth of sugar maple. Although there were no statistically significant differences in the average height of seedlings 2 years after seeding, only the 33 and 67 percent shade treatments had seedlings taller than 3 feet.

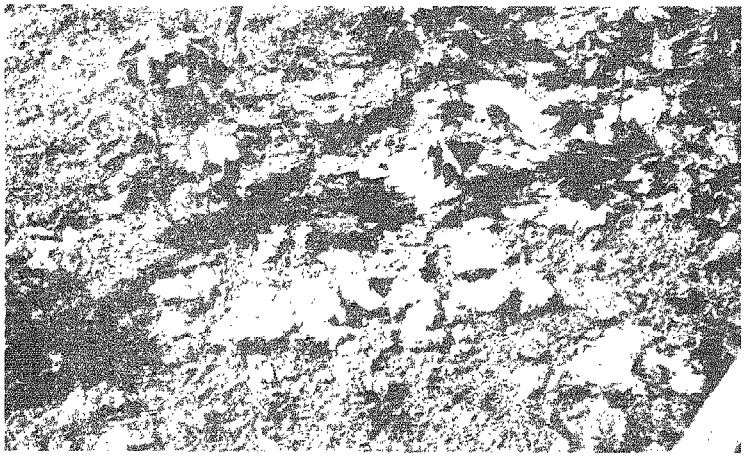


Figure 7-2.— Large plates of hardwood sawdust such as these prevented germinated sugar maple seeds from growing through.

Logan (1965) also grew seedlings under four levels of shade (87, 75, 55 and 0 percent). After 5 years, seedlings grown in full sunlight were significantly shorter than those in the other three treatments, but reduction in light had much less effect on root and shoot weights. Shade improves survival, probably by helping to prevent desiccation of freshly germinated seeds. Shade also helps to conserve water by retarding evaporation from the seedbed surface, and it may improve growth by increasing the availability of soil moisture.

Irrigation. In a study by Carl et al. (1973), watering significantly increased the shoot and root dry weights, and shoot height and diameter of seedlings. Height growth differences due to treatment were more apparent after the second and third growing seasons than after the first. However, too much moisture, particularly late in the summer, may result in succulent growth that can be killed by early frosts. High levels of soil moisture in a nursery may produce seedlings with low root/shoot ratios, which may reduce the survival of outplanted seedlings. Therefore, it is recommended that seedlings be given ample water early in the growing season for good growth, but that watering be reduced in late August and September to harden off the seedlings.

Disease, insects, and weeds. In our experience, sugar maple seedlings do not generally have serious disease problems. Hepting (1971) says that *Rhizoctonia solani* occasionally causes damage, and he cites a report of *Sclerotium bataticola* having killed seedlings in an Illinois nursery. U.S. Department of Agriculture Handbook No. 470 (1975) describes a number of hardwood nursery diseases, but none is specifically mentioned as attacking sugar maple. This may be because there has been very little experience raising sugar maple and little study of its diseases has been necessary.

It is better to prevent disease than to cure it. If good cultural procedures are followed, disease problems are minimized. Proper fertilization, watering, and cultivation help maintain seedlings in a vigorous, healthy state, able to withstand pathogens. Sprays and dusts are also helpful in preventing disease, but are usually not a cure. Also, rotating beds among different species helps to reduce disease problems.

Because of the increasingly stringent regulations covering the use of pesticides, it is difficult to make specific recommendations for the various diseases. Therefore, it is recommended that any specific pathogen be identified, and a program for control be planned by an expert. Such help can usually be secured from the pathology department of your state college or university, or your state department of agriculture.

Insects usually cause more damage to sugar maple seedlings than diseases, and a close watch should be kept to detect insect attacks early so control measures can be taken. Insects damage leaves, stems, and roots. Baker (1972) discusses a number of insects that attack sugar maple forest trees; many of these insects also attack seedlings. Several of the more common insects that damage hardwood seedlings are discussed by Williams and Hanks (1976). The most obvious damage is that done by the leaf feeders. However, no less serious, though not so apparent, is the damage done by sucking insects and root feeders.

Some of the more common leaf feeders are the larvae of the eastern tent caterpillar, the forest tent caterpillar, the gypsy moth, and the saddled prominent (Figs. 7-3A, 7-3B, 7-3C, and 7-3D). Insects that cause damage by sucking plant juices include aphids, scale insects, and leafhoppers. The latter have been a serious problem in our experimental nursery, causing considerable reduction in seedling growth. A striking example of the damage done to sugar maples by leafhoppers is reported in the American Nurseryman (1972), and in Agricultural Research (1972). Root feeders include wireworms, white grubs, and cutworms. Several species of cutworms also feed on aboveground portions of plants. Nematodes, although not insects, are root feeders, and are often included in discussions of insects. Before using any pesticide, it is best to get a positive identification of the pest in ques-

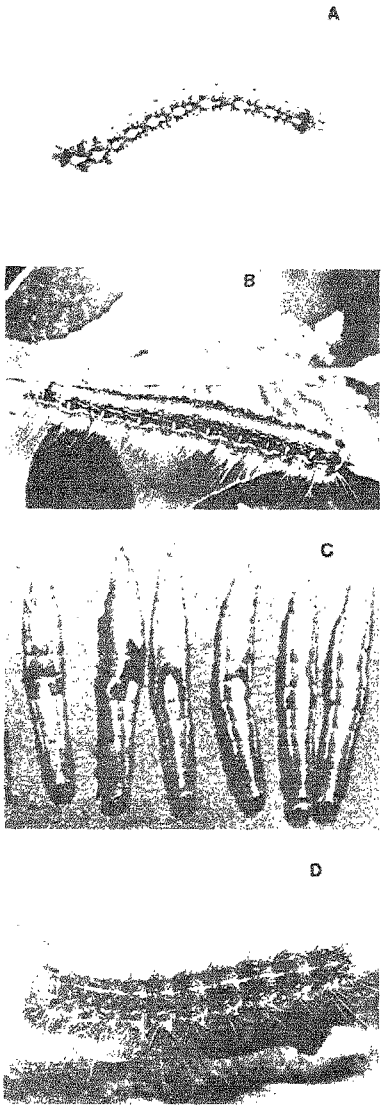


Figure 7-3.—Examples of caterpillars and larvae that feed on sugar maple seedlings: (A) forest tent caterpillar; (B) eastern tent caterpillar; (C) saddled prominent; and (D) gypsy moth.

tion, together with a prescription for control, from an expert.

Weeds are a serious problem in sugar maple seedbeds. They compete for space, nutrients, and moisture essential to the seedling crop. Fumigation will kill weeds and weed seeds that are in place, but does not offer complete control. Weed seeds that blow in from surrounding areas after fumigation find an ideal seedbed. Fumigation also destroys mycorrhizae which, for hardwoods, are slow to reinvade the seedbeds. So far, we have not found a preemergence herbicide that will kill the weed seeds but not the sugar maple seeds. Dimethyl tetrachloroterephthalate (DCPA) is an herbicide that was reported for nursery weed control for hard maple at the 1967 Northeastern Area Nurserymens' Conference. However, others in general conversation say that the application has to be precisely timed, or the germinating sugar maple seeds will also be killed.

We use "Roundup" in our experimental nursery to kill established weeds prior to seedbed preparation. But for the first growing season after seed germination, we resort to the expensive, laborious hand weeding of our experimental seedbeds. Mony (1954) and Baker (1962) report on mechanical cultivators that can be adapted for weeding larger nurseries. After the first year, we use "Casoron"[1] for the control of weeds in our seedbeds. Whenever any herbicide is used, however, the manufacturer's instructions should be scrupulously followed.

Mice have also caused damage by girdling the bark or cutting off small seedlings. Keeping grass mowed and the area free of weeds helps eliminate protective cover for the rodents. This helps reduce their numbers, and thus the amount of damage they do. Rodents can be trapped, but probably the best way to eliminate them is by the use of registered, prepared baits. We use zinc phosphide-treated oats placed in bait stations throughout the nursery area. Stoeckeler and Jones (1957) also recommend baiting a bordering zone 200 feet outside the nursery area. The bait should be placed where non-target animals will not have access to it.

Rabbits also cause damage at times by cutting off seedlings. They can usually be effectively excluded by fencing. This fence should be high enough to prevent the rabbits from entering during periods of deep snow or heavy snowdrifting. Rabbits that remain in the area or gain access to it after it is fenced have to be trapped or shot.

Pruning. Root/shoot ratios and the type of root system are important in the survival and growth of outplanted seedlings. It is generally recommended that high-quality seedlings selected for outplanting have a high root/shoot ratio (Carlson 1972, Hawley and Smith 1954). Pruning the root system tends to retard stem growth while stimulating the production of a heavier, more fibrous root system. This gives a higher root/shoot ratio, as recommended. In addition to improving seedling development, root pruning also makes the seedlings easier to handle. Verticle pruning reduces the number of interlaced roots, making the seedlings easier to lift with less root damage, and the more compact root system makes them easier to plant. Preliminary work at our nursery has shown that vertical pruning stimulates root proliferation of sugar maple, but further studies are needed.

Sugar maple has opposite branches, which frequently results in a forked seedling if the terminal bud dies. When this happens, some top pruning is necessary to help shape the seedling. More experimental work is needed to determine the effects of pruning branches on growth and development of sugar maple.

Handling Seedlings

To help reduce the damage to planted seedlings caused by deer browsing (See Chapter 8), we sug-

gest planting seedlings 6-foot or larger in reforestation projects or for orchard establishment. However, 6-foot seedlings cannot be lifted with conventional lifting equipment; they must be dug by hand or with some type of mechanical digger. We have used a plain front-end bucket loader on a tractor, but it damaged the seedlings considerably. We have also used a front-end loader equipped with tines, and this does a satisfactory job of lifting seedlings. Seedlings that have been transplanted usually have a more compact root system, and can be lifted fairly easily by hand. Although we have not yet tried one, a conventional tree digger would probably work very well for lifting the transplanted seedlings.

Sugar maple seedlings are usually lifted in the fall, after they have hardened off. They can then be fall planted, or heeled-in, or placed in cold storage for spring planting. If digging is delayed until spring, the seedlings may have broken dormancy before the seedbeds can be worked.

The survival and growth of any plantation will depend to a large extent on the quality of the planting stock. Although seedling grades have been established for some hardwoods (Limstrom 1963, von Althen 1972), there are no grades for sugar maple. If deer browsing is not a problem, a general rule might be to plant as large a seedling as practicable, keeping in mind that the seedlings should have high root/shoot ratios. Any seedlings that are obviously too small, diseased, or damaged should be discarded.

Seedlings that are acceptable for planting should be packaged immediately to prevent drying out of the tender root tips and damage from handling. If the stock is large and to be planted immediately, it can be placed in a stock tank with its roots covered with water and transported to the planting site in the tank. The stock should be held in cold storage and kept moist if it cannot be packaged within a day. While the large seedlings present some problems in packaging, the smaller seedlings can be packed by conventional methods such as the jellyroll or Olsen bale. The kraft bag can be used for smaller seedlings, and it is becoming more popular. These methods are fully described by Williams and Hanks (1976).

Sugar maple seedlings can be stored safely for extended periods if necessary. Perhaps the easiest method, and certainly the least expensive, is by heeling-in. Williams (1963) reported that fall-lifted hardwood stock that had been heeled-in survived overwintering and grew as well as spring-lifted stock. We have frequently used this method successfully. The hardened-off seedlings are lifted and the diseased and damaged seedlings are culled. Williams and Hanks (1976) recommend using only sandy soil for heeling-in, even if it must be hauled in. A trench is dug deep enough so the roots can be covered to 1 inch above the root collar without bending the roots. This trench can be dug by hand, if there aren't too many seedlings, or with a plow. The seedlings are culled and the good seedlings are then placed in the trench and covered with soil. Drench the seedlings after they have been heeled-in to wash the soil around the roots to eliminate air pockets. Additional trenches parallel to the first one can be dug as needed. The trenches should be far enough apart to avoid exposing the roots of the previous row, but close enough so space is not wasted. A mulch can be placed on top to protect the seedlings from alternate freezing and thawing and deep frost. However, we have not had to mulch the seedlings in northern Vermont, probably because of the deep snow cover. Seedlings overwintered in this manner are readily available for spring planting.

The seedlings can also be kept in cold storage at about 0.5°C (Webb and von Althen 1980). This is expensive but it does have some advantages over heeling-in: Heeled-in seedlings may break bud during a prolonged warm spell. Also, a cold room can be used to store a large quantity of lifted seedlings temporarily and they can be graded and counted after the ground freezes.

Chapter 8

Planting Sugar Maple

by
Harry W. Yawney

Planting Sugar Maple

Interest in planting sugar maple has been rekindled in recent years and has been growing steadily. It comes, for the most part, from sugarmakers wanting to start new sugarbushes. The production of maple syrup, once thought to be a dying industry, has been made profitable by the development of innovative technology such as plastic pipeline, vacuum pumping, and new sap processing systems. And another factor stimulating interest in planting is the possibility of increased syrup production from genetically superior, high-yielding sugarbushes.

Sugar maple has been planted for over 200 years. In 1793, Rush mentioned in an essay on sugar making that appeared in the transactions of the American Philosophical Society, a Pennsylvania farmer who averaged a pound of sugar from 3 gallons of sap collected from trees he had planted 20 years before. (It is interesting to note that Rush indicated it took 5 to 6 gallons of sap from forest-grown trees to produce the same amount of sugar.) In his article, Rush also noted that Thomas Jefferson had planted maple trees on his Virginia farm for the express purpose of producing sugar. It seems that the merit of gathering sap from roadside trees was obvious to the colonists, and plantings during the colonial period undoubtedly account for the large, stately, evenly spaced sugar maples that still line both sides of many country lanes throughout New England.

A book by Jones published in 1832 provides some little-known facts about the sugar maple tree. The book is a compilation of published articles that contained much of what was then known about the maple sugaring process, including the advantages, both economic and "*medicinal*", of maple sugar over cane sugar. From several of these articles, it is clear that the Quakers in America at that time perceived in the sugar maple tree a means of destroying the slave trade. They believed that if the world markets could be supplied with a cheaper sugar than that produced on the slave plantations of the West Indies, there would be little incentive for slavery. Jones, an Englishman, was concerned about the troubled world conditions of his time, and hoped the information he compiled in his book would encourage the widespread planting of sugar maple throughout England. Jones reasoned that if a sufficient number of trees were planted, England could eventually produce enough domestic sugar to become free of her dependency on an uncertain foreign sugar supply. With his compilation of articles, Jones included instructions for ordering sugar maple seedlings from Northern America and instructions for planting (Fig. 8-1).

Although sugar maple and other hardwood species have been planted for many years, the small amount of information that has accumulated suggests that hardwood plantations are difficult to establish. Hardwood planting began as a conservation measure during the late 1800's, dating almost from the beginning of the conservation movement in this country. Planting to reclaim idle lands in North Carolina was begun in 1890 (Hassis 1930), and records of planting in Indiana date back to 1903 (DenUyl 1951). Hardwood planting began in New York in 1909 (Eliason and Littlefield 1967).[1] In Ontario, Canada, hardwood plantings were carried out around 1880 (von Althen 1977). Both state and federal agencies undertook large-scale hardwood plantings, and bulletins and leaflets with hardwood planting recommendations were printed for public use (Brown et al. 1914, Tillotson 1921, Kittredge 1929, Mattoon 1930, Hetzel 1939). Reforestation efforts with hardwood species reached a peak with the Civilian Conservation Corps in the 1930's. The number of hardwood plantings made is not known, but it must be assumed to be considerable. In the Tennessee Valley drainage alone, Allen (1953) reported that the number of hardwood seedlings of various species planted up to 1946 exceeded 72 million. These plantings, however, resulted in discouragingly few successes, and after 1950 reforestation projects using hardwood seedlings all but ceased as a forestry practice.

In West Virginia, Tryon (1956) asked the question: "Why have hardwood plantings failed so often in a region where high quality timber grows so well?" Winch (1937), in his analysis of hardwood planting in New York, provided some insight into the problems involved. He concluded that the most significant factors contributing to poor growth, and often complete failure, were (1) planting on sites not suitable for hardwoods, (2) competition from field vegetation, and (3) damage caused by animal feeding. Later studies reached similar conclusions (Wallihan 1949, Stoeckeler and Limstrom 1950, Allen 1953, Zanger 1956, von Althen 1964). Our experience in Vermont indicates that sugar maple planted on a suitable site with weed control and protection from animal damage, should grow to a tappable size of 10 inches in 20 to 25 years.

[1] Eliason, E. J., and E. W. Littlefield. 1967. What about hardwood planting? New York State Conservation Dep. Unpublished office report.

INSTRUCTIONS FOR PLANTING.

It is necessary to pay particular attention to what is said in the extracts about the soil in which the Sugar Maple grows. Dr. Rush says, "They grow chiefly in the richest soil, and frequently on stony ground: springs of the purest water abound in their neighbourhood."—Mr. Michaux says, "The trees grow on excellent land."—Captain Carver says, "The hard Maple (meaning the Sugar Maple) likes best, hills and high places."—Mr. Weld says, "The Sugar Maple is never seen but upon good ground;" and he adds, "There are two kinds of this valuable tree in Canada, the one called the *Swamp Maple*, from its being generally found upon low-lands; the other the *Mountain or Curled Maple*, from growing on high dry ground, and from the grain of the wood being very beautifully variegated with little stripes and curls." From the tree growing as here mentioned, on good dry upland ground, and in stony places, it is commonly called, in America, the *Rock Maple*, hence it is not proper to plant it in low lands or damp soil, but in such lands as are above described.

And to give the trees proper source of nutriment, they should be planted at fifteen feet distance, which will give 225 feet square to each tree; that will admit of planting about 200 on one acre. Where there is abundance of ground, the distance may be twenty feet, or as the proprietor thinks proper; but more than fifteen feet is not absolutely necessary.

The ground should be opened several days before the trees are put in, and good earth brought from another place, and mixed with that dug out; the whole turned over and over for five or six days, and spread a little, that it may attract the nitre from the air.

If it should be rainy weather, a little hillock to be raised round the tree, and just touched with the spade, to prevent too much rain from entering the hole; but if dry weather, then the tree to be often watered with water that has been exposed to the sun at least 24 hours.

Before putting in the tree, all the points of the little twigs should be clipped, to refresh them.

As to the rest, the experienced gardener will know well how to succour the tree according to the weather.

The white or swamp Maple will also be furnished for those who wish to have that species to plant in wet grounds.

Acer Saccharinum Plantation Office,

6, Great St. Helen's, London,

Where orders are received for furnishing young trees or saplings of the North American and Canadian Sugar Maple Tree, on the following

CONDITIONS:

The tree to be five feet high at the least.

The price six shillings the tree.

Two shillings a tree to be paid at the time of giving the order, the rest on the delivery of the trees.

The orders to be executed according to the priority of their dates.

The trees to be delivered at London, Bristol, or Liverpool, in November, December, January, February, or March, in every year.

Note.—*Orders to be given before the first of July.*

Figure 8-1.—These instructions for ordering and planting sugar maple seedlings appeared in the book by Jones which was published in England in 1832.

The Planting Site

Choosing the proper site is probably the most important consideration (von Althen 1977). Sugar maple grows on a variety of soil types, but thrives only where the soils are fertile, medium textured, and well drained (Godman 1965). Occasionally, sugar maple can be found on dry, shallow soils, but the trees are not thrifty and growth is slow (Hickok et al. 1931, Westveld 1933). Sugar maple does not grow well in heavy clay soils. Because sugar maple has rather specific site requirements, it is essential, as von Althen (1979) cautioned, to determine soil texture, depth of topsoil, drainage, and general fertility of the proposed site before any planting is done.

Good growth can be expected on soils classified as sandy loams and silt loams, but the best growth should occur on loam soils. Generally, soils for sugar maple plantings should have a silt plus clay content between 30 and 50 percent (Stoeckeler and Limstrom 1942).

Sugar maple can tolerate a wide range of soil acidity, but Wilde (1958) recommends a pH between 5.5 to 7.5 as optimum for planting sugar maple. The fertility requirements for sugar maple given in Table 8-1 can be used to evaluate the suitability of proposed planting

Table 8-1.—Characteristics of forest soils supporting productive stands of sugar maple. Data are for the upper 8 inches of the soil profile (From Wilde and Patzer 1940)

pH	5.79 ± .12
Base exchange capacity (meq/100 g)	13.76 ± .9
Total N (%)	0.185 ± .012
Approximate level of available N per acre (lb)	41
Available P_2O_5 per acre (lb)	136.7 ± 12.4
Available K_2O per acre (lb)	242.3 ± 17.5
Replaceable Ca (meq/100 g)	8.3 ± .9
Replaceable Mg (meq/100 g)	2.1 ± .3

sites. The data shown were developed in the Lake States by Wilde and Patzer (1940), based on an extensive sampling of productive natural sugar maple stands growing on loam or silt loam soils.

County soil survey reports prepared by the Soil Conservation Service can be extremely useful for selecting potential sugar maple planting areas. Mapping is normally done on the basis of soil series. Smaller mapping units are used on agricultural lands to indicate different phases of a soil series, delineated according to stoniness, steepness of slope, or some other dominant soil feature. The reports will indicate texture and depth of the topsoil and of the various horizons, moisture drainage characteristics, type of parent material, and general productivity. Selection of potential planting areas from the soil survey should be followed by an on-the-ground examination by a soil scientist to verify its suitability.

The soils best suited for growing sugar maple are also the best and most productive agricultural soils, so areas available for planting may be limited. But this is changing; in states such as Vermont much of what was agricultural land is now in transition from open to wooded, and fields and pastures that are becoming overgrown with brush and tree saplings may offer suitable planting sites.

Old fields generally are not thought to be good planting sites for hardwood trees. This is true of old fields where continued cropping and poor farming practices resulted in erosion of the topsoil and organic matter, and depleted the available nutrients and water supply by severly altering soil structure. Such an area would indeed be a poor choice for a sugar maple plantation. In Vermont, the recent trend away from what was once about 65 percent agriculture to a landscape now 75 percent forested is not due entirely to depleted soil conditions but to other economic factors governing the agribusiness. Many fields and pastures were little affected by past use; many were under good management while in agricultural use, and thus are good potential planting sites.

As these fields were abandoned, they were quickly invaded by aggressive brushy vegetation. The growth rate of this vegetation provides some indication of the productivity of these sites. Observations of hardwood plantations in Indiana by Carmean et al. (1976) suggest that shrub or tree cover that invades abandoned fields is beneficial to the site by improving soil conditions that favor planting hardwoods even on marginal farm land. They found that hardwood seedlings grew faster on old fields that are reverting to a forested condition because the soils were modifed physically, chemically, and biologically by a well-stocked stand of trees. Accordingly, the best soils for planting hardwoods are to be found under existing forests where the soil environment has remained relatively undisturbed.[2]

[2] Hannah, P. R. (Professor of Forestry, University of Vermont). Personal communication.

Either old fields that are reverting to forest conditions or sites that have long supported forest stands are suited for planting sugar maple. However, as pointed out in the next section, good site preparation and weed control are essential to the success of sugar maple planting, and the choice of a planting site may be decided by the economics of clearing the site. Land most recently abandoned by agriculture will be the easiest and least costly to prepare for planting.

Control of Competing Vegetation

It is essential to free seedlings from competing vegetation. This requires site preparation before planting to remove existing vegetation, and weed control for several years after planting (Fig. 8-2).

Vegetation influences seedling survival and growth in several ways. Most obvious is competition for light, moisture, and nutrients. Other effects include mechanical damage from snow acting on heavy, overtopping herbaceous cover, and damage by mice and rabbits, for which dense stands of weeds and grasses provide ideal habitats. An



Figure 8-2.—A suitable site, elimination of competing vegetation, and protection from animal damage is necessary for good growth. This sugar maple tree, planted in 1971, is about 4.5 inches in diameter.

effect that is not so obvious is allelopathy—the process whereby biochemical substances released into the environment from one plant may be toxic to a neighboring plant. While the concept of allelopathy is not new (Tukey 1969), only in recent years has evidence begun to trickle in to suggest that allelopathy and not the direct competition for moisture and nutrients may have been the major cause of past hardwood planting failures.

Several herbaceous species in an old-field plant community contain allelopathic compounds that inhibit nitrogen-fixing bacteria in the soil (Rice 1964). The implication of this where these and similar herbaceous plants are found is that in time the soil will be depleted of nitrogen, and the available phosphorus, potassium, and other nutrient elements may become limiting. Carmean et al. (1976) speculated that similar allelopathic influences may be the reason for the poor hardwood growth they observed in their old-field plantings in Indiana. Similarly, allelopathy may explain the poor results in one of our studies (Yawney and Carl 1970). Differences in growth between sugar maple seedlings planted in old field sod and those planted on plots with site preparation and weed control were striking. Our data showed that 4 years after planting, while survival was good, the seedlings in sod grew very little and were essentially the same size as when they were planted (Fig. 8-3). Growth of these seedlings did not appear to be influenced by any factor other than the presence of the old-field weeds and grasses. In contrast, on the plots where the weeds were essentially eliminated, there was a significant increase in growth even though these seedlings were heavily browsed by deer. The inhibitory effect of weeds and grasses on sugar maple seedling growth is demonstrated in a study by Zarger (1956) in Tennessee, who reported that 8 years after planting, many sugar maple seedlings were still hidden by the heavy growth of grasses and weeds.

The effectiveness of weed control during the first few years after planting will largely depend on the intensity of site preparation (von Althen 1977). In unused pastures, site preparation may involve no more than plowing and disking; where brushy vegetation and trees are present, heavy equipment may be necessary to prepare the planting site. On sites with steep topography or numerous large stumps, complete site preparation may not be possible, and herbicides may be the only means of controlling unwanted vegetation. Von Althen (1977) states that the method used will depend on soil condition, topography, accessibility, density, and composition of the existing cover, and the cost of the various methods under consideration. He adds: "Under no circumstances, however, should the success of a plantation be jeopardized for an initial saving in the cost of site preparation and weed control."

Plowing and disking the whole plantation area is probably the best method of site preparation. It not only eliminates all vegetation but also destroys the habitat and protective cover of mice and rabbits. When preparing the whole area is not feasible, von Althen (1976b and 1981) recommends cultivating or herbiciding strips 6 to 9 feet wide. For best results, he suggests that the soil be turned over by rototilling and plowing and disking several times before planting. If herbicides are to be used, the spraying should be done during the growing season before planting. Von Althen's recommendations include the herbicide "Roundup" to kill standing weeds and grasses.

Site preparation, regardless of method, provides only a temporary respite from weed competition. Reinvasion by weeds is rapid—often they fully occupy the prepared areas before the first growing season is well under way. Forest sites that have been cleared will quickly be revegetated by the rankest kind of growth. The sudden appearance of a variety of herbaceous species will be accompanied by vigorous sprouting if the stumps are not removed or sprayed with herbicides. Because post-planting weed control is absolutely necessary for the success of



Figure 8-3.—After four growing seasons, sugar maple seedlings planted without weed control had increased in height by only 4 inches.

hardwood planting (von Althen 1977), it is essential that the planting area be "set-up" during site preparation to permit access with spraying or mowing equipment.

We keep our plantation free of weeds by applying herbicides in a swath about 3-feet wide on either side of the row of trees (Fig. 8-4). Weeds and grasses between rows are controlled by mowing two or three times each year. The herbicide "Casoron" (G-4), applied in the granular form at the rate of 150 pounds per acre, has been used with success as a pre-emergence treatment. However, "Casoron" tends to lose its effectiveness in late summer, necessitating a follow-up treatment. We found "Roundup" highly effective for controlling weeds during the growing season. It is a systemic herbicide that enters through the leaves and is translocated to the roots, killing the entire plant. Because it will damage sugar maple, it must be applied carefully around small trees to keep the spray from hitting the leaves. "Roundup" is generally applied at the rate of 2 to 4 quarts per acre, depending on the height of the weeds to be sprayed. (Before applying any herbicide, check both state and federal regulations concerning its use and follow directions on the label).

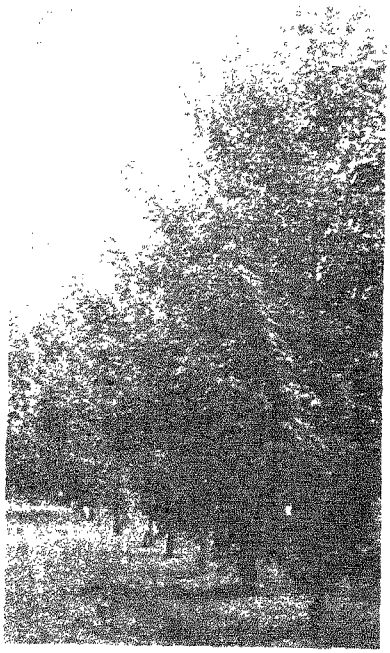


Figure 8-4.—Herbicides are used to kill weeds around the base of each tree. Weeds between rows are controlled by mowing two or three times each year.

Animal Damage

Protecting seedlings from animal damage is just as important as selecting the proper planting site and eliminating competing vegetation. The extent of animal damage that can occur is documented in Stoeckeler and Limstrom's (1950) survey of sugar maple and other hardwoods planted in the Lake States; they found that more than 80 percent of the seedlings were damaged by deer browsing. Wallihan (1949), in his analysis of northern hardwood plantations in New York, indicated that the risk of serious damage by heavy concentrations of mice and rabbits was so great that the feasibility of hardwood planting was questionable without some effective means of control.

Deer and rabbits damage seedlings mainly by browsing and clipping the terminal and lateral branches; mice damage them by girdling the stems near the ground. Seedlings may be killed outright or form multiple stems. When the terminal bud is destroyed, multiple stems develop; repeated browsing reduces the seedling to a bush with little probability of ever developing into a suitable tree (Fig. 8-5).

The extent of damage is related directly to the abundance of local populations, and is greatest during the winter months when other food is scarce (Pearce 1937). Aldous (1938), however, says that certain hardwoods, particularly maple, are choice browse for deer and likely to be among the chief items in their spring, summer, and fall diets. Our own observations (Yawney and Johnson 1974), indicate that sugar maple seedlings are browsed throughout the year except during periods of deep snow, but because our planting site was at a high elevation, the deer wintered at lower elevations. There is little doubt that sugar maple is subjected to year-round browsing by deer, and constant protection is needed.

Basal feeding by rodents can cause serious damage to sugar maple, particularly when rodent populations are high. Figure 8-6 shows a natural stand of young northern hardwood trees; although yellow birch and beech were present in abundance with some red maple, the damage was restricted to all the sugar maples.

Measures to control rodent damage might include trapping or poisoning, but neither of these methods appears to be practical. Spencer (1955) cited an example: In the Pacific Northwest rodents were

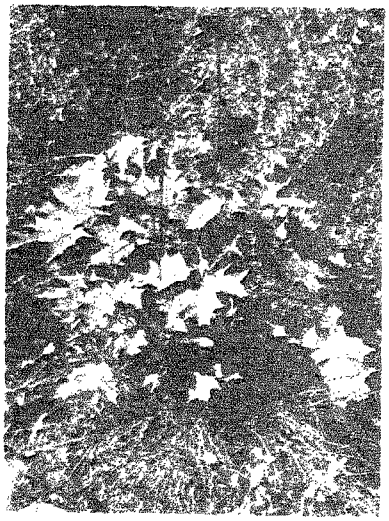


Figure 8-5.—Sugar maple seedlings browsed by deer produce multiple stems and have little probability of developing into suitable trees.



Figure 8-6.—Although other species were in this natural stand of northern hardwoods, rodents completely girdled only the sugar maples.

effectively poisoned out of 500 acres in late fall. By the following May, the population had returned to the same level. He advanced two reasons for this: reinvasion by rodents from outside the area, and increased breeding rates when the low population levels are not the result of unfavorable environmental conditions. A more practical approach it seems, would be to control the amount of damage rather than the animal population. Where basal feeding is a problem, trees will need to be protected until the bark is rough enough to discourage it (Fig. 8-7).

One way to discourage mice and rabbits is to eliminate their favorite habitats—dense grasses, weeds, and brush. Spencer (1949) states: "Where clear cultivation is practiced, these rodents will not be a problem." The reduction of mouse and rabbit activity is an added benefit from site preparation and aftercare to control competing vegetation.

Perhaps the most effective method of preventing damage by deer is animal-proof fencing. It may be justified in small plantings for special purposes, such as our clonal bank of sugar maples that were selected for their high sugar content, but fencing is too expensive for general use. Small individual enclosures made of hardware cloth give adequate protection for the first year or two against all types of animal feeding. However, protection from deer becomes a problem again when seedlings are exposed above the screens (Fig. 8-8). Tubes or sleeves made of polypropylene netting, 6 inches in diameter and 5 feet in height, have been used in Pennsylvania to protect black cherry seedlings from deer browsing with good results (Marquis 1977).

In studies of deer browsing habits in the Adirondacks, Pearce (1937) concluded that, in general, the height to which trees must grow to escape the effects of browsing was 6 feet. This has led us to speculate on the possibility of planting sugar maple stock of this size. This would be a radical departure from current cultural practices both in the nursery and in the field, but we feel that successfully estab-



Figure 8-7.—An 8-inch sugar maple completely girdled by winter-feeding rodents. Seedlings should be protected by screens until the bark is rough enough to discourage this type of damage.



Figure 8-8.—Sugar maple seedlings were heavily browsed by deer after they outgrew the 30-inch high protective screens.

lishing stands would justify the increased production, handling, and planting costs.

Planting

Hardwoods should be planted during the dormant season, preferably in the spring because of the risk of frost heaving and winterkill (Limstrom 1963). Fall planting has been successful in Vermont (Yawney and Carl 1970). Snow, which came shortly after planting and remained throughout the winter, evidently provided good protection against the danger of frost heaving.

When planting in the spring, it should be done as soon after snow melt and soil thaw as field conditions permit (Dumbroff and Webb 1978). According to Morrow (1950), the roots of sugar maple reach their height of growth activity between late March and early April. Dumbroff and Webb (1978) found that this period of root activity has important physiological implications for survival and growth. Spring planting usually takes place when seedlings have already undergone a burst of root growth and most of the hormonal and metabolic changes required for the critical period of shoot emergence have occurred. Von Althen and Webb (1978) reported significantly greater survival and height growth for sugar maples planted in April than for those planted in May and June.

Proper care of seedlings during planting is important for maximum survival. Until they are planted, seedlings should be kept in the shade and kept moist and cool, and care should be taken to minimize the period of root exposure. Planting is best done by preparing holes large enough to accommodate the root systems in their natural position with a mattock or pointed shovel. On sites where soil conditions permit, a power post-hole digger with a 12-inch auger (Fig. 8-9) will prove to be a boon. From his experience in Ontario, von Althen

Table 8-2.—Number of trees per acre required at various spacings for three planting designs

Spacing	Trees/acre	Spacing	Trees/acre	Spacing	Trees/acre
feet	*no.*	*feet*	*no.*	*feet*	*no.*
5 × 10 =	871	5 × 12 =	726	6 × 12 =	605
10 × 10 =	435	10 × 12 =	363	12 × 12 =	302
10 × 20 =	217	10 × 24 =	181	12 × 24 =	151
20 × 20 =	108	20 × 24 =	90	24 × 24 =	75
Final number of crop trees/ acre	108		90		75



Figure 8-9.—Where soil conditions permit, hand-held (or tractor mounted) post-hole diggers greatly facilitate planting.

(1976b) recommends that fertilizers not be used during planting. He found that the growth response to fertilizers applied at this time did not warrant the expense.

Attention should be given to the design of the planting and the spacing between trees. Lancaster et al. (1974) suggested that an adequately stocked sugarbush should have between 80 and 100 well-distributed trees per acre. Different planting designs to achieve this spacing are suggested in Table 8-2. Planting more than the desired number of crop trees per acre provides the option of selecting the best trees to leave, and also a hedge against mortality. The closest spacings in Table 8-2 permit three thinnings before the final spacing is reached. An advantage of the close spacings is that the time required for the planting to reach a closed canopy condition, and therefore the time when weed control is necessary, will be shortened. Although the spacing between rows is not critical, distances between rows should be wide enough to accomodate equipment for weed spraying or mowing. Trees should be planted in rows with a suitable downhill pitch to simplify the installation of a pipeline system.

Chapter 9

Rooting and Overwintering Sugar Maple Cuttings

by
Harry W. Yawney
and
John R. Donnelly

Vegetative Propagation of Sugar Maple

Scientists at the Northeastern Forest Experiment Station's Sugar Maple Laboratory in Burlington, Vermont have been studying methods to propagate sugar maple (*Acer saccharum* Marsh.) vegetatively, to develop procedures that will allow propagators to reproduce mature sugar maple trees asexually, particularly those selected for high sap-sugar content. By vegetative propagation, new trees or clones may be obtained that are genetically identical to the selected tree. After the genetic evaluation phase of our selection program is completed, clonal stock propagated from the "sweet trees" may be used to establish high-yielding sugarbushes.

Although some research was done to develop air-layering and grafting techniques, the major emphasis in our vegetative propagation program has been on rooting sugar maple cuttings.

Rooting Cuttings

The propagation of sugar maple by rooting cuttings includes two distinct phases: (1) root initiation and development, and (2) overwintering rooted cuttings.

Factors Affecting Root Initiation and Development

It is well known that the age of the parent tree can significantly affect rooting response: cuttings from juvenile trees will root easier and faster and overwinter more successfully than will cuttings from mature trees of the same species. We found this to be true with sugar maple. Quite probably, the age of our experimental trees contributed to the difficulty we experienced in vegetatively propagating sugar maple. But we continue to use cuttings from mature trees because the trees selected for high sap-sugar content in our improvement program were at least 50 years old (Fig. 9-1).

Rooting response of individual trees can range from zero to 100 percent. How well cuttings taken from a sugar maple tree for the first time will root cannot be predicted. Rooting trials, therefore, are necessary to establish the rooting potential of a given genotype. The potential for rooting in sugar maple appears to be subject to strong genetic control (Gabriel et al. 1961, Donnelly and Yawney 1972). Parent trees tend to be consistent in rooting ability from year to year. It is not known why cuttings from some sugar maple trees root better than cuttings from other trees. We were unable to detect any correlation between endogenous auxin content of cuttings and rooting ability (Greenwood et al. 1976).

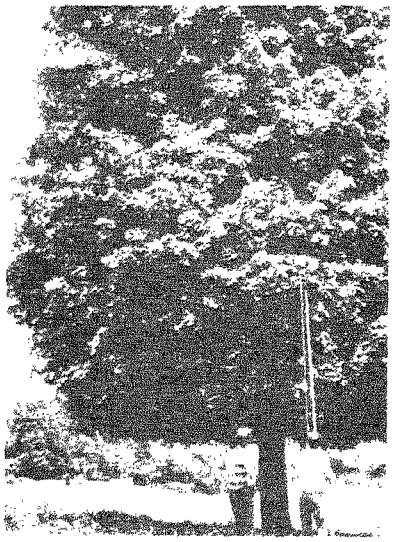
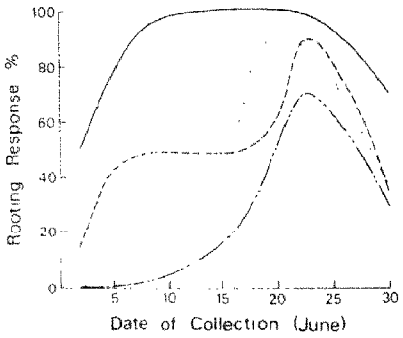


Figure 9-1.—Collecting cuttings from a mature tree. To prevent desiccation, the cuttings are immediately placed in a container and kept cool and moist until stuck in the rooting bed—preferably the same day.

The frequency and rate of root development differ considerably among genotypes. For example, we observed that cuttings from one tree were 80 percent rooted with roots up to 10 cm long after only 4 weeks, while cuttings from other "good rooters" did not begin to have roots until after 6 weeks. Some variation in rooting from one year to the next may be noted in cuttings taken from the same tree. Although environmental effects may be a factor, this variation may also be attributed to our inability to take cuttings at the precise moment of maximum rooting potential. However, with experience, and particularly after working with cuttings from the same parent tree for several years, the chances for obtaining maximum rooting are greatly increased.

Working with sugar maple cuttings collected during different seasons of the year, Koelling (1968) found that maximum rooting is achieved with greenwood cuttings taken during the month of June. Apparently it is at this time that shoots are at the physiological and anatomical stage of development most conducive to root formation. Figure 9-2 shows the rooting percentage of cuttings collected twice weekly from four trees during the month of June. Some variation is noted in peak response (70, 90, 90, and 100 percent) among the four trees. But considerably greater variation is evident in the length of time that cuttings are at their maximum potential for rooting. One tree rooted well for nearly 3 weeks, whereas the other three trees rooted well only at one collection period. This emphasizes the importance of proper timing in collecting cuttings. These differen-

Figure 9-2.—Individual tree differences in the relationship between date of collection and rooting response of sugar maple cuttings. Each line represents cuttings from a different tree (Donnelly 1977).



ces in the length of time that plants retain their potential for developing adventitious roots may explain some of the clonal variation frequently observed by propagators attempting to root cuttings from selected plants.

Because seasonal weather conditions influence the rate and pattern of tree growth, the optimum date for taking stem cuttings will vary from year to year. As a general guide, the external, visible characteristics of the developing shoot (Fig. 9-3) that coincide with maximum rooting are: leaves have just reached full size and are bright green; the base of the petioles shows signs of reddish-purple coloration; shoots begin to stiffen slightly and lenticels are pronounced; and terminal buds are barely visible as two dark brown scales about 2.5 mm in height (Donnelly 1977).

We examined the relationship between shoot size and rooting response (Donnelly 1974). In general, our data support the assumption that large cuttings root better than small ones, but we observed large tree-to-tree variation. Cuttings from some trees rooted relatively well, regardless of size. For other trees, rooting response and cutting size were closely correlated, and for some trees, rooting response was poor, regardless of cutting size. Because of tree-to-tree variation, rooting response on the basis of cutting size cannot be predicted. But, this should not obscure the fact that there tends to be a positive correlation between cutting size and rooting response, and propagators may increase their chance of success if they take advantage of this relationship.

Rooting hormones are commonly used to stimulate adventitious root formation in cuttings of a wide variety of plant species. We therefore tested the effects of several types and concentrations of rooting hormones on sugar maple (Donnelly 1971, Donnelly and Yawney 1972). These included: (1) Hormodin No. 3[1] (0.8% IBA powder), (2) Jiffy Grow[2] (0.5% IBA + 0.5% NAA liquid), (3) Jiffy Grow diluted 1:1 with distilled water, (4) diluted Jiffy Grow plus Hormodin No. 3, (5) talc containing 0.5 percent IBA (indolebutric acid), (6) talc containing 1.0 percent IBA, (7) talc containing 2.0 percent IBA, (8) talc containing 4.0 percent IBA, and (9) distilled water (control). Hormone type or concentration did not significantly affect rooting response. But, differences between trees in response to hormone concentration were observed. Figure 9-4 shows the variation in rooting of cuttings from three different trees. Cuttings from one tree rooted well (60 percent) without hormone treatment, and decreased in rooting percentage as the concentration of the applied hormones was increased. Cuttings from another tree also rooted well (60 percent) without hormones, but rooted better after treatment with exogenous hormones. Cuttings from a third tree rooted poorly (5 percent) without applied hormones, but rooting increased to approximately 45 percent with hormone applications. Where the use of hormones showed a positive effect, maximum rooting was achieved with hormone concentrations approaching 1 percent. Con-

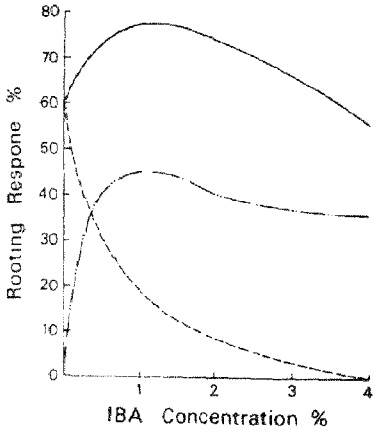
[1] Hormodin No. 3™ (powder formulation containing 0.8% IBA) is manufactured by the Merck Chemical Division, Merck and Company, Rahway, N.J.

[2] Jiffy Grow™ (liquid formulation containing 0.5% IBA + 0.5% NAA) is manufactured by G & W Products, P.O. Box 337, Estacada, OR.



Figure 9-3.—Stage of sugar maple shoot development typical in greenwood cuttings collected for rooting during the month of June.

Figure 9-4.—Individual tree differences in the response of cuttings to various concentrations of IBA. Each line represents cuttings from a different tree (Donnelly 1971).



centrations higher than 1 percent appeared to inhibit rooting.

The reason rooting responses to hormone treatment differ is not known. However, we hypothesize that it may be due to inherent differences in the endogenous auxin concentrations within the three trees studied. If auxin concentrations are low, applied hormones would have a stimulating effect; but if the cuttings contain high levels of endogenous auxin, additional amounts might be toxic and inhibit rooting. Thus we suggest that, when taking cuttings from a tree for the first time, you treat half of the cuttings with rooting hormones and do not treat the other half so you can choose the procedure most appropriate for that tree.

It is important that cuttings do not become desiccated during collection. If at all possible, take cuttings early in the morning while the shoots are turgid and the day is still cool. Place them immediately in layers between cool, moist sphagnum moss in some type of container for transporting to the rooting chamber, and stick them the same day.

Our rooting facility (Fig. 9-5) is a 6- x 18-m quonset hut greenhouse covered with corrugated fiberglass. Either 50 percent saran shade or shading compound is used to help reduce daytime temperatures. The greenhouse is equipped with thermostatically controlled coolers and exhaust fans. The 120-cm-wide rooting beds are built at ground level on a 30-cm-deep bed of gravel. They are 15 to 20 cm deep and consist of a 1:1 mixture of shredded sphagnum moss and horticultural-grade perlite. The temperature of the rooting medium is maintained at about 25°C with underlying heating cables. An intermittent mist is operated from 4 a.m. to midnight and is controlled by a time clock. The mist is on 1 to 2 seconds every minute. Supplemental lighting (150-watt incandescent lamps, 1 meter above the beds) provides a 20-hour day length.

Before sticking, the greenwood cuttings are wounded at the basal end by making light scrapes about 2.5 cm long on opposite sides of the stem through the bark to expose living tissues, and dipped into talc containing 0.8 percent IBA. (If last year's wood is still attached, it should be broken or cut off before the cutting is treated.) The cuttings are stuck to a depth of about 5 cm.

Given the right set of circumstances, such as properly timed collections from trees of known rooting potential, expeditious handling with the appropriate hormone treatment, and adequate rooting facilities, adventitious roots can be expected to appear on sugar maple stem cuttings 1 to 3 months after sticking.

Overwintering Rooted Cuttings

Atkinson (1964) pointed out that the major obstacle to developing a successful program was not only rooting, but also the overwintering survival of newly-rooted cuttings. The problem, simply stated, was that sugar maple cuttings that did root would, more often than not, fail to break bud and resume growth the next spring.

Overwintering survival, after summer rooting of cuttings, is a

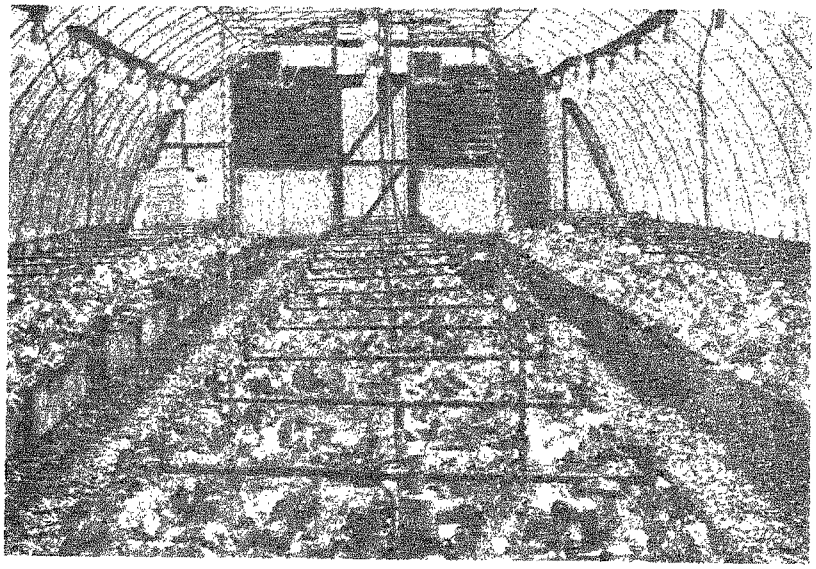


Figure 9-5.—The rooting facility at the Burlington laboratory is a 20- x 60-foot plastic covered greenhouse.

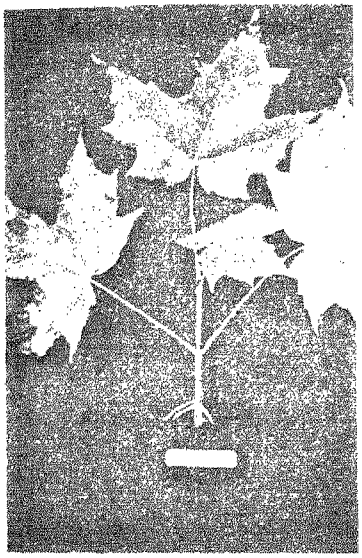


Figure 9-6.—Newly developed adventitious roots on sugar maple cuttings approximately 1 to 2 cm long. The cuttings are potted when roots are at this stage of development.

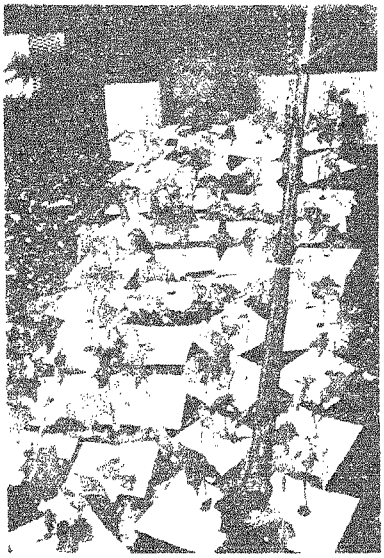


Figure 9-7.—After potting, the cuttings are kept under mist for an additional 2 to 3 weeks to allow roots to develop in the pots.

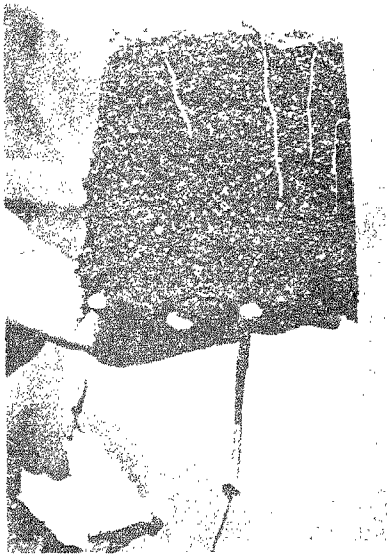


Figure 9-8.—When roots are visible at the sides of the ball (usually in 1 to 2 weeks after potting), the cuttings are removed from the mist and transferred to greenhouse benches to grow on their own.

problem common to other species. Waxman (1961, 1965) suggested that survival in dogwood and azalea would be increased when cuttings were stimulated to flush and produce a new growth of stem and leaves during the same growing season when they were rooted. With sugar maple, we found that budbreak followed by an active growth period also significantly increased survival over winter.

We discovered that overwintering survival was greatly enhanced by keeping the cuttings in the rooting bed for as short a time as possible. The technique to accomplish this is as follows. Examine cuttings for visible signs of roots 4 weeks after sticking and every week thereafter. When roots are 1 to 2 cm in length (Fig. 9-6), remove the cuttings from the rooting bed and pot them. Potting when roots are at this stage of development minimizes the risk of root damage, facilitates the actual potting, and provides moisture and nutrients for the growing roots.

Cuttings should be potted in 15- to 20-cm-diameter pots with a 1:1:1 mixture of loam, peat, and perlite supplemented with lime and fertilizer according to the recommendations of Boodley and Sheldrake (1972). Water the cuttings after potting. Because the root systems are so small at this time, and to protect the plants from becoming desiccated, the potted cuttings are kept under a mist system (Fig. 9-7) for 2 to 3 more weeks. However, to prevent the mist from overwatering the cuttings, the pots should be covered. We used plastic cards or dishes that have been cut with a slot and fitted around the cuttings. The root systems at this stage tend to develop very rapidly in the pots. Generally, the roots will grow through the soil and appear at the side of the pots in 1 to 2 weeks after potting (Fig. 9-8). When this occurs, remove the cuttings from the mist system and transfer them to greenhouse benches. Appearance of roots at the sides of the pots will indicate extensively developed roots capable of absorbing sufficient moisture without supplemental mist. We suggest that cuttings be maintained under a 20-hour day length. In our greenhouse, cool-white fluorescent and incandescent lamps provide about 400 foot-candles of supplemental light.

By keeping the time that cuttings are under mist to a minimum, this procedure enhances the cuttings' ability to overwinter successfully. Cuttings treated in this manner appear to be in much better condition physiologically; therefore, a certain number of cuttings will flush and grow (Fig. 9-9) shortly after rooting without forced budbreak.

Cuttings that do not flush can be forced by applying gibberellic acid (GA) (75% K salt) to the buds (Yawney et al. 1978). In experiments to force budbreak, GA used as a foliage spray was applied with an atomizer to some rooted cuttings daily and to other rooted cuttings every 4 days over a 16-day period. Concentrations tested were 0,100,

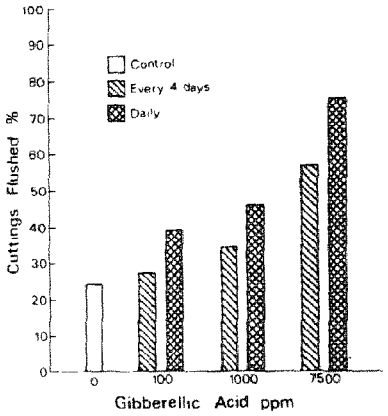
1,000 and 7,500 ppm (Fig. 9-10). The 7,500-ppm concentration applied daily was the best treatment; over 70 percent of the cuttings flushed. Spray applications of GA were subsequently compared with applications of GA with an eyedropper to buds; there was no significant difference between the two methods of application.

After flushing, cuttings should be permitted ample time to photosynthesize and store reserve carbohydrate. With the 20-hour day length and suitable temperatures, we maintain the rooted cuttings in a growing condition until mid- or late December. At that time, with shorter days and lower temperatures, the cuttings are hardened off over a 3- to 4-week period in preparation for overwintering. An overwintering period of 6 to 8 weeks at 2°C is sufficient to satisfy the dormancy requirements of the rooted cuttings. We use a walk-in cooler for this purpose. After overwintering, the cuttings are returned to the greenhouse to resume growth.



Figure 9-9.—A sugar maple cutting putting on new growth shortly after rooting. Cuttings that flush in the growing season when they are rooted have a much higher chance of surviving overwintering.

Figure 9-10.—The effects of different concentrations of gibberellic acid applied daily and every 4 days to force budbreak in rooted cuttings of sugar maple.



Air-Layering

Air-layering stimulates root development on branches that are still attached to the original tree. Cunningham and Peterson (1965), concerned with developing workable propagation techniques that could be applied to sugar maple, tested this method and described it in considerable detail. Additional information can be found in Hartman and Kester (1975). Briefly, the procedure described by Cunningham and Peterson (1965) is as follows: One- or two-year-old branch wood is first wounded by making a 1-inch wide girdle deep enough to remove the cambium at the point where roots are desired. The wound is dusted with a root-inducing hormone powder, covered with moist sphagnum moss, and wrapped with a waterproof material (preferably clear plastic film). After a few weeks, when roots have formed and grown through the sphagnum moss (Fig. 9-11), the branch is severed below the roots and planted like a seedling. At this point, several precautions should be taken to promote survival: The authors suggest reducing the leaf area, planting in sheltered areas to protect the branches from wind, and maintaining good soil moisture conditions.

Cunningham and Peterson (1965) demonstrated that branches of sugar maple can be rooted by air-layering with good success. In one of their experiments they reported success rates from 51 to 100 percent among the six trees they compared. However, they experienced difficulties in overwintering similar to those encountered with rooted cuttings. Of the 426 rooted air-layered branches planted, only 142, or 33 percent, were alive the next year.

The development of roots on air-layered branches is similar to root development in cuttings. Air-layers are made at the time when the leaves on new growth have reached full size—at the same stage of growth (about mid June in northern Vermont) when cuttings are taken. (As in cuttings, timing of air-layering is critical for maximum rooting). Roots on air-layers may be evident as early as 4 weeks, but may require as much as 12 weeks to develop. Cunningham and Peterson (1965) observed that, "The earlier rooted branches are removed from



Figure 9-11.—Roots developing on an air-layered sugar maple branch. When air layer is at this state, the branch is cut below the roots and planted.

the parent tree and started on their own roots, the better the chances are for their overwinter survival."

Although air-layering may be used to advantage under certain circumstances, it has one major disadvantage: Branches on some trees selected for propagation may not be readily accessible.

Grafting

Another method, probably the one most commonly used by plantsmen in vegetative propagation, is grafting. A host of grafting methods have evolved for reproducing a large variety of commercially important and exotic plants. The grafting procedures most widely used are described in detail by Hartman and Kester (1975).

According to Kriebel and Gabriel (1969), bud grafting is used almost exclusively, and with a high degree of success, by commercial nurserymen for the vegetative propagation of sugar maple. Attempts at the Burlington laboratory to use bud grafting on lined-out nursery root stock during three successive seasons resulted in complete failure. Other grafting methods utilizing scionwood under greenhouse conditions were also tried. The results of these early tests, which included the whip, side, bottle and cleft grafts, were more promising: Successful takes as high as 75 percent were obtained. During the succeeding years, we found that the side or veneer grafts (Fig. 9-12) consistently gave us the highest takes.

Our results suggest that differences noted between trees may be due to genetic differences in graftability. We also found that grafting success varied from year to year. No reasons for this year-to-year variation are known, but there were probably differences in grafting techniques; i.e., when and under what conditions the scions were collected and how they were handled, the treatment and handling of the rootstock, and the experience of the grafters. Kriebel and Gabriel (1969) stated that scion vigor was a critical factor in the survival of grafted scions. They obtained a much higher percentage of successful grafts from vigorous than from slow-growing trees. Our own experience also pointed to the importance of scion vigor.



Figure 9-12.—Scionwood of sugar maple side-grafted to a seedling root stock.

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Section IV Chapter 10

Economics of Maple Sap and Syrup Production

Sap Collection Systems

by Neil K. Huyler

There are two methods of maple sap collection—the traditional bucket system and, more recently, the plastic tubing system. The plastic tubing system is an improvement in sap production technology, but some maple producers remain unconvinced that the economic gains from the tubing system will exceed its cost.

As in any business, many factors have to be considered to insure profit. Factors such as investment, depreciation, interest, operating expenses, taxes, and income are all important in making management decisions. This chapter will consider these and other factors for the bucket and tubing collection systems.

Economics of maple sugar production was not a major consideration for early settlers—they produced maple primarily as a sweetner for household use and barter (Huyler and Garrett 1979). The modern maple producer, however, produces a cash crop to provide supplemental income which is vital to small communities in the maple region (Bell 1955, Willits and Hills 1976). In addition, there is a trend toward large-scale operations that provide all or a major part of their owner's income. Costs of production are important in their business decisions.

Economic Evaluation of Bucket Systems

Investment

Costs incurred in the production of maple sap include equipment, labor, material, sugarbush value or taphole rental, and management. Of these, the largest cost for

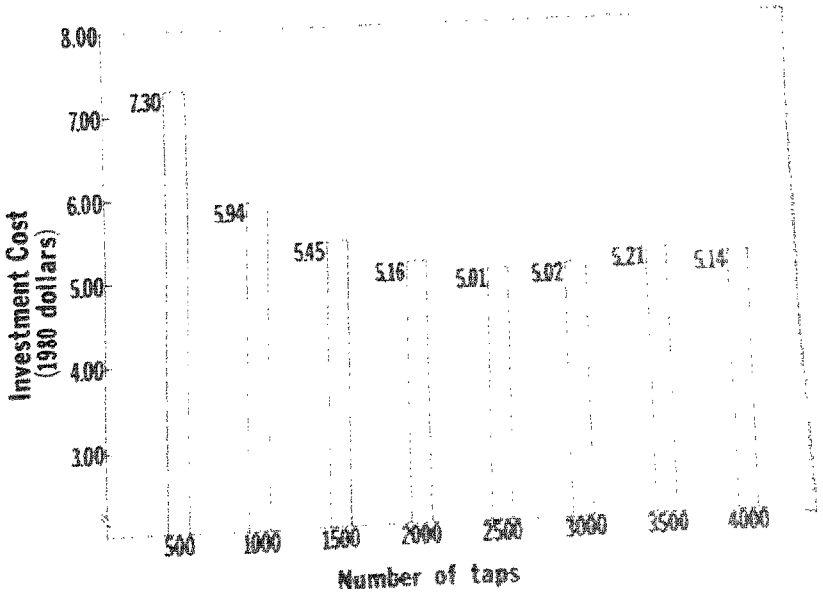


Figure 10-1.—Investment cost per tap for bucket sap collection system.



Figure 10-2.—Equipment and labor for a bucket operation.

a new producer or a producer replacing equipment is the investment in new sap production equipment (Huyler 1975, Kearl 1970).

The investment cost for the bucket method of sap production can be substantial: The average investment requirement for a bucket system in 1980 is approximately $5.16 per tap. The range is from a high of $7.30 for a 500-tap operation to $5.14 for a 4,000-tap operation (Figs. 10-1 and 10-2). The three main items of investment—bucket, spout, and cover—account for more than three-fourths of the investment requirement.

The investment per tap is greatly influenced by the size of operation or number of taps installed. The reason is simple; as the number of taps increases, the cost per tap for equipment such as power tappers, storage tanks, and hand tools declines as it is averaged over a larger number of taps (Fig. 10-1). Table 10-1 is a list of equipment required to operate a bucket system; it can be used to determine investment cost for a complete bucket operation.

Table 10-1.—Equipment requirement for bucket systems

Item	Quantity
Gathering pails	2 per man
Bucket, spout, cover	1 set per tap
Power tapper	1 per operation
Bucket washer	1 per operation
Hand tools	1 each per operation
Sap sled and gathering tank	1 each up to 3,000 taps; 2 each for more than 3,000 taps
Sap storage	1 gallon storage capacity per tap
Tractor	Prorated according to use (hour/season)

Labor

Labor is also an important cost item in the production of maple sap. Finding seasonal labor is becoming more difficult each year. From time and motion studies of commercial bucket operations, the average amount of labor required for a maple season is 12.3 minutes per tap. The range was from 9.7 to 13.9 minutes per tap.

Table 10-2 can be used as a yardstick to compare the labor input to your operation with what we found the average of several opera-

Table 10-2.—Average labor time for each sap production work activity for bucket systems

Activity[a]	Labor-minutes/ tap	Percentage
Preparation	0.2	1.6
Set-up	2.6	21.1
Gathering	7.3	59.4
Take-down	1.3	10.6
Clean-up and storage	.9	7.3
Total	12.3	100.0

[a] Preparation time—cleaning and repairing equipment, storage tank preparation, etc.
Set-up time—tapping, setting spouts, scattering and hanging buckets.
Sap gathering time—inspecting buckets, gathering sap, dumping ice or spoiled sap.
Take-down time—disassembling the system.
Clean-up and storage—cleaning and storing all equipment.

tions to be. If your labor input is lower than average, there may be areas where your labor efficiency can be improved.

Annual Operating Cost

Once the maple producer has invested in sap collection equipment and goes into sap production, operating costs will be incurred. These include depreciation on equipment, interest on the investment, labor, materials, taxes, and tap rental.

The annual cost for bucket equipment can be determined by using a 30-year straight-line depreciation schedule and a 12 percent interest charge on the investment. The interest charge will vary from year to year. The objective is to recover completely the original investment plus the cost of borrowing money (interest) by allocating an amount annually over the useful life of the investment.[1] To this fixed operating cost, the variable operating costs of labor, materials, and tap rental are added to arrive at the total annual operating cost.

Labor is usually paid on a per-hour basis. The computation should include not only the operator and family labor, but also any hired labor used during the sap season. Materials such as gas, oil, etc. used in sap production are variable yearly expense items and are charged at current market price to the operator.

Also include a land overhead cost. Taxes must be paid on the land, and there is an economic loss in timber value when a maple tree is tapped. To account for taxes and loss in timber value, a flat rate of $.15 per tap (based on average prevailing rates in Vermont) is charged to the production of sap. The flat rate is used because local tax rates and timber values differ.

Table 10-3.—1980 Average operating cost per tap for bucket systems (in dollars)

Number of taps	Annual[a] equipment cost	Labor cost	Material[b] cost	Rental cost	Total annual cost
500	1.02	0.82	0.11	0.15	2.10
1,000	.79	.82	.09	.15	1.85
1,500	.72	.82	.08	.15	1.77
2,000	.67	.82	.08	.15	1.72
2,500	.64	.82	.08	.15	1.69
3,000	.65	.82	.07	.15	1.69
3,500	.66	.82	.07	.15	1.70
4,000	.67	.82	.06	.15	1.70
Mean	.73	.82	.08	.15	1.78
Percentage of total	41	46	5	8	100

[a] Includes cost of tractor prorated according to usage.
[b] Includes operating cost for gas, oil, and maintenance.

Combining these costs, the mean annual operating cost per tap in 1980 for the bucket sap collection system was $1.78 (Table 10-3). The two major cost elements, accounting for 87 percent of the total cost, are annual equipment cost and labor. If we assume that it requires the sap from four taps to produce 1 gallon of maple syrup, the average sap cost per gallon of syrup would be $7.12 for the bucket system.

Break-even Size

A useful business management tool is the break-even analysis. This relates costs and income for various levels of production to determine at what point, or number of taps, income from the sugarbush just covers the cost of operation. This is important in deciding whether a sugarbush has enough potential taps to be put into commercial production.

The factors that must be known to determine break-even size are:

1. Average sap sweetness or sugar content measured in degrees Brix[2] and its current price per gallon.
2. Expected or average yield of sap per tap in gallons.
3. Average annual cost for the current year.

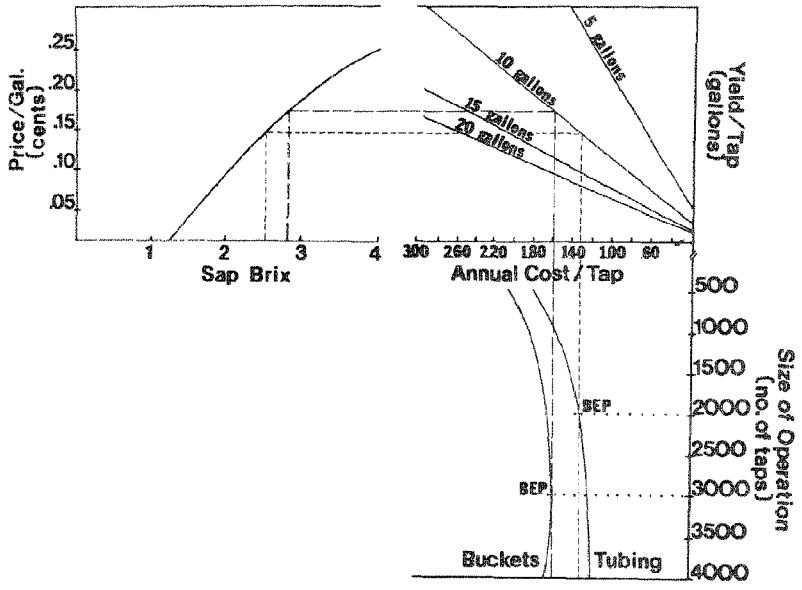
Figure 10-3 is a graphic presentation of these factors using 1980 production cost and average yield data. For the bucket collection system to break even approximately 3,000 taps would be required. This can be determined by entering the graph at 2.8°Brix sap; going vertically up until the sap price line is intersected; following the line horizontally until the 10 gallons of sap/tap yield line is intersected; going vertically down until the annual cost curve is intersected at the 3,000-tap

$$a = V \left[\frac{i(1 + i)^n}{(1 + i)^n - 1} \right]$$

where a = the annual cost;
i = interest rate;
V = investment cost;
n = number of years the equipment is depreciated.

[2] One degree on the Brix scale is equivalent to 1 percent solids (sugar content) by weight.

Figure 10-3.—Break-even sizes for bucket and tubing with vacuum systems.



level. This graph can be used to approximate other break-even points if the two factors, sap sweetness and expected or average yield of sap per tap for the sugarbush, are known.

Discussion

The initial investment in new equipment for the bucket collection system is substantial. This fact alone discourages most new producers from using it. The high annual cost of the bucket system is also a major factor. This is not to suggest that a person who can purchase used equipment at a much lower cost or the producer who has his equipment paid for cannot make a profit. It does, however, place economic constraints on new commercial-size (500 taps or more) bucket operations.

Another major factor that may limit the use of buckets is the availability of seasonal labor. As noted, bucket systems are highly labor-intensive; and each year it is becoming more difficult to find seasonal labor. These two factors, high investment and the need for seasonal labor, will no doubt make new commercial-size bucket operations less attractive in the future.

Economic Evaluation of Plastic Tubing Systems

Investment

Sap extraction using plastic tubing with vacuum is an advance in sap production technology (Fig. 10-4). However, in certain parts of the maple-producing region, adoption of the tubing system has been slow. The major reason given is that sap producers are unconvinced that there would be any economic gain. Recent economic studies, however, do not substantiate this concern (Huyler 1975, Gunter and Koelling 1975).

The question that most potential tubing users ask is, "What will be my total investment for tubing sap production equipment?" The average initial investment costs (in 1980) for the tubing system without and with mechanical vacuum were $2.69 and $3.53 respectively. The addition of vacuum to the system costs from $2.48 per tap for the 500-tap operation to $.31 per tap for the 4,000-tap operation (Table 10-4, Fig. 10-5).

The tubing system is similar to the bucket system in that as size (number of taps) increases, invest-

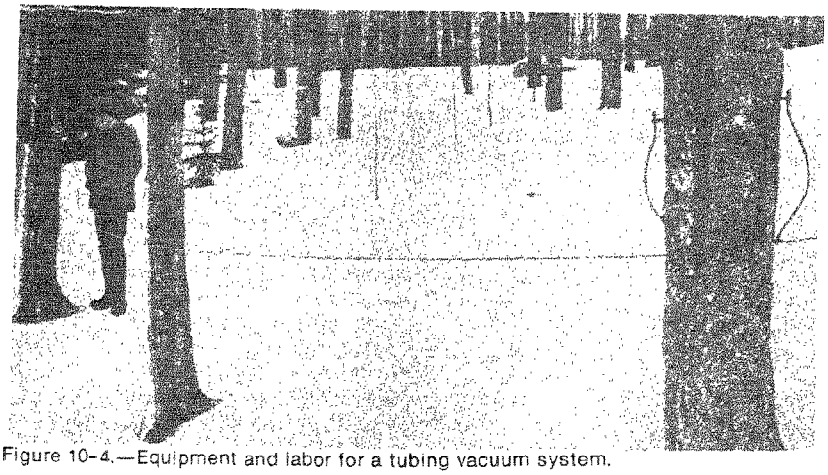


Figure 10-4.—Equipment and labor for a tubing vacuum system.

Table 10-4.—1980 Equipment cost for a tubing system with and without vacuum (in dollars)

Item	Number of taps							
	500	1000	1500	2000	2500	3000	3500	4000
Spouts	100.00	200.00	300.00	400.00	500.00	600.00	700.00	800.00
5/16" Tubing @ $.05/ft.	413.00	825.00	1238.00	1650.00	2063.00	2475.00	2888.00	3300.00
1/2" Conduit @ $.09/ft.	115.00	230.00	345.00	460.00	575.00	690.00	805.00	920.00
3/4" Conduit @ $.11/ft.	108.00	216.00	325.00	432.00	540.00	648.00	756.00	864.00
1" Conduit @ $.23/ft.	—	203.00	305.00	406.00	508.00	609.00	711.00	812.00
5/16" Tees	50.00	100.00	150.00	200.00	250.00	300.00	350.00	400.00
Large tees	5.00	6.00	9.00	12.00	15.00	18.00	21.00	24.00
5/16" Connectors	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00
4-Way wyes	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00
Spring clips & hose clamps	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00
Miscellaneous (tools, etc.)	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00
Sap storage	524.00	1048.00	1048.00	1048.00	1048.00	1048.00	1572.00	1572.00
Power tapper	235.00	235.00	235.00	235.00	235.00	235.00	235.00	470.00
Materials	52.00	93.00	135.00	177.00	219.00	261.00	203.00	345.00
Approximate total cost	1632.00	3216.00	4180.00	5140.00	6103.00	7064.00	8451.00	9747.00
Per tap	3.26	3.22	2.79	2.57	2.44	2.35	2.41	2.44
Vacuum[a]	1240.00	1240.00	1240.00	1240.00	1240.00	1240.00	1240.00	1240.00
Cost of vacuum per tap	2.48	1.24	.83	.62	.50	.41	.35	.31
Total cost per tap with vacuum	5.74	4.46	3.62	3.19	2.94	2.76	2.77	2.75

[a] Approximate additional cost of adding a vacuum system.

ment cost per tap decreases up to about 3,500 taps; then it remains nearly constant (Fig. 10-6).

Table 10-5 is an equipment list for the tubing system. This table can be used to estimate the amount of equipment investment required by multiplying by the current price of the equipment.

For the tubing system, the additional cost of a vacuum system will depend on the type of vacuum system employed. In this analysis the system was a dry vacuum type, which includes a vacuum pump and an evacuation pump to empty the sap from the vacuum tank. This adds, on the average, about $.41 additional investment cost per tap for a 3,000-tap operation (Fig. 10-5).

Vacuum systems. The application of vacuum to a tubing system was introduced in the early 1960's.

Figure 10-5.—Investment cost per tap for tubing system with and without vacuum system.

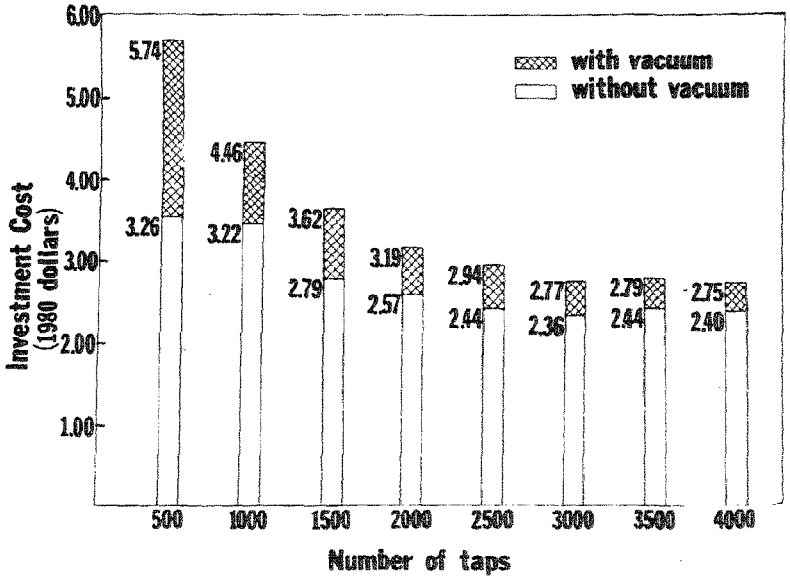


Figure 10-6.—Investment cost for bucket and tubing vacuum system.

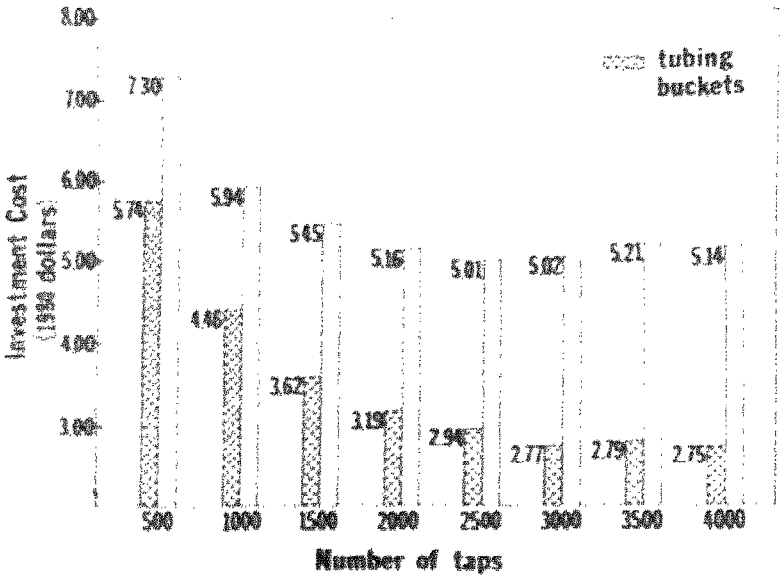


Table 10-5.—Standard equipment requirement for tubing system

Item	Quantity
Spouts	1 per tap
5/16" Tubing	15 ft. per tap
1/2" Mainline	2.0 ft. per tap
3/4" Mainline	1.2 ft. per tap
1" Mainline	.7 ft. per tap
5/16" Tees	1 per tap
4 Way wyes	.02 per tap
5/16" Connectors	1 per 300 ft. of 5/16" tubing
1/2" Connectors	1 per 100 ft. of 1/2" line
3/4" Connectors	1 per 100 ft. of 3/4" line
1" Connectors	1 per 100 ft. of 1" line
5/16" End caps	2 per 4-way wye
1" x 3/4" Reducer	1 per 500' of 3/4" line
3/4" x 1/2" Reducer	1 per 500' of 1/2" line
Power tapper	1 per operation
Pruning shears	1 per operation
Spring clips or hose clamps	1 per connection
Pliers	1 per operation
Spout puller	1 per operation
Hammer	1 per operation
Sap storage tanks	2 gal. minimum storage per tap
Marking tags and paint	2 per line
Vacuum pump assembly	1 per operation

Tests indicated that sap yields with vacuum were approximately twice those with gravity flow (Smith and Gibbs 1970). Studies of 15 commercial-size sugarbushes for two sap seasons showed that tubing with vacuum increased the yield by an average of 28 percent over that of similar size bucket operations. For further information on vacuum systems, see Section 1, Chapter 3.

The most obvious question for a producer is whether adding a vacuum system would be economical. One way to answer this question is in terms of payback period; that is, the length of time required for the income received from the additional yield of sap to equal the cash paid for the vacuum system.

If we achieved the 28-percent increase in sap yield observed in the test, the payback period would be approximately 1-1/2 sap seasons for a 3,000-tap operation. Consider the following computation:

A sugarbush operator with 3,000 taps averaging 8.28 gallons per tap annually invested $1,250 in a vacuum system. Using the 28 percent expected increase, the bush will now yield 10.56 gallons of sap per tap—a 2.3 gallon per tap increase. Using the price for 2.5°Brix sap of $.137 per gallon yields an increase in sap value of $.32 per tap (2.3 gallons/tap X $.137/gallon). The total increase in value is therefore $960.00 ($.32/tap X 3,000 taps). One can see that adding vacuum to this bush will repay approximately three quarters of the cost of the vacuum system the first year. We recommend that producers using the tubing system consider the addition of vacuum.

Labor

The use of plastic tubing instead of buckets reduces the labor time significantly (Huyler 1975, Gunter and Koelling 1975). Also, labor is distributed in such a way that the owner-operator can spend more time at the sugarhouse during sap-flow periods (Table 10-6).

Table 10-6.—Average labor time for each sap production work activity for tubing systems

Activity[a]	Labor-minutes/ tap	Percent-age
Preparation	0.6	6.3
Set-up	5.4	56.2
Checking tubing	1.7	17.7
Take-down	1.0	10.4
Clean-up and storage	.9	9.4
Total	9.6	100.0

[a] Preparation time—cleaning and repairing equipment, storage tank preparation, etc.
Set-up time—installation of mainlines and small tubing lines, tapping, setting spouts.
Checking tubing—checking the tubing system for leaks and making necessary repairs.
Take-down time—disassembling the system.
Clean-up and storage time—cleaning and storing all equipment.

In recent studies, total labor time per tap for installing tubing ranges from 7.8 to 12.0 minutes, with the average of 9.6 minutes per tap. At an hourly wage rate of $4.00 per hour, the installation of one tubing tap would cost about $.64.

Table 10-6 shows the average labor time for each work activity for the tubing system. Notice that the set-up time requires 56 percent of the total labor time. This is critical in tubing systems because an improperly installed system will reduce sap yield.

Annual Operating Cost

To estimate the annual return from a maple operation, the annual operating cost must be known. Cost elements include depreciation on equipment, interest on investment, labor, materials, and cost associated with use of the maple tree (rental cost).

Table 10-7.—1980 Average operating cost per tap for tubing-vacuum systems (in dollars)

Number of taps	Annual equipment cost	Labor cost	Material[a] cost	Rental cost	Total annual cost
500	1.01	0.64	0.08	0.15	1.88
1,000	.76	.64	.06	.15	1.61
1,500	.62	.62	.04	.15	1.43
2,000	.55	.64	.04	.15	1.38
2,500	.50	.64	.04	.15	1.33
3,000	.47	.64	.04	.15	1.30
3,500	.47	.64	.03	.15	1.29
4,000	.45	.64	.03	.15	1.27
Average	.60	.64	.05	.15	1.44
Percentage of total	42	45	3	10	100

[a] Includes operating cost of gas, oil, and maintenance.

For tubing systems we used a 10-year straight-line depreciation schedule for all tubing equipment. A 12-percent interest charge on the investment cost was also included. All labor was paid $4.00 per hour, including operator and family labor. The materials used in sap production were charged at actual 1980 cost. Also included was a rental charge per tap to account for land taxes and the economic loss in timber value due to tapping the trees. This charge was a flat rate of $.15 per tap and was based on the average local prevailing rates in Vermont.

The annual operating cost for plastic tubing vacuum systems in 1980 ranged from $1.88 per tap for a 500-tap operation to $1.27 per tap for a 4,000-tap operation (Table 10-7), for an average of $1.44 per tap compared to $1.78 per tap for bucket systems (Table 10-8). The two major cost elements, labor and equipment, account for about 86 percent of the total operating costs.

If we assume that it requires the sap from four taps to produce 1 gallon of syrup, then the sap cost per gallon of syrup would be about $5.76 for the average size plastic tubing operation.

Break-even Size

The break-even or zero profit point for tubing with vacuum operations is approximately 2,000 taps, using 1980 price and cost figures. The same factors are used to determine a break-even point as in bucket operations—sap sweetness and current price per gallon; expected

Table 10-8.—Contrasted total average operating cost per tap for tubing-vacuum and bucket systems (in dollars)

Number of taps	Total operating cost	
	Tubing[a]	Buckets[b]
500	1.88	2.10
1,000	1.61	1.85
1,500	1.43	1.77
2,000	1.38	1.72
2,500	1.33	1.69
3,000	1.30	1.69
3,500	1.29	1.70
4,000	1.27	1.70
Average	1.44	1.78

[a] Includes snowmobile operating cost
[b] Includes tractor operating cost

average yield of sap per tap; average annual cost for the current year. Figure 10-3 is a graphic presentation of these factors, using 1980 cost figures for tubing systems. Refer to the section on the break-even point of bucket operations for the procedure for using the graph.

Conclusion

It is important that each sugarmaker keeps accurate cost records so that areas of high cost can be pinpointed and steps can be taken to reduce these costs. The key for a successful maple operation is to increase the overall efficiency of the operation to keep costs of production under control and to maintain an acceptable margin of profit.

Chapter 11

The Economics of Open-Pan Evaporators

by Neil K. Huyler

Since maple syrup production is still primarily a farm business, no two maple operations have identical production costs. Many operations use older wood-fired plants with equipment fully depreciated and, therefore, carrying no equipment costs (Kearl 1970). Further, many different wage rates prevail in the maple-producing region.

To evaluate the total annual cost of production fully, both noncash items, such as interest on capital and depreciation on building and equipment, and cash items, such as labor, fuel, electricity, taxes, insurance, and miscellaneous expenses should be combined. The sum is the true total annual cost of production.

Costs: Capital Investment, Annual Production Cost

Essential to any new business are two forms of capital: investment capital to assemble the physical resources required for production; and operating capital or financial reserves to assure operation during the start-up period (Buffa 1973). Once the start-up is completed and a product is in production, the income from sales can be used to cover the cost of labor, fuel, and materials.

Capital Investment

An operating maple producer or an entrepreneur planning to invest in a maple syrup processing plant must allocate money for such items as land, processing equipment, buildings, and storage facilities. As plant size increases, total capital investment increases; however, land and building costs do not increase in direct proportion to the volume of syrup produced—1 acre of land is sufficient for both small and large operations, and building size does not double as volume doubles.

A breakdown of total capital investment for small, medium, and large maple syrup operations by fuel types is presented in Table 11-1. Small, medium, and large maple operations using oil-, wood-, or gas-fired evaporators differ little in total capital requirements. In 1980, a small plant required $11,641 outlay, whereas medium and large size plants required $15,709 and $18,554, respectively.

Processing equipment is the largest single component of investment cost, approximately 55 to 60 percent of the total investment. Larger operations also require specialized equipment for syrup drawoff, finishing, and packaging.

Processing equipment for liquid propane (LP) gas-fired systems requires the highest investment and wood-fired the least investment. However, because of the additional cost of a wood storage shed for the wood fuel system, the total investments for all three types of fuel are nearly equal.

Annual Production Cost

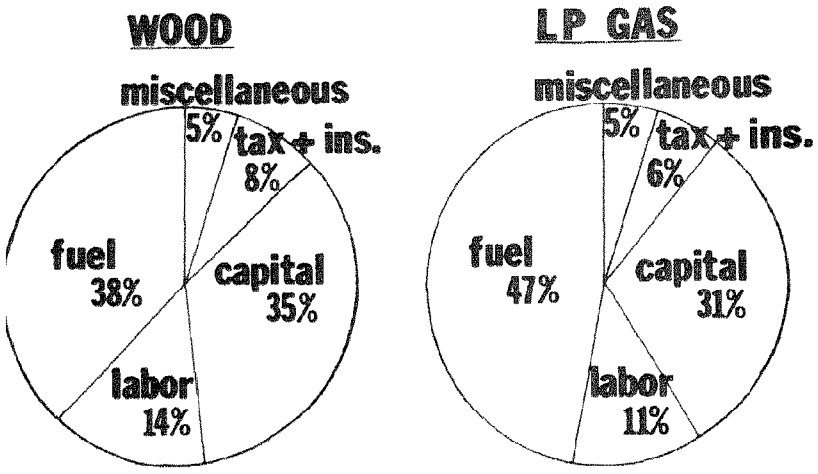
Depreciation and interest. Of the several "noncash" costs in any business, depreciation is usually the least understood and the one that many maple producers disregard in their cost analysis. The primary importance of depreciation is its effect on income taxes, and this should be reflected in the cash flow or net profit (Hedgecock and Mullin 1971).

Interest on borrowed capital is also an important cost item in estimating the annual production cost. Interest is simply the rental price of money that has been borrowed to go into operation. For this analysis, an annual interest rate of 12 percen was charged to the capital investment.

Capital cost accounts for approximately 30 percent of the total annual cost of processing sap to

Table 11-1.—Investment cost for small, medium, and large maple operations in 1980

Item	Investment cost in 1980 dollars		
	5′ x 12′ Small 1500-2000 taps 375-500 gal. syrup	5′ x 16′ Medium 2100-3000 taps 525-750 gal. syrup	6′ x 16′ Large 3100-4000 taps 775-1000 gal. syrup
Land (1 acre)	$ 2,000	$ 2,000	$ 2,000
Building @ $6.64 sq. ft.	$ 2,125	$ 4,515	$ 4,515
Wood shed @ $4.17 sq. ft.	$ 640	$ 960	$ 1,280
Processing equipment			
Oil rig	$ 6,942	$ 8,609	$11,209
Wood rig	$ 6,431	$ 8,009	$ 9,710
Gas rig	$ 7,516	$ 9,194	$12,039
Total oil	$11,067	$15,124	$17,724
Total wood	$11,196	$15,484	$17,505
Total gas	$11,641	$15,709	$18,554



l cost for three types of fuel
750-gallon maple syrup

of syrup products; however, these labor inputs are attributed to marketing costs, not processing.

Energy costs. Oil and LP gas are the most expensive fuels utilized by producers, normally accounting for 49 and 47 percent of total annual cost, respectively (Fig. 11-1 and Table 11-2). Wood is the least expensive fuel, normally accounting for 38 percent of the total annual cost.

The cost of energy in the processing of maple syrup products relates directly to the efficiency of the evaporation system used. Wood-fired evaporators normally operate between 40 and 50 percent efficiency (see Section V, Chapter 12), oil-fired evaporators between 60 and 65 percent efficiency, and gas-fired evaporators between 65 and 70 percent efficiency.

Energy requirements for processing pure maple syrup can be expressed in a fuel-to-syrup ratio. Operators who use oil normally use between 3.5 and 4.0 gallons of No. 2 fuel oil to process 1 gallon of syrup. Wood-fired evaporators consume approximately 1 cord of wood for every 25 to 30 gallons of syrup produced. Gas-fired evaporators consume approximately 5 gallons of LP gas to produce 1 gallon of syrup.

In terms of energy cost per gallon of syrup for the three fuel types, No. 2 fuel oil at a price of $1.01 per gallon of oil would average $4.04 per gallon of syrup; wood at the price of $65 per cord would average $2.60 per gallon of syrup; and LP gas at the price of $.757 per gallon of gas would average $3.79 per gallon of syrup (Table 11-2). Although wood is the least expensive fuel, moisture content, density, and total volume received in purchase must be monitored to ensure maximum economic benefit.

Taxes, Insurance, and Miscellaneous Costs

Other costs incurred in maple syrup processing include taxes, insurance, and miscellaneous items such as electricity, cleaning materials, etc. These costs are generally minor in relation to the total cost of operating the plant. Together they constitute only about 12 percent of the total annual cost of producing a gallon of syrup. Even so, they

Table 11-2.—Annual production costs for small, medium, and large maple processing plants by fuel types

Item	No. 2 fuel oil			Wood			LP gas		
	Small	Medium	Large[a]	Small	Medium	Large	Small	Medium	Large[a]
	Dollars per gallon of syrup								
Depreciation & interest									
Building	0.54	0.77	0.58	0.71	0.93	0.74	0.54	0.77	0.58
Processing equipment	1.86	1.54	1.50	1.72	1.43	1.30	2.01	1.64	1.61
Taxes & insurance[b]	.47	.48	.38	.52	.53	.43	.47	.48	.38
Labor[c]	1.30	.87	.65	1.40	.93	.70	1.30	.87	.65
Fuel[d]	4.04	4.04	4.04	2.60	2.60	2.60	3.79	3.79	3.79
Electricity & misc.	.48	.54	.56	.40	.40	.40	.42	.44	.44
Total	8.69	8.24	7.71	7.35	6.82	6.17	8.53	7.99	7.45

[a] Small, medium, large represent an average annual production of 500, 750, 1000 gallons of syrup respectively.
[b] Taxes were estimated @ $4/$100 for building investment. Insurance was estimated @ $.75/$100 of original investment less land.
[c] Labor was charged @ $5/hour for both family and hired labor – 130 hours of boiling time for LP gas and oil and 140 hours for wood-fired.
[d] Fuel was charged @ $1.01/gal. for No. 2 fuel oil, cordwood @ $65/cord, and LP gas @ $.757/gal.

should not be overlooked in the cost of production (Table 11-2).

Total Annual Cost

Fuel, capital (interest and depreciation), and labor account for over 75 percent of the total annual cost for all fuel types. For oil-fired evaporators the total annual cost ranges from $8.69 to $7.71 per gallon of syrup (decreasing as size or production level increases); the total annual cost of operating wood-fired evaporators ranges from $7.35 to $6.17 per gallon of syrup (decreasing as production level increases); gas-fired evaporator costs range from $8.53 to $7.45 per gallon of syrup (decreasing as production level increases) (Table 11-2).

Of the evaporators, a wood-fired system has the lowest total annual cost. This is directly attributable to the lower cost of fuel, but this cost will vary, of course.

It should be noted that the costs shown in Table 11-2 are the costs of processing sap to syrup. To get the total cost of producing a gallon of syrup, the cost of sap must be added.

Table 11-3.—Total costs of making pure maple syrup for three fuel types (in dollars per gallon of syrup)

Activity	No. 2 fuel oil	Wood	LP gas
Sap production costs	5.76	5.76	5.76
Processing costs[a]	8.24	6.82	7.99
Total costs	14.00	12.58	13.75

[a] This does not include packaging or marketing costs.
Note: These cost figures are for a medium or 750 gallons of syrup production level. Small production levels (500 gallons) would have a slightly higher total cost, and high syrup production levels (1000 gallons) would have a slightly lower total cost.

The average annual cost of sap production for tubing systems in 1980 was $5.76 per gallon-of-syrup equivalent. This includes the cost of capital (interest and depreciation), labor, and miscellaneous costs. Adding the cost of processing to the cost of sap production gives the total cost of producing a gallon of maple syrup.

Table 11-3 shows the sap production cost for a production level of 3,000 taps or 750 gallons of syrup added to the processing cost per gallon of syrup for three fuel types. The oil-fired evaporator had a total production cost in 1980 of $14.00 per gallon of syrup; wood-fired, a cost of $12.58 per gallon; and gas-fired, a cost of $13.75 per gallon.

Discussion

Processing cost has been most significantly affected over the past 8 years by the increasing price of energy. Specifically, the price of No. 2 fuel oil rose from an average of $.18 per gallon in 1971 and $.24 per gallon in 1974 to $1.01 per gallon in 1980-81. With the conventional oil-fired evaporator requiring about 3.5 to 4 gallons of fuel oil for each gallon of syrup produced, the increase in total processing cost since 1973-74 due to fuel oil alone was approximately $3.06 per gallon of syrup. Energy accounts for about 49 percent of the total cost of processing sap to syrup.

From 1974 to 1980 average farm price for all grades of maple syrup increased from $9.91 to $15.60 per gallon. The price of energy alone is erasing a large part of any gain from the rise in the average market price of maple syrup.

Capital costs, especially plant equipment and building, have increased an average of 8 to 9 percent per year since 1974. This has also caused a significant increase in cost, since they account for about 30 percent of the total processing cost.

Farm wages have also risen since 1974 but have not had as much impact on total processing cost as have fuel and capital costs. This is primarily because labor makes up only about 12 percent of the total annual processing cost and, in certain cases, the owner-operator does not charge for his or her labor in the sugarhouse. If there is a charge, it is usually at a lower rate than if outside labor was hired.

Overall, total annual processing cost has tripled since 1974, whereas average farm price for all sales in the U.S. increased only 57 percent. This economic fact points to the need for the industry to utilize any improvements that will stabilize or reduce energy cost and also to keep accurate cost records so that other areas of high cost can be pinpointed and controlled.

Chapter 12

Efficiency of Wood-Fueled Evaporators

by Lawrence D. Garrett

The technology of making maple syrup has progressed significantly from the potash kettles of years ago. Today the open-pan evaporator is still in use; however, its thermal efficiency is vastly improved by heat exchangers, tubular pans, baffles, and improved firing techniques. Several brands of open-pan maple sap evaporators have been manufactured during the last 100 years. Although evaporators have been modified to burn oil and gas, a significant proportion of the units operating today are wood-fired (Kearl 1970).

In the United States and Canada it is estimated that between 12,000 and 15,000 sugarhouses are presently using open-pan evaporators. The percentage of total syrup production currently being produced with wood is unknown, but studies in Pennsylvania, New York, and Wisconsin indicate that significant numbers of wood-fired evaporators are still in use (Pasto and Taylor 1962, Kearl 1970, Acker et al. 1970).

The basic parts of the wood-fired evaporator are the arch, grates, pans, and stack. In general, gas- or oil-fired evaporators differ from wood-fired evaporators in that the grates are removed and the combustion chamber is redesigned. The oil or gas burners are usually positioned in the front of the arch in place of the wood firebox doors.

The rapidly rising prices of fuel oil and gas have diminished the value of the convenience and higher evaporator efficiency of these fuels. However, wood fuel is highly variable, and the producer must consider all factors which will affect the relative cost of using wood versus another fuel. Variables such as purchase price, volume to be sold, wood type and its moisture content can have a great influence on the actual cost per Btu.

Factors Affecting Efficiency and Economics of Using Wood Fuels

Purchase Price

The type of wood burned by syrup producers typically has little utility for other uses. Often it consists of stems and tops of cull timber, logging residues, sawmill slabs and other industrial residues. Very often it comes from cultural operations in the producer's sugarbush (Kearl 1970, Pasto and Taylor 1962).

If a maple producer obtains his own fuel-wood, he will incur between $20 and $30 out-of-pocket cost for each cord. If labor is included, it should be valued between $3 and $5 per hour and about 3 to 5 hours are required per cord. This would be an average total cost of $42 per cord. If the producer buys wood, it will cost $50 to $70 per cord split.

Because maple producers have good general knowledge of wood products, they probably receive a full cord when wood is cut or purchased, and their knowledge of wood's burning characteristics probably enables them to obtain the better, denser woods, which have higher heating values per unit volume.

Fuel Volume

Fuelwood is measured on a volume basis and the unit most commonly used is a cord. A full cord is a stack of wood 4 feet high, 4 feet wide, and 8 feet long with a volume of 128 cubic feet. However, the 128 cubic feet is a nominal measure and includes air space as well as solid wood. In all cases something less than 128 cubic feet of solid wood is actually exchanged when a cord of wood is sold.

Tree stems are never uniform in size and shape and are not perfect cylinders. Any deviation from perfect cylinders, such as limbs, knots, crook, and sweep, will decrease the amount of solid wood in the cord and increase the amount of air space. In general, the smaller, longer, and more crooked the stems, the fewer the cubic feet of solid wood in a cord (Table 12-1).

The impact of reduced volume becomes apparent when viewed as an additional cost. For example, wood purchased at $60 per cord actually costs $72 if the cord contains only 75 cubic feet of solid wood instead of the 90 cubic feet which is an accepted upper limit (Table 12-2).

Fuel Type

Oven-dried wood of any species has the same energy content per pound, about 8,600 Btu. However, the Btu content of a volume of wood such as a cord or cubic foot varies greatly because of differences in wood density or weight per unit volume.

Table 12-3 shows weight per cord of woods generally used by maple producers. The density of balsam fir is only half that of oak. The weight of an oven-dry cord of fir will only be half that of oak, and consequently, it will have only about half the Btu content of a cord of oak.

Using the conversion factors in the third column to characterize the heat equivalence from different classes of wood, a producer can derive his actual cost for equivalent heat value. That is, if beech and fir each cost $70 a cord, the actual cost of fir to the producer is $127, because 1.81 cords of fir are needed to yield as much heat as a cord of beech

Fuel Moisture Content

A third factor directly affecting fuel cost is moisture content. Typically, green sapwood of northern hardwoods contains approximately .5 to .7 pound of water for

Table 12-1.—Solid wood content, in cubic feet, of stacked roundwood cord by dimension and type of wood[a]

Material	Middle diameter & length					
	Diameter (6″)		Diameter (6″-12″)		Diameter (12″)	
	4′ length	8′ length	4′ length	8′ length	4′ length	8′ length
Softwoods						
Straight	87	84	92	90	98	96
Crooked	75	71	84	79	88	86
Tops & branches	67	60	—	—	—	—
Hardwoods						
Straight	79	78	88	85	95	92
Crooked	70	65	78	74	84	81
Tops & branches	58	50	—	—	—	—

[a] Source: U.S. Department of Agriculture, Forest Service, Lake States Forest Exp. Stn., Forest Res. Dig., May, 1935.

Table 12-2.—Affect on cost of obtaining less than 90 cubic feet of solid wood in a cord purchased for $60.00

Actual volume received	Conversion value	Actual cost/cord wood received
Cubic feet/cord	*90 ÷ Actual volume*	*Dollars*
90	1.00	60.00
85	1.06	63.60
80	1.13	67.80
75	1.20	72.00
70	1.29	77.40
65	1.38	82.80
60	1.50	90.00
55	1.64	98.40

each pound of wood, a 30 to 40 percent moisture content measured on a wet basis.

The maple producer should strive for wood with moisture content between 20 and 25 percent. This is accomplished by stacking and covering the wood and allowing it to dry for 1 year. Dried wood offers a clear economic advantage.

Studies of commercial evaporators using solid wood fuels reveal that evaporator efficiency drops significantly with the use of wetter fuels. Table 12-4 reports the results of tests with three commercial operators using wood of increasing moisture content. Increasing moisture in fuels from 22 percent to 40 percent caused evaporator efficiency to drop from an average of 52.8 percent to 27.7 percent.

Evaporator Design

The open-pan evaporator using solid wood fuel requires a long firebox to accommodate 3- to 4-foot lengths of wood. The firebox design promotes a long flame extending under the back pan. The upward sloping arch from the back of the firebox to the bottom of the stack causes turbulence in the hot gases and forces them into the flues of the back pan, improving heat transfer to the maple sap.

Heat transferred to the sap in an open-pan evaporator results in direct evaporation to the atmos-

Table 12-3.—Affect of wood density of different species on cost of equal heat value at $70 per cord[a]

Species class	Weight per cord[b]	Conversion value	Actual cost for equivalent heat value
	lb		*Dollars*
(1) Red & white oak,[c] hard maple, beech, birch	3744	1.00	70
(2) Soft maple, cherry	3180	1.18	83
(3) Cottonwood, aspen	2160	1.73	121
(4) Pines, true firs, spruce	2070	1.81	127

[a] Assume 90 cubic feet solid wood.
[b] Using oak, hard maple, beech, and birch heat yield as a base; all woods air dried to 20 percent moisture content wet basis.
[c] Oven-dry weight.

Table 12-4.—Relative efficiencies of solid wood fuels in open-pan maple syrup evaporators (in percent)

Operator	Fuel type and moisture level[a]				
	Dry split hardwood (22% MC)	Partially dry hardwood (26% MC)	Wet split hardwood (32% MC)	Green split hardwood (40% MC)	Operator average efficiency
1	66.3	45.4	38.2	30.4	45.1
2	49.5	43.6	32.5	28.4	38.5
3	42.7	33.2	32.1	24.4	33.1
Average of all tests	52.8	40.7	34.3	27.7	

[a] All moisture contents expressed on wet basis.

phere. Theoretical efficiency of the evaporator is 100 percent. That is, if the heat energy of 1 pound of steam (1,000 Btu) is supplied directly to the sap, 1 pound of water (1,000 Btu heat equivalent) should be evaporated. To accomplish 100 percent efficiency requires that there be no heat loss in the process, which is an unattainable goal. In general, higher efficiencies on oil-fired commercial maple evaporators range from 70 to 75 percent (Raithby 1978, Garrett et al. 1977). Studies reveal that commercial evaporators using dry hardwood as a fuel operate at efficiencies close to 50 percent with a range of 40 to 60 percent (Huyler and Garrett 1979).

Firing Method

The worst possible method of firing is to open both doors and load the fire completely down when the hot coals are in their final combustion stage. This firing method always decreases efficiency in evaporation, compared to firing through only one door at a time.

Table 12-5 illustrates the effect of correct firing on evaporator efficiency. Of the three operators studied, Operator 1 had the evaporator fire doors open the least amount of time per hour and the evaporator was always more efficient than those of Operators 2 and 3.

How to Increase Evaporator Efficiency

The Best Wood Fuel

As outlined earlier, the best woods to use are the dense hardwoods seasoned to a low moisture content. Using less dense woods such as aspen and softwoods means less Btu per cord (Table 12-2). This also means the evaporator must be fired more often, decreasing its efficiency. Lower evaporator efficiency increases the amount of fuel and labor needed to produce a given volume of syrup.

Using wood with high moisture content reduces efficiency and causes operating problems. More wet wood than dry wood has to be burned to produce the same heat yield. Heat from the combustion process is required to evaporate the water in wood, generally the moisture escapes in stack gases as heated water vapor, and that lowers evaporator efficiency.

The Best Firing Method

The most effective firing method is to open one door of the evaporator at a time, feeding one t three sticks on that side of the fire box. This method should reduce th total door opening time to 35 to 45 seconds per firing. Usually, 20 to 2 openings per hour are required, so doors may be opened from 12 to 2 minutes per hour. This method keeps one half of the fuel load at good burn level at all times. A goo

Table 12-5.—Number of minutes per hour fire door was open and wood moisture content related to evaporator efficiency for three commercial operators

Operator	Wood fuel moisture content (%)				Operator average	Evaporato efficiency
	22	26	32	40		
	Minutes/hour					*Percent*
1	15.9	16.1	13.7	20.9	16.6	45.1
2	16.1	19.1	21.7	22.6	19.9	38.5
3	21.9	29.9	24.9	19.6	24.0	33.1
Average	18.0	21.7	20.1	21.0	20.2	

burn creates a luminous flame path under both pans. This forces hot gases up to the pan surface producing greater heating of the pans and more effective evaporation.

The operator must keep his evaporator in good repair and use proper firing techniques. Using dry, dense hardwood with proper operating procedures can mean a significantly lower fuel cost than with oil or gas.

Chapter 13

Improvements in Sap Processing Techniques

by Lawrence D. Garrett
Neil K. Huyler
Paul E. Sendak

The cost per gallon of syrup processed is inversely related to the thermal efficiency of the evaporator—the higher the thermal efficiency, the lower the processing cost per gallon of syrup. As indicated in Chapter 12, the type of fuel affects efficiency. If wood is burned, its moisture content and density and the operator's firing method all affect efficiency and therefore, cost.

By examining the sources of heat loss in an open-pan evaporator, we identified potential areas for conservation (Garrett et al. 1977, Duchacek et al. 1978). A major heat loss occurs in the steam above the evaporator pans. A heat exchanger or sap preheater was designed to use this heat to raise the temperature of incoming sap.

Heat is lost in stack gas up the flue and through the walls of the arch. The latter loss can be cut by insulating the walls of the arch. The loss up the stack can be decreased by installing baffles in the arch to increase heat transfer between the hot gases and the pan surface.

It is also possible to redesign the open-pan evaporator to increase its thermal efficiency. One new design that has shown promise in early testing is the tubular sap pan design which operates, in principle, like the water tube boiler.

Even with gains in thermal efficiency, the open-pan evaporator remains inefficient, but very energy-efficient techniques to remove water from sap can be substituted. One such technique that we have tried is vapor recompression, which uses mechanical energy and some supplemental heat to recover and reuse the heat in steam evaporated from the sap.

The Sap Preheater

The sap preheater uses waste steam to preheat incoming sap. This energy can raise the temperature of cold sap (40°F) to above 190°F. Raithby (1978) developed a well-designed series flow preheater that incorporated the tube bundle into a steam hood. A condensate pan was added so that water that condensed on the tubes would not drip back into the evaporator. In Raithby's tests, the efficiency of an oil-fired evaporator was increased by 15 percent.

The purpose of our research was to develop a sap preheater that not only achieved the same increase in efficiency as the series flow design, but was easier to make, especially for a sugarmaker; was flexible enough to fit under the many types of steam hoods already in place; and had a lower sap feed head requirement. The design that satisfied these goals was the parallel flow preheater.

Study Methods

Preliminary studies of the open-pan evaporator indicated that most evaporation and heat transfer occurs from the sap inlet to the center of the sap or flue pan. This makes the area above the sap pan the best location for the preheater. Two identical 4- × 10-foot Lighting evaporators, installed to manufacturer's specifications, were com-

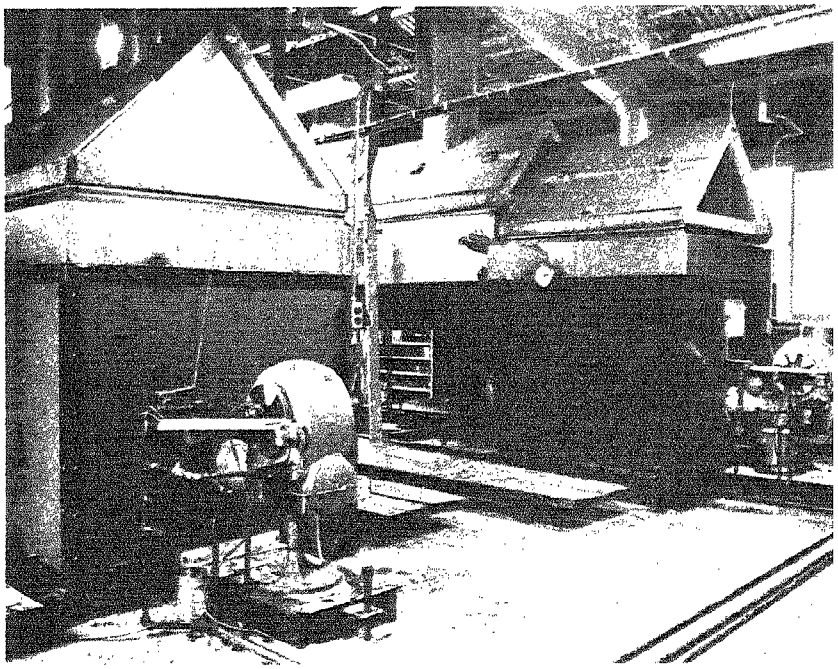


Figure 13-1.—Identical 4- by 10-foot Grimm test evaporators used to test effectiveness of heat exchangers (Garrett et al. 1977).

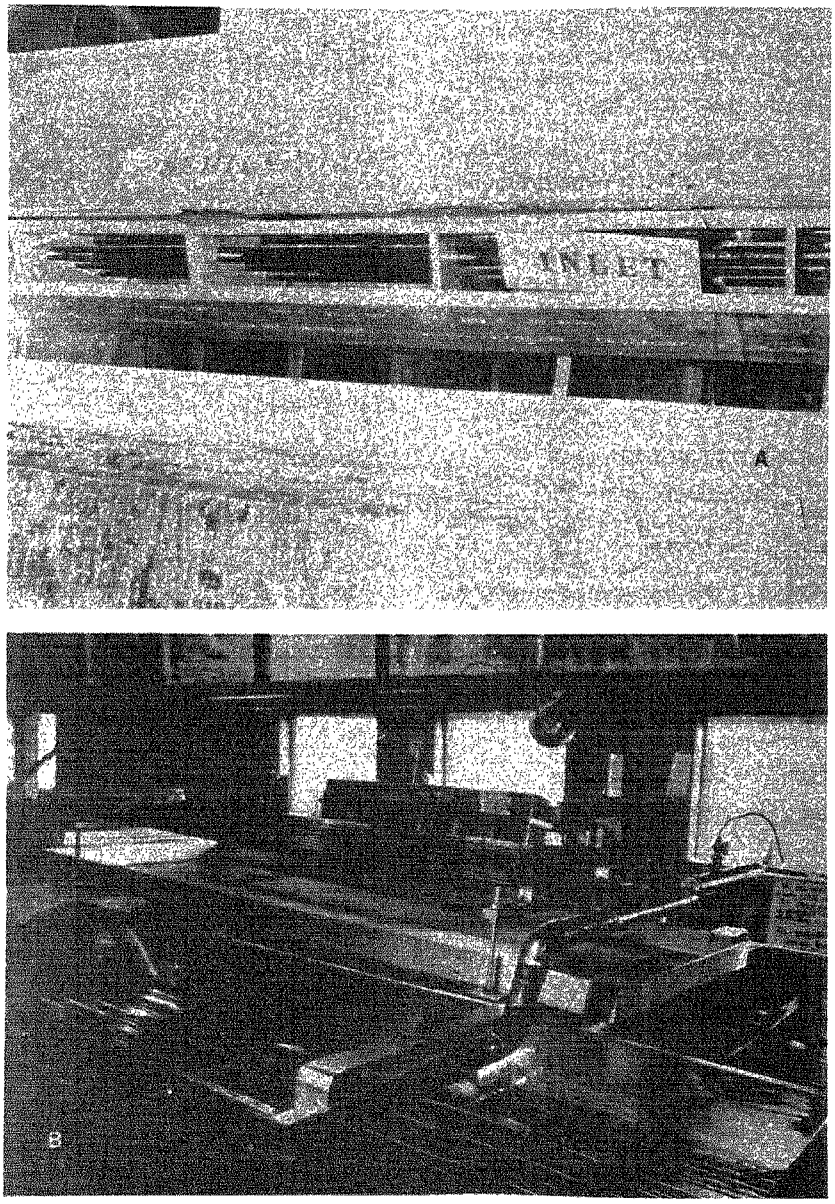


Figure 13-2.—Experimental series (A) and parallel flow (B) heat exchangers (Garrett et al. 1977).

pared in a controlled experiment to determine the increase in efficiency attributable to a sap preheater (Fig. 13-1).

One evaporator without a preheater served as a control. A series flow preheater was tested as well as the parallel flow design (Fig. 13-2). Experiments were conducted to define the optimum size for the preheater and the best operating techniques. A prototype preheater was also built for a 6- × 19-foot commercial evaporator for testing. It was designed to operate with less, as well as more than enough tubing for heat transfer.

Results

Without the preheater, the average evaporator efficiency was 73 percent; with a series flow preheater it averaged 84 percent. The average efficiency increase was more than 15 percent (Table 13-1).

However, to prevent surging in the tube bundle that causes flow-restricting air locks, the head—the vertical distance between the sap tank and the regulator box—may have to be increased to as much as 6 feet (Fig. 13-3). In many sugarhouses this cannot be accomplished easily.

Table 13-1.—Effect of series flow heat exchanger on efficiency of a 4- by 10-foot oil-fired maple syrup evaporator[a] (Garrett et al. 1977)

Test	Percent efficiency	
	Without exchanger	With exchanger
1	72.9	82.0
2	71.0	84.5
3	74.4	79.9
4	72.2	87.8
Average	72.6	83.6

[a] 10 gallons of oil fired per hour.

Chapter 13

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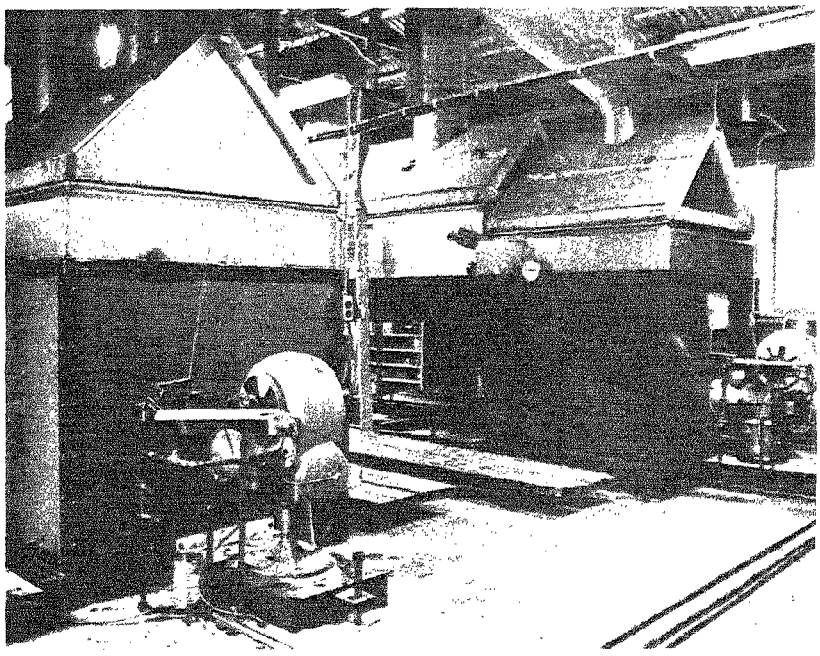


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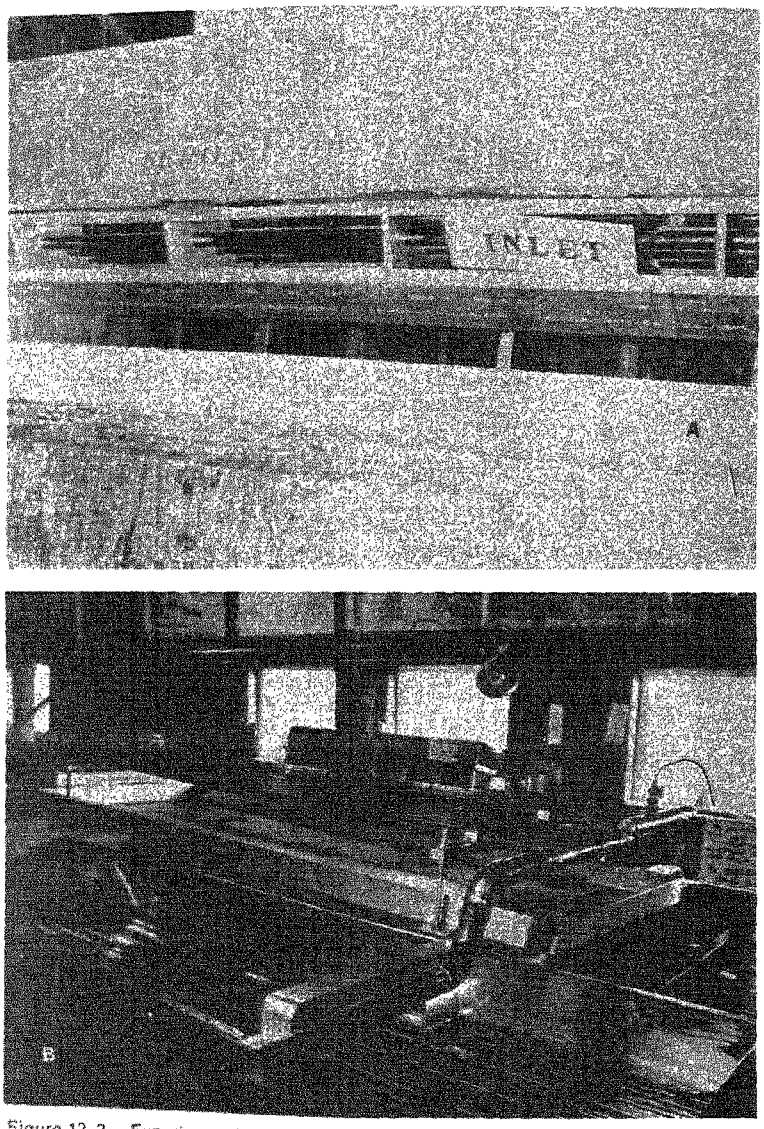


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[a] 10 gallons of oil fired per hour.

Figure 13-3.—Head requirements for series and parallel flow heat exchangers using different tube diameters (Garrett et al. 1977).

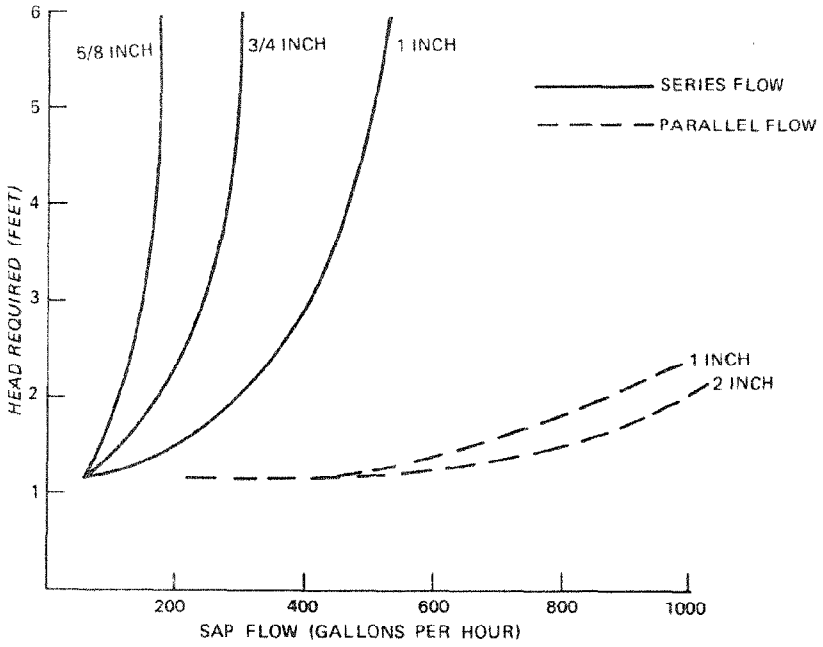


Table 13-2.—Efficiency analysis of parallel flow sap preheater on a commercial maple syrup evaporator (Garrett et al. 1977)

Item	Without preheater	With preheater (tubing length)		
		77 feet	134 feet	190 feet
Sap				
Sugar content (°Brix)	2.58	3.32	3.36	3.09
Temperature				
Cold (°F)	44	33	36	38
Hot (°F)	—	164	194	206
Flow (gal/hr)	286.4	346.3	350.5	355.8
Syrup produced (gal/hr)	8.8	12.8	14.5	11.6
Water evaporated (lb/hr)	2320	2686	2713	2752
Distillate (lb/hr)	—	357.4	439.8	504.8
Oil (lb/hr)	221.2[a]	222.5[b]	222.5[b]	222.5[b]
Average efficiency (%)	61.21	71.39	71.93	72.75
Average increase (%)	—	16.49	17.37	18.72

[a] 19,551 Btu/lb.
[b] 19,519 Btu/lb.

A parallel flow preheater performed as well as the series-flow design in increasing efficiency. For example, in tests on a 6- x 19-foot evaporator, efficiency was increased an average of 18 percent, from 61 percent to 72 percent (Table 13-2).

In addition, the parallel flow preheater offers the following advantages: The manifold design allows the fabricator to increase the preheater surface area by adding more tubes. This can result in cost savings by minimizing design changes for evaporators of different sizes. The manifold design also has much lower head requirements for the sap feed tank. The preheater can be made free-standing or hung from the hood, and its low profile allows it to fit under most existing hoods without modification. Airlock is eliminated by the small vent in the upper manifold.

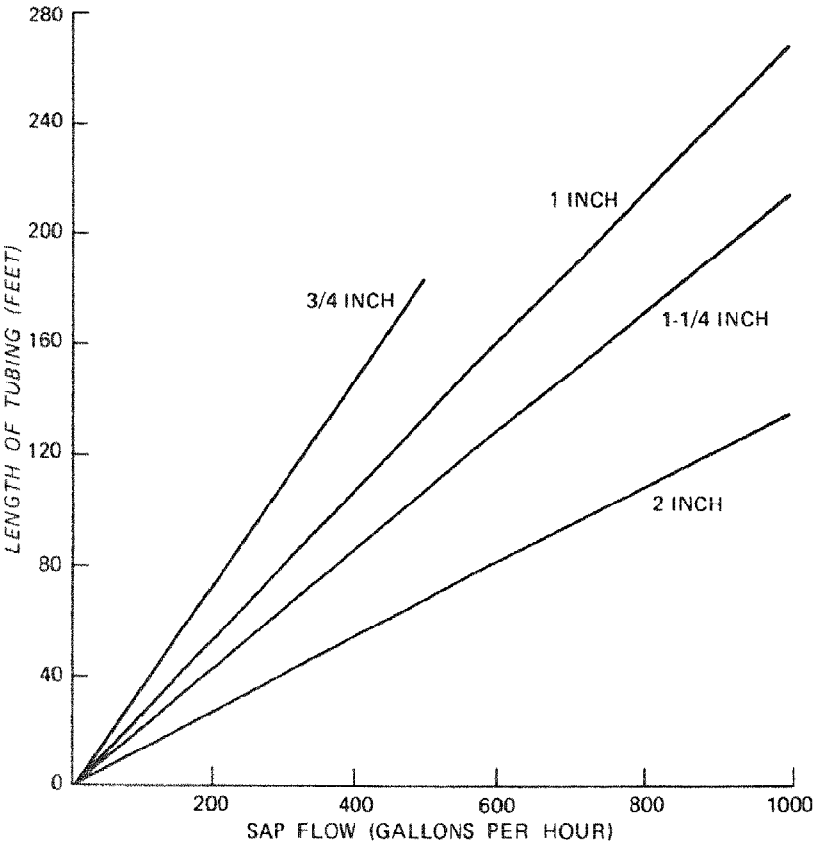
Design Specifications

The surface area of copper tubing required for efficient preheating of sap depends on the flow rate of the sap, velocity of the sap through the tubes, and the inlet and outlet temperatures required. A heat transfer coefficient of 200 Btu per hour, per square foot of surface area, is acceptable for raising the temperature of the sap from 40° to 190°F. The size and length of tubing required to maintain that heat transfer is shown in Figure 13-4 and in Table 13-3 for selected sap flow rates.

Heat exchangers can be made to accommodate a higher flow rate by adding more tubes or by increasing the tube size. To maintain the same heat transfer, shorter lengths of larger tubing are required. For example, 48 feet of 3/4-inch tubing is required for a sap flow of 130 gallons per hour; if 1-inch tubing is used, only 35 feet is required (Fig. 13-4).

A commercial design of a parallel-flow heat exchanger using 1-inch tubes is shown in Figure

Figure 13-4.—Length of tubing required for parallel flow heat exchangers using different tube diameters at different flow rates (Garrett et al. 1977).



13-5. Major components are identified. The unit has 1-1/2-inch manifolds connecting the ten 1-inch tubes. Although boxed manifolds are shown, tubular manifolds can also be used. The diameter of inlet and outlet piping from manifolds is always 1/4 inch smaller than the manifold, or 1-1/4 inches for the unit shown. A 3-inch curved copper tube (1/4-inch inside diameter) at the top of the outlet end of the heat exchanger will prevent airlocks. All tubes should be installed with a 2- to 5-percent slope (with sap entering at the low side).

A damper improves the operation of any heat exchanger. The damper is installed in the steam stack, about 18 inches above the ridge of the steam hood so that a slight positive pressure is maintained in the hood. The pressure prevents cold air from leaking into the hood and around the tube bundles, which can reduce efficiency significantly. The damper can be adjusted properly by closing it until a whiff of steam is emitted from the hood base.

Effect of Preheating on Quality of Syrup

Preheating sap alters only slightly the normal evaporation process. Heat is applied through a contact vessel made of copper rather than English tin or stainless

Table 13-3.—Specifications for parallel flow preheaters on conventional evaporators[a] (Garrett et al. 1977)

Sap flow (gal/hr)	Tube size	Tube length	Manifold size	Lateral spacing of tubes	Head	Number of banks	Number of tubes per bank	Diameter of hood stack[b]	Inlet and outlet tube
	Inches	*Feet*	*Inches*		*Feet*			*Inches*	
50	3/4	20	1-1/4	1-3/4	1.2	1	6	6	1
130	3/4	48	1-1/4	2	1.3	1	8	8	1
370	1	105	1-1/2	2-1/4	1.5	1	12	12	1-1/4
500	1-1/4	106	1-3/4	2-1/4	1.7	1	8	14	1-1/2
1000	1-1/4	212	2	2-1/4	2.0	2	16	16	1-3/4

[a] Tube slope of 2 to 5 percent, and 1/4-inch pressure relief tube for all flow rates.
[b] With damper.

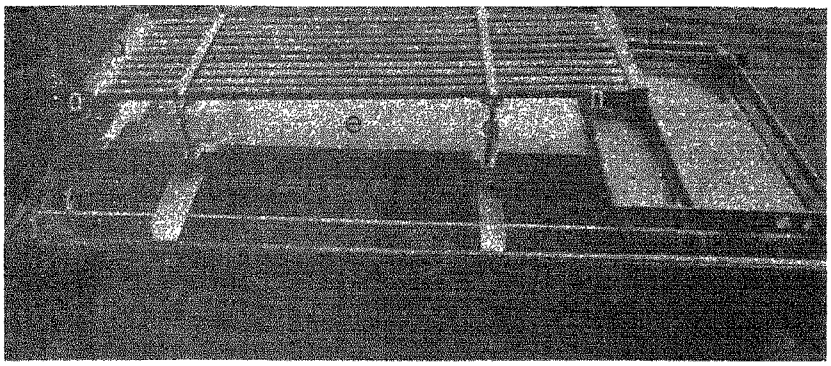


Figure 13-5.—A commercial version of a free standing parallel flow preheater showing: (a) sap inlet; (b) connector manifold; (c) tube bundle; (d) pressure release tube; (e) drip pan; (f) drip pan drain; (g) elevating rods; (h) sap outlet (Garrett et al. 1977).

steel. Analysis of syrup produced with and without a heat exchanger indicates that preheating had no significant effect on the syrup's physical or chemical properties or flavor (Garrett et al. 1977).

Economic Return

There are different ways to analyze a capital investment such as a sap preheater. As indicated in Chapter 10, the average annual cost of collecting and delivering 34.4 gallons of 2.5 percent sap to the sugarhouse from a medium size sugarbush was $5.20 or about $0.15 per gallon in 1980. In Chapter 11, the cost to process a gallon of syrup in a medium size oil-fired operation was $8.24 in 1980. This adds to a total production cost of $13.44 per gallon.

A sap preheater can reduce labor, fuel, and associated costs at the expense of additional investment for the preheater. An analysis of an operation producing 750 gallons of syrup shows that if a preheater increases the hourly evaporation rate by 15 percent, there would be a 6.9 percent decrease in processing costs and a 4.5 percent decrease in total production costs (Table 13-4). In addition, a minor income tax advantage would accrue because of the capital investment.

Greater cost savings can be achieved if the increased production capacity attributable to the preheater can be utilized. Then, the original cost figures can be divided by 862.5 gallons of syrup, which is an increase in production capacity of 15 percent over the 750 gallons. Table 13-4 shows a further reduction in processing costs to $7.35 or 10.8 percent and a 6.6 percent reduction in total production cost.

Table 13-4.—The effect of a sap preheater on annual costs (1980) of maple syrup production

Item	Annual cost without preheater (per gallon of syrup)	Annual cost with preheater (per gallon of syrup)	
		Maintain production	Increase production 15%
	Dollars		
Sap production costs	5.20	5.20	5.20
Processing costs			
Building	.77	.77	.67
Equipment	1.54	1.54	1.34
Preheater	—	.21	.18
Labor	.87	.74	.76
Fuel ($1.01/gal)	4.04	3.43	3.51
Taxes and insurance	.48	.49	.42
Electricity and miscellaneous	.54	.46	.47
Total processing cost	8.24	7.64	7.35
Total production cost	13.44	12.84	12.55

Baffle Designs for Raised Flue Oil-Fired Evaporators

Engineers have demonstrated that properly designed combustion chambers and baffles in steam boilers lead to greater efficiency. Since evaporation of maple sap is similar in many ways, these same principles were applied. Baffling in

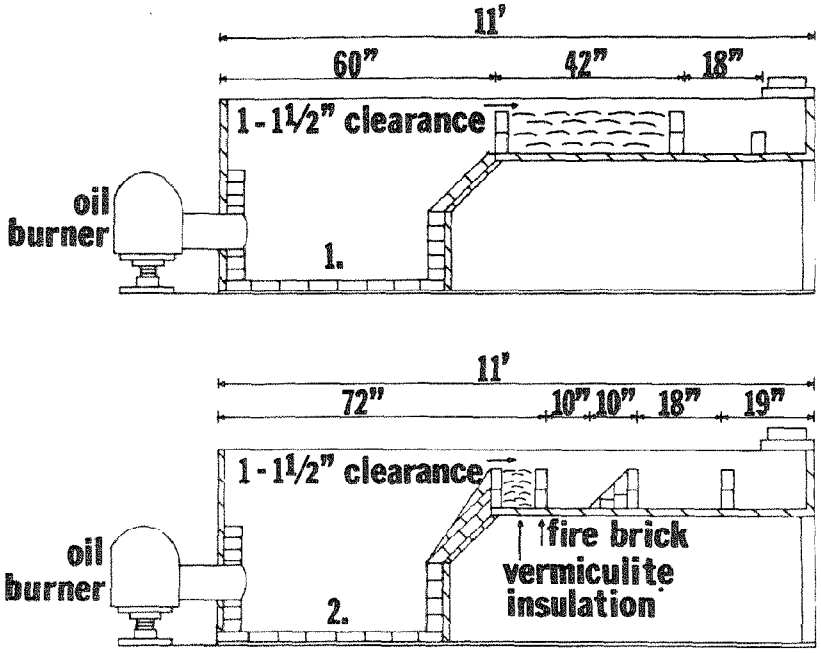


Figure 13-6.—Geometry of baffle designs: (1) design recommended by Grimm Company and (2) design recommended by Professor Desilet.

Table 13-5.—Evaporator efficiency test results for two baffle designs

Item	Control[a]	Baffle Design 1	Baffle Design 2
Fuel oil input (lb/hr)	60.89	61.01	60.95
Water evaporation rate (lb/hr)	687.90	729.81	735.70
Average sap Brix	2.1	2.2	2.2
Stack temperature (°F)	540	530	528
Syrup draw off (gal/hr)	2.1	2.3	2.3
Evaporator efficiency (percent)	66.1	70.1	70.6

[a] No baffling used.

creases the velocity of the hot gases and also creates a better mixing of the gases as they travel under the flue pans, thus increasing heat transfer to the pans.

Experiments on two types of baffle designs have shown that the baffles increased evaporator efficiency. Baffle number one is recommended by Grimm Company for the raised flue oil-fired evaporator. Baffle number two is recommended by Professor Denis Desilet, Agricultural Engineer, Laval University (Fig. 13-6).

Both baffles are easy to install in the evaporator with little additional cost for materials. Baffles are easily constructed from refractory fire brick and vermiculite insulation.

Test Results

The two designs were constructed and tested against a control in which no baffles were used. Table 13-5 shows the results of the test. Both baffle designs increased evaporator efficiency by about the same amount: on the average, 6.4 percent. The evaporator efficiency without baffles was 66.1 percent; with Design 1, 70.1 percent, and with Design 2, 70.6 percent.

The constriction caused by the baffle increases the velocity of the hot gases passing between it and the sap pan. It also forces the hot gases up into the raised flues. The end of the baffle, where the space between the arch and pan widens, causes turbulence in the hot gases. This turbulence improves the mixing of the gases, thus creating a more uniform gas temperature under the pans. Design 2 is actually three baffles and is probably superior to Design 1 in creating turbulence in the hot gases.

Economic Effect

Although an increase in efficiency of 6.5 percent may seem small, it can be obtained for a very low cost in materials. The price of fuel oil was $1.01 per gallon in 1980 and at 70 percent efficiency, it requires 1 gallon of fuel to evaporate 10 gallons of water. From 2.5 percent sap, 33.4 gallons of water must be evaporated to produce a gallon of syrup, requiring about 3.4 gallons of oil. At $1.01 per gallon of oil, the cost would be $3.37.

If the overall efficiency of the evaporator without baffling was 65

percent, it would require 3.6 gallons of oil per gallon of syrup or $3.64, an increase of $.27. At an annual production of 750 gallons of syrup the savings in fuel oil would total $202.50.

Oil Burner Suggestions

Using oil-fired evaporators in many of our field studies, we have a few suggestions that may help maple producers using oil to gain some efficiency without much investment. All of the following suggestions should be carried out before the sap season, using water in the evaporator.

Fire the evaporator at least 1 hour to reach a normal or steady state condition before attempting measurements or adjustments. Check the stack temperature with a stack thermometer in the bottom half of the first section of pipe above the cone. If it is over 600°F, you are probably wasting heat. You are either burning too much oil, or your combustion chamber and baffles are not installed correctly. You should try to achieve a temperature of about 550°F.

A smoke test is also very important in evaporator efficiency. It indicates how cleanly the oil burners are running. Most oil burner repairmen have a smoke test kit. The smoke test should be taken in the 1/4-inch hole drilled to take stack temperature. If there is more than one oil burner on the evaporator, they should be smoke tested and adjusted *one at a time*. The smoke test should read between 1 and 2, which indicates good combustion. Higher than 2 would cause excess scoting on the syrup and flue pans and indicates incomplete combustion of the oil. This can be corrected by increasing the air flow into the burner.

The stack smoke can also be checked by eye, but not as accurately. Observe the smoke coming out of the stack against the sky. If you can see gray or black smoke, the oil burner isn't getting enough air. Open the air vent on the side of the burner a little at a time until the smoke just disappears. After each burner is adjusted individually, turn them all on and check the smoke again—it should be clear.

An oil burner serviceman should make the original adjustments to new burners. But the burners shouldn't be neglected from year to year. The burner nozzles should be cleaned or replaced when needed. With the ever-rising cost of fuel oil, maple syrup producers should take advantage of any means of increasing the efficiency of their evaporators, including burner maintenance.

Tubular Evaporator Pan

A prototype inclined-tube maple sap evaporator pan has been developed by Duchacek (1978).[1] The new design is an improvement on the flue-type sap pan and is based on the proven inclined tube steam boiler.

The heated surface of a conventional evaporator pan offers three resistances in series to heat flow—the resistance of the gas film on the fire side of the surface, the pan wall itself, and the boiling action on the sap side of the wall. The resistance of the gas film is more than 90 percent of the total resistance to heat transfer. But the vigorous boiling action in the flues of the sap pan obstructs the full entry of sap into the flues, thus interfering with heat transfer by limiting contact with the heated surface.

The inclined-tube design is an attempt to overcome these two problems. Combustion gases flow perpendicular to the tubes and the resulting turbulence mixes the hot and cooler gases downstream of each tube. This mixing decreases the thermal and velocity boundary layer (gas film) resistance to heat transfer. Sap flows through the tubes by free convection, assisted by the buoyant effect of the vapor bubbles from the boiling taking place within the tubes.

Study Methods

The 4- × 6-foot raised-flue sap pan was removed from a 4- × 10-foot Lighting evaporator. The arch was modified and a prototype tubular pan was made and installed. The tubular pan had 46 percent of the surface area of the pan it replaced and was made of stainless steel and heliarc welded throughout. The evaporator's performance was monitored so that thermal efficiency could be determined.

A 4- × 10-foot dropped-flue evaporator was operated simultaneously as a control. The syrup pans on the two evaporators were identical, but the tubular sap pan had 46 percent of the area of the dropped-flue pan. The control evaporator was also monitored so that thermal efficiency could be determined. Both evaporators were fired with No. 2 fuel oil in a single oil burner. Tests were conducted by boiling water and sap at various firing rates from 8 to 12 gallons of oil per hour. The testing period included three sap seasons—1975, 1976, and 1977.

Results

Testing identified several problems with the design. The tubular pan tended to foam more readily than the conventional pan and the sap level regulator box did not compensate for this increased foaming and consequent surface level change. In addition, the lack of match between the oil burner and the tubular pan, which had less than half the surface area of the pan it replaced, and between the front pan and tubular pan, adversely affected performance.

These difficulties were largely overcome by reducing the fuel-flow rate, redesigning the firebox, introducing defoamer on a regular and more frequent schedule, and modifying the regulator box to sense the

[1] More detailed design and performance data is contained in Duchacek, Howard, and Fred M. Laing. 1977. Preliminary report on the tubular flue pan versus the fin-type flue plan. Unpublished Final Rep. on file. USDA For. Serv., Northeast. For. Exp. Stn., Broomall, Pa.

sap level in the back pan more effectively. Final tests during the 1977 season indicated an average efficiency for the tubular unit of 57 percent versus 70 percent for the conventional unit. However, the tubular unit had less than half the surface heating area of the standard unit.

To adjust for the differences in surface area, standard heat transfer methods were used to extrapolate the observed tubular evaporator performance to a unit equal in surface area to the conventional or control evaporator. These projections indicate an efficiency of 77 percent for the tubular unit compared to 70 percent for the control, an increase of 10 percent (Duchacek 1978).

Follow Through

The results from three seasons of tests were encouraging. However, we needed to test a full-size unit to substantiate the extrapolated performance. We also recognized that the design of the prototype was more complex than it needed to be, adding significantly to the labor involved in fabrication. A final design change was made, and its effect on performance was tested on the prototype and found to be nil.

A redesigned unit called the W-Type tubular pan was built and tested during the 1980 sap season. The surface area of the new pan was equal to the conventional flue pan used as a control—160 square feet. The results of the tests largely confirmed the prediction: the full-size tubular pan increased overall evaporator efficiency by an average of 8.5 percent.

Economic Evaluation

The W-Type tubular sap pan was custom made for $2000. It replaced a 4- × 6-foot raised flue sap pan that had a value of $1104 in 1980. If a manufacturer went into commercial production of the tubular pan, presumably significant economies in fabrication would be realized.

However, if it is assumed that the new pan design will add about $900 to the cost of a 4- × 10-foot evaporator, can the increased investment be justified? Assuming an increase in pan life of 50 percent attributable to the welded stainless steel construction versus soldered English tin, an annual interest rate of 12 percent, and an increase in thermal efficiency of 8.5 percent, the saving in oil at $1.01 per gallon just equals the increased annual equipment cost. In addition, there would be a small saving in labor and a small income tax advantage because of the increased capital investment. It is assumed that analysis of evaporators of different sizes would yield results in proportion to those of the 4- × 10-foot evaporator.

The economic evaluation seems premature without an accurate cost of commercial manufacture of the tubular pan. However, assuming that the cost would not be higher than that of a custom-built pan, the investment seems justified either as a replacement for a worn-out flue pan or in a new evaporator.

Vapor Compression Evaporators

The practical limits to the thermal efficiency for the open-pan evaporator for maple processing are being approached. Oil-fired evaporators, which are widely used in the maple industry, require 3 to 4 gallons of oil for each gallon of syrup produced. Their average steam efficiency equivalent is 1.5:1; 1.5 pounds of steam energy equivalent is required to evaporate 1 pound of water (Garrett et al. 1977).

In 1980, the cost of processing a gallon of syrup on a large oil-fired open-pan evaporator was $7.71, and more than 50 percent of this was for fuel alone (see Chapter 11). Fuel, labor, and other direct costs account for 68 percent of total cost. Only 32 percent is amortized capital cost; thus there is little flexibility for realizing economies of scale with this technology.

Today there are several commercial maple operations in the United States and Canada producing syrup continuously by methods other than straight conventional open-pan evaporation. These include thermal evaporation under vacuum and its extension to multiple-effect evaporation, vapor compression evaporation, and reverse osmosis. There are other methods of concentrating sap to a higher sugar content. These include flash evaporation, ultrafiltration, and freeze concentration. Some of these methods are or can be used to preconcentrate sap before it is finished to standard density on a conventional evaporator.

Although these systems offer great potential energy savings in concentrating sap, they also require a higher investment for a given production capacity. For that reason, systems such as vapor compression evaporators may be limited to larger processing plants.

The process of vapor compression and mechanical compression evaporators have been used for desalinating salt water since World War II. However, they had not been evaluated for use in processing high viscosity liquids such as maple syrup. We have demonstrated that the process is economically effective and is capable of producing a high-quality syrup.

Garrett (1977) analyzed quality control and engineering data from initial tests of maple syrup processed with a standard salt-water vapor compression evaporator (VCE). On the basis of the evaluations, significant modifications were made to the standard unit so that it would be more suitable for processing a product of high sugar density such as maple syrup.

The redesigned system, as noted above, is large-scale. The unit tested was 10 feet high and occupied a floor space of 98 square feet (14 × 7). It can convert 850 gallons of 2.5°Brix sap to 25 gallons of standard density syrup hourly. The

purchase price in 1977 exceeded $100,000.

VCE Prototype Operating Characteristics

A VCE system concentrates sap to syrup in two steps. The dilute sap solution entering the system is preheated in a heat exchanger that absorbs the heat from newly made distillate coming from the evaporation chamber (Fig. 13-7). The feed is then introduced into a recirculation loop connected to the initial concentration chamber. Here a part of the liquid is vaporized when it comes in contact with the heating bundle, thus increasing the concentration of the solution. The syrup then passes by gravity to a second concentration chamber where it reaches the desired concentration. The finished syrup is discharged from the system by a pump.

The steam generated from the two concentration chambers is combined and passes through a wire-mesh demister to remove any entrained droplets. The steam is then compressed, which raises its temperature, and piped through the heat tubes; the steam is condensed by the cooler concentrate on the outside of the tubes, thus giving up its latent heat of vaporization and most of the energy required to evaporate an equivalent amount of water from the sap solution.

Heat loss requires that a small amount of heat be continuously added to the system. This heat is provided by electric heaters in a boiler that reboils a small portion of the distillate. During normal operation, a pressure switch on the shell cycles one heater on and off to maintain the needed amount of steam.

A VCE system requires only 0.047 pounds of steam equivalent per pound of water off. This compares to 1.5 pounds of steam in a conventional maple syrup evaporator and 1.1 pounds of steam in th most efficient single-effect boilers. The comparative thermal efficiency of a vapor compression system is

$$21 \text{ or } \frac{1}{0.047}$$

as compared to 0.67 or

$$\frac{1}{1.5}$$

for the conventional open-pan evaporator.

Table 13-6.—Operating characteristics of redesigned vapor compression evaporator at various sap concentrations (Garrett 1977)

Sap concentration	Sap input	Syrup output at 66.5°Brix		Total processing cost per gallon of syrup (1977)
		gal/hr	lb/hr	
°Brix	*gal/hr*			
1.5	5167	10.6	117	$5.17
2.0	5216	15.1	166	$3.64
2.5	5259	18.9	209	$2.44
3.0	5303	23.0	253	$2.38

Distillate output: 5050 lb/hr; heat equivalent: 240 Btu/hr; evaporating efficiency: 21.0.

Figure 13-7.—Schematic of redesigned vapor compression evaporator (Garrett 1977).

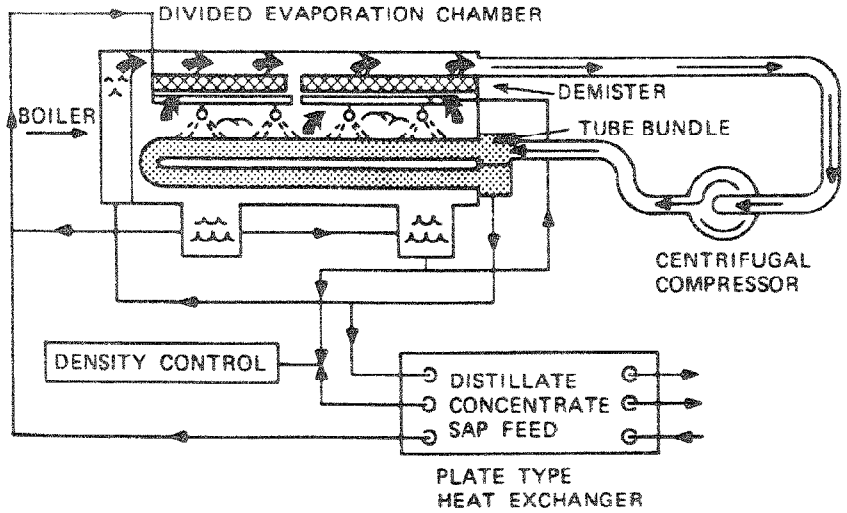


Table 13-6 shows the operati characteristics of the redesigned VCE and the processing costs to produce a gallon of syrup. For example, in 1977 it cost $2.44 to pro ess a gallon of syrup from 2.5 percent sap. On a conventional oil-fir evaporator the comparable 1977 cost was $3.82.

Syrup Quality

U.S. Grade A, Dark Amber syrups produced from a VCE unit were compared to Dark Amber syrups produced on a conventiona evaporator using sap from the sam batch. The syrup from the VCE un was judged good to excellent in flavor and characteristic of the grade and color.

There are chemical differences between syrups produced in a VCE and a conventional evaporator, but these differences do not indicate major differences in the product (Garrett 1977). The VCE also produced a quality distilled water. None of the metal or mineral salts exceeded 0.1 part per million.

Economic Effectiveness

The economics of vapor compression processing technology and its level of application are determined by several production factors unique to the maple industry. Maple sap is high in unit weight (8.3 pounds per gallon), but low in unit value ($0.15 per gallon); the average ratio of sap volume to syrup volume is 34.4 to 1. Consequently, transportation costs are incurred for 97 percent of the sap volume (water) which is removed and discarded. Maple sap production is geographically dispersed so that transportation cost increases as the distance from tree to sugarhouse increases. With increases in sugarhouse processing capacity, the sap procurement zone increases, increasing sap cost.

In addition, the production period is limited to 6 weeks on the average. This is an incentive for a large plant to increase its hourly capacity to provide a large syrup production base over which to spread capital costs.

Although average production may be the goal, the availability of maple sap in a plant's procurement zone can fluctuate as much as 30 percent from one year to another due to weather alone. This is crucial to plants that require heavy capital investment and, therefore, high annual capital amortization if plant capacity is underutilized most years. Maple syrup processing also requires considerable energy for water evaporation and development of color and flavor. And energy is fast becoming the highest cost input in food processing.

Taking into account all of the above constraints, a VCE plant affords greater return on invested capital than the conventional maple syrup processing system. The reason is its significantly lower processing cost per unit of production.

Table 13-7.—Total annual costs (1977) for a vapor compression maple syrup processing plant producing an average of 8,000 gallons per year (Garrett 1977)

Cost item	Cost	Useful life (yrs)	Annual cost (1977)	Percent of total
Capital costs[a]				
Building	$ 6,798	20	$ 744.38	
Sap storage (32,000 gal @ $.60/gal)	19,200	20	2,102.40	
Syrup storage (7,000 gal @ $2.00/gal)	14,000	20	1,533.00	
PCVC 850	106,000	20	11,607.00	
Equipment	9,900		1,084.05	
Total	$155,898		$17,070.83	87
Operating costs				
Electricity (70.4 kW x 403 hr @ $.05/kWh)			$ 1,418.56	
Operating & routine maintenance (114 hr @ $3.00/hr)			342.00	
Cleaning chemicals ($60/wash X 3 washes/season)			180.00	
Annual maintenance supplies			448.00	
Annual preparation and maintenance labor (27 hr @ $3.00/hr)			81.00	
Total			$ 2,469.56	13
Total annual costs			$19,540.39	100
Annual processing cost/gal				$2.44

[a] Capital costs amortized at 10 percent.

Table 13-7 presents estimated annual operating costs for a plant using vapor compression equipment. The estimated cost of $2.44 per gallon of syrup produced is significantly lower than the $3.82 per gallon reported by Garrett et al. (1977) for the conventional evaporator system. All capital investment is amortized at 10 percent for time periods indicated. Operating costs are actual costs associated with operating the plant.

Total Annual Processing Costs

Sixty-eight percent of the processing cost with conventional evaporation technology is operating or direct costs; 32 percent is capital or fixed costs. Consequently, increasing production has little impact upon the cost of each unit produced.

The processing cost structure of a vapor compression plant is the reverse: the physical plant is costly, but energy-efficient. Capital or indirect costs are 87 percent of total processing costs, whereas operating or direct costs are only 13 percent (Table 13-7). Thus, the greater the production, the lower the unit cost of production.

Since the primary costs of a VCE plant are capital, the plant will incur these costs regardless of pro-

Table 13-8.—Economic effectiveness of redesigned vapor compression evaporator at various production levels

Annual syrup output	Total processing cost per gallon of syrup (1977)
Gallons	
3780	$5.17
5360	$3.64
6770	$2.44
8210	$2.38

Distillate output: 5050 lb/hr; heat input: 240 Btu/hr; evaporating efficiency: 21.0.

duction level. Therefore, the lower the production level, the higher the unit costs. Potential investors should be aware of the cost effect of decreases in production due to weather or plant failure. A VCE plant designed for annual production of 7,000 to 9,000 gallons can cut production by 35 percent and still produce syrup at a processing cost approaching that of a conventional plant (Table 13-8).

Return on Investment

Huyler and Garrett's study of 14 conventional maple syrup operations in Vermont revealed an internal rate of return of 10 to 14 percent on invested capital (Huyler and Garrett 1979). Producers studied did not approach the plant size studied here, but studies by Kearl (1970), Acker et al. (1970), and Pasto and Taylor (1962) indicate that the cost structure of the conventional sugarhouse permits little unit cost reduction with increased production capacity.

An analysis of the internal rate of return for the VCE indicates that a plant owner who decides to sell syrup at retail could have invested $150,000 in 1977 and earned 12 to 18 percent interest over the next 20 years on the investment (Garrett 1977). If he could borrow capital at 8 to 10 percent, he could expect to return 4 to 8 percent to management. Returns to the plant owner who wishes to wholesale his syrup would be less than if he retailed the syrup at a higher price. The wholesaler would receive returns on invested capital ranging from 10 to 16 percent, and the venture should afford a return of 2 to 6 percent to management. These figures should be treated as guides for potential investors. But each potential investment opportunity is unique and should be analyzed in that light.

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Section V Chapter 14

Maple Syrup Products Marketing

Market Structure of the Maple Industry and Syrup Grading Standards

by Paul E. Sendak and W. Lyman Jenkins

The world supply of pure maple syrup is produced in a relatively small area, including parts of Quebec, Ontario, and the Maritime Provinces in Canada and the New England, Mid-Atlantic, and northern Midwestern states in the United States. There are about 12 thousand maple producers in Canada, averaging slightly less than 1,000 taps each. Annual Canadian production for the past decade (1970-79) averaged 2.237 million U.S. gallons (24.607 million pounds). About 90 percent of the total Canadian maple production is made in the Province of Quebec (Table 14-1).

The marketing of maple products in Canada is centered around a few large cooperatives and marketing syndicates which purchase almost 70 percent of the syrup produced. The largest of these is located in Plessisville, Quebec; it purchases either part or all of the production of about 5 thousand syrup producers. The syrup is sold in 30-gallon drums and color graded by machine (spectrophotometer) when it is received by the cooperative. The cooperatives and syndicates are oriented toward a few large buyers of dark maple syrup in the U.S. and Canada, but they also market large quantities of table grade syrup in bulk lots and in retail containers. Figure 14-1 is a schematic diagram of the marketing of syrup in Canada. The arrows show direction of movement and their width shows the relative amounts of syrup. These amounts shift slightly from year to year, depending on the proportions of the different grades.

Almost two-thirds of all the syrup produced in the U.S. is made in Vermont and New York (Table 14-2). Annual U.S. production in the past decade (1970-79) averaged 1.084 million gallons (11.921 million pounds). There are a little more than 4.9 thousand maple producers in the U.S., with an average of slightly less than 1,000 taps each.

About 60 percent of the syrup produced in the U.S. is sold in retail containers by the producers. The other third of the syrup production is sold in bulk drums to processors or packers who package it for retail sales as pure maple syrup or further process it for use in blended maple products or as flavoring in other products. Marketing cooperatives handle only a small portion of the maple syrup produced in the U.S. Figure 14-1 is a schematic diagram of the marketing of syrup in the U.S.

Table 14-1.—Production of maple syrup in Canada by province (in thousands of U.S. gallons)

Province	Average 1970-79	1979
Quebec	2036	2594
Ontario	181	217
New Brunswick	12	14
Nova Scotia	8	16
Canada Total	2237	2841

Source: Statistics Canada, Agricultural Division, Crops Section, Catalogue 22-204.

It does not show the distribution of the syrup imported from Canada.

Syrup and maple sugar imported from Canada into the U.S. averaged 1 million gallons syrup equivalent annually from 1970 to 1979. This average is 45 percent of the syrup produced in Canada for that same time period and is 92 percent of the amount of syrup produced in the U.S. Accurate records are not available, but most of this syrup goes to blend or table syrup makers and other food manufacturers. Some is also sold in retail containers.

In their comprehensive study of the maple industry, Taylor and his co-workers (1967) traced the long-term decline in maple production through 1964. They concluded that the decline of the U.S. maple industry was due mainly to supply problems. Demand then, as now, appeared strong and maple prices paralleled the general price level. However, the total number of farms in commercial maple-producing counties declined at a rapid rate during the decade 1950-59. The maple business, supplementary to the major farm activity, ended when the major farm activity ended.

They note that maple production did not decline as rapidly as did number of producers. This is due mainly to the loss of smaller and less efficient operations, and the increase in size of the remaining operations.

Taylor et al. (1967) end their analysis on an optimistic note. They saw the beginnings of activities that had the potential of stopping or perhaps reversing the decline in production. Some of these are new technology, promotional efforts of state and national producer groups, and government programs.

Unfortunately, many of the industry statistics formerly collected by the Federal government and used by Taylor et al. (1967) have been discontinued. One exception is the annual production figures for the commercial maple states, of which there are now only 9 compared to the 11 reported in 1964. Statistics for Minnesota and Maryland are no longer reported.

Production averaged 1.145 million gallons annually in the 5 years, 1975-79; in the period 1970-74, it averaged 1.023 million gallons; and from 1965-69, 1.147 million gallons. The long-term decline in production appears to have reached its lowest point in the 5-year period 1970 to 1974 and begun a return to the level of a decade ago. The state production figures show a similar trend with only two states—Maine and Pennsylvania—steadily decreasing in 5-year average annual production from 1965-69 to 1975-79. New Hampshire had the largest relative increase in production, up 53 percent from 1965-69 to 1975-79. Vermont had the largest increase in gallons produced, up 58 thousand gallons on the average from 1965-69 to 1975-79.

Statistics on numbers of producers are no longer available. However, based on the average production of 1975-79, the average size maple operation of 936 taps reported by Taylor et al. (1967), and the average four taps that it takes to produce a gallon of syrup, there were 4,891 producers in the U.S. Taylor et al. (1967) indicate that there was a decrease in number of producers from 1949 to 1959 of 62 percent, from 27,843 to 10,514. The decrease from 1959 to 1969 is estimated at 53 percent, from 10,514 to 5,572. But from 1969 to 1979 the

Table 14-2.—Production of maple syrup in the U.S. by states (in thousands of U.S. gallons)

State	Average 1975-79	1979
Vermont	400	465
New York	322	315
Wisconsin	92	92
Michigan	84	85
Ohio	81	90
New Hampshire	72	76
Pennsylvania	57	57
Massachusetts	29	30
Maine	8	9
U.S. Total	1145	1219

Source: Crop Reporting Board, Statistical Reporting Service, U.S. Department of Agriculture, Washington, D.C. 20250.

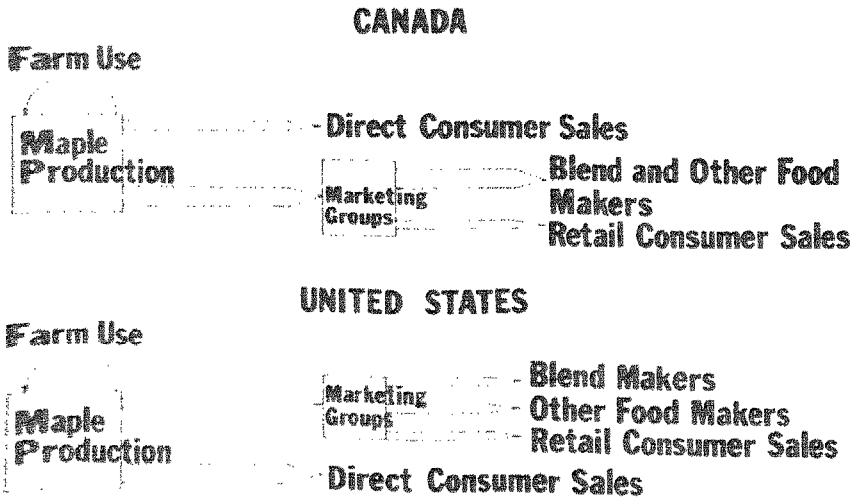


Figure 14-1.—Schematic of the distribution of syrup from producer to final consumer in Canada and the U.S.

number of producers appears to have stabilized.

The U.S. maple producers are organized into state producer groups, usually active at the county level. These state groups are affiliated with the North American Maple Syrup Council. The Council promotes research on problems of production and marketing in the maple industry. It publishes the *Maple Syrup Digest*, which presents research applications and other items of interest to the industry.

In 1975, the International Maple Syrup Institute was formed with members from the United States and Canada representing all aspects of the maple industry. The organization's goal is to promote pure maple syrup in general throughout North America through voluntary taxation of members. The Canadian Federal and Quebec Provincial Governments provided money to help initiate the Institute's programs; the U.S. Department of Agriculture provided cooperative research programing.

Direct involvement by the U.S. Government in the maple industry is minimal. However, the U.S. Department of Agriculture has funded continuing programs in maple industry research through the Forest Service and the Agricultural Research Service and has published standards of identity for pure maple syrup. In addition, maple extension programs are supported in the maple states. The tariff on imported maple products was abolished in 1972, but probably had been ineffective since World War II (Sendak 1972).

In Canada, and more specifically the Province of Quebec, government has played a more direct role in the maple industry. Research commitment hasn't been on a continuing basis as in the U.S. but on a project basis. In addition to setting product standards, the Quebec and Federal Canadian Governments have contributed to product promotion, and the Quebec Government has made incentive payments to producers, first to encourage the use of aluminum buckets, and more recently, to encourage the use of the plastic pipeline sap collection system.

The elements for stabilizing or increasing maple production as outlined by Taylor et al. (1967) are still present. Industry organizations have become international, encompassing the whole maple-producing region. Government programs have continued in research and extension. New technology, especially in plastic tubing for sap production, has been widely adopted. Demand for syrup remains strong. These activities have influenced production over the past 5 years but more time is needed to insure that the long-term decline in production has been reversed.

Methods of Grading Maple Syrup

History of Maple Grades

Color standards for syrup were first developed by Bryan (1910). He developed a standard technique and produced 20 caramel-glycerine solutions, which reproduced the range in color of pure maple syrup.

In 1930, Balch was unable to reproduce Bryan's original solutions consistently and proposed spectrophotometer readings for the 20 caramel-glycerine samples. The percent transmittance of each of Bryan's 20 samples was recorded. Then, duplicate sets were made by matching the percent transmittance values (Balch 1930).

In 1940, the U.S. Department of Agriculture, Division of Grades, adopted visual standards for the grading of maple syrup. These standards were to be the caramel-glycerine solutions designated by Bryan as numbers 6, 8, and 10. These solutions were made up using the corresponding spectrophotometric values derived by Balch: 75, 60.5, and 44 percent transmittance (USDA 1940).

The problem with caramel-glycerine solutions is that they fade with time and exposure to light. To solve this problem, Brice and co-workers (1950) at the USDA Agricultural Research Service developed glass color standards, which are visually the same as the three caramel-glycerine standards prepared by the official method. The glass standards were prepared from a single melt of amber glass sheets which were cut into small chips. Each chip was ground and tested in a spectrophotometer to be identical to the master standard (Brice and Turner 1956).

In 1961, Vallieres, an official in the Quebec Ministry of Agriculture, determined spectrophotometric values for the three reference caramel-glycerine solutions used by the U.S. However, he used a different size and shape spectrophotometer cell for his measurements (Vallieres 1961). Vallieres obtained the values 62.0, 47.0, and 27.6 percent transmittance for the three solutions. For simplicity, these were rounded off to 65, 45, and 25 in his final recommendations, which were then incorporated into the Quebec regulations. Thus, the spectrophotometer was classified as the official and legal method of grading maple syrup in Quebec using Vallieres' method and values obtained with caramel-glycerine solutions.

Current U.S. and Canadian Grading Systems

Today, there are several separate grading systems for pure maple syrup (Table 14-3). The lightest color table grade syrup is termed either "*fancy*," "*light amber*," or "*extra light*." The middle grade may be called "*A*," "*light*," "*medium amber*," or in Wisconsin, "*fancy*." The darkest table grade is either designated "*B*," "*medium*," or "*dark amber*." Non-table grade syrup, which is generally used for blending with cane or corn syrup or as a flavoring agent, is designated either "*C for processing*," "*dark*,"

Table 14-3.—Current grades of maple syrup

State or country	Standard				
Canada (Federal and Quebec)	*Number 1 Extra Light* Transmittance not less than 75%	*Number 1 Light* Transmittance between 60.5 and 75.0%	*Number 1 Medium* Transmittance between 44.0 and 60.5%	*Number 2 Amber* Transmittance between 27.0 and 44.0%	*Number 3 Dark* Transmittance less than 27.0%
United States (USDA)	*Grade A Light Amber* Not darker than light amber color standard (NDLA)	*Grade A Medium Amber* Not darker than medium amber color standard (NDMA)	*Grade A Dark Amber* Not darker than dark amber color standard (NDDA)	*Grade B for Reprocessing* Darker than dark amber color standard (DDA)	Substandard
New Hampshire New York Maine Massachusetts Pennsylvania	Have adopted U.S. Standard grade names and colors, with minor definitional changes in some states.				
Michigan	No state grades				
Ohio	No state grades				
Vermont[a]	*Fancy* NDLA	*Grade A Medium Amber* NDMA	*Grade A Dark Amber* NDDA	*Grade C* DDA	—
Wisconsin (optional)[b]	--	*Fancy* NDMA	*A* NDDA	*Manufacturing Grade* DDA	—

[a] Vermont allows the use of the USDA grade names on Fancy and Grade A syrups sold in other states.
[b] The USDA Standard may be used instead of the Wisconsin specification or no grade need be specified.

"*amber*," "*manufacturing grade*," or "*B for reprocessing*." A fifth classification appearing in several grading systems is "*substandard*." This apparent confusion in grade names will be reduced as more of the states adopt the U.S. standard.

State and U.S. federal grading systems utilize a visual standard and, therefore, light transmittance is not mentioned in the grading regulation. In Canada, although field grading is done visually, the legal standard is light transmittance.

Change in Grading Systems

There have been recent changes in the U.S. and Canadian federal standards for grading maple syrup. One major feature of the new federal grading systems in Canada and the U.S. is the new names given to the grades of maple syrup. (USDA 1979). These names are compared in Table 14-3. Aside from the obvious differences in the names of the grades, the Canadian law has two grades corresponding to U.S. Grade B and does not have an equivalent to substandard (Canada Agricultural Products Standards Act 1977).

Also, in the new grading law in Canada, the spectrophotometric values which will be used for grading syrup have been changed back to those originally determined by Bryan for caramel-glycerine solutions. The method of grading in the U.S. remains the glass color comparator. Research has demonstrated that these two methods do not yield consistent results. The reason for this is that the coloring agents in maple syrup are somewhat different from pure caramel. A syrup and a caramel-glycerine solution that are visually the same color will yield different percent transmittances when measured at a single wavelength in a spectrophotometer. Syrups are consistently graded higher using the color comparator than they are in the spectrophotometer using values derived from caramel-glycerine solutions.

There are three general classes of maple flavors which can be termed as the "fancy" maple bouquet, "base" maple flavor, and "caramel" flavor. The "fancy" flavor is very volatile and aromatic. It is defined as delicate and yet smokey, and is frequently called "maple bouquet." The flavor is characteristic of early season syrups that have a light amber color.

The "base" flavor has been defined as that maple flavor characteristic of medium amber table syrups. In general, it has a certain blend of caramel flavor and stronger aromatic flavors of the fancy syrups. This flavor is more common in the medium amber syrups, but probably exists in the largest cross-section of syrups produced for the table market.

The "caramel" flavor is normally attributed to the browning reaction of invert sugars and is generally more common in the "dark amber" syrups. A more bitter, acrid caramel flavor is characteristic of the darker grade "B for reprocessing" syrups.

It should be understood that the flavor of a particular grade of pure maple syrup, like its color, differs. No two syrups have precisely the same flavor. Flavor changes just as color changes continuously from light to dark syrups. Although grading regulations use color and flavor designations to set limits on a particular grade, it can't be assumed that all syrups within these limits taste the same.

Product Identification

The most concise definition of maple syrup is found in the U.S. Food and Drug Administration Standard of Identity for Maple Syrup (USFDA 1974) which states:

> Maple syrup is the liquid food derived by concentration and heat treatment of the sap of the maple tree (Acer) or by solution in water of maple sugar (maple concrete) made from such sap. It contains not less than 66 percent by weight of soluble solids derived solely from such sap.

Most grading regulations that contain a definition of syrup have wording similar to this.

The requirement of 66 percent solids (66°Brix) at 68°F (20°C) is universal in the U.S. and Canada, except for two states: New Hampshire has a minimum density of 35°Baumé, which is equivalent to 65.8°Brix, while Vermont requires a minimum density of 36°Baumé, which is 66.5°Brix.

Maple Flavor

The true product being marketed in pure maple syrup is maple flavor. It is the only attribute of pure maple products that distinguishes them from other products. The grading system should then define the standards for maple flavors and any quality or preference differences in these flavors.

Alteration

The different maple laws and regulations have various degrees of specificity regarding prohibited alterations of the product. The Vermont law or regulation, for example, discusses maple syrup "which has not been bleached or lightened in color by artificial means." The new Canadian law requires that the product "meets the requirements for a true maple product when analyzed according to the methods of the Association of Official Analytical Chemists."

Chapter 15

Consumer Attitudes About Pure Maple Syrup

by Paul E. Sendak

Most maple marketing research has focused on the seller, who most often is also a maple producer. The most recent publication on marketing methods is the Special Report of the Maple Marketing Task Force (1972). Taylor and Pasto (1968) have written the most comprehensive report on marketing practices throughout the industry. Gunter and Koelling (1975) and England and Tompkins (1956) have reported on marketing practices in Michigan and Vermont, respectively. Willits and Hills (1976) provide practical information on syrup grading, handling, storage and packaging, and on making other maple products.

Until recently, little attention has been paid to the final consumer of maple syrup. Perhaps this has resulted from the large proportion of direct sales from producer to final consumer (Taylor and Pasto 1968). But a growing desire to expand markets for maple syrup means that producer and consumer will be separated by the normal marketing structure: producer—marketing intermediaries—final consumer. Information about consumers in these markets becomes more critical to the success of the marketing effort.

Are pure maple syrup users a select group of gourmets and bon vivants? Research with maple syrup users indicates that they are not. They are generally representative of the larger population they are a part of, containing about the same proportions in age, income, and household size as would be found in a random sample of the entire population (Sendak 1974, 1978).

In 1971, an estimated 7.5 percent of the households in the continental United States used maple syrup at least once during the year. This limited use coupled with the higher price for maple relative to the commercial table syrups has led to the description of pure maple syrup as a luxury item.

This is an unfortunate label. Pure maple syrup is a fancy food, but its degree of fanciness depends largely on where it is purchased relative to the point of its production. In the rural areas where it is made, maple syrup approaches the definition of a staple food much more closely than it does in New York City.

This basic difference in marketing between local (rural) markets and distant markets is useful for analyzing consumer survey data. Differences in marketing practices within and outside the maple-producing region affect pricing and availability. These in turn influence purchase and use habits.

For example, the roadside stand, sugarhouse, or farmer's house are the most important retail sources of pure maple syrup in the maple-producing region. The retail grocery store or supermarket is the most important retail source of pure maple syrup outside the maple region. The most frequently purchased size of container in the maple-producing region is the gallon, followed by the quart. Outside the maple region, it is the pint, followed by the quart. Most respondents in the maple-producing region purchase pure maple syrup in the spring—during the producing season; outside the area most respondents purchase pure maple syrup in the winter—the season of greatest use. Within seasons, there are more repeat or multiple purchases of maple syrup outside the region than there are inside the region, probably reflecting the smaller average container size.

Consumer Knowledge

Does the average consumer know the difference between pure maple syrup and maple-flavored commercial table syrups? In the region of maple syrup production he is more likely to recognize a difference, but this ability diminishes quickly as we move away from this region. Outside of the maple-producing region 56 percent of the people interviewed in a survey thought that one of the brands of commercial table syrup was pure maple syrup. Product identification could be a serious marketing problem outside the maple-producing region.

With consumers uncertain of product identification, it is not surprising to learn that they know almost nothing about syrup grades. Syrup grading standards are based on the association of color and flavor, but grade names imply a quality difference where, for all practical purposes, there is none.

In a national survey, maple users were asked a series of questions based on the grading standards. Three questions required associating grade level with syrup density, flavor intensity, and color. The percentages of correct responses for the three questions were 18, 12, and 48 percent, respectively. When the same questions were administered to a group of maple producers and their spouses at a national gathering of the industry, the percentages of correct responses were 81, 86, and 98 percent, respectively.

Confusion over grade standards erodes consumer confidence in a product. If the consumer is unable to judge quality or ensure some consistency in product from one purchase to another or among sellers, a marketing problem is evident.

Purchasing and Use Patterns

The differences in purchasing patterns between regions imply very different marketing approaches. Selling at the production site usually means selling during the production season, in large containers most likely metal or plastic. Selling in retail grocery stores usually means selling small glass bottles through a broker, with peak sales in fall and winter.

Regardless of the time of purchase, maple syrup is used most in the colder months of the year. It is used most often as a topping on other foods, traditionally cold-weather breakfast foods. Almost all respondents (94 percent) used maple syrup on pancakes, followed by waffles (59 percent), and French toast (52 percent).

Retail Packaging

Retail packaging has been a chronic problem in the maple industry partly because there are many thousands of producers packaging relatively small quantities of maple by almost as many methods as there are producers. Standardization might be a partial solution, but any attempt at standardization should recognize the different markets and consumer preferences within those markets—for example, plain small glass bottles in the grocery store, mid-size durable containers for mail order, and fancy decorative containers for gift shops and tourist sales.

In the maple-producing region consumers purchase large containers because they are more economical. Large containers are made of metal or plastic. Consumers have expressed a preference for plastic over metal. In smaller sizes, they have expressed a preference for glass over metal.

Outside the maple-producing region consumers purchase smaller containers because they are usually the only sizes available. The containers most often sold outside the maple region are of glass. Consumers liked glass but some indicated a preference for plastic containers (Sendak 1974). A study of consumers in six large urban centers in North America found a preference for a 12-ounce glass bottle (Quebec Dep. Agric. 1976). The consumers felt a smaller bottle was priced too high for the amount of syrup in it. They felt a tin or plastic container created the impression of a luxury product which would be fine for a gift but not for everyday use.

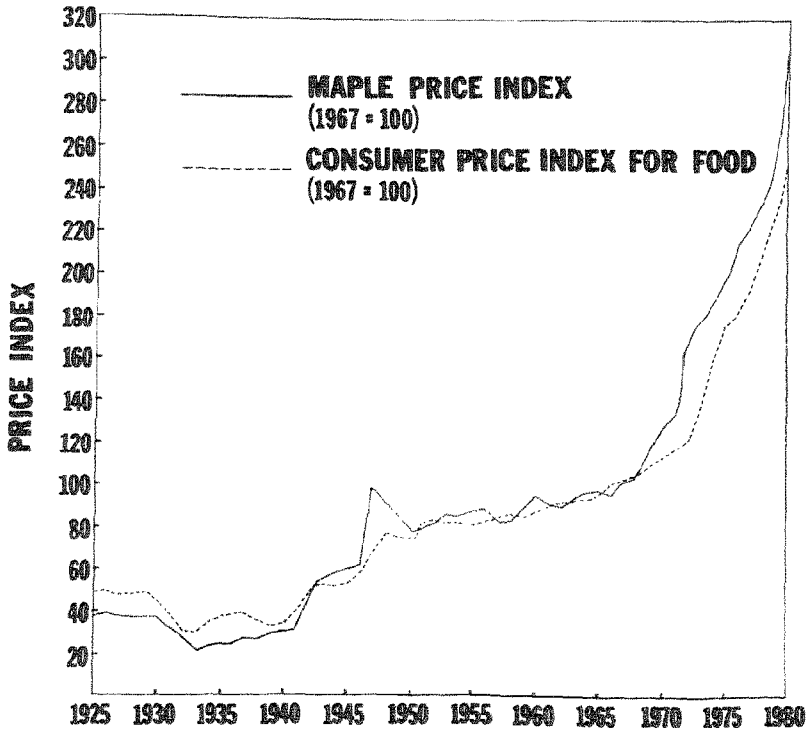
Labeling should not be ignored. The traditional lithographed syrup can use images of the colorful production process to motivate sales. A consumer study found a preference for trees and buckets on the package label (Quebec Dep. Agric. 1976). This same study also found a preference for the words "100% pure maple syrup."

Product Pricing

Historically, the price of maple syrup has followed the price of food in general. Figure 15-1 shows the relationship between the All Food Consumer Price Index and a price index created for maple syrup. The trend of the two indexes has been about the same with two major exceptions. During sugar rationing in World War II the demand for maple as a sweetener was artificially stimulated with predictable results. As soon as rationing ceased, the price of maple reverted to its former trend.

More recently, the early 1970's, the maple price index climbed more rapidly and has stabilized at a higher level than the price index for all food. Perhaps this indicates a more permanent shift in the pricing of maple. The index is based on prices received at the farm. Indica-

Figure 15-1.—The price index for maple prices received at the farm compared to the Consumer Price Index for food from 1925 to 1980.



tions from the Vermont Department of Agriculture (Willard 1978) are that producers are selling a larger percentage of their production at retail, thereby increasing the average price received at the farm without increasing the average price of maple to the consumer.

There has been little quantitative study of the elasticity of supply or the price elasticity of demand. Elasticity explains how the quantity of syrup supplied or demanded will change when there is a change in syrup price. The industry's supply curve appears to be in the inelastic range (Sendak 1972). That is, a change in price of a given magnitude brings about a much smaller change in quantity supplied; supply is not very responsive to price changes in the short run. Less is known about long-run supply. The maple resource is plentiful and widespread, but perhaps factors other than price are more critical to long-run supply. We may speculate that such things as landownership patterns, landowner attitudes, the influence of government policy toward maple syrup production and income derived from it, and the tax on resource ownership may have more effect on long-run supply.

There has only been one study that gives some indication of the price elasticity of demand or how quantity of syrup demanded will change with a change in syrup price (Sawyer et al. 1979). The authors found evidence that the demand was elastic in the range of then-current retail prices. When demand is price elastic, a decrease in price will be more than offset by an increase in quantity demanded, yielding a greater total revenue to the industry. This is encouraging because it serves as an incentive for cost-cutting techniques in production and marketing to lower syrup prices.

Consumer Preference for Grades

As noted earlier, consumers are poorly informed about the meaning of maple grades. In one preference study the three grades of table syrup and Log Cabin were evaluated in a blind products test (Sendak 1978). Each respondent compared two products. There were 1018 respondents about equally divided among four cities—two in the maple-producing region and two outside it.

There were differences in taste preferences for pure maple syrup and Log Cabin syrup between respondents living in the syrup-producing region and those far from the region. It seems likely that the greater opportunity to use pure maple syrup in the syrup-producing region is a major factor in this result.

Preference rates for pure maple syrup versus Log Cabin syrup were about the same for maple syrup users and nonusers in the syrup region. Preference for different grades of maple syrup are at variance with the grading standards: The standards place a premium on lightness of color and delicacy of flavor, but the survey participants either did not recognize the difference among grades or preferred a darker color and more robust flavor.

The largest difference in syrup preference was in the cities outside the syrup-producing region, where Log Cabin syrup was preferred by an average of 66 percent. Habit is a likely explanation of this: Log Cabin syrup is the most widely used table syrup in the four cities, and especially in the two cities outside the maple area.

The inability to distinguish the flavors of different grades of pure maple syrup may be caused by the number of flavors the average consumer encounters in the table syrups generally used. In this survey and in an earlier investigation of pure maple syrup users, several different brands and types of table syrup were in the participants' homes at the time of the study. The participants in this survey who lived outside the region judged the difference between grades of pure maple syrup to be much less than the difference between pure maple syrup and Log Cabin syrup.

In another study (Quebec Dep. Agric. 1976), consumer preference was determined for four pure maple products—Canada Number 1, Light syrup; Canada Number 3, Dark syrup; a mixture of Canadian table syrup grades and commercial syrup grades; and a pure maple syrup with an intensified maple flavor (Willits and Hills 1976).

Although the results did not overwhelmingly favor any one product, there was a preference for the Canada Number 1, Light syrup. But the fact that there was not much difference in the preference rates among these products may be a more important result.

Another study, though limited in scope and conducted more than 20 years ago, offers some insight into the difference between local and distant maple markets. England and Tompkins (1956) obtained preference rankings for the three table grades of syrup from 220 respondents in Vermont. Ninety percent of the respondents were maple syrup users and the group consumed an average of 2 gallons of maple syrup and 1 pound of maple candy a year per household. This compares with national average incidence of maple use of 7.5 percent and consumption of 2 3/4 pints per user household (Sendak 1974). Eighty-one percent of the respondents preferred a light-colored syrup (U.S. Grade A, light amber), 4 percent a medium color (U.S. Grade A, medium amber), 7 percent a dark color, (U.S. Grade A, dark amber), and 3 percent a commercial brand of table syrup. Five percent had no preference.

Sawyer et al. (1979) tested the effect of syrup grade on purchase rate in a marketing experiment. The experiment was conducted in the Boston area with 300 participants. Grade showed no effect at all on the purchase rate.

The implications for marketing are clear. To increase the use of pure maple syrup, a promotion campaign will be required to acquaint

consumers with maple syrup characteristics, particularly flavor. The disparity between grade and price and consumer preference should be resolved. For example, the sale of a product is not helped by a New Hampshire Grade B designation. The implication to the consumer, who knows nothing about the product, is that it must be inferior to New Hampshire Grade A.

To change from grades to a more descriptive evaluation such as light, medium, and dark amber seems appropriate. The use of the descriptive terms within one level of product quality is a preferred approach. The survey results indicate that two descriptive classes, such as light and dark, might be even more appropriate.

Product Promotion

The Boston study examined the effect of product information on purchase rate. Product information merely consisted of a poster comparing the ingredient list on the labels of three brands of commercial table syrups with pure maple syrup. Purchase rate of pure maple syrup without the information was 28.0 percent of total syrup purchases of respondents. With the information poster present, the purchase rate for pure maple syrup increased to 41.3 percent.

Several studies suggest that product promotion should start with consumer education. Consumers, especially outside the maple-producing region, are not familiar with pure maple syrup characteristics, especially taste or flavor, nor do they understand the syrup-grading standard.

The one study that dealt with factual information at the point-of-purchase yielded encouraging results. This type of advertising, including advertising of a more promotional nature, seems to increase sales. Individual sellers might use it to best advantage; image-type promotion might best be left to an organization representing the maple industry in general.

Chapter 16

Retail Containers for Pure Maple Syrup

by Paul E. Sendak

Retail containers for pure maple syrup may be made of tinned steel, glass, or one of several plastics. They normally range in size from 8-ounce (1/2 pint) to 128-ounce (gallon). In addition, they come in a variety of shapes, with different types of closures and labeling. There have been problems with retail maple containers as far back in the history of the industry as one cares to look. Most problems may be traced to short supply of containers, poor workmanship, substitution of unsuitable containers, or poor packing methods.

There are basically two problems in packing syrup in the retail container. The first is to use proper packing procedures to ensure a sterile pack; the second is to minimize changes that take place in the syrup in the retail container over time.

Pure maple syrup should always be packed hot (180°F or above). If syrup is reheated for packing, it should not be heated over 200°F, because heat may cause excessive darkening. Filled containers should be placed on their sides to pasteurize the closure and head space. The containers should be left to cool with sufficient distance between them to avoid stack burn or darkening at prolonged high temperatures (Willits and Hills 1976).

Hayward (1946) studied the effects of storage temperature, air oxidation, mold growth, and daylight on maple syrup stored in sealed glass test tubes. He plotted syrup color as a function of time for each study treatment, and concluded that syrup darkens with increasing storage temperature and air oxidation for a given storage time, but that mold growth and daylight had a negligible effect on color.

Underwood and his coworkers (1974) studied the effects of containers on the three table grades of maple syrup stored in four types of containers under three storage temperatures for 6 months. The syrups darkened excessively in the two types of plastic containers used in the experiment.

In a similar study, storage time was added as a factor and density, pH, flavor, and iron and tin content were added as measures of syrup stability (Sendak et al. 1978). Syrup stored in three of the four types of plastic containers studied darkened over time, and with increasing storage temperature. Syrup stored in tinned-steel cans became lighter over time, and with increasing temperature, because of the increase of tin in the syrup. Although the pH of the syrup decreased with increasing temperature, the pH of syrup in plastic containers decreased more than syrup stored in glass and tinned-steel containers. Flavor differences were slight. Figure 16-1 shows the interior of one of the controlled environments used in the experiment.

In another experiment, Morselli and Sendak (1980) evaluated two batches each of the three table grades of syrup under three controlled temperatures, in light and in darkness, at three storage intervals in six types of containers (glass, plastic, and tin). The syrup was analyzed for light transmittance (color), density, pH, invert sugars, phenols, and amino nitrogens and evaluated for flavor. In addition, syrup stored in tinned-steel containers was analyzed for iron and tin.

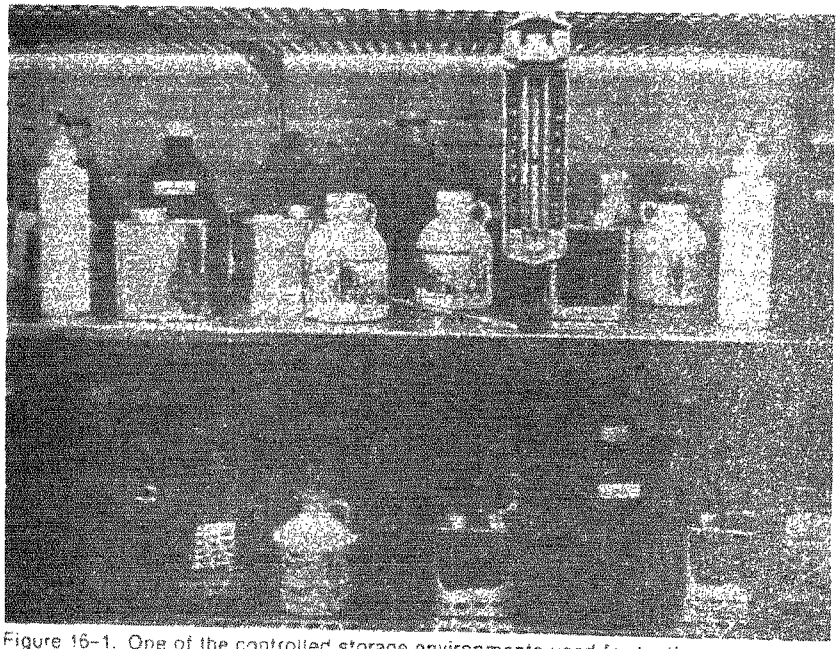


Figure 16-1. One of the controlled storage environments used for testing containers (Sendak et al. 1978).

The containers significantly affected syrup color, density, pH, metal content, and flavor, but had no effect on invert sugars, phenols, and amino nitrogens content. The results confirmed the earlier study (Sendak et al. 1978), although U.S. Grade AA syrup (U.S. Grade A, light amber), the only grade used in that study, darkened earlier in all plastic containers at all temperatures. U.S. Grade A, dark amber, syrup darkened to Grade B after 6 months, while U.S. Grade A, light amber, darkened but didn't change grade in the plastic containers. All syrups lightened in color after 9 months of storage at room and warm temperature in tin cans. Some slight changes occurred also in syrup stored in glass containers. Greater changes occurred at room and warm temperature than in the cold temperature.

Syrups of all three grades kept frozen in glass containers for flavor evaluation darkened slightly over time, but their flavor was best preserved. The only syrup consistently ranked lowest by the flavor panel was stored in tin coated with fruit enamel.

Maple syrup is a natural and, therefore, variable product. Two similar syrups may behave differently in identical storage environments and containers. Temperature is the most important factor in the storage environment: Temperatures below 25°C are not detrimental to stored syrup; however, the colder temperatures down to freezer temperatures seem most favorable to syrup storage. Temperatures much above 25°C may cause major changes in the stored syrup.

Time is important to the extent that changes observed at higher temperatures over short storage times will be observed at lower temperatures over longer storage times. Syrup should not be packed in the retail container until it is ready for sale.

Syrup stored in plastic containers will darken with time. Therefore, syrup on the borderline of a grade should be marked with the next lower color grade. The pH of syrup will decrease faster in plastic containers than in other types of containers. Although it is not as much of a problem, syrup stored in tinned-steel will lighten over time, and with increasing temperature. Syrup in glass or coated tin will also darken in time, but not nearly as much as in plastic.

As new containers are made available for syrup, maple producers should test them before packing any large quantities of syrup in them. Note the grade and flavor at time of packing and place a control in the freezer in a small glass jar. Pack the syrup sample in the new container and store it in a warm place for 3 to 6 months. Then check the syrup against the control; any serious problems with the new container will be evident. More than one person should taste the syrup. This simple test could save a lot of time and trouble if the new container is unsuitable for maple syrup.

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Sugar maple research: Sap production, processing, and marketing of maple syrup. Gen. Tech. Rep. NE-72. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1982. 109 p.

This report summarizes sugar maple research at the Northeastern Forest Experiment Station's George D. Aiken Sugar Maple Laboratory in Burlington, Vermont, covering: (1) sap extraction and collection (the sap flow mechanism, tapping, and plastic tubing pipeline systems) and management of the sugarbush; (2) genetic improvement of the sugar maple tree for sap-sugar production; (3) propagation and planting, including the rooting of sugar maple cuttings; (4) economics of maple sap and syrup production (which examines sap collecting systems, evaporator designs, and alternative methods of processing sap into syrup); and (5) the marketing structure of the maple syrup industry.

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