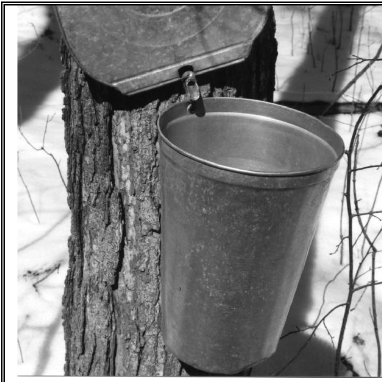


MANAGING NATURE'S CANDY FACTORY

Historical Background:

It is said that one of the old Ojibwa legends reads something like this :

> ***"Nokomis was the grandmother of Nanibojou, the Great Magician. One autumn day, she was being chased by a band of evil Wendigo Spirits. She found a hiding place in a clump of maples in their fall colours of yellow, orange and red. The Wendigos mistook the leaves for fire and left her to die in the flames. This mistake saved her life. Nanibojou was so grateful that he gave the maple trees a sweet, sugary sap."***

The actual period when the Aboriginal Peoples began to make maple sugar is lost in the annals of time. When European explorer Jacques Cartier came to Canada in 1540, he documented his introduction to maple syrup. The native people collected maple sap in bark buckets and boiled away the water by placing fire-heated stones into hollowed basswood logs filled with maple sap. They usually produced crude, dark maple sugar, a form that allowed easy transport from place to place. They used it in ceremonies and as a sweetener or candy (a scarce commodity in the forest), which they often used as a trading item. Maple sugar was the main source of sweetener for new settlers until the import of cane sugar from the Caribbean in the mid-1800's. Today, maple syrup is appreciated more for its unique, tantalizing flavour than for its sweetening power.

Economic Value:

Today, the maple syrup industry is well-developed and expanding. Over the five-year period 1992-96, 3.7 million gallons of syrup and nearly one-half million pounds of maple sugar were produced annually in Canada. Quebec produced 89% of the maple syrup and 67% of the maple sugar, followed by Ontario (7% and 20%), New Brunswick (3% and 9%), and Nova Scotia (1% and 4%) respectively.

Maple products contribute significantly to Ontario's economy. There are approximately 2200 sugarbushes in operation, maintaining over one million taps. 20% of the sugarbushes and 29% of the taps are located in three areas of Ontario (Lanark and Huron Counties and Waterloo Regional Municipality).

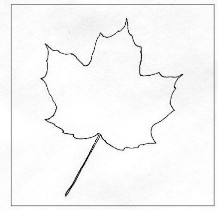
Over the 5-year period 1992-96, Ontario produced 1.3 million gallons of syrup, worth 53 million dollars. In that same period, nearly one-half million pounds of sugar worth three million dollars were sold. Most sales of each were at the farm-gate.

The maple syrup industry is limited to an area known as the Eastern Deciduous Forest, not only because of the prevalence of maple species, but because of the favourable conditions for sap flow, which are :

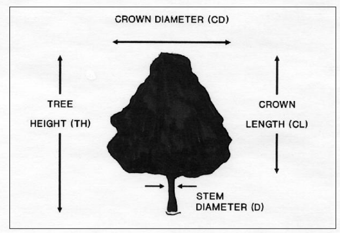
- cold winters, inducing a deep tree-dormancy;
- extended spring season in which temperatures consistently vary from 5^0C in daytime to below 0^0C at night.

Further explanation is available in the CIF pamphlet "Maple Sap Flow: the inside story".

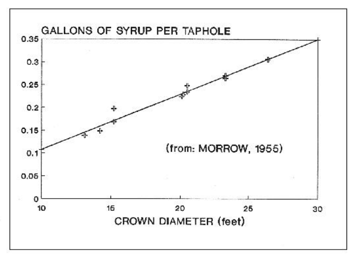
Characteristics of High-Production Trees :



1. Species : all maples produce a sugary sap, but sugar maple (*Acer saccharum*) usually has a higher sugar content and is more widely distributed than the other maple species. Most commercial maple syrup is derived from the sugar maple.



2. Crown Length : choose crowns where ratio crown length to tree height (i.e., CL/TH) is > 50%. Crown size is a measure of photosynthetic capacity of the tree and affects the amount of sugar produced by the tree.



3. Crown Width : choose crowns where ratio of crown diameter to tree diameter (i.e., CD/D) is > 20:1. Syrup yield per taphole increases with crown width. Such trees are usually widely-spaced with little side shade.

4. Crown Position : choose crowns that are in the main canopy receiving direct sunlight (dominant or codominant), not crowns that are shaded (intermediate or suppressed). This Table shows that sap-sugar content decreases as crown light availability decreases for sugar, red, and silver maple.

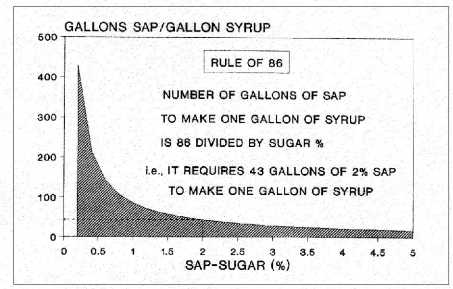
EFFECT OF CROWN POSITION ON SAP-SUGAR CONTENT (Larsson and Jaciw, 1967)

CROWN POSITION	SUGAR MAPLE		RED MAPLE		SILVER MAPLE	
	NO. TREES	SUGAR %	NO. TREES	SUGAR %	NO. TREES	SUGAR %
DOMINANT	23	2.6	23	2.7	13	2.2
CODOMINANT	28	2.5	15	2.4	39	2.2
INTERMEDIATE	15	2.3	9	2.3	10	2.0
SUPPRESSED	10	1.9	8	2.0	16	2.1

5. Leaf Density : choose trees whose leafy crowns are not transparent (i.e., crown has a normal volume of normal-sized leaves.

6. Leaf Colour : choose trees with no symptoms of decline or dieback (i.e., leaves should be normal size and colour (lots of chlorophyll).

7. Sugar Density : maple sap is usually about 2.0% sucrose, but some "sweet" trees are consistently higher than others due to genetic control. Sugar density is important in syrup processing because it determines the number of gallons of sap required to make one gallon of syrup. The "Rule of 86" is used to estimate sap volume requirements for syrup.



For maple syrup operations to be viable as an economic enterprise, a minimum of 1000 taps are usually required, with 70 to 90 taps installed per acre . However, the number of taps that can be carried per acre is a function of tree size. Excessive tapping (see Photo) can cause potential loss of tree vigour and sap production.

ALLOWABLE NUMBER OF TAPS PER TREE

STEM DIAMETER (inches) AT 4.5-FOOT HEIGHT	NO. TAPHOLES PER TREE
< 10	0
10 - 14	1
15 - 19	2
20 - 24	3
25 +	4

AN OVERTAPPED TREE

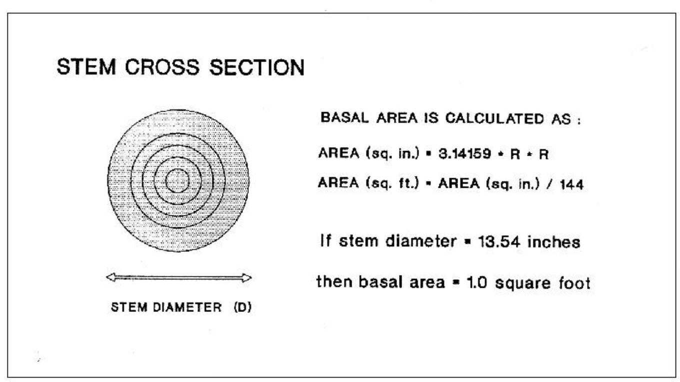
Sugarbush Management:

For maximum production, the crowns of tapped trees must receive adequate light in order to promote photosynthesis. High tree-vigour will promote rapid closure of tapholes, and grow wide sapwood rings necessary to ensure high sugar storage and resultant sap flow. Therefore, growing space may have to be adjusted periodically to allow crown expansion, sustain rapid growth, and increase tree diameter.

This adjustment involves thinning the stand according to a prescribed density model, based on information about the current condition of the stand.

Stand data can be obtained from an inventory sample, using several small plots in which trees are recorded individually by diameter class (D) and species.

For use in the model, tree diameters are converted into "Basal Area" (BA) units, which express tree size as circular cross-sectional areas (see Diagram).

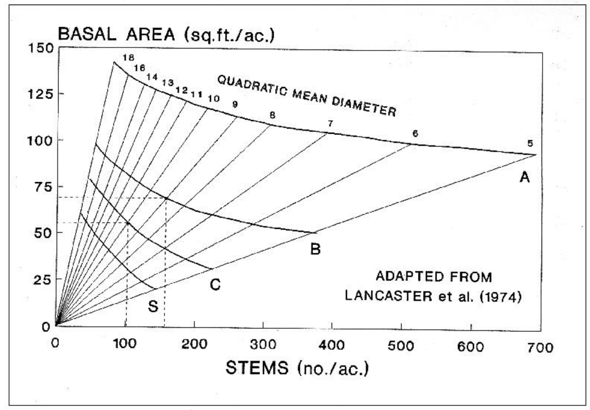


Alternatively, stand basal area can be estimated directly from systematic sampling points using a wedge prism calibrated to count basal area values directly from sightings on individual trees around a sampling point.

In order to use this thinning model ("Stocking Chart"), the diameter of the tree of average basal area (known as Quadratic Mean Diameter or "Dq") must be determined.

For example:
if the stand basal area is 100 sq.ft./ac.,
and the number of trees is 200 stems/ac., then
the Mean Basal Area /Tree (MBA) is 100/200
= 0.5 sq.ft./tree.

Therefore,
if Tree BA (sq.ft.) = ((D*D/4)*3.14159/144), then
Dq(in.) = √ ((MBA*4*144)/3.14159) = 9.575.



To use the model shown in the diagram, the stand values for stems per acre (X-value) and basal area per acre (Y-value) are located on the graph to determine stand Dq. To determine the required values (after thinning), a post-thinning Dq is chosen and the basal area and stems (per acre) are read from the graph at the intersection of the "C-Line", which is the optimum density for sugar production in a well-established even-aged forest stand. The post-thinning Dq will normally be a little larger because the trees selected for retention will usually be in the larger sizes to promote higher production.

If the stand had been managed from a young age, when tree diameter was small (say 6 inches), then the density would be adjusted to the "S-Line", which is optimum for stands managed intensively for a long time.

If the stand has trees of various sizes (i.e., an uneven-aged stand), a table derived from the model can be used to estimate proper spacing.

STOCKING LEVELS FOR IMPROVING SAP PRODUCTION (from Lancaster et al., 1974)

AVERAGE STAND DBH-CLASS (inches)	S - LEVEL *		C - LEVEL **	
	NO. TREES PER ACRE	TREE SPACING (feet)	NO. TREES PER ACRE	TREE SPACING (feet)
6	126	19	160	16
8	98	21	140	17
10	79	23	105	20
12	64	26	86	23
14	54	28	76	24
16	46	31	70	25
* : S-LEVEL = MANAGEMENT STARTED AT SAPLING OR POLE STAGE				
**: C-LEVEL = POLE AND LARGER STAND NOT PREVIOUSLY THINNED				

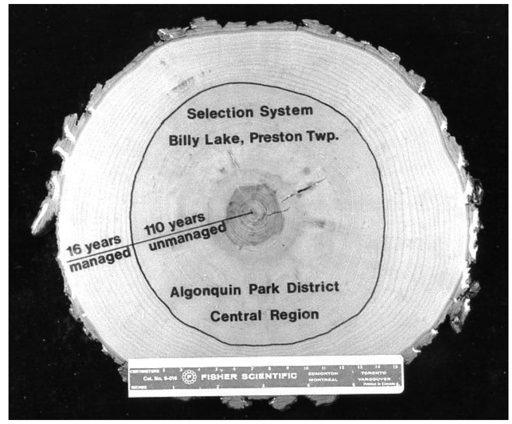
Some precautions should be exercised when thinning the maple sugarbush:

- Sugar maple is a shade-tolerant, late-successional species sensitive to sudden exposure;
- Periods of environmental stress may induce negative effects such as crown dieback;
- Occurrences of prolonged or repeated insect defoliation, combined with years of hot, dry weather, are especially stressful;
- Thinning, and even tapping, may have to be postponed in stressful years to preserve tree health.

This Table shows that the sap-sugar content of trees with crowns in dominant and codominant positions increased with thinning intensity because of the increased light availability. Trees with intermediate crowns were not very large due to their inferior position in the stand leaf canopy and did not respond to thinning because their crowns were still partly shaded. Thinning increases the rate of diameter growth so that trees will progress faster into sizes that permit a greater number of taps.

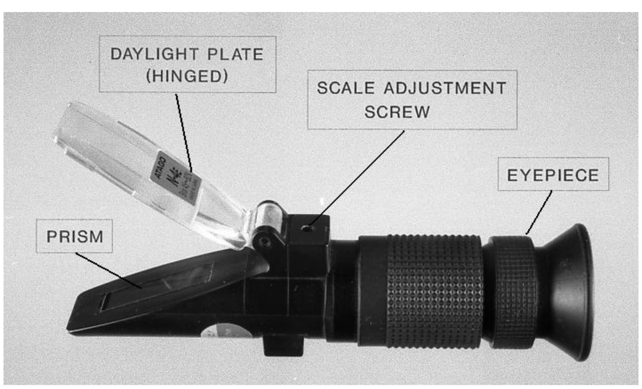
EFFECT OF THINNING INTENSITY ON SAP-SUGAR CONTENT AFTER EIGHT GROWING SEASONS (Jaciw and Larsson, 1967)

CROWN POSITION	THINNING INTENSITY		
	HEAVY	MODERATE	NONE
	SAP-SUGAR (%)		
DOMINANT	2.9	2.7	2.6
CODOMINANT	2.9	2.7	2.5
INTERMEDIATE	2.3	2.4	2.3

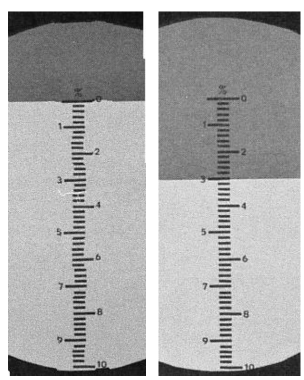


Sugar maple sap-sugar values as high as 8% have been found in Ontario. The sugar content of tree sap can be easily determined using a sugar refractometer (see Photo). A sugar solution (such as sap) will bend (refract) light rays in proportion to its sugar content. A refractometer is calibrated to measure this directly and can be used to select syrup-crop trees to be retained when thinning the sugarbush. Even small trees can be sampled by "micro-tapping", using hypodermic syringe needles to harvest a few drops of sap, sufficient for testing. Using this technique, the sweetest trees can be reserved from cutting for later tapping. Average sap sweetness may vary from year to year, but the "sweet" trees will usually maintain a superior sap-sugar content.

SUGAR REFRACTOMETER



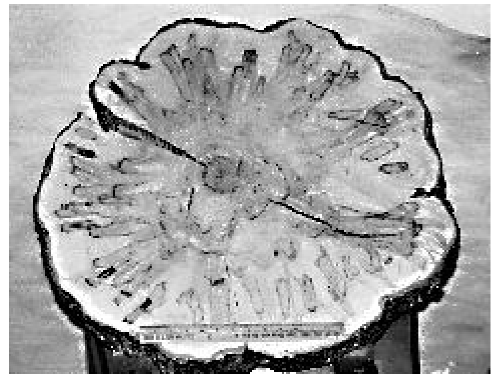
SUGAR SCALE



WATER **SAP**

MICRO-TAPPING

In intensive sugarbush management, such sweet trees may be "cloned" (vegetatively reproduced using rooted cuttings) and planted at wide spacing in a "sugar orchard". Such plantations would require 20-to-40 years to become productive, depending on soil quality and degree of management effort (tending, fertilization, etc.).



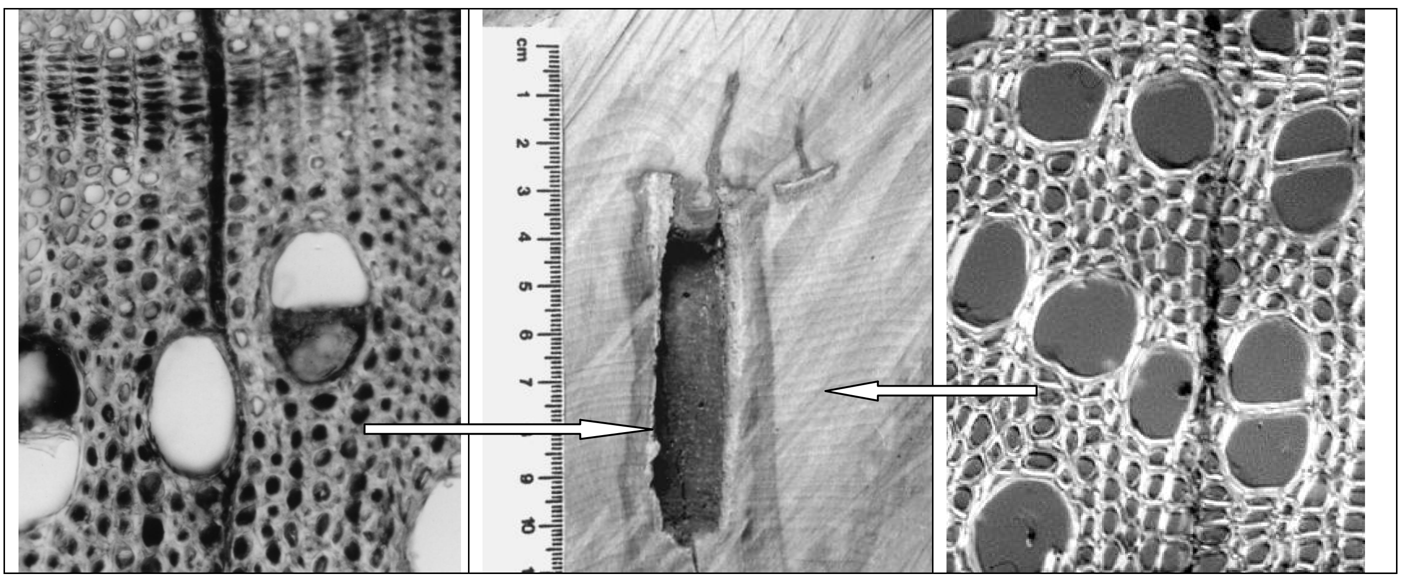
While standard accepted sugarbush management practices generally have little impact on tree health, the injury caused by tapping seriously affects wood quality. Drilling holes into the wood in order to extract sap upsets the internal gas-liquid balance, causing biochemical stress in the associated cells.

This stress provokes a genetically-controlled defense mechanism of sugar maple in which the sugar stored in cells is metabolized into phenolic compounds. Interestingly, these phenols are chemically related to the red colours of autumn maple foliage. These simple phenols link together (polymerize) into dark greenish-brown chemicals which appear as stained wood.

Such compounds are impervious to water, and thus tend to seal the wound, re-establishing a normal cellular state in the surrounding tissue. The wood is also highly mineralized and has a higher pH (less acidity) than normal tissue (not suited to fungi). Such wood is difficult to kiln-dry and its value is substantially reduced.

The wood tissue in the immediate vicinity of the taphole may become infected with micro-organisms such as bacteria, which will plug sap-conducting cells (vessels) and stop sapflow. Decay fungi may also infect the taphole, causing the wood to rot. However, the phenols produced as a defense mechanism are toxic to fungi and will limit the extent of rot development to a narrow band around the taphole, extending about a foot above and below the wound. For this reason, the stain is often referred to as "Protection Wood"

PROTECTION WOOD **TAPHOLE** **NORMAL WOOD**



Rapid closure of the taphole, related to fast diameter growth associated with the selection of vigorous crop trees and the appropriate thinning schedules, will also tend to limit the growth of these decay fungi. Proper tending procedures based on sound scientific evidence will help to ensure future generations of sweet maple.

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