

## Sap Collection from Small-Diameter Trees

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For several years, we conducted research on the collection of sap from small-diameter maple trees. This document outlines the basic concepts, techniques, and applications of this type of sap collection.<sup>†</sup>

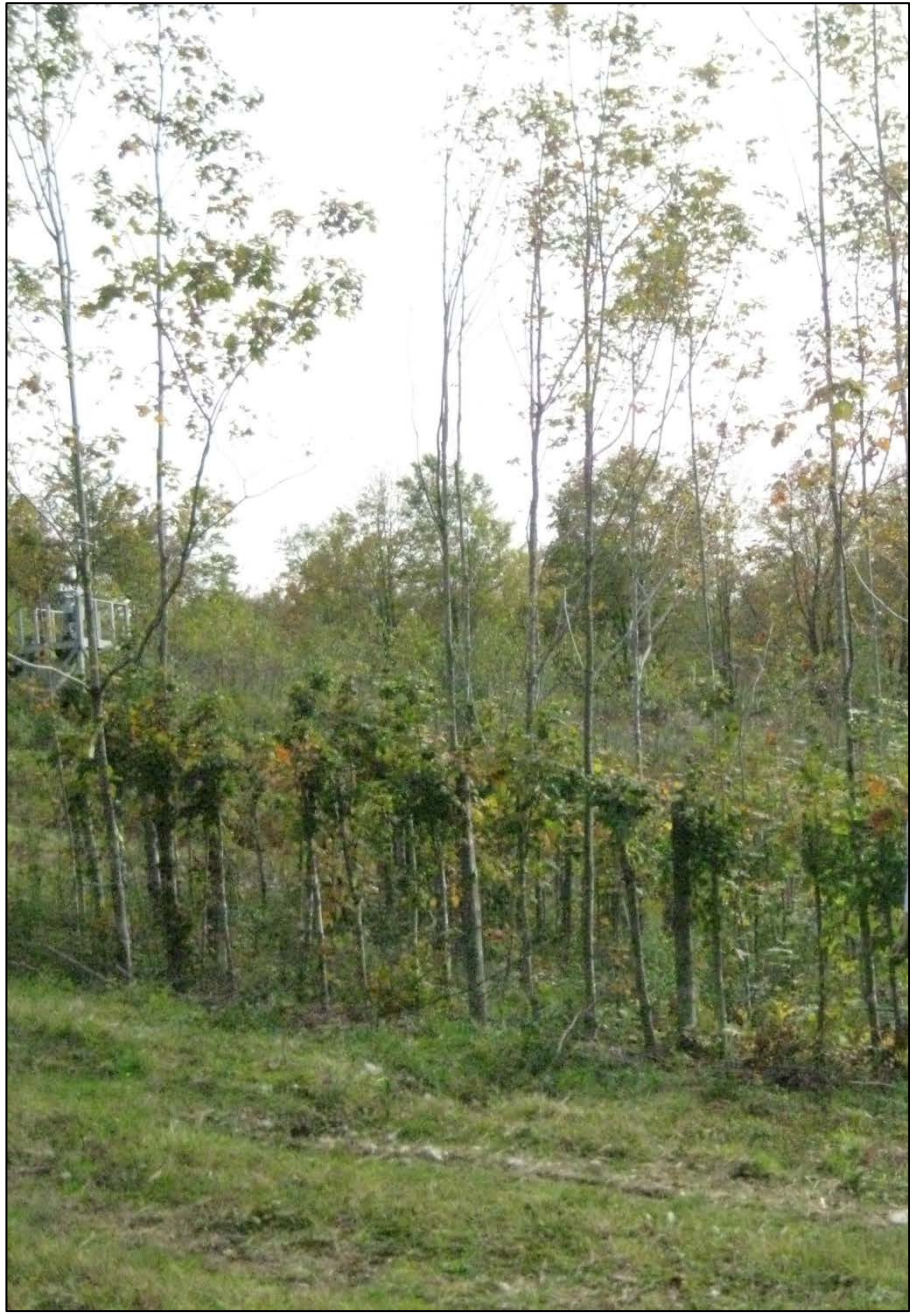
The fundamental premise of this type of sap collection is that sap is collected from the cut surface of small-diameter trees rather than through a taphole drilled in a larger stem. Initial cuts on intact trees are made approximately 5-6' above ground level at a height reasonably convenient for running tubing (Figure 1). The cut is most easily accomplished using a sharp bow-saw. Sap is collected from the cut surface of the stem using a cap-type fitting connected to a tubing system with vacuum (Figure 1). Vacuum is necessary; otherwise sap flows will be negligible. The cut to the stem needs to be as clean as possible to facilitate optimum sapflow, and care should be taken not to damage remaining bark tissues during the cutting process. The area of the stem where the cap is placed should be as smooth and free from defects as possible to facilitate a vacuum-tight fit. A clear zone of smooth bark approximately 3-4" long should extend below the cut to allow a good seal with the sap collection cap. Good sanitation practices should be used to avoid contamination of the cut stem. The cut top of the tree could be put aside and used later for mulch or fuel. The stem should be cut immediately before significant sap flows would be expected to occur.

The basic physiological processes that underlie sap collection from small-diameter trees are the same as those in mature trees – sugar is loaded into sap in response to fluctuating freezing and thawing temperatures, and sap flows require above-freezing temperatures. Because of this, sap collection with small-diameter trees will frequently begin and end at similar times to mature forest trees, and the season will also proceed similarly and mirror that of mature trees. Larger sap flows and higher sugar contents will typically be observed after freeze-thaw fluctuations. Sugar content and sap flow will gradually decrease over time during above-freezing temperatures, and sap flow will ultimately cease when freeze-thaw fluctuations end and warmer temperatures lead to decreased sap flow and the development of unfilterable and/or off-flavored sap. However, these factors can sometimes be modulated in small-diameter trees since they may, under certain conditions, thaw earlier and faster than forest trees due to their relatively small size and, in some cases, open-grown locations that facilitate warmer localized conditions than in the forest. The top of the tree is not essential for any of these to occur – sugar is loaded into sap from cells in remaining stem and root tissues, and localized above-atmospheric pressures develop. However, because head pressure is not present, the use of vacuum is absolutely required for sap collection from small-diameter trees.

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<sup>†</sup> Please note that the methods, system, and devices described in this document are covered under claims of US Non-Provisional Patent Application 14/381,884 and cap fittings required to implement sap collection from small-diameter trees are not yet being commercially manufactured.





**Figure 1.** Sap collection from small-diameter trees. Trees before cutting (*upper left*), sap collection from cut trees (*lower left*), and regrowth from cut stems (*right*).



Cutting the stem and collecting sap from the entire surface is essential for sap collection from small-diameter trees. The surface area available for sap collection is significantly larger than what is accessed with a standard taphole and spout and because of this, collecting sap from cut stems results in greater sap yields than trees of the same size tapped with a standard taphole and spout. Cutting the stem and removing the top is not typically lethal to young saplings. Rather, new branches and leaves will sprout from dormant buds located under the bark of the remaining stem during the following growing season as long as two conditions are met: 1) the tree is exposed to a reasonably good amount of light, and 2) the tree is of sufficiently small diameter, generally < 4" dbh (Figure 2). For these reasons, sap collection from small-diameter trees is generally applicable only with open-grown trees that are less than 4" dbh. Just as in mature, intact trees, leaves from the new growth will photosynthesize and produce sugars that will be stored in the stem and root tissues, and ultimately harvested during sap collection in subsequent maple production seasons. However unlike mature trees, sugar storage and access is concentrated into a much smaller area.



**Figure 2.** New growth emerging from dormant buds beneath the bark of cut stems (*left*), and regrowth from cut stems (*right*).

Trees can be re-cut for sap collection the subsequent season after re-sprouting. The new cut is made lower on the stem, generally between 6-12" below the top, at a location beyond the majority of the stained wood generated in response to the previous year's cut (note that sometimes the central portion of the stem is stained naturally). The fresh cut surface should be predominantly clear, white wood. Re-sprouting and new growth will generally occur again during the following growing season, and the process can be repeated with successive annual cuts made in a similar manner until useable stem is exhausted, or sap collection from the remaining stem becomes difficult due to logistical factors (low height, etc.). This type of sap collection can also be performed with multiple-stem trees, in which several stems originate from a single root system (Figure 3). In multi-stem trees, each annual cut is made on a new,

previously uncut stem until all intact stems are used; subsequent cuts are made as described for single-stem trees (Figure 3), but rotating among available stems.



**Figure 3.** Multi-stemmed tree cut for a second year of sap collection. Note the prior year's cut stem with resprouted new growth to the right.

Sap yields from individual small-diameter trees are very low compared to larger trees used for standard maple production, generally between 2 – 5 gallons of sap, and 0.02 – 0.07 gallons of syrup equivalent per tree. The optimum diameter is 2-2.5" – sap yields from trees smaller than this tend to be substantially lower, and this method should not be used with stems less than 2" in diameter. Sap yields from multiple-stem trees are typically greater than those from single-stem trees. While yields per individual tree are quite low, the small size of these trees allows for large numbers of trees to be planted and grown in small areas, enabling substantial sap yields in aggregate from a limited land area. For example, at a planting density of 1,000 trees per acre, this system could result in total annual syrup yields of up to 70 gallons per acre. Thus, using this technique, maple trees could be planted and grown on open, flat land as a perennial agricultural crop, similar to vineyards or high-density apple orchards (Figure 4). Using nursery stock with a genetic predisposition for higher sap sugar content could substantially increase the yields obtainable per acre. Considerable additional research is required to determine the appropriate techniques and to do cost/benefit calculations on this approach.





**Figure 4.** High density apple orchard in Ontario. © Queen's Printer for Ontario, 2016.  
[www.omafra.gov.on.ca/neworchard/english/apples/index.html](http://www.omafra.gov.on.ca/neworchard/english/apples/index.html)

Perpetuation of sap collection from small-diameter trees over the long-term in a crop system can be accomplished using a variety of strategies. Because of greater sap yields and the relative ease of long-term annual sap collection, multi-stem trees are likely the optimum tree type to be used in this application. In this type of system, individual maple saplings are planted, and “coppice” cuts are subsequently made at the base of the stem in order to promote a multiple-stem growth form. Sap collection can begin when individual stems reach 2" in diameter, and annual sap collection can continue as described previously using intact stems first, and then using previously cut and re-sprouted stems, until useable stems are exhausted. At this point, coppice cuts could be used to initiate new, multi-stem growth from the existing root systems. If tree growth is too rapid, sap could be collected from more than one stem per season, although yields are likely to be impacted to some degree.

Systems with single-stem trees are also possible – sap collection can begin after planted saplings achieve 2" in diameter. Similar to the multi-stem system, new growth could be initiated from the root system with coppice cuts when the useable stem was exhausted. In both system types, rotation strategies would be required to ensure sap collection could continue annually during the period when new stems were being regenerated on the original trees. This would occur more frequently in a single-stem system.

Alternatively, in some circumstances it may be possible to use a strategy in which subsequent cuts are postponed to allow new branches to develop an adequate diameter for sap collection. However, yields from these branches may be lower than those obtained from the main stem.

This system facilitates maple production on land previously unsuitable for maple production (e.g. flat, nonforested), and using less land area than is required in the traditional maple sap harvesting system, which requires large areas of forested land with mature maple trees. It also expands the scope of the type of crop and harvest system able to be used for maple syrup production from a wild-crop system in which sap is collected from existing trees in a mature forest, to a planted and cultivated perennial agricultural crop. In doing so, it creates and expands opportunities for maple producers to increase their production and grow their businesses, or initiate new operations. It also creates opportunities for farmers to plant and cultivate maple to produce maple syrup as one of their diversified agricultural crops. *It must be emphasized that this is not a system that would replace standard maple production.* There is currently no overall net economic advantage to this approach. For example, reduced costs in land acquisition and maintenance (taxes, thinning, road construction, upkeep) for syrup production from large trees are offset by costs of planting stock and intensive plantation management. Additionally, sap collection from small-diameter trees still requires the same climatic conditions as standard maple production – a period of winter dormancy followed by fluctuating above- and below-freezing temperatures. This system could simply provide an alternative perennial crop for farmers, or a means for maple producers to expand or initiate operations without the need for adding significant amounts of acreage. In addition to these potential benefits, this system may provide a means to mitigate to some degree the reduction in freeze-thaw cycles expected as a result of climate change, since small trees are likely to require smaller temperature fluctuations around the freezing point to induce sapflow. Moreover, this technique and system could also be used to collect sap from other sap-producing species, including birch, walnut, maple species not typically used for maple production, and others. Further research is needed in this area.

To date, our research has been conducted on individual, pre-existing small-diameter single- and multi-stem trees, and we have not completed studies in which trees have been planted expressly for this type of sap collection and subsequently used for harvest. There are numerous aspects of this type of sap collection and system that will require extensive research to gain a fuller understanding, and for development, refinement, and optimization, and on which research has not been conducted to date. These include all facets of establishing and managing crop systems, including optimum planting densities and organization, optimum characteristics of nursery stock (age, species, etc.), the length of time required for trees to reach harvestable diameter, and optimum harvest rotation strategies to facilitate sap collection in the long-term. For multi-stem trees in particular, the timing and best methods of coppice cuts used to stimulate the multi-stem growth form, as well as any pruning or training required to achieve an optimum growth form for sap collection, will also require research to determine. In addition, other factors such as practices required for organic production, fertilization and irrigation requirements, weed and pest management strategies, and long-term sap yields from trees in crop systems, will also require investigation. The planting and management system developed by the Willow Project at the State University of New York College of Environmental Science and Forestry (SUNY-ESF) for willow biomass plantations provides useful information and insight into a similar system,



however not all practices are applicable to a system for maple production ([www.esf.edu/willow/](http://www.esf.edu/willow/), [www.esf.edu/willow/documents/ProducersHandbook.pdf](http://www.esf.edu/willow/documents/ProducersHandbook.pdf)).

### Sap Collection from Regenerating Stands

While primarily applicable for circumstances in which trees are planted in open-grown conditions and grown for subsequent sap harvest, there are other instances in which large numbers of small-diameter maple trees already exist. Can this system be used in these circumstances? A key requirement for the long-term perpetuation of this system is the resprouting and regeneration of new growth from the cut stems, which requires a sufficient amount of light. This factor will ultimately limit the application of this system in situations outside of open-grown conditions

Stands that are regenerating after being cleared for pasture or harvest are often comprised of a large number of small-diameter maple trees (Figures 5 and 6). If the ultimate goal in these stands is to develop a mature sugarbush used for traditional maple production, thinning must be conducted in order to promote the growth and crown development of future crop trees. For example, in stands where the average tree diameter is 2" (in which densities can be as high as 5,000 or more trees per acre), it is recommended that an initial thinning be conducted to retain approximately 200 crop trees per acre.<sup>1-3</sup> It may be possible to combine the task of thinning with sap collection from small-diameter trees for a few years in order to obtain some production and income from syrup produced in the stand during the development of the stand into a mature sugarbush. This approach would help to offset some of the cost of thinning and other forest management in young stands being ultimately developed into a sugarbush.



**Figure 5.** Regenerating stand near a maple operation in Vermont during the winter.



**Figure 6.** Regenerating stand from Figure 5 during the summer.

We have conducted some preliminary investigation of sap collection from trees in regenerating stands to determine the sap yields attainable from these trees and the level of resprouting achieved in these lower-light conditions. We collected sap and quantified syrup yields from 24 small-diameter trees (average dbh = 2.3") in a regenerating stand during the 2015 production season. The results of this study indicated sap yields from these trees were relatively low, between 0.02 and 0.06 gallons of syrup equivalent per stem, although this was from a single very short collection season (4/1 – 4/18/15). Despite the generally lower light conditions experienced by these saplings, regeneration of the cut stems the following growing season was quite good. Many saplings had vigorous regrowth, and only 1 of 24 trees failed to resprout (Figure 7). Thus, it appears likely that sap collection from small-diameter trees in regenerating stands could be combined with thinning to promote the development of crop trees, however the sap yields may be relatively low, and resprouting would ultimately be limited by the amount of available light. Whether the economics of implementing this practice would be favorable would largely depend on the specific circumstances of each individual situation, including the number of trees per acre available for sap collection, the availability of existing tubing systems in the area, and the costs of thinning.





**Figure 7.** Resprouting and new growth from maple saplings cut for sap collection the previous spring in a regenerating maple stand.

## References

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