SUGAR MAPLE SAP YIELDS USING ONE OR TWO TAPHOLES PER TREE

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When sugarmakers set up a sap collection system in their woods, they generally have three goals in mind: to collect as much sap as possible, to collect high quality sap, and to preserve their trees for future years of sugaring. This article will discuss one way we might influence the first goal of maximizing sap collection. While many sugarmakers continue to increase their yield from individual tapholes, using the latest information about pumps, spouts, tubing design, and spout sanitation, there is also continuing focus on limiting damage to tapped trees by limiting the number of tapholes in each tree. Every taphole is a small wound, and internally the wound results in an area of the wood that is compartmentalized - walled off from the trees' sap flow system. The ability of the tree to maintain its vitality depends in part on the number, size and spacing of these compartmentalized areas, as does our ability to tap each year into functional wood that will yield a good flow of sap. Studies currently underway at the University of Vermont Proctor Maple Research Center (PMRC) are examining the effects of accumulating internal taphole damage on the ability to support future tapping, as well as related subjects such as the effects high vacuum sap extraction might have on tree growth, all with the goal of developing new sustainable tapping guidelines. However, along with focusing on the possible negative effects of tapping and sap extraction, it is important to examine how certain practices might lead to greater sap yields.

Many producers refer to some established tapping guidelines for advice on the number of tapholes to place in trees of different diameters. These guidelines, however useful, may not be based on science, and are certainly inconsistent. For example, the North American Maple Producers Manual, 2nd edition (2006), offers two guidelines: the "traditional" version suggests one tap in a minimum 10" DBH tree, a second tap in a 15" tree, a third in a 20" tree, and so on; while the "conservative" version suggests one tap in a minimum 12" DBH tree, a second in an 18" tree, and no more than two tapholes. Additionally, sugarmakers who must follow rules for their organic certification will find that these rules vary considerably depending on the certifying organization: for example, NOFA Vermont allows a second taphole in a minimum 15" DBH tree, New York in a minimum 14" tree, Ecocert in Canada in a minimum 16" tree, but Maine limits the second taphole to a minimum 21" tree. Some of these differences may be the result of perceived differences in the growth rate of trees in each region, as trees with higher radial growth rates can support more areas of compartmentalized wood.

Before setting up this research, I polled Vermont sugarmakers in an annual survey about their tapping guidelines; specifically, in what diam-

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eter tree would they place a second taphole. At the time of this survey (2009), fully 50% of the 128 producers who used more than one tap in trees of any diameter, claimed that they placed a second tap in a tree as small as 16" DBH. Most of these producers used high vacuum. In subsequent polling of audiences, I have found far fewer sugarmakers who admit to placing a second tap in trees this size; for many the cut-off is 18" DBH. Based on these responses, and the current published guidelines, I chose to examine sap yield from 1 or 2 tapholes in trees of two size classes: approximately 16" DBH, and approximately 19" DBH.

METHODS

The study took place during 2010 and 2011 using sugar maples located at the PMRC in Underhill Center, VT. Twenty healthy trees with sound trunks were selected, and divided into two groups; 10 trees averaged 16.1" DBH and 10 trees averaged 19.5" DBH. Sap was collected in 4 gallon vacuum chambers attached to the trees (Figure 1), these chambers allow the researcher to capture and measure sap from an individual taphole while the taphole is under vacuum. Chambers were connected to the tapholes via new droplines and new 5/16" spouts (Darveau in 2010 and Leader standard spouts in 2011). Vacuum was achieved using an oil-cooled liquid ring pump, and the vacuum level at the taphole was approximately 24" Hg.

Each tree had two 1.5" deep tapholes drilled on opposite sides of the trunk and staggered from each other vertically by approximately 2 feet. Tapholes were placed on the east and west sides of the trunk in 2010, and on the north and south sides in 2011. Each dropline was fitted with a valve which would, when closed, completely shut off the flow of sap from the taphole (Figure 1). Thus, by opening or closing the dropline valves, sap was collected from either one of the tapholes, or from both tapholes. The treatment consisted of collecting sap from one taphole in five 16" trees and five 19.5" trees, and from both tapholes in the remaining trees. At the end of each sap run, or every few days, the treatment was reversed by changing the valve position, so that the one-taphole trees became two-taphole trees, and vice versa. The location of the single open taphole was also varied with each run (i.e.

Figure 1. Vacuum chambers for capturing sap from individual tapholes. Arrows point to valves on each dropline that allow the tapholes to be opened or closed.

from east to west in 2010). In each tree the valve position was switched approximately 12 times during each of the two collecting seasons.

RESULTS AND DISCUSSION

In Northwestern Vermont, weather conditions varied considerably between the two years of this study. In 2010, the study trees were tapped on February 25th and the season ended 36 days later. There were few freeze-thaw cycles during this period and two long stretches without freezing temperatures. Sap was collected on 28 days during the season. In 2011 the trees were tapped on February 17th and the season ended 53 days later. There were many freeze-thaw cycles. Sap was collected on 26 days during the season.

In 2010, all trees yielded more sap during the time that both tapholes were open, with an average of 45% more sap collected with two tapholes open in the 16" trees, and 59% more sap collected with two tapholes in the 19.5" trees. In 2011, the increase in yield with two taps averaged 57% in 16" trees and 79% in 19.5" trees (Table 1). The average increase for both years was 52% in the 16" trees and 66% in the 19.5" trees. Statistically, the increase in sap yield using two vs. one tapholes was highly significant, using a two-tailed T test, for each year and each diameter class.

While a second taphole did not yield twice as much sap as a single taphole, the increase with the second taphole observed in this study was more than expected. Previous experiments studying the vertical and horizontal flow of sap within a tapped sugar maple have shown that when sap begins to flow toward a taphole, it initially moves in a vertical direction. This can be demonstrated by observing the rapid decrease in pressure above and below a taphole that is just drilled (or opened with a valve, as in this study). Within several hours, there is evidence of horizontal sap flow, as the pressure in the trunk on the opposite side of the taphole also decreases. Over time, the pressure decreases over a large area of the trunk, indicating that a considerable area of the tree is contributing sap to the open taphole. When there is more than one taphole, the areas of the trunk contributing sap to each hole soon overlap. The amount that these two areas overlap is related to the distance between the holes and the amount of time that the sap has been flowing.

Table 1.

Year	Tree DBH	Mean increase w/2nd tap	Increased yield with 2nd tap: range
2010	16"	45%	17% - 82%
2010	19.5"	59%	8% - 93%
2011	16"	57%	-36% - 84%
2011	19.5"	79%	38% - 91%
Both yrs.	16"	52%	
Both yrs.	19.5"	66%	

Higher vacuum levels may also increase the amount of overlap. The more distant the tapholes are from each other, as happens when tapping the opposite side of larger and larger trees, the longer it will take for the overlap to occur, and thus, the greater the increase with a second taphole.

This was borne out by the greater

increase in yield with a second taphole from larger trees seen in this study. In addition to distance between the holes, the other major variable is the duration of the sap run. As mentioned above, the sap runs-i.e. the number of hours between freezes-were generally longer in 2010 than in 2011.

A closer examination of the data showed that during sap runs that lasted less than 24 hours, the average increase in yield with the second taphole was close to 90%, but during sap runs that lasted 3 days or longer, the average increase with a second taphole was less than 50%. Thus, a more "traditional" spring with many freeze-thaw cycles is more likely to bring benefits to the sugarmakers with two-tapped trees, compared to the more recent weather conditions seen in much of the maple region, where freezes are followed by long stretches of warm weather.

The increase in sap yields recorded in this study - 52% and 66% in 16" and 19.5" DBH trees respectively, may sound very inviting to producers wishing to collect more sap, but several caveats should be observed.

First, this study took place in one location over two years in northwestern Vermont, using 20 trees, and the results seen here may not carry over to all other sites. The trees used in the study were all healthy; trees with significant dieback have been shown to yield less sap and may not respond well to higher tapping intensity.

Second, adding taps to trees adds more places for vacuum leaks to occur, and adds equipment that must be maintained and often replaced. Most importantly, increasing the number of tapholes adds to the amount of brown, compartmentalized wood in the trunk. Eventually, if this compartmentalized wood is added to the trunk at a rate faster than it can be replaced by new wood growth, it will become more and more likely each year that a drill bit will strike brown wood. This will result in a hole that will produce less sap, no sap, or poor quality sap. Spacing the holes vertically along the trunk by using long droplines and tapping as high as possible some years will help spread out the brown wood. Likewise, drilling shallower holes, even though research may show that holes deeper than 1.5" can produce more sap, is one way to avoid striking a buried compartment from an old taphole.

Slow-growing trees are particularly susceptible to this problem. For producers using buckets, where the holes are placed in a narrow vertical band, the addition of more tapholes is particularly problematic because the wound compartments are not spread as they would be with tubing and long droplines.

As mentioned above, new tapping guidelines for sugar maple are being developed at the PMRC with research data collected by researchers Dr. Abby van den Berg, Dr. Tim Perkins, Mark Isselhardt and myself. Many variables must be examined, such as the sap yield from different numbers of tapholes, the yield from different taphole depths, the average growth rate of sugar maples across the region, and the effects of carbohydrate (sap sugar) removal on tree growth. We hope that these science-based guidelines will in the future provide guidance that the current conflicting guidelines may not offer.

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