Tree Size and Maple Production~ Forest Science Theme

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Maple syrup is a woodland crop (Willits and Hills 1963). On some levels, the springtime activity of harvesting sap hasn't changed much since humans first learned the practice. Trees are regenerated naturally for the most part. New holes must be made each spring. Sap must then be collected and boiled to create the unique, amber sweetener. In terms of cultivating crop trees, maple producers tend to favor sugar maple (*Acer saccharum*) and more recently red maple (*Acer rubrum*) at the expense of other species. Trees are tapped year after year while some old individuals die (or are removed) and create openings to allow the younger generation to exploit the newfound sunlight.

For many there is a perception that the methods used by sugar makers have not changed much over the years. Perhaps this perception is reinforced by the imagery used by many to market maple syrup. The imagery could be described as iconic to the point of nostalgic. While buckets remain a legitimate practice for the collection of sap, it remains as limited by the availability of labor as it was 100 years ago. So except for the comparatively few who collect with hundreds to even a few thousand buckets, most producers have adopted plastic tubing as their preferred method (Heiligmann et al. 2006). The evolution of tubing from simple labor saving device to production boosting technology has taken more than 50 years. The materials, supplementary vacuum applied to the tubing system, and increased ability to track down leaks are responsible for the record average yields enjoyed by today's maple producers (NASS 2017, Perkins et al. 2015).

There are several important factors that affect the yield of sap from trees during the production season. These generally fall into four categories: tree characteristics, tapping, vacuum, and spout/tubing sanitation. On tubing, where large numbers of trees' sap are blended together it is difficult to observe the impacts each of these has on sap yield. However, by doing controlled research studies it is possible to discern the relationships among certain characteristics and practices. Some of what is now considered common knowledge in the maple industry; such as the understanding that 5% more sap is harvested for each 1" Hg vacuum applied to the tap hole (without an increase in internal staining) comes directly from such research (Wilmot et al. 2007).

One relationship that is sometimes overlooked is the one between tree size and yield. With buckets, it was fairly easy to keep track of trees that were good producers and those that did not produce so well. It was also easy to observe the effect of tree size on yield and it was generally understood that small trees generally produce fairly modest quantities of sap. Sometimes the expense associated with tapping these trees means only a minimal net profit. Since every connection on a tubing system is a potential leak, and because every tree produces, in addition to sap, some amount of gas during a thaw which needs to be evacuated by the pump to keep the vacuum level high, time might be better spent doing few, more productive taps, and therefore keeping vacuum levels on a smaller number of trees higher. Perhaps by thinning out a thick stand of small trees, the residual crop trees will grow faster and achieve tappable size sooner and increase their size (and syrup yield) faster. Finally, it is important to understand at what point trees should (and more importantly, SHOULD NOT) be tapped in terms of sustainable production practices.

In order to develop models of tree size and yield to answer some of these questions, we measured the sap volume and sugar content from approximately fifty individuals along a wide range of sizes during the 2016 and 2017 seasons. Different areas of the UVM Proctor Maple Research Center (PMRC) forest were used each year. We used sap collection chambers (Figure 1) connected to vacuum pumps. Tapholes were drilled to 1.5" from the outside bark and connected to a dropline leading to a single chamber for sap to collect in. Vacuum was maintained at about 25" Hg throughout the spring season. Collection was stopped at the time that the UVM PMRC production ended. Sap depth was measured as needed during the season to keep chambers from overflowing and converted to volume. Sugar content was measured with a Misco digital refractometer. Syrup yields were calculated from volume and sap sugar content using the revised Jones Rule of 87.1 (Perkins and Isselhardt 2013) and are expressed in lbs/tap.

The two seasons had overall similar levels of average production, although sap volumes were higher in 2016, but sap sugar content was lower than that found in 2017. In general, there was a strong relationship between tree diameter and syrup yield (figure 2). Smaller trees produced far less syrup than larger trees in both years, with trees under 5" diameter typically producing in the range of 1-2 lbs of syrup, or only about half that of a tree 10" diameter. As size increases beyond 10", syrup yield continues to

Figure 1. Study tree showing dropline and vacuum chamber for sap collection.

increase nearly linearly. Intuitively, under vacuum sap collection conditions at least, this makes a lot of sense. Producers can conceptually think of trees as being similar to pipes that are stuck upright in the ground, but filled with a wood matrix of tiny pores containing water. As the pipe gets larger, the number of pores increases, and the volume of water that can be held in those pores also increases. At least this would be the case for trees that don't have a lot of heartwood or compartmentalization from previous tapping. Even then, the volume of wood in the upper portion of the stem and in branches far exceeds that in the stem, so the non-conductive wood (heartwood and tapping scars) would have only a relatively modest impact on sap volume in the stem.

While these results will be used in several of our ongoing and future studies on maple production sustainability and economics over the next few years, the overall immediate take-home messages from this work are that:

- small trees produce relatively little sap
- the relationship between tree size and yield is fairly consistent and tends to be linear
- in general, each 1" increase in tree diameter results in approximately 2 gal more sap or 0.67 lbs more syrup.

Of course the volume of sap removed during the season is only half of the story, there is also the extraction of sugar to consider. If you assume that all the stored nonstructural carbohydrates (NSC or sugar and starch combined) within a given tree are available to both tree and sugar maker then 20% of the 5" trees total would have been removed. That assumes that all stored NSC in a given tree is truly available to both plant and producer (something that has yet to be fully documented) (Isselhardt et al. 2016). This number drops off considerably as you reach more 'traditional' sized trees. There are many unknowns about what represents the critical level of NSC stored in a given tree or said another way, how much is too much. Hopefully the combination of results from ongoing long term studies and new understanding about how trees allocate NSC will help shed light on this important issue.

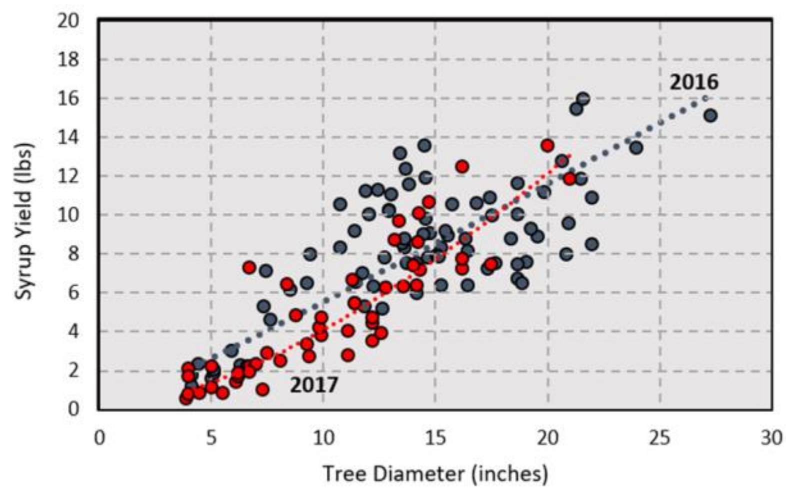

Figure 2. Relationship between tree diameter and syrup yield (lbs) for the 2016 (blue) and 2017 (red) sap flow seasons in Underhill, Vermont. Best-fit trend lines are shown by dotted lines. R^2 = 0.704

Portions of this work were previously published in *The Maple Syrup Digest* and *The Maple News*.

Perkins, T., Isselhardt, M. and van den Berg, A. 2017. Understanding the relationship between tree size and yield. *The Maple News* Vol 16:9, pp 1 & 36.

Isselhardt, M.L., Perkins, T.D. and van den Berg, A.K. 2018. Tree Size Matters. Maple Syrup Digest 57(1): 36-38

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