Maple Digest 54(2): 14-19.

Research: Trees and sap

Does Masting Really Lead to Lower Sap Sugar Concentrations?

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Maple producers often wonder about how the weather and various stresses affect the health and productivity of maple trees. In a recent issue of the *Maple Digest*, (February 2015) an article by Joshua Rapp showed a link between masting (heavy seed production) in the fall of one year and significantly reduced maple syrup production in the following spring season. Rapp describes research previously published in the journal *Forest Ecology & Management* with his co-author Elizabeth Crone. In both papers, they hypothesize that since sugar maples rely on stored nonstructural carbohydrates (NSC) to produce seed during a masting year, there would be less NSC available in sap the following year. Thus, in sugaring seasons following a seed year, the sap sugar concentration (SSC) from trees would be lower than normal, and thus syrup production should be correspondingly lower in that year. While this is an interesting theory that certainly has some merit for further investigation, the methods by which the theory was tested have seri-

ous flaws that lead to significant doubt in the conclusion. The rest of this article outlines some of the key problems with this study and offers suggestions on how this theory could be tested with more relevant data.

A serious flaw in this logic of this study is the author's use of syrup production totals to calculate SSC. If the authors wanted to test a theory that seed production results in lower SSC the following year, then they should have simply looked at SSC instead of syrup production totals. Limitations in their data sources likely caused them to take the route they did, but that doesn't excuse this faulty logic. As the authors note, it is common knowledge that syrup production is based on both SSC and total sap volume. You could have a situation where SSC was very high but production was low simply because sap volume was down (or vice versa). To illustrate this point, consider the most recent example during a masting year for sugar maples at the Cornell Uihlein Maple Research Station in Lake Placid, NY. During the year 2013 there was a heavy seed year for sugar maples in our sugarbush. Therefore according to the author's theory, syrup production should have been down in 2014. Indeed, 2014 was a worse year in terms of total syrup production than was 2013, so on the surface their theory proves correct.

Looking deeper however, we find that this simple link doesn't offer a good explanation. Regional syrup production was down in 2014 for many producers not because of low SSC, but rather due to low sap volumes resulting from a severe winter with extremely cold temperatures in March extending into April. The length of the 2014 season was therefore very short in many locations. In fact, SSC was actually higher than average in 2014 season, hovering around 3% for most of the season (based on personal observations), which allowed syrup production totals to only be slightly down even though sap volumes were significantly lower due to the shortened season. According to the authors' theory, SSC should have been significantly lower than average in 2014 due to the investment in seeds the trees made in 2013. Although 2014 turned out to have lower production than 2013, it was entirely weather dependent and had nothing to do with lower SSC. In fact, a somewhat elevated 2014 season SSC resulted in syrup production higher than it would have been otherwise. This is only one example to disprove this hypothesis, however the bottom line is that using syrup production totals as a proxy for SSC has obvious limitations.

Second, the reliance on USDA National Agricultural Statistics Service (NASS) data for syrup production totals presents serious problems. First, the authors attempted to factor in the fact that the industry is growing by fitting a trendline to the data and looking at the difference in the overall trends. However a much simpler and better solution would have been to look at yields per tap. Even this approach fails to take in to account the fact that yields per tap have also been rising, especially over the last decade as producers employ better practices to achieve higher vacuum and improve sanitation practices, and as large, very technologically advanced operations were added. Yields per tap in Vermont have risen significantly over the past decade, even more so than in New York and Maine. This has nothing to do with seed pro-

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duction, but instead reflects a greater adoption of the latest technologies in sap collection.

However, this minor critique is dwarfed by the fact that the NASS data suffers from a serious lack of underreporting by maple producers. Furthermore, the NASS data may be becoming less representative of the maple industry as a whole as new producers enter the market, but are not (yet) represented in their databases. Consider the fact that Bascom Maple Farms reports that they bought more bulk syrup out of New York two years ago than NASS reported was produced in the entire state. We know the NASS data underestimates actual production, but we don't know by how much in each state, nor do we know how much it underestimates it now versus in the past. Until we can get a much higher proportion of producers to report their syrup crop numbers, utilizing NASS data to test scientific hypotheses can be problematic at best. It is certainly in our best interests as an industry to have every producer fully report their data to NASS each year. Having accurate data that we can rely on would help in many ways, including in the scientific research being described here.

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Finally, what is perhaps most troubling about this study is that it only spans a short time period and the actual data don't really conform to the hypothesis upon deeper inspection. This study spanned over 17 years, during which there were three years identified as having a large seed crop: 2000, 2006, and 2011. Although these data were not shown in the *Maple Digest* article, they were clearly shown and described in the paper published in *Forest Ecology & Management*. Some highlights from the written descriptions of the sugaring season following these mast years from the NASS reports for 2001, 2007, and 2012 offer other information, though:

2001: In the five New England states, the 2001 maple season was rated too cold for optimum production. Output from all states, except Connecticut, fell below the previous year. Temperatures were reported to be 58 percent too cold, 31 percent favorable, and 22 percent too warm, reducing yields in Maine, New Hampshire and Vermont. Most reports indicated that there was too much snow to gather sap. The sugar content of the sap was slightly above average, requiring approximately 39 gallons of sap to produce a gallon of syrup.

2007: Vermont led all states in production with 450,000 gallons, a decrease of two percent from 2006. Sugar content of the sap for 2007 was down from the previous year. On average, approximately 45 gallons of sap were required to produce one gallon of syrup. This compares with 44 gallons in 2006 and 40 gallons in 2005.

2012: The 2012 maple syrup season in New England was considered too warm. A series of heat waves in March ended the season for many, and resulted in a significant drop in maple syrup production.

To recap, syrup production was down in 2001 because it was too cold and snowy, even though sugar concen-

tration of the sap was up. Syrup production was a mere 2% lower in 2007 and sap sugar concentrations were reported to be only very slightly less (2%) than the previous year, requiring 45 instead of 44 gallons to produce a gallon of syrup. In 2012, SSC wasn't reported because it wasn't even worth mentioning given the summer-like temperatures experienced in the middle of March that cut the season short by several weeks. The 2012 data point in Figure 1 of the Rapp article had the lowest "Relative Syrup Production" of all. Removing that single data point would very likely render the model results insignificant as the years 2001 and 2007 are very similar to all other years in "Relative Syrup Production" despite their following masting years. This more detailed examination of the data is extremely troubling for the authors' theory. Having only one of the data points actually report a decrease in SSC (of only 2%) is far from scientifically defendable.

Fluctuations in sap sugar concentrations, as with many aspects of sap flow, remain a mystery to some extent. Although seed production undoubtedly can impact SSC levels, there are many other factors that could have a greater impact. We simply don't know everything that causes differences in SSC between various trees, locations, or seasons. However, to suggest that a previous year's seed production has a greater impact on total syrup output than the weather during the current sugaring season, which is known to strongly influence sap flow, just doesn't make any sense.

The anatomy and physiology of maple trees and the process of sap collection places limits on the influence that any one sink (demand for sugar, such as seed production) can have on SSC. A tree ring in a maple stem acts as a single unit in some cases, but as a collection of units in others. Since maple trees generally have a number of rings that conduct sap and store carbohydrate (sapwood), and tapholes access sap within a broad zone around the taphole, the sap collected by maple producers originates from a fair number of annual rings within the tree. Given this fact, the contribution of any one ring having low carbohydrate storage in one year (due to heavy seed production) to the overall SSC found in the sap is likely to be heavily muted. This argument is strongly supported and demonstrated by several studies conducted after the 1998 ice storm in northern New Eng-

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land and New York. Studies in Ontario, New York and Maine all found that trees with 50-75% crown loss in the ice storm produced as much sap and had wood carbohydrate levels over the next several years similar to trees that had little or no crown damage. It is hard to imagine that heavy seeding resulting in a reduction in carbohydrates in one annual ring could produce a greater impact on SSC than the loss of half or more of the crown of a tree.

Despite the problems with this study, the authors' theory does hold some merit, and is worthy of being tested, although there are certainly better approaches to answering this question. If enough Vermont sugarmakers have good records of SSC dating back over the past 17 years and are willing to share their data, we may be able to predict if SSC was indeed lower than average following a seed year. This would only include three masting years and would not be considered a definitive report, but it would certainly be an improvement over the current study. To properly test this hypothesis, a broad and detailed database of records on masting, sap sugar concentration, and other environmental variables is required that can be combined with climatic records to construct a model of various factors influencing sap sweetness. If you know of such a database, I encourage you to contact us at mlf36@cornell.edu or (518) 523-9337.

Along those lines, the UVM Proctor Maple Research Center (PMRC) does have records of SSC measured as part of its operation from 1988-2015. While a detailed analysis is still being conducted, the average SSC over that time for the entire sugarbush is 2.1°Brix, and 2001, 2007, and 2012 (also heavy seed years at PMRC) are 2.6, 1.6 and 2.1° Brix respectively (one higher than normal, one lower than normal, and one normal SSC), which does not support the hypothesis that heavy seed years consistently produce low SSC. What is clear from these data is what all maple producers already recognize, and numerous studies (in both peer-reviewed and maple industry literature) have repeatedly demonstrated since research on sap flow began: that temperature and precipitation have the strongest influence on syrup yields during the season through their effects on sap flow, and that variations in SSC, while present, are generally fairly modest from year-to-year.

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In the meantime, it's never too late to start keeping more detailed records to help understand what is happening in your own sugaring operation. The more data that is made available to NASS and to researchers for analysis, the better we can understand what factors influence tree health and syrup production, for the betterment of the entire maple industry.