Reduced Sap Yields When Tapping Into Non-Conductive Wood

Mark Isselhardt, Maple Specialist, University of Vermont Extension

Trees such as sugar maple (Acer saccharum) use xylem tissue to transport massive amounts of water during the growing season as part of photosynthesis. Tapping maple trees involves drilling into this conductive wood (CW) in order to gain access to the sugar enriched sap. The tapping process represents a wound to the tree also stimulates the trees wound response mechanism (Chapeskie et al. 2006). This mechanism is the same for any injury to the tree including but not limited to; ice storm or wind damage, animal damage as well as mechanical damage associated with tree harvesting activities. The wound response system is commonly referred to as CODIT or Compartmentalization Of Decay In Trees (a term formalized by US Forest Service researcher Alex Shigo).

The CODIT model relies on two key facts about tree physiology. First, trees are highly compartmented plants and are therefore designed to reduce the likelihood of infection from spreading from compartment to compartment (Shigo and Marx 1977). Another way of saying this is that trees are structured with internal barriers designed to reduce the free movement colonizing microorganisms. This is considered a passive process. Second, when trees are wounded the injury stimulates the tree to "compartmentalize" or wall off the wound so as to avoid systemic infection and decay. This is an active process, whereby trees devote some of their stored nonstructural carbohydrates to the creation of protective chemical compounds which include the staining familiar to anyone who has seen boards or firewood cut from tapped maple trees. The stained area of wood around a taphole is rendered nonconductive (NCW) to liquid passage (this includes during the growing season as part of photosynthesis or during the sap collection period of late winter/early spring). The area of NCW typically does not extend much wider than the taphole itself but much more above and below.

Because of this, the annual collection of maple sap requires new tapholes be drilled each year. The process of tapping demands that the individual drilling the hole decides where best to place the new taphole, often with limited information about what lies beneath the bark. There is a tremendous amount of variability in terms of the volume of NCW generated by tapping. On average the volume is about 50 times the volume of the taphole itself but has been observed to be nearly 200 times the size of the taphole and as little as 15 times the size of the taphole (van den Berg 2020).

Sugarmakers know that tapping into areas of nonconductive wood will likely result in reduced sap yields. However, tubing systems obscure the sap produc-

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tion of any individual tree and spreads the losses of sap associated with hitting stained wood over all trees in a given sugarbush. This in part explains why the magnitude of the reduction in sap yield is not well understood.

According to a recent survey of more than 300 maple producers in the northeast United States, nonconductive wood was hit during tapping on average 4.5% of the time and the responses ranged from 0-41% of the time (UVM Extension 2019 unpublished). Previous research has explored factors that impact the likelihood of tapping into NCW. Significant factors include but are not limited to; dropline length, taphole diameter, tapping intensity (number of taps/tree) and stem growth (van den Berg and Perkins 2014). Other work touched on the relationship between the amount of conductive wood exposed while tapping and yields (Wilmot et al. 2007). But to date, there has been no direct investigation as to the relationship between the percent of NCW is intercepted while tapping and sap yield. The present study sought to understand the relationship between the amount of NCW in a given tap how and the amount of sap collected, as well as understanding if other factors (sap sweetness) might impact total yields between treatments.

Methods

Tapping

The experiment was conducted at the University of Vermont, Proctor Maple Research Center, Underhill, Vermont during the 2018 and 2019 seasons. Twenty previously tapped sugar maple trees were measured for diameter at breast height (dbh or 4.5′ above ground) and divided into two equal groups: trees intentionally tapped into stained, nonconductive wood (NCW); and tapholes drilled into, clean, conductive wood (CW).

A new 5/16″ diameter maple tapping-specific tapping bit was used each year. All trees were tapped on the same day, February 26 (2018) and February 19 (2019). Each tree received a single, 5/16″ taphole drilled to a depth of 1.5″. Tapholes were drilled within 45 degrees of the same cardinal direction (2018-East, 2019-South). A new, 5/16″ white MaxFlow spout (CDL USA) was used for all tapholes. Trees receiving the NCW treatment were tapped 1″ directly above an existing taphole. Trees in the control or conductive wood (CW) group were tapped according to best practices to avoid existing tapholes. All wood chips and bark produced during drilling was collected for each tree through the use of a plastic apron held below the taphole. Wood chips and bark were placed in individual sample vials, immediately frozen and saved for subsequent lab analysis.

Sap collection

Each sample tree was connected its own 3/16″ tubing line with industry standard fittings. The sap from each tree was collected a separate 12″x36″ PVC chamber. Liquid depth was measured regularly throughout the season with a metal yard stick. Depth was converted to volume and reported in US gallons. Each sap measurement included a measurement of sap sweetness with a digital refractometer (Misco) and reported as ^{0}Brix. The sum of all sap collected is reported as well as the "syrup equivalent" which was calculated based on the updated "Jones Rule of 87.1" (Perkins & Isselhardt 2013).

Wood tissue analysis

Wood tissue collected from each taphole was processed in the lab. Sample fragments were visually inspected with a dissecting microscope and sorted into one of three categories; conductive wood, nonconductive wood, and bark. When a particular fragment held more than one type of tissue a razorblade was used. Wood chip mass was measured using a precision lab balance. Average wood chip mass for both CW and NCW was recorded for all sample trees. The percent NCW was compared with total syrup production (pounds of syrup equivalent) for 2018 and 2019.

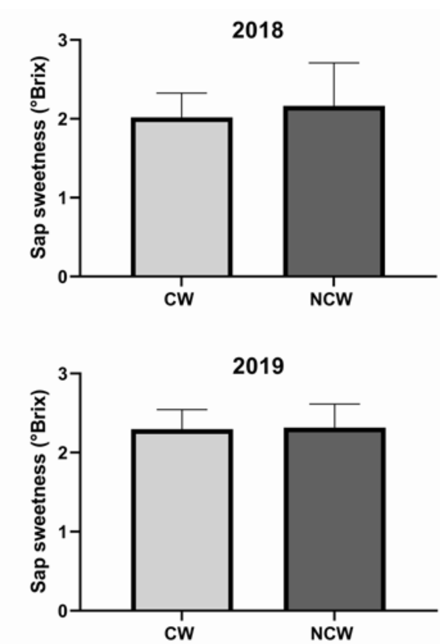

Figure 1: Average sap sweetness from trees tapped into conductive (CW, n=10) and nonconductive (NCW, n=7) wood during the 2018 and 2019 maple season

Statistical analysis

Statistical analyses were performed using Prism 9.2 for Windows (GraphPad Software LLC) to examine differences in sap volume and sap sugar concentration between trees with tapholes drilled into CW and NCW respectively. A simple linear regression was also used to examine the relationship between the percentage of NCW and syrup equivalent produced from a given taphole.

Results

Trees in each treatment group had similar average diameters; NCW 11.6" dbh and CW 11.4" dbh.

In 2018, the first year of the experiment, all ten trees tapped in the CW or control treatment produced tapholes with no stained wood (NCW). Three of the ten trees receiving the NCW treatment failed to produce evidence that the taphole intersected with any NCW and given that the purpose of the experiment was to define the impact on sap yield of tapholes drilled into nonconductive wood, they were therefore removed from subsequent analysis. In the second year, 2019, all NCW tapholes hit some amount of stained wood.

The sap collected from trees with NCW tapholes was not different in terms of sweetness than that of sap col-

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lected from trees with only CW tapholes in either 2018 or 2019. In 2018 the mean ^{0}Brix for CW treatment was 2.0 with a range from 1.6 to 2.6. This compared to sap collected from NCW tapholes with a mean value of 2.16 and a range from 1.4 to 2.8. The results were similar in 2019 although both treatments saw higher average levels of sap sweetness. In 2019 sap collected from CW tapholes had an average sweetness of 2.29 and a range from 1.8 to 2.6. This was similar to the average sap sweetness in tapholes drilled into NCW which had an average sweetness of 2.31 and a range of 1.9-2.9 respectively (Figure 1).

Sap volumes were significantly lower in the NCW treatment compared to the CW treatment in both 2018 and 2019. The average amount of sap collected from CW tapholes in 2018 was 26.9 gallons (±3.43) compared to just 6.8 gallons (±3.59) from the NCW treatment. In 2019 the average amount of sap collected from CW tapholes was 18.3 gallons (±2.74) compared to 8.8 gallons (±2.14) in the NCW treatment (Figure 2). Greater variability in sap production was observed trees in CW treatment in 2019 compared to 2018. Although no stained wood was observed in any CW tapholes there could be other variables that influenced yield in those trees.

The average syrup equivalent was calculated for both treatments. In 2018, trees in the CW treatment yielded .43 (± 0.04) gallons of syrup per tap whereas trees in the NCW treatment yielded 0.23 (± 0.06) gallons of syrup equivalent. In 2019, trees in the CW treatment yielded .47 (± 0.02) gallons of syrup per tap whereas trees in the NCW treatment yielded 0.23 (±0.02) gallons of syrup equivalent.

By combining the syrup equivalent data with wood chip mass data it is possible to compare the amount of NCW in a taphole with the amount of syrup produced (Figure 3). A strongly negative, linear relationship was observed between the amount of NCW intercepted by the taphole and the amount of syrup equivalent produced. The simple linear regression of the 2018 data resulted in an r2=0.882. In other words, the amount of stained wood in a taphole explained roughly 88% of the syrup equivalent produced. In 2019 the amount of stained wood in a taphole explained roughly 74% (r2=0.742) of the

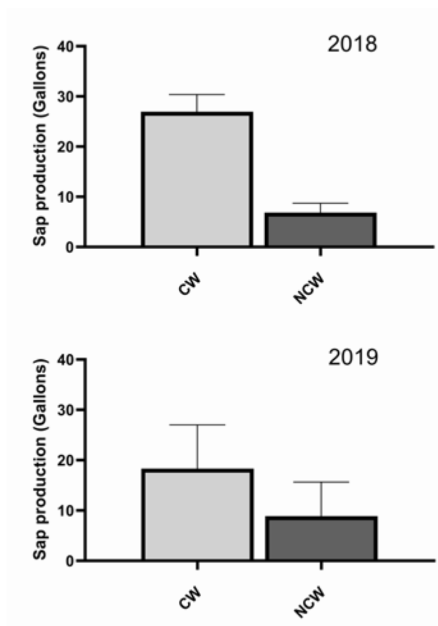

Figure 2: Average total sap production (US gallons) from trees tapped into conductive (CW, n=10) and nonconductive (NCW, n=10) wood during the 2018 and 2019 maple season.

syrup equivalent produced.

Discussion

The results show a strongly negative linear relationship between the amount of NCW intercepted while tapping and the amount of sap loss in a given season. If a taphole hits 50% stained wood a sugarmaker can expect at least a 50% less sap from that taphole. This study did not investigate at what point a new hole should be drilled given a certain amount of stain. This decision would be not only based on the cost associated with loss of sap production but also the impact on the sustainability of adding more NCW (van den Berg et al. 2021). If a new taphole is drilled and only produces dry, soft and stained wood chips, the tapping bit has hit not just NCW but a column of decayed wood. There are likely other signs of decay and the tree should be considered for removal during the next round of forest management activity or allowed to remain and provide structural diversity but removed from the sap collection system.

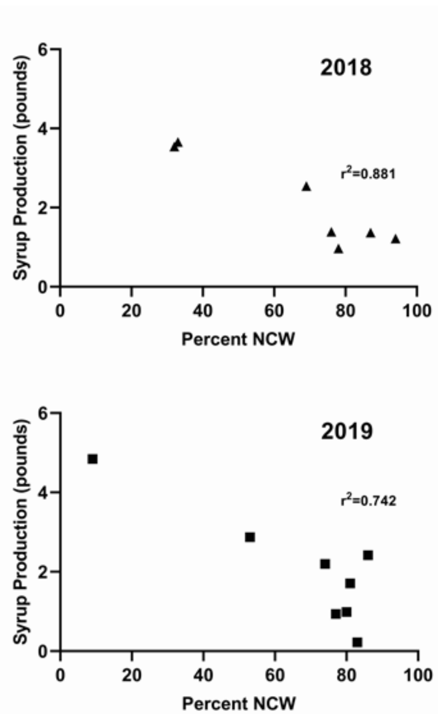

Figure 3: Relationship between syrup production (syrup equivalent calculated from sap volume and sweetness) and percent of nonconductive (NCW) wood in a taphole (NCW chip mass/CW chip mass).

The size of the stained column of nonconductive wood is variable and the orientation of the column can deviate greatly from vertical. This point was made clear when in 2018, nearly a third of the tapholes drilled just 1" above an existing taphole failed to produce any stained wood chips. This finding highlights the importance of taking time when considering taphole placement and calls into question the long term success of applying a strict tapping pattern. Sugarmakers should monitor the amount of NCW intercepted while drilling tapholes and at the very least keep track of the number of times stained wood is hit. The results suggest that practices that help reduce the likelihood of hitting NCW such as utilizing the entire tapping band, tapping below the lateral line, drilling as far away from previous years taphole, and above all else taking time to avoid hitting stained wood, can have a significant impact on syrup yields.

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