Effects of Tapping Depth on Sap Volume, Sap Sugar Content, and Syrup Yield Under High Vacuum

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Tapping depth strongly influences both sap yield and wounding. Numerous studies have focused on the amount of sap produced with different depths, the most extensive work conducted by Morrow (1963), who found a tendency for increasing sap yields with increasing taphole depth. However, this work was conducted on gravity with 7/16" tapholes, so is less informative to most producers using 5/16" spouts and vacuum.

More recently, researchers at the UVM Proctor Maple Research Center (Wilmot et al. 2007, Wilmot 2014) examined tapping depth (including bark) under vacuum (20-24"Hg) and found increasing sap yields with deeper taphole depth up to 2 ½", and suboptimal sap yields at depths of 1 ¼" or less. Taphole depths deeper than 2 ½" were not considered because of the negative consequences on sustainability.

With respect to wounding, research has demonstrated that the volume of stained wood generated by the tree in response to tapping is proportional to the size of the wound, and thus deeper tapholes result in larger volumes of wood that is nonconductive to sap (Renaud 1998, Wilmot et al. 2007, Perkins and van den Berg, unpublished data). Large accumulations of nonconductive wood are not only potentially detrimental to tree health, but also to sap yields, as tapholes drilled into stained wood produce significantly less sap (Perkins et al. 2016, Isselhardt, unpublished data).

Shallower tapholes can result in more sustainable yields and tree health over the long-term, because the reduced volume of wound created results in more conductive wood being available for tapping in general, and for growth to more rapidly bury the wound and allow shallow tapping over the same spot. Guidelines outlined in the 2006 edition of the North American Maple Syrup Producers Manual recommend tapholes extend no more than 2" into the wood (excluding bark) and be as shallow as practicable to reduce the probability of tapping into nonconductive wood and reduce its accumulation. However, because tapping depth affects yields in the current year, it is important to have quantitative information on the impact of tapping depth on sap yields so that producers can make choices to optimize all of the affected parameters – current year yields, the accumulation of nonconductive wood, and ultimately yields over the long-term.

Because vacuum enables substantial lateral and vertical movement of sap toward the taphole, the changes in technology and equipment that have occurred since the most recent research on taphole depth, including higher levels of vacuum and tightness of spout material and fittings, are likely to impact the effect of taphole depth on yields. In this study we reevaluated tapping depth to examine whether there is a point of diminishing returns in terms of syrup yield and wounding.

Methods

All research was conducted at the UVM Proctor Center in Underhill, Vermont, during the 2018, 2019 and 2020 sap flow seasons (February-April). A total of 1,280+ trees in a single stand (approximately 60% sugar maple and 40% red maple ranging from 9″ to 44″ in diameter) were arranged across 16 mainlines. Mainlines averaged 81 trees (range 44-113) with roughly equal average diameters and were connected to an individual small hybrid releaser equipped with a counter to determine the volume of sap collected for each. Releasers were calibrated near the end of each season to determine the volume of sap released with each dump. Vacuum to all mainlines was supplied by a common Busch pump pulling 24-26″ Hg. Each mainline was assigned one of four tapping depth treatments, yielding four replicates for each treatment each year. For the 2018 season, tapping depths were 1″, 1 ½″, 2″, and 2 ½″. In 2019, depths were 1 ½″, 1 ¾″, 2″ and 2 ¼″. In 2020, tapping depths tested were 1 ½″, 2″, and 2 ½″.

Trees were typically tapped in mid late January each year by a single individual, and depth for each treatment was set using a piece of tubing as a bit stop. Clear polycarbonate 5/16″ Leader Check-valve spouts were used for all treatments. The total number of releaser dumps for each mainline was multiplied by dump volume to determine total sap volume and sap yield (gal/tap) for each mainline, and the average for each tapping depth treatment. Sap sugar content of each mainline was measured periodically with a handheld Misco refractometer, and sap sugar content calculated on a volume weighted basis. Syrup yield (gal syrup/tap) was calculated for each mainline from sap volume and sugar content using the Revised Jones Rule (Perkins and Isselhardt 2013), then averaged for each depth treatment. For each season, 1 ½″ was used as a control and set to be 100% to allow a comparison across years.

Results

Average sap yield (gal sap/tap), sugar content (° Brix), and syrup yield (gal syrup/tap) with 1 ½″ deep tapholes as 100% are shown in Figure 1A, 1B, and 1C respectively. The trendline of sap yield (Figure 1A) with increasing depth shows a strongly curvilinear response, with 1″ tapholes producing slightly under 60% of the amount of sap as 1 ½″ tapholes, leveling out between 1 ¾″ and 2″ depth. Sap sugar content (Figure 1B) is slightly higher in 1″ tapholes than in deeper tapholes, but rapidly levels out at 1 ½″ and deeper. Taken together, sap volume and sugar content produce syrup (Figure 1C). The trendline of syrup yield with 1 ½″ tapholes set as 100% shows the dominant influence of sap yield on syrup production. Syrup yield from 1″ deep tapholes is 62% of a 1 ½″ taphole, with increasing syrup production as tapholes are drilled deeper until

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plateauing at 1 ¾″ and above. R2 values for a 2-order polynomial were significant for all three parameters (sap volume, sap sugar content, syrup yield), indicating the robustness of the model fit.

Discussion

Although hydraulic conductivity of individual vessel elements and sap sugar content most likely decreases with increasing ring age, the ability of strong vacuum to move sap both vertically and laterally towards the taphole appears to moderate the influence of taphole depth on syrup yield once a sufficiently deep taphole is achieved that allows sap to move out of the taphole and vacuum to be transferred into the stem. Therefore, deep tapholes are not required to maximize syrup yield from maple stems. When using vacuum, a taphole of 1 ¾ - 2″ deep including bark produces a maximum syrup yield with a minimum loss in conductive wood and is therefore both the most economically advantageous and the most sustainable tapping practice. While shallow tapholes do result in far lower staining, the considerably lower syrup yield makes the practice less economically viable. Our recommendation therefore is that in most cases producers using vacuum sap collection use tapholes no deeper than 2″ for sap collection. For trees on the smaller side of the tapping range, or for individuals exhibiting slow growth, low vigor, or with a large amount of preexisting nonconductive

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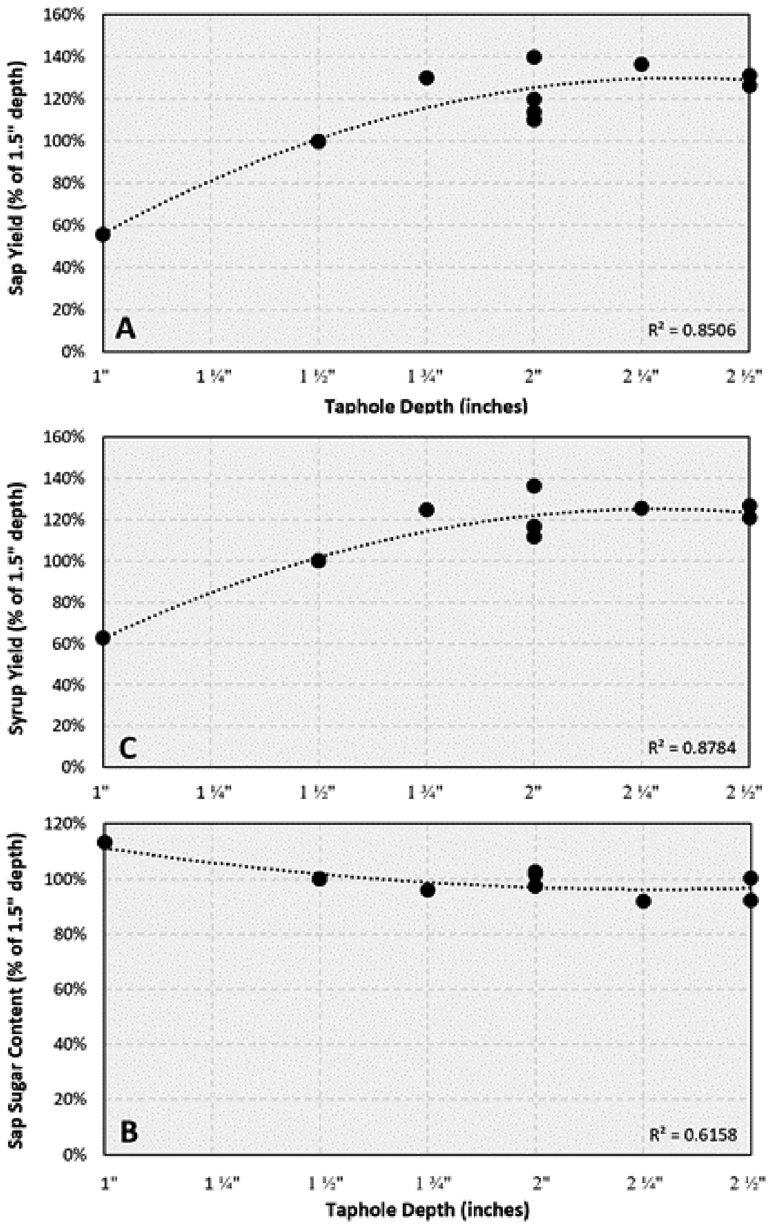

Figure 1. Sap yield (A), sap sugar content (B), and syrup yield (C) from tapholes drilled to depths from 1” to 2 ½” (including bark) in sugar maple stems expressed as a percentage of the tapholes at 1 ½” deep from 2018, 2019, and 2020. Number of independent samples (mainlines) for each depth is indicated in figure C. The R2 value for a fitted 2 order polynomial (dashed line) is shown indicating the proportion of variance explained by the model curve.

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wood, shallower tapholes (1 ½″ or less) may be more appropriate and result in higher yields over the long-term (due to reductions in the frequency nonconductive wood is tapped into), despite the lower syrup yields in the near-term. In these cases, implementing thinning and other management practices to encourage more vigorous tree growth can also help more rapidly bring about conditions where deeper tapping depths, and higher current-year yields, are possible.

Acknowledgements

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