Sustainable tapping guidelines for birch syrup production in the Northern Forest

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- Test tapholes were determined to be the most reliable indicator to determine when to tap birch trees to obtain maximum sap yields.
- The volume of nonconductive wood generated by taphole wounds in birch trees was quite large, and relatively high radial growth rates are required to ensure that tapping is sustainable when following standard tapping guidelines.

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http://www.nsrcforest.org

Project Summary

Maple syrup production is a vital part of the Northern Forest's economy and working landscape, using forests sustainably to harvest and produce a natural product and provide jobs, generate income, and create business opportunities that support prosperous families, communities, and businesses. However, maple producers in the region face increasing challenges to maintaining profitable operations due to rapidly rising costs of production. Adding birch syrup production is a practical way for many producers to address this issue and provide additional revenue to help their operations remain profitable. However, a lack of science-based tapping guidelines and management practices specific for birch sap collection presents significant barriers to both the ecological sustainability and profitability of this practice. Thus, the overall goal of the proposed work is to develop a set of sustainable tapping guidelines and management practices for birch syrup production in the Northern Forest. To accomplish this goal, we conducted a study to determine the volume of nonconductive wood (NCW) generated by taphole wounds in birch trees, and used these data with a model of the tapping zone to determine the growth rates and tapping practices required for tapping birch trees to be sustainable in the long-term. We also conducted an experiment to determine the optimum time to tap birch trees in order to achieve maximum sap yields. Results indicated that the volume of NCW generated by taphole wounds in paper birch trees was quite large, averaging 220 times the volume of the taphole wound. With these NCW volumes, minimum radial growth rates required for tapping birch trees to be sustainable when following standard tapping guidelines ranged from 0.32 to 0.38 cm per year. Modified tapping practices (increased dropline length, reduced tapping depth, etc.) or thinning can be used to increase the sustainability of tapping if minimum growth rates are not present. The optimum timing of tapping was also observed to be quite variable, however tapping trees after test tapholes installed in a few representative trees began to drip sap at a reasonable rate (a few drops per second) was found to be a reliable indicator of when trees should be tapped to obtain maximum possible yields from birch trees. Producers can use this information to ensure that they use tapping practices that will result in sustainable outcomes and obtain the maximum possible sap yields from their trees. This will ultimately help ensure that the addition of birch syrup production will help their maple operations remain profitable, supporting the long-term economic sustainability of maple syrup production in the Northern Forest, and ensuring that it continues to provide economic opportunities in the region through a sustainable use of its forest resources.

Background and Justification

- A key challenge within the Northern Forest region is fostering economic development that supports thriving rural communities while maintaining the integrity of the forested landscape. Maple syrup production is an activity which has traditionally achieved this balance by using the region's forest resources sustainably to provide income and generate jobs and economic opportunities.

- To remain both profitable and viable, maple syrup producers must find ways to compensate for steadily rising costs of production without significantly increasing syrup prices for consumers. Increasing revenues by diversifying maple operations to include the production of birch syrup is a simple and effective solution to this challenge for many producers. Birch syrup is quite valuable (~$80/quart retail), and can be produced using existing equipment in maple operations during a sapflow season that occurs after the maple season ends, using birch trees that are already abundant in and near many maple operations.

- However, a potential barrier to the use of birch syrup production as an ecologically-sustainable method to increase the revenues of maple operations is that specific tapping guidelines and management practices for birch sap collection do not currently exist. Tapping guidelines are a set of best practices, such as spout size, tapping depth, and dropline length, aimed at preventing tree health from being compromised as a result of tapping and sap extraction. They are essential to ensure annual sap collection is a sustainable practice. In addition, other best management practices, particularly the optimum timing of tapping trees, are essential to ensure that sap yields from birch trees are maximized, and thus that birch syrup production is a profitable activity. Thus, it is critical to develop a set of tapping guidelines and management practices for birch syrup production that are science-based, and that both ensure tree health is fostered, and that maximum sap yields can be obtained. This will help make certain that birch syrup production in the Northern Forest will be a sustainable practice that results in the best possible economic outcomes for producers, and that the addition of birch production will help maple operations remain profitable and continue to provide opportunities for economic growth and development in the region.

Background and Justification

- The overall project goal was to develop a set of sustainable tapping guidelines and management practices for birch syrup production in the Northern Forest. This overall project goal was be met by accomplishing 3 supporting objectives: 1) Determine the optimum time to tap birch trees in order to achieve maximum sap yields, 2) Determine the volume of NCW generated by tapholes in birch trees, and 3) Determine the minimum growth rates and tapping practices required for tapping birch trees to be sustainable.

Methods

Timing of Tapping

- 30 healthy paper birch trees at UVM-PMRC were randomly assigned to one of 3 timing of tapping treatments:
  - "Early" (Trees were tapped before pressure development was observed or test taps were exuding sap)
  - "Test taps" (Trees were tapped after test tapholes in nearby trees began exuding sap as a substantial rate, a few drops per second)
  - "End of maple season" (Trees were tapped immediately after the maple production season ended)

- Each tree was tapped with a standard 5/16" maple spout and connected to a plastic chamber that enables the collection and quantification of sap from individual trees under vacuum. Vacuum was maintained throughout the duration of the experiment at standard maple industry levels (~25" Hg). Sap volume and sugar content from each tree were measured daily, and at the end of the production season these data were used to calculate the total volume of syrup equivalent produced by each tree. The experiment was repeated in the 2015 and 2016 seasons, and data from both years were used to calculate the overall mean syrup yields for each treatment.

Methods

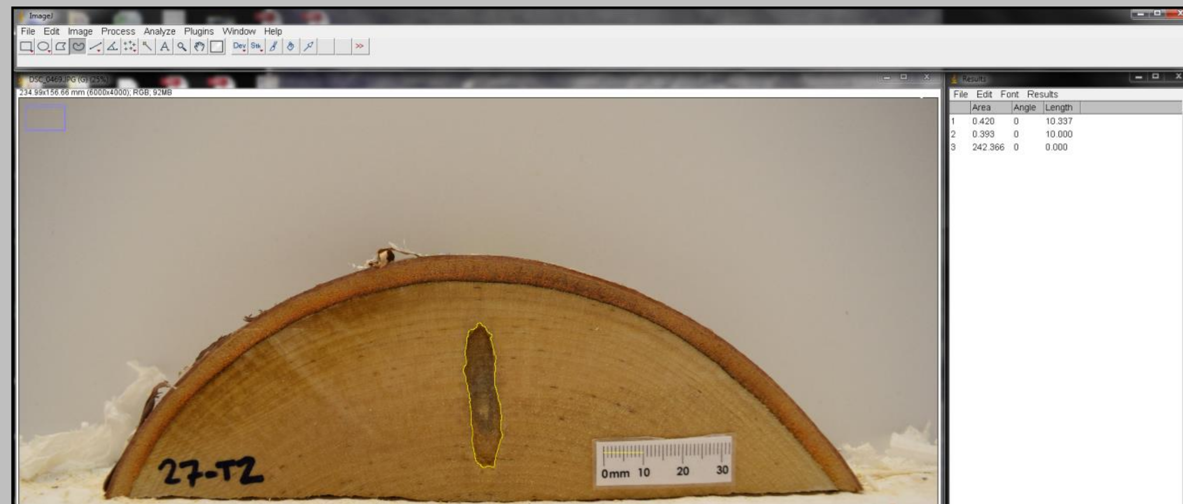
Volume of NCW Generated by Taphole Wounds

- Forty healthy paper birch trees with an average dbh of 9.6” (range, 7.9 – 12.7”) were selected and tapped during the spring 2015 sapflow season following current standard tapping practices (5/16” spout, 2” tapping depth). In fall 2015, each tree was felled, and a portion of the stem containing the taphole wound (approximately 4' above and below the taphole) was cut and removed. Subsequently, each stem segment was cut with a chop saw into 2" cookies beginning in the center of the taphole. Each cookie was then photographed with a scale using a digital camera. The area of NCW in each cookie was then measured using ImageJ image analysis software, and these data were used to calculate the total volume of NCW generated by the taphole in each tree, the volume of NCW in proportion to the size of the taphole wound, and the total length of the NCW column.

Methods

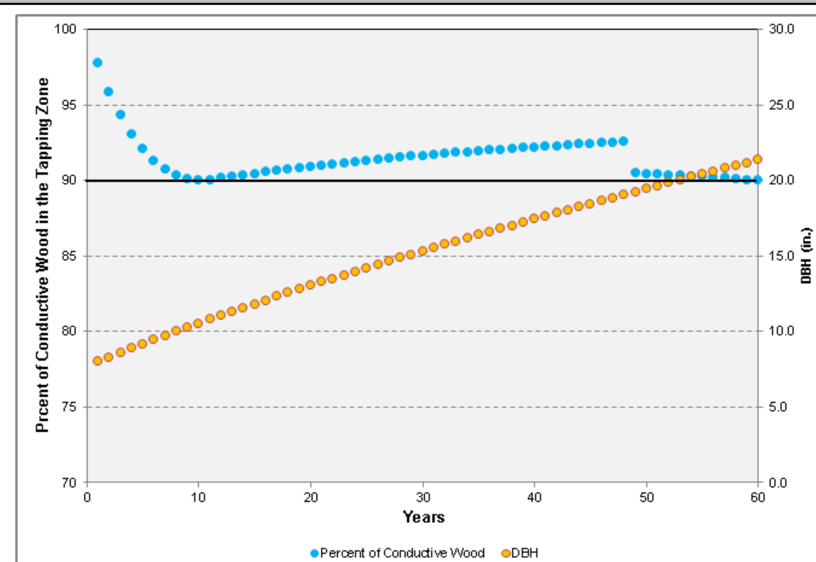
Volume of NCW Generated by Taphole Wounds

- To accomplish Objective 3, NCW volume data were input into a "Tapping Zone" model previously developed by our team (van den Berg *et al.* 2016). The model estimates the proportion of NCW in the tapping zone of a tree over time based on inputs of growth rates, tapping practices (e.g. spout size, tapping depth), and using known values for the volume of NCW generated by each taphole. An excessive accumulation of NCW in the tapping zone will affect tree water transport (as well as sap yields), and indicates tapping practices are not appropriate and that growth rates are not sufficient to replenish the NCW generated by the tapping practices being used. Thus, for tapping to be sustainable, the proportion of NCW in the tapping zone must remain very low with repeated tapping over time, less than 10%, and the model can thus be used to assess the sustainability of various tapping practices. Likewise, growth rates used by the model can be varied to determine the growth rates required for specific tapping practices to be sustainable. The model was used to determine the minimum growth rates required to maintain NCW levels below 10% when using current standard tapping practices (Spout size = 5/16", Taphole Depth = 1.5", Dropline length = 30"), and thus assess the tapping practices required for tapping birch trees to be sustainable in the long-term.



Example of measuring NCW area in an image of a birch cross-section with ImageJ software. Areas were used with cookie depth (2") to calculate NCW volume.

	Enter values into blue cells:
Current tree DBH (inches)	8
Dropline length (inches)	30
Spout size (inches)	5/16
Tapping depth (inches)	1.5
Number of taps	1
Basal Area Increment Needed for NCW to remain less than 90% of the tapping zone (in^2)	**3.9**
Lowest Proportion of Conductive Wood in the Tapping Zone (60 Years)	90%



Output from Tapping Zone Model used to estimate minimum growth rate required for tapping to be sustainable following specified tapping practices

Results
Timing of Tapping

- The birch sapflow seasons of 2015 and 2016 were extremely different from one another, with 2016 marked by exceptionally low sap yields across the northeastern US. The results for each year were thus analyzed separately.
- Data from both years are presented in Table 1. In 2015, there was an overall significant difference in yields between the timing of tapping treatments, with the Early and Test Taps treatments resulting in significantly greater yields (gallons of syrup equivalent) than trees that were tapped after the maple production season concluded. In 2016, there was a marginally significant ($p < 0.08$) overall difference in yields between the timing treatments, however the Early treatment resulted in significantly lower yields than the End of Maple Season treatment. It should be noted, however, that the yields in all 3 treatments in 2016 were approximately 1/3rd lower than in 2015, and this could have impacted any differences observed between the treatments.
- These results indicate that inherent variability in sap yields between years may sometimes confound impacts of the selection of the timing of tapping. However, despite the variability observed, some practical conclusions can be drawn: 1) Waiting until the maple season concludes may result in significantly lower yields in some years, 2) Tapping somewhat early (when using vacuum) is not likely to significantly negatively impact yields, and 3) Tapping trees based on observations of when test tapholes begin running substantially appears to be an effective strategy to ensure optimum yields are obtained.

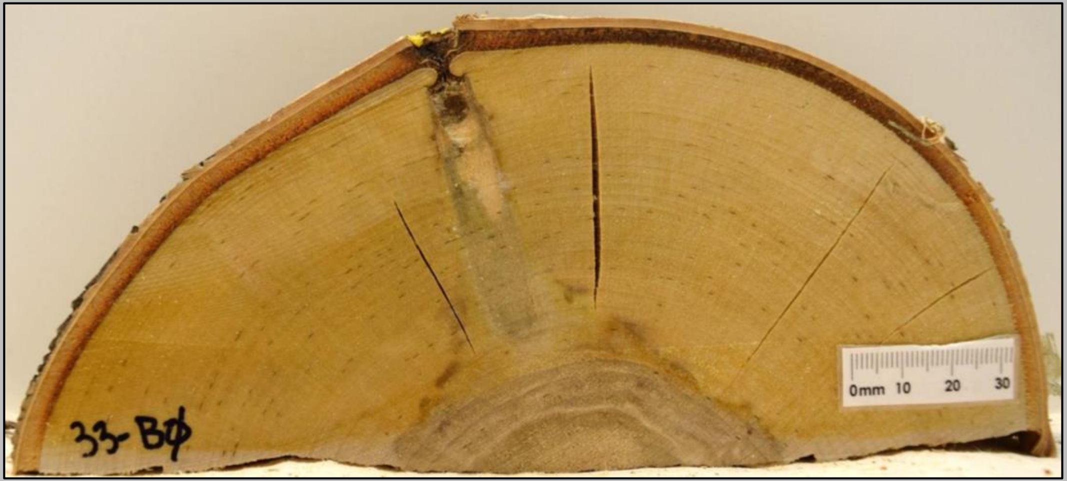
Table 1. Average sap yield, sugar content, syrup yield per tree, and season length for paper birch trees tapped with 3 timing of tapping treatments in 2015 and 2016. *p*-values are for one-way ANOVA comparing overall means syrup yield between the treatments, and individual Students *t*-tests between each treatment. † indicates comparison made with nonparametric Wilcoxon Rank Sums tests.

Treatment	# of trees	Mean Total Sap Yield (gal)	Std Err	Mean Total Syrup Equiv. (gal)	Std Err	Mean Sap Sugar Content (%)	Std Err	Tap Date	End Date	Season Length (days)	Overall Mean	Pairwise Comparisons Early	Test Taps
2015													
Early	9	40.5	10.0	0.37	0.08	0.8	0.04	4/7/15		27	0.0138†	---	---
Test Taps	8	33.8	9.1	0.36	0.10	1.0	0.05	4/14/15		20		0.4705†	---
End of Maple	9	14.9	2.6	0.16	0.03	0.9	0.06	4/19/15	5/3/15	15		0.0062†	0.0485†
2016													
Early	8	12.3	2.7	0.11	0.03	0.8	0.02	3/16/16		50	0.0829	---	---
Test Taps	7	15.8	1.7	0.19	0.02	1.0	0.02	4/13/16		22		0.0745	---
End of Maple	9	17.9	2.4	0.19	0.03	0.9	0.02	4/17/16	5/4/16	18		0.0400	0.8557

Results

Volume of NCW Generated by Taphole Wounds

- The size of NCW columns was highly variable between trees (Figure 1), and columns were generally quite large. Some of this variability appeared to be driven by instances where the NCW column generated in response to the taphole intersected and interacted with areas of existing NCW (the central column of discolored wood, branch scars, etc.), which resulted in much larger or longer NCW columns.

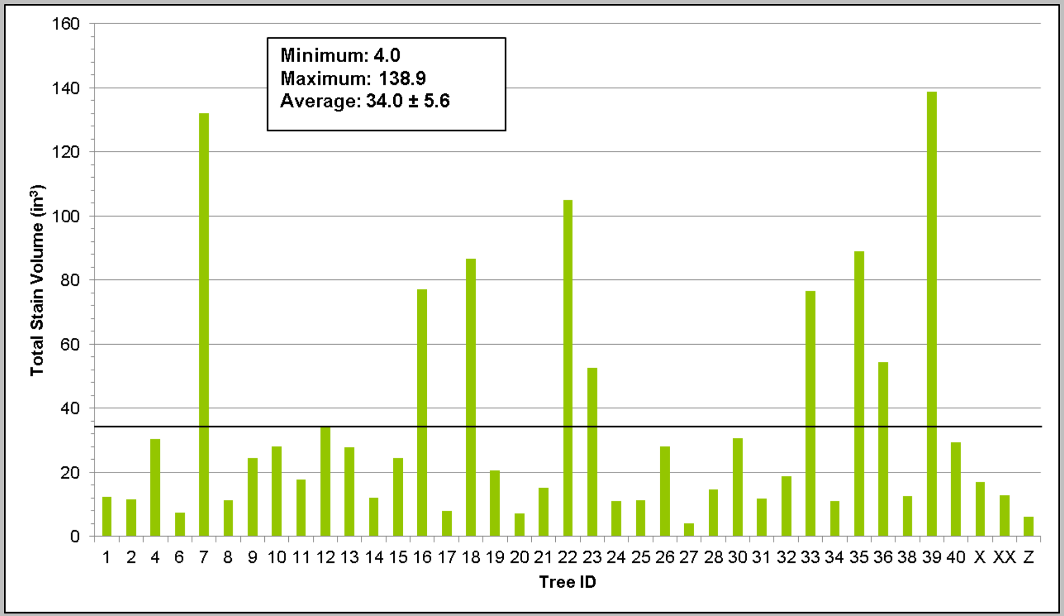


Taphole associated stained wood that has merged with NCW from a pre-existing central column of discolored wood

Example of the upper portion of a NCW column generated in response to a taphole wound in a paper birch tree.

Results

Volume of NCW Generated by Taphole Wounds



- The average volume of NCW was 34.0 in^3 (± 5.6) (Figure 1), and wounds were on average 221.6 (± 36.6) times the size of the taphole wound (Figure 2).

Figure 1. Volume of nonconductive wood generated by taphole wounds in 40 healthy paper birch trees.

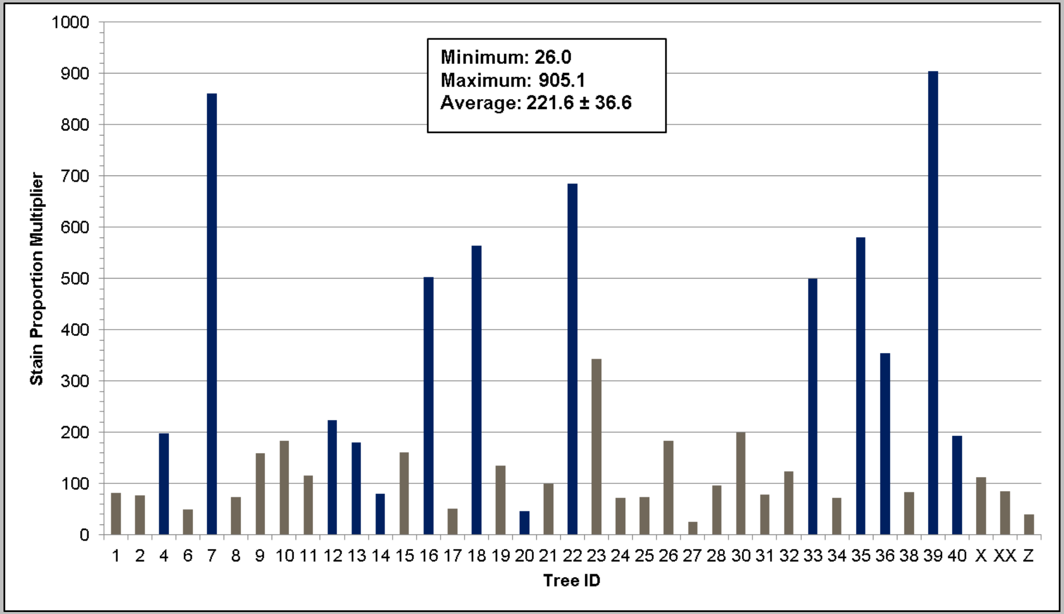


Figure 2. Size of nonconductive wound columns in proportion to the size of the taphole wound in 40 healthy paper birch trees.

Results

Volume of NCW Generated by Taphole Wounds

- These volumes were much greater than those observed previously for maple trees, which have NCW columns that average only 49.2 (± 5.1) times the size of taphole wounds (Figure 3).

- Without any further analyses, these data alone indicate that caution should be used when tapping birch trees for sap collection, as the level of NCW developed is likely to be much greater than typical observed in maple.

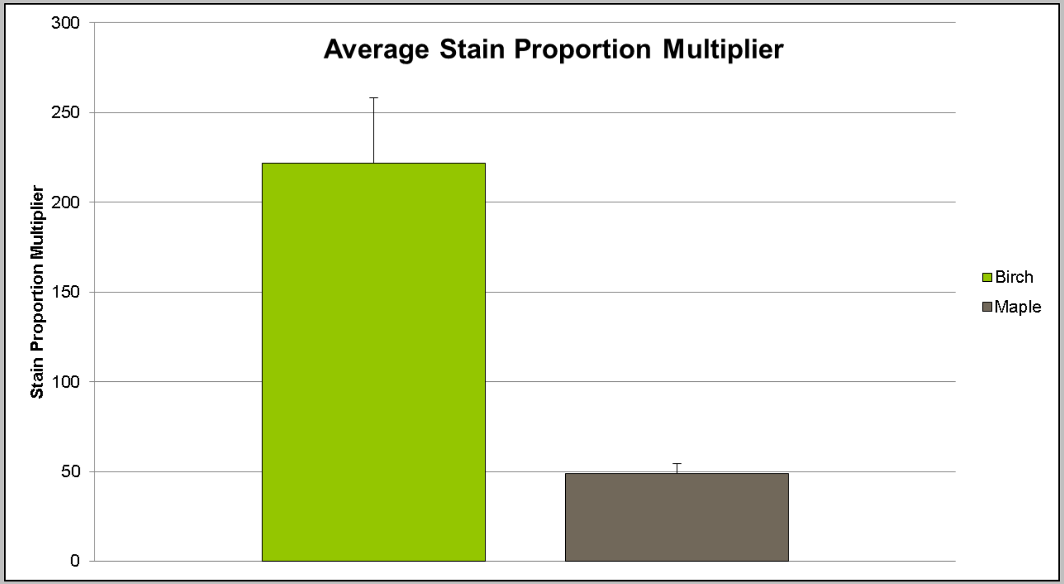


Figure 3. Mean size of nonconductive wound columns in proportion to the size of the taphole wound in paper birch and maple trees. 40 healthy paper birch trees.

Results
Volume of NCW Generated by Taphole Wounds

- The NCW volume data were used with a model of the tapping zone to calculate for trees of each dbh class from 8-22” the minimum growth rates required to maintain a NCW volume <10% of the tapping zone for 60 years when following current standard tapping guidelines. The results indicate that due to the generally large size of NCW columns generated by taphole wounds in birch, birch trees require substantially high radial growth rates in order to ensure an adequate replenishment of conductive wood, and to prevent an excessive accumulation of NCW in the tapping zone (Table 2).

- For producers, growth rates of birch trees to be tapped for sap collection should be checked to ensure sustainability of tapping practices. If growth rates are found to be lower than the required minimums, tapping practices can be modified to increase the likelihood of sustainability (van den Berg *et al.* 2016) – increasing dropline length, reducing tapping depth, and increasing minimum tree diameter can reduce the accumulation of NCW. Stand management practices, particularly thinning, can also be used to increase radial growth rates and enhance sustainability of tapping for sap collection.

Table 2. Minimum growth rates required for NCW in paper birch trees to remain below 10% of the tapping zone volume for 60 years when tapped following current standard tapping guidelines: spout size = 5/16”, tapping depth = 1.5”, dropline length = 30”.

DBH	BAI (cm^2)	Ring width (cm)	BAI (in^2)	Ring width (in)
8	24.9	0.38	3.9	1/7
10	29.3	0.36	4.5	1/7
12	33.8	0.35	5.2	1/7
14	38.3	0.34	5.9	1/7
16	42.8	0.33	6.6	1/8
18	47.3	0.33	7.3	1/8
20	51.9	0.32	8.0	1/8
22	56.4	0.32	8.7	1/8

Conclusions and Outreach Efforts

- Installing test tapholes in representative trees and waiting until sap exudes from these holes at a reasonable rate (a few drops per second) can be used as a reliable indicator of when to tap birch trees to obtain maximum sap yields. Tapping slightly earlier than this when using vacuum is unlikely to be detrimental; waiting to tap until after the maple production season has concluded may result in significantly reduced yields in some years.

- If they have sufficient radial growth rates, birch trees can be tapped sustainably following current standard maple tapping guidelines. If minimum growth rates required are not present, tapping practices can be modified (increased dropline length, reduced tapping depth, etc.) or stand thinning can be conducted to increase the likelihood of sustainable outcomes.

- The study concluded March 30, 2017, so most outreach efforts are just beginning. Presentations of study results will be made to producers and other stakeholders at industry conferences and meetings, including Vermont Maple Extension Conferences and other state and provincial producer association meetings. A technical article and a tapping zone model producers can use to evaluate the sustainability of their practices are in preparation, as is an article for a peer-reviewed scientific journal.

Implications and Applications in the Northern Forest Region

- Producers will be able to use the results of this work to help guide decisions of when to tap birch trees to ensure optimum sap yields are obtained, ultimately increasing the efficiency and profitability of their birch sap collection and syrup production operations.

- Producers will also be able to use these data to guide their tapping practices in order to ensure that tapping their birch trees for sap collection is sustainable over the long-term.

- Ultimately this will help ensure that birch sap collection is a practice that producers in the Northern Forest can use to generate income and increase the profitability of their operations through a sustainable use of the region's forest resources.

Future Directions

- Future research will need to focus on better elucidating the physiological cues that trigger the onset of stem pressure development in birch trees, and forest management practices to maintain sap collection from birch trees in the Northern Forest over the long-term.

List of products

- van den Berg, A.K., Isselhardt, M.L., and Perkins, T.D. 2018. Identifying sustainable practices for tapping and sap collection from birch trees. Agricultural Sciences 9:237-246. DOI: 10.4236/as.2018.93018
- Tapping Zone model for birch sap collection*, electronic resource, (in preparation)*
- “Nonconductive wood generated by taphole wounds in birch trees”, The University of Vermont Extension Vermont Maple Conference, Brattleboro, VT, January 21, 2017.
- “Birch sap yields, sapflow physiology, internal wounding, and tapping practices and guidelines”, 1st International Birch Sap and Syrup Conference, Paul Smiths, NY, June 13, 2015.
- “Birch production in maple operations”, Vermont Agency of Natural Resources, Montpelier, VT, February 24, 2015.
- “Birch production in maple operations”, The University of Vermont Extension Vermont Maple Conference, Hyde Park, VT, January 24, 2015.