Maple Syrup Digest

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Descaling Pans
Invasive Worms

The Newsletter of the North American Maple Syrup Council


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Greetings from your President

As I am writing these notes the holiday season is winding down. I hope everyone had a great Christmas, and I wish everyone all the best for 2018.

Canada and many parts of the US have been thrust into a severe deep freeze with very little relief in sight. The forecasters are saying we are experiencing colder than normal temperatures. This morning, as I headed into work, the wind chill temperature was -39 C. With weather like we are having right now, it is hard to believe many of us will have already started sugaring or will be thinking about it very soon by the time this is printed.

I have heard of a select few that have made syrup already, cashing in on this past fall's freeze-thaw cycle. Congratulations to those who are brave enough to tap in the off-season and receive some of the sap the maples are willing to give up.

Over the past few months, some of the items the Council has been working on behind the scenes include: reviewing our current meetings' structure; adding some more conference calls; producing more supplements for the *Maple Syrup Digest*; possible updates to the *North American Maple Syrup Producers Manual*; and updates to our website, to name a few.

We especially want to hear from producers about the *Manual* and whether publication of a revised edition would be valuable to you. Please take a moment to complete a brief online survey to help inform our decision. You can find the link on our homepage at www.namsc.org.

If your local associations or municipalities have maple events, festivals or functions please send us the information as soon as possible so we can get them on the Maple Month site, at http://www.maplemonth.org/.

Many thanks to those who have contributed to the Digest. Thank you, Winton, for your continued hard work, and hats off to the researchers, specialists, producers, advertisers, dealers, and many others. Keep up the good work and keep the articles and submissions coming.

There was a huge list of contributors to the North American Maple Syrup Council Research Fund published in the last edition of the *Maple Syrup Digest*. I would like to thank each and every one of you. Without your continued support, research in our industry would be very difficult, limited, or not exist at all. Again, thank you and please feel free to contribute to the fund at any time (see page 46).

With the ever-increasing costs of maple equipment, labour, fuel, packaging materials, containers and many other expenses, we must be that much more efficient in our operations. Take the time this season and invest in making sure your collection system is clean, tight, free from leaks, and set up properly. Whether you use buckets or tubing, if you don't have

President: continued on page 7

In this issue...

President: continued from page 5

sap you can't produce syrup.

Be careful with your final product. Taste every batch and make sure you pack it at the right temperature, you have the right density, and that you have the clearest syrup possible.

All the best to everyone this maple season, and may we all experience an abundant and flavourful crop.

Cheers,
David Briggs, President, NAMSC

Cover photo: Gathering sap at the Kidder Sugarhouse in Copengagen, NY. 1930's. Courtesy of the collection of Michael Girard.

We want to hear from you!

The Council would like guidance from sugarmakers about a number of our projects.

Research grants: Are there particular topics you'd like the Council's Research Fund to support research on?

***Digest* supplements:** Are there topics you'd like to see covered in upcoming practical skills guide supplements to the *Maple Syrup Digest*?

Please email your ideas to editor@maplesyrupdigest.org.

And please fill out the form gathering information to inform future versions of the *North American Maple Syrup Producers Manual*. Follow the link at www.namsc.org.

Effect of Chemical Descaling of Evaporator Back Pans During the Season on the Properties of Maple Syrup

Fadi Ali, Jessica Houde, Stephane Corriveau, Carmen Charron, Mustapha Sadiki
Centre de recherche, de développement et de transfert technologique acéricole Inc.

Maple sap is processed into syrup on an open traditional evaporator by a thermal treatment. Increasing the Brix during evaporation involves the concentration of elements existing naturally in the sap, such as sugars and mineral ions, to almost a saturation point. Many reactions can occur during the evaporation step between some of these ions and other compounds like organic acids (Allard and Belzile., 2004). This will result in the formation of suspended heavy complex in the syrup. Some of these complex will deposit on the surface of evaporator pans as scale which will form a persistent layer during heating (Isselhardt et al., 2002).

Many factors can affect the rate of scale formation, such as sap composition, sugar content of concentrate feeding the evaporator, intensity of heating, depth of liquid, and the roughness of the pan's surface. A rough surface will have a greater tendency to promote nucleation and scaling than a smooth surface (Arzate et al, 2013). Air injection for instance, does not have the potential to lower the thickness of scale formed on evaporator pans (Van den Berg et al, 2009).

The scale can take many forms depending on its chemical composition. Calcium, magnesium and manganese are the most common minerals found in scale (Isselhardt et al., 2002). The amount and characteristics of scale will also change throughout the season and from one season to another depending on the composition of the sap (Gallander, et al., 1967; Perkins and Van Den Berg, 2009). Unfortunately, very little data is available on the chemical composition of scale such as sugars, mineral salts and organic acids.

The presence of scale is known to cause many problems, such as the overheating of the evaporator, the reduction of heat transfer, and the efficiency of production, which will affect the color and flavor of maple syrup (Heiligmann et al., 2006). To overcome these problems, a periodic shutdown and cleaning of the evaporator is necessary to remove the scale from the surface of the evaporator. Many methods can be used like manual clean, descaling with a food grade acid solution with or without reversing the flue pans (Allard and Belzile., 2004; Perkin and Van den Berg, 2009). Many acid detergents are available for maple syrup producers. These detergents are composed of various acids like Phosphoric, Nitric, Chloric, and Sulfuric and their salt complex. Vinegar (acetic acid) is naturally present in maple sap (Lagacé et al, 2015). For this reason, acetic acid was chosen to be tested for cleaning the back pans during the season. The objective of this work was therefore to investigate the effects of using this acid on the chemical composition and the sensory quality of syrup produced after cleaning. The main goal is to ensure that no acid residues can be found in syrup and that its sensory properties are not affected.

Cleaning operation:

Maple syrup producers regularly experiencing a scale formation problem in their evaporator were solicited to participate in this project. Four producers from different regions of Quebec, Canada were chosen based on specific criteria (availability of equipment, number of taps, number of annual cleanings). The size of the sugarbushes studied ranged from 10,000 to 20,000 taps. Three producers had a traditional evaporator and one producer had an evaporator equipped with an automatic cleaner. Two of the traditional evaporators were wood-fired evaporators and the other two were oil-fired. All producers used sap concentrate from 11 to 15 °Brix to feed their evaporator. The brix of concentrate was maintained at the same level before and after cleaning.

Three tests (ER-1, ER-2 and ER-3) were carried out on the evaporator equipped with an automatic cleaner between the middle and end of the season while one test was made on each of the three traditional evaporators (ER-4, ER-5 and ER-6) at the middle of season. So the cleaning procedure was repeated three times for each type of evaporator. Thirty-one barrels of syrup (32 imperial gallons each) were produced between each cleaning test on evaporator equipped with automatic cleaner. However, 45 to 88 barrels of syrup were produced before cleaning on each traditional evaporator at the middle of season. Heat intensity and liquid depth in back and front pans was maintained at the same values before and after cleaning to avoid their effect on the quality of produced syrup. Before cleaning, processed sap was removed from back and front pans at the end of production. Then, physical state of scale on the pans was recorded. Pans were then rinsed with cold water by a pressure washer before acid solution was applied.

Cleaning was made with a diluted solution of acetic acid at a concentration varying from 3.5% to 3.9%. Cleaning and rinsing procedures were adapted depending on the type of evaporator. For the traditional evaporators, cleaning was carried out according to the following steps:

1. Cleaning procedure:

   a. Cleaning solution was prepared in the feeding tank of the evaporator by adding acetic acid concentrated at 56% to a predetermined filtrate volume. This method was employed to avoid many potential risks (fall, splash) of adding the concentrated acid directly into the back pans and to ensure the homogeneity of the solution. The required volume of water was set in order to be slightly greater than the volume of back pans.

   b. The cleaning solution was then transferred to back pans.

   c. The solution was heated to 80-85°C (176-185°F) by running the evaporator to reach the required temperature and then turned off.

   d. The pans were left filled with the hot cleaning solution overnight.

2. Rinsing procedure:

   a. The next morning, the cleaning solution was removed and the pans were rinsed many times with water. First, a primary rinse was made with a pressure washer to remove soft, wet pasta-like scale and to detach some remaining small pieces of scale.

Scaling: continued on page 11

Scaling: continued from page 9

b. Then, a second rinse was done by immersing back pans into cold filtrate for at least five minutes.

c. The last rinse was made by filling the pans with new filtrate, then heating it to boiling by running the evaporator and keeping the pans immersed for at least five minutes.

d. Three samples of the last rinsing solution (hot filtrate) were taken from three different places in the pans for pH measurement. If the average pH was higher than 5, rinsing was satisfactory and finally completed with a last rinse by pressure washer with a cold water or filtrate. However, if pH was less than 5, second rinse was made with another hot filtrate.

For the evaporator equipped with an automatic cleaner, cleaning was made according to the following steps:

1. Cleaning procedure;

a. Cleaning solution was prepared in a separated tank by adding concentrated acetic acid at 56% to a predetermined volume of hot filtrate at 80-85°C (176-185°F).

b. Then, hot cleaning solution was recirculated in the back pans with an automatic cleaner during many hours until the pans became clean. The number of cleaning hours depended upon the thickness of the scale and the percent of the pan surface covered.

2. Rinsing procedure;

a. After cleaning, the solution was discarded and the same steps to rinse the pans from the cleaning agent were followed. First, a primary rinse was made with cold water using a pressure washer.

b. Then, cold filtrate was recirculated in the pans by the automatic cleaner for 15 minutes followed by a recirculation of new hot filtrate during an additional 15 minutes.

c. The pH of the final filtrate was measures as it was for the traditional evaporators, following the same procedure to determine if rinsing was completed. A final rinse with cold water was made with the automatic cleaner for 10 to 15 min.

Sampling:

Two samples of sap concentrate feeding the traditional evaporator were taken during the last hour before cleaning and during the three hours after cleaning. Likewise, samples of corresponding syrups were taken before and after cleaning. Two samples of sap concentrates and produced syrup were taken during the last hour before cleaning. Likewise, samples were taken during three hours of syrup production after cleaning.

Samples were taken also from the last hot filtrate used to rinse the pans. Total soluble solids (Brix), pH, conductivity, and acetic acid content were measured for those samples. Content of mineral ions were measured in all produced syrups.

Properties analyzed:

The pH of samples was measured by using a PHM82 Radiometer pH-meter supplied by VWR (Toronto, ON, Canada). Total soluble solids were measured by an AR200 Digital Hand-Held refractometer of Reichert Scientific Instruments (Buffalo, NY, USA). The electrical conductivity was measured by an electric conductivity meter (WTW; COND 3400i). Minerals analysis was

Scaling: continued on page 13

Scaling: continued from page 11

analyzed by ICP/OES, optima 430 from PerkinElmer (Woodbridge, ON, Canada) by the IRDA laboratory. Acetic acid was analyzed using a Shimadzu Prominence liquid chromatographic system purchased from Mandel Scientific (Guelph, ON, Canada). The sensory evaluation of produced syrups was assessed by three experts of Maple Syrup Inspection Division of Centre ACER. Statistical analysis of data was performed using XLSTAT (Addinsoft, Paris, France). Mean values for concentrated sap were compared using analysis of variance (ANOVA) with the Tukey multiple comparison test to evaluate the significant difference between the means ($p < 0.05$). Standard deviation (SD) is presented alongside the means in tables of results.

Results and Discussion:

Descaling and rinsing efficiencies

Scale formed on back pans of tested evaporators varied from a brown and white-beige crust to a simple orange-brown film (Figure 1). The average thickness of measured scale was 0.22 mm. Cleaning with acetic acid solution removed the scale in both evaporator types. The removal rate reached 100% for the traditional evaporators and varied between 75% to 95% for the automatic cleaner evaporator, depending on the time of the cleaning cycle and the volume of syrup produced before cleaning.

Figure 1: Sample of dried scale recovered from back pans of traditional evaporator.

As cited above, producers with traditional evaporators produced more barrels of syrup before cleaning than those equipped with an automatic cleaner. Consequently, time of cleaning varied from 2.5 hours to 15 hours for the evaporator with automatic cleaner and from 12 to 18 hours for the traditional evaporators.

Average physicochemical characteristics of hot filtrates used for rinsing the pans of both types of evaporator are shown in Table 1. After rinsing, the last hot filtrates had a pH higher than 5.0 for both systems with very low concentration of acetic acid. However, the pH of the last filtrate used for rinsing the automatic cleaner evaporator was higher than pH of filtrate obtained with the traditional evaporator. A lower residual concentration of acetic acid in this filtrate was also observed (less than the quantification limit). This indicates that a complete removal of residual acetic acid from the surface of the pans was accomplished. Results shown in Table 1 show that no traces of acetic acid remained in the pans of the evaporator, especially when the pH of the final rinsing filtrate was higher than 6. The electrical conductivity of filtrates was also found to be low after rinsing both type of evaporators. It increased very slightly after rinsing from 14 to 17 (µS/cm) indicating a removal of similar amount of mineral ions remained on back pans.

Scaling: continued on page 14

Parameters	Automatic cleaner		Traditional	
	Before rinsing	After rinsing	Before rinsing	After rinsing
pH	6.4 ± 0.2[a]	6.3 ± 0.1[a]	6.2 ± 0.5[a]	5.3 ± 0.4[b]
Electrical Conductivity (µS/cm)	24.4 ± 25.3[a]	38.9 ± 27.3[b]	7.7 ± 1.7[a]	25.5 ± 7.3[b]
Acetic acid (mg/kg)	0.07* ± 0.0[a]	0.8* ± 0.6[a]	0.25* ± 0.0[a]	9.6 ± 7.9[b]

*: concentration is less than quantification limit=1 (mg/kg).

Table 1: Physicochemical properties of last hot filtrate before and after rinsing of back pans for the two types of tested evaporators.

Scaling: continued from page 13

Syrups composition and properties:

Syrups produced before and after cleaning had similar chemical characteristics. No significant changes in the Brix, pH and electrical conductivities were observed on tested syrups (Table 2).

Likewise, syrups had similar content of main mineral ions as shown in Table 3. Potassium (K+) and calcium (Ca++) remained the two main mineral ions in all produced syrups. The concentration of calcium and phosphor was increased slightly in syrup produced after cleaning the evaporator with the automatic cleaner. This is probably related to the higher heat transfer of cleaned pans, which led to a reduction of syrup's cooking time

Type of evaporator	Automatic cleaner		Traditionnal	
Parameters	Before cleaning	After cleaning	Before cleaning	After cleaning
Brix (%)	67.5 ± 0.3[a]	67.6 ± 0.5[a]	66.1 ± 0 9[b]	66.5 ± 0.4[b]
pH	6.8 ± 0.2[a]	6.7 ± 0.2[a]	7.0 ± 0.3[b]	7.0 ± 0.04[b]
Electrical Conductivity (µS/cm)	198 ± 38[a]	208 ± 49[a]	230 ± 50[b]	208 ± 35[b]

Values with the same letter are not different significantly ($p > 0.05$).

Table 2: Physicochemical properties of maple syrups produced before and after cleaning with solution of acetic acid.

and the precipitation of these ions on the pan's walls.

Light transmittance of most of the syrups produced after cleaning was increased, especially for syrup produced on evaporator (ER-6) which increased by 13.9%. Slight decreases from 1% to 5.7% occurred with syrups produced on the evaporators (ER-4) and (ER-2).

This later increase is possibly due to a greater heat transfer in back pans after removing the thick scale formed during the production of 88 barrels of maple syrup. Even with this noticeable increase in transmittance, syrups remained in the same color class as before cleaning. In general, chemical cleaning with a solution of acetic acid allowed the production of a syrup with a similar or higher transmittance in comparison to those produced before cleaning.

Sensory evaluation showed that, after cleaning, syrups retained the same taste as before cleaning. Two syrups of each evaporator type had good taste before and after cleaning. One syrup with a good taste but a light off-flavor was also detected for both types of evaporator before and after cleaning. Therefore, this specific light off-flavor seems to be persistent even after a cleaning operation (Table 4).

According to these results, cleaning of back pans with acetic acid solution as

Scaling: continued on page 16

Content (mg/L)	Automatic cleaner		Traditional	
	Before cleaning	After cleaning	Before cleaning	After cleaning
Potassium (K^+)	2476 ± 253[a]	2508 ± 217[a]	2466 ± 654[a]	2405 ± 644[a]
Calcium (Ca^{++})	818 ± 525[a]	1090 ± 844[b]	715 ± 367[a]	808 ± 318[a]
Magnesium (Mg^{++})	189 ± 55[a]	210 ± 78[a]	248 ± 89[a]	253 ± 69[a]
Manganese (Mn^{++})	3.3 ± 2.3[a]	7.4 ± 9.2[a]	50 ± 80[a]	38 ± 58[a]
Phosphor (P^{+++})	4.7 ± 3.9[a]	8.2 ± 9.6[b]	6.2 ± 4.6[a]	5.0 ± 3.1[b]

Values with the same letter are not different significantly ($p > 0.05$).

Table 3: Contents of mineral ions in maple syrup produced before and after cleaning with acetic acid (mean ± SE).

Type of evaporator	Automatic cleaner		Traditional	
Syrup taste	Before cleaning	After cleaning	Before cleaning	After cleaning
Good flavor	2	2	2	2
Good with light off-flavor (√-VR4)*	1	1	0	0
Good with light off-flavor (√-VR1)*	0	0	1	1

√: Slight trace of undesirable taste and odor.
VR1: Unpleasant taste and odor of natural origin.
VR4: Unpleasant taste and odor of unidentified origin.
*: According to table of syrup taste classification by inspection division of Centre ACER

Table 4: Taste of maple syrups produced before and after cleaning of both tested evaporator types.

Scaling: continued from page 15

it was performed in this study would not significantly affect the composition and the commercial properties of maple syrup.

Contents of acetic acid

The average concentration of acetic acid in syrups produced before and after cleaning are presented in table 5. In general, it showed no significant increase in the concentration of acetic acid in syrup produced after cleaning of evaporators. No significant increase was recorded in syrup produced after cleaning of three evaporators tested (Er-1, ER-3, and ER-4). Also, a significant decrease in acetic acid in syrups produced after cleaning was observed for two evaporators (Er-5 and Er-6).

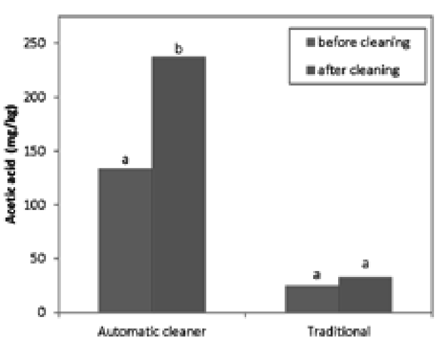

Figure 2: Average concentration of acetic acid in maple sap concentrates before and after cleaning of tested evaporators.

So, syrups produced with five tests did not show any significant increase in the concentration of acetic acid related to cleaning with acetic acid. Syrup produced after cleaning of evaporator Er-3 had a notable but not significant increase while syrup produced after cleaning of evaporator Er-2 had a light but significant increase. This increase stayed during the three hours of production of a large volume of syrup following cleaning which would not be realistically related to residual amount of acetic acid used for cleaning. This can be explained by the sharp increase of average concentration of acetic acid in sap concentrate used immediately after cleaning of the evaporator equipped with automatic cleaner (Figure 2). This increase would hardly come from a residual amount of acetic acid knowing that the concentration of acetic acid was stable and relatively high in sap concentrates during the three hours of production after cleaning for Er-2 and Er-3.

Further, the average concentration

Type of evaporator	Sugarbush	Concentration of acetic acid (mg/kg)		FC-(acid/°Brix) (after/before)
		Before cleaning	After cleaning	
Automatic cleaner	ER-1	303 ± 4.9^{a}	304 ± 5.7^{a}	0.9
	ER-2	356 ± 10.4^{a}	418 ± 29^{b}	1.0
	ER-3	1093 ± 52^{a}	1780 ± 436^{a}	0.9
	Average	**584 ± 442^{a}**	**834 ± 821^{a}**	**0.93**
Traditional	ER-4	220 ± 8.2^{a}	171 ± 40^{a}	0.6
	ER-5	639 ± 6.7^{a}	357 ± 76^{b}	0.7
	ER-6	357 ± 70^{a}	298 ± 20^{b}	0.6
	Average	**405 ± 214^{a}**	**275 ± 95^{b}**	**0.64**

Values with the same letter are not different significantly ($p > 0.05$).

FC: concentration factor

AF: after cleaning

BE: before cleaning

Table 5: Average concentration of acetic acid in maple syrup produced one hour before and three hours after cleaning with acetic acid (mean±SE)

of acetic acid in the last hot filtrate after rinsing of back pans of these evaporators was very low and around 0.6 (ppm). It is likely, however, that microbial activity in sap concentrate was stimulated after the cleaning. This is specially observed for the third test performed at the end of season (Er-3) when the atmospheric temperature was higher. The concentration of acetic acid in the syrup produced before cleaning of Er-3 was 3.6 times higher than concentration recorded in syrup produced in Er-1 (Table 5) showing a great variation in the natural concentration of this compound. Therefore, this apparent increase could be explained by the naturally higher concentration of acetic acid previously found in the corresponding sap concentrate used immediately after cleaning of this evaporator.

As explained above, acetic acid is an organic acid which is present naturally in maple sap. So, to follow the variation of its concentration between sap concentrates and corresponding syrups, concentration factor of this acid between these products were estimated. This permitted evaluation of the presence of residual amounts of cleaning acid in produced syrups. The ratio of concentration factors after cleaning and before cleaning was less than one for all tests (table 5). This shows that the concentration of acetic acid in syrup produced after cleaning of all evaporators including Er-2 and Er-3 is related to its natural concentration found in the corresponding collected concentrates.

Since no change was observed in the concentration of acetic acid in sap concentrate used for traditional evaporators (Figure 2), no increase was recorded in its concentration in the corresponding syrup produced after cleaning (Table

Scaling: continued on page 19

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Scaling: continued from page 17

5). This is also the case for syrup produced after cleaning of evaporator ER-1 at the middle of season. Therefore, we can assume that syrups produced after cleaning with both types of evaporator do not contain significant amounts of residual acetic acid used for cleaning.

Conclusion

Back pans of evaporators can be effectively cleaned with a 4% solution of acetic acid. This is a simple and low cost method for pan descaling during the season. The results showed, first, that cleaning with acetic acid solution allowed a good descaling of pans. Second, the composition and properties of syrups produced after cleaning were similar to those of syrup produced before cleaning. Third, syrups produced after cleaning were not affected by residues of acid when a good rinsing procedure was employed such as the one performed in the present work. It is recommended to ensure that the pH of the last hot rinsing filtrate is higher than 6.0 after cleaning. This way, descaling of back pans of evaporators with acetic acid during the sugar season can be a safe and suitable method for the production of regular and certified maple syrup.

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Do invasive Worms Threaten Northeast Maple Forests?

Margaret Skinner, Jessica Rubin, Josef Gorres & Bruce L. Parker
Entomology Research Laboratory, University of Vermont

Some maple producers have reported low sugar maple regeneration that could be related to the presence of worms. Earthworms are not native to Canada and most of the northeastern USA. While European species have been here since colonization by early settlers, Asian earthworms have only recently become established in northern hardwood forests. This second wave of invasion by *Amynthas* species is of concern to forest ecologists because of its potential disruption to the forest.

Amynthas species are commonly known as Alabama jumpers, snake worms, wrigglers or crazy worms because of their very active behavior. Earthworms have always been thought to be native organisms that enhance soil fertility. Few realize that most are actually exotic or that some species are invasive and pose a threat to sugarbush health by consuming the soil organic layer and disturbing the forest floor structure and chemistry. While the worms won't directly kill trees, the profound changes in soil fertility, biodiversity and physical soil structure that they cause may reduce maple seedling regeneration and could jeopardize future sugaring plans.

Over the past three years, scientists at the University of Vermont have gathered data in northeast maple forests to determine if these nonnative species affect forest soil structure, understory plant diversity, maple regeneration, and invasive plant species. This article highlights our findings from research conducted in sugarbushes in Vermont, New Hampshire, Massachusetts, New York, and Connecticut, covering five USDA plant cold hardiness zones: 4a, 4b, 5a, 5b and 6a.

Earthworm biology

Earthworm biology is complex, having two reproductive strategies. Some species are hermaphrodites with both female and male reproductive organs in the same individual. These reproduce sexually and are genetically diverse. Other species are parthenogenic which usually lack male organs and reproduce asexually. For these species it takes just one worm to start a new colony and invade a forest.

We estimate that one *Amynthas* worm can produce as many as 20 cocoons per season; each cocoon containing 1-3 eggs. They are an annual organism. The eggs within the cocoon hatch in the spring as temperatures warm. Adults die in November with the onset of winter. However, a 90-day growing season is sufficient for earthworms to become reproductively mature and produce the next generation. Cocoons of most earthworms are very resistant to adverse conditions and are cold hardy to -40oF, making worm management very difficult.

There are several groups of earthworms, each occupying a distinct area in the forest floor. *Amynthas* spp. and *Lumbricus rubellus* live in the litter and humus and are likely the most damaging worms in sugarbushes. They deprive plants of their germination medium and the place where most of their roots intermingle with mycorrhizal fungi. In contrast, *Lumbricus terrestris*, the common night crawler, makes deep, vertical burrows, where it drags leaf litter and then feeds on fungi and bacteria that grow on it. They cap off their burrows with piles of castings (called middens) to prevent predators from entering.

In the northern hardwood forest, earthworms can contribute to a reduction in understory vegetation, including less maple seedling survival. The loss in maple seedlings has been attributed to an interaction between the effect of earthworms and deer browsing. Earthworms indirectly reduce the density of understory herbaceous vegetation, leaving only young woody vegetation on which the deer feed.

Research questions

1. Which worm species are present in sugarbushes and in what cold hardiness zones?
2. Is there a relationship between the presence of earthworms and maple regeneration?

Methodology

Over the past three years, we have sampled in 35 different sugar maple stands in five cold hardiness zones. In each stand we selected four 1 m2 plots in which we counted and identified the understory and overstory vegetation. We also examined the area within a 5-m radius, counting maple seedling and sapling, and invasive plant species. In two of the plots we used the standardized Invasive Earthworm Rapid Assessment Tool (IERAT) to rank damage to the forest floor. An IERAT score of 1 indicates no damage, while 5 indicates severe damage. The rating is based on inspecting the age of leaf litter, extent of the organic horizon, and signs of earthworms (middens and casting layers). In these two plots we also examined the earthworm community, excavating a ¼-m2 area to a depth of 4-6 inches and counting the species present.

Findings

Earthworms, including the most destructive *Amynthas* species, were found in all cold hardiness zones examined. In sites with worms, densities of 8-28 earthworms per square meter were typically found. Other minor worm species were also encountered. Over the 3-year period, more than 50% of the sites sampled were rated as heavily damaged (IERAT 4-5); whereas 31% were ranked as no- or low-damage (IERAT 1-2) (Figure 1).

Worms: continued on page 23

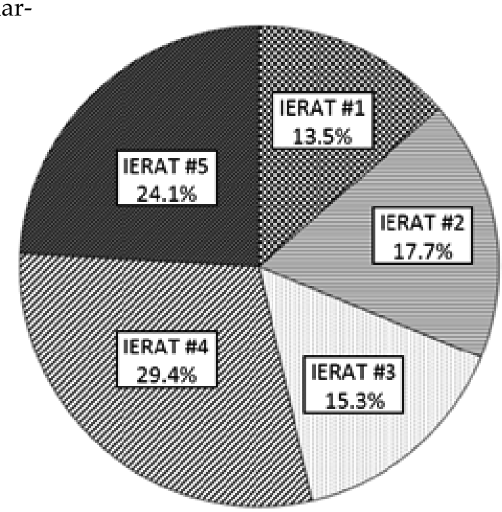

Figure 1: Percentage of sugarbushes according to IERAT damage category (1 = no damage; 5 = severe damage), averaged over the 2015-2017 study period.

Worms: continued from page 21

Maple forests with the highest damage ratings were infested with *Amynthas* spp. and *Lumbricus terrestris*. Amynthas worms voraciously devour leaf litter, leaving in their wake a thin leaf litter layer and an extensive layer of loose, granular castings. The net effect is fewer herbaceous plant species and maple seedlings. *L. terrestris* also caused extensive damage, resulting in limited leaf litter in late spring and a compacted soil surface. The presence of these species usually resulted in an IERAT damage class of 5.

There were instances where worms were not observed but forest damage was still detected. This may be because earthworms are not active year round, and can be missed depending on the sampling time. *Lumbricidae* are often inactive in the summer and burrow down for protection from heat and drought, and can escape detection under these conditions. Earthworms in the family *Megascoecidae* tend to be active in the summer, but their numbers vary greatly depending on moisture and temperature. The characteristic forest damage recorded by IERAT implies the presence of worms, even if they are not observed. For this reason, our analysis uses forest damage class rather than worm abundance as the independent variable.

We found that a higher IERAT damage rating did not reliably predict understory plant diversity, nor the occurrence of invasive plant species. However, the number of maple seedlings decreased as the IERAT damage class increased. In addition, when *Amynthas* worms were present, the number of maple seedlings was always greatly diminished. No maple seedlings were found in *Amynthas*-

Worms continued on page 26

Worms: continued from page 23

infested sites located in cold hardiness zones 4a, 4b and 5a. In zones 5b and 6 (in Connecticut), seedlings were present even when *Amynthas* worms were observed, suggesting that multiple factors affect the amount and diversity of the understory vegetation.

Solutions

There are no management solutions currently because all known vermicides (agricultural chemicals toxic to earthworms) have been banned and no new ones are certified or on the market. Therefore, when possible, prevention is the best strategy. If you don't yet have invasive earthworms in your sugarbush, make every effort to keep them out. Typical vectors include discarded fish bait (esp. night crawlers), plant exchanges by garden clubs and distribution of horticultural material (plants, soil, mulch, compost). Don't throw away used plant or soil material associated with other horticultural or agricultural activities in the vicinity of a sugarbush. Inspect nursery materials, and if they are infested with worms or their cocoons, wash off the roots before planting. Discourage fishing with live bait in or near sugarbushes. Monitor your forests for earthworm damage by looking for earthworm castings, diminished organic layers and decreases in understory plants.

If earthworms have already invaded your sugarbush, plant species with deep taproots to help stabilize the trees as the forest floor structure changes. Increase the amount of organic matter on the forest floor by leaving branches and other plant debris in your sugarbush. Work is underway to devise ecologically sound management solutions, including naturally-occurring microbial organisms, such as entomopathogenic fungi or bacteria. Stay tuned for new developments in this sector.

References

Worm Watch: a science-based education & national volunteer monitoring program used to identify ecological changes in the environment (https://www.naturewatch.ca/wormwatch/)

Great Lakes Worm Watch: valuable resource of research, worm identification, forest ecology, resources (http://www.greatlakeswormwatch.org/)

Vermont Invasives: information about identification, biology, management, distribution, and citations for earthworms and many other species (https://vtinvasives.org/invasive/earthworms)

UVM Entomology Lab: http://www.uvm.edu/~entlab/Forest%20IPM/Worms/InvasiveWorms.html

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Ask Proctor

Timothy Perkins, Ph.D., Director
University of Vermont Proctor Maple Research Center

The University of Vermont
Proctor Maple Research Center

Why are my tapholes leaking, and what can I do about it? *(Part 2)*

The previous article focused on one type of "leaking" taphole issue that maple producers commonly experience. This time I'll focus on yet another question about "leaking" tapholes, which is the presence of small bubbles near the spout. Very often neither of these are actual leaks, but instead, are merely what are perceived by producers to be leaks.

This type of "leak" is indicated by the presence of very small bubbles as sap exits the taphole. Close to the tree the bubbles are tiny, but grow in size as they move out of the spout and into the dropline. One important characteristic is that these bubbles move fairly slowly, perhaps an inch every couple of seconds.

Rather than being leaks in the spout/tubing system, these small bubbles are actually gases coming out of the wood of the tree and are quite natural. Like most living things, trees respire as they utilize stored sugars as part of their normal metabolic processes. The gases produced during respiration result in emboli (bubbles) in the wood vessels. In order for transpiration to occur in the summer, these emboli must be eliminated from the tree's plumbing system. Typically, in maple trees, this happens through the dissolution (dissolving) of bubbles back into solution during the buildup of pressure within the stem in the spring. The higher pressure that is generated dissolves the gas bubbles back into the liquid, and the vessels are thus rendered functional again, and ready to supply leaves with water. However, if there are wounds in the stem, as pressure builds up, these gas bubbles can also escape along with the sap that is exuded.

Years ago, when buckets were used for sap collection, there really wasn't much notice taken of this phenomenon. Although scientists have known for a long time of the gases produced by trees, many maple producers didn't – there wasn't any real need to think about it. Fast forward to present day, put tubing on the spout, and bubbles stand out. For maple producers using clear polycarbonate spouts and high vacuum, the bubbles are even more noticeable and it is often an obvious, but erroneous, conclusion that these gas bubbles are leaks.

So how do you tell if bubbles observed in spouts and tubing are from leaks or from tree gases? If you're not on vacuum, it doesn't matter a lot. As long as sap is not dripping outside the spout, it isn't a leak you need to be greatly concerned about. For producers on vacuum, bubbles may either be natural tree gases, or a leak. The simplest way to tell the difference is to observe the speed and periodicity of bubbles. If bubbles are moving rapidly, and if there is a relatively unbroken "train" of bubbles (a series of small bubbles one immediately after another), then it is probably a leak. In that case, maple producers should check for nicked tubing, a cracked spout, or another source of the leak. If the leak is very near the spout or coming out of the spout itself, sometimes a slight tap on the spout to ensure that it is properly seated in the taphole will solve the problem. It is certainly possible for spouts to heave due to extreme freezes.

If bubbles are very small when first coming out of the taphole, but grow larger as the transit the spout, and they only move relatively slowly in the stream of sap, then are likely due to tree gas. In this case, the best course of action is to do nothing. Hitting the spout harder to seat it won't stop the gases, but may create microleaks between the spout and the taphole – which will only create a problem that can't be fixed, if you make it worse by hitting the spout harder and harder in an attempt to stop it.

Normal gas bubble exudation is shown at https://goo.gl/9M2wQA (video courtesy of Mark Isselhardt, UVM Maple Extension).

Tree gas production will also be much more copious on warm days. This is often why producers on vacuum will see a slight vacuum drop in their tubing systems during a warm spell. As more tree gases are produced, it must be moved out of the tubing system to maintain the same vacuum level.

The overall aim of this and the preceding article is for producers to gain a better understanding of some common issues that at first glance appear to be problems but, in reality, are not. Being able to recognize what is really a leak takes some time and thought and experience, but in the long run, knowing the difference and how and when to act will help producers achieve higher sap yields.

NAMSC News

The North American Maple Syrup Council (NAMSC) held a conference call for delegates on January 24, to discuss ongoing work and future projects. Items discussed included:

Maple Producers Manual Survey

The Council is polling sugarmakers to determine demand for future editions of the *North American Maple Syrup Producers Manual*. If the *Manual* is to be republished, we want to make sure that it is as useful as possible, so members are being asked about what chapters should be revised, and what publication format would be most useful. If you have not yet filled out the online survey, please visit www.namsc.org and follow the link on the home page.

Annual Meeting Format

Consideration is being given to how the annual meeting can best serve to meet the needs and interests of our members, and how business can be conducted most efficiently to make the best use of the limited time that we have. Additional workshops, keynote speakers, panel discussions, and other ideas are all being discussed. Members with ideas of what would be most useful are encouraged to send their ideas to Executive Director Mike Girard (mgirard@simscroft.com) and President David Briggs (dsbriggs@nbnet.nb.ca).

Maple Digest Supplements

The two, color, Practical Skills Guide supplements to the *Maple Syrup Digest* published last year were well received, and plans are under way for more.

Off-Flavor Kits

The off-flavor kids developed by Mark Isselhardt at UVM Extension and sponsored by the NAMSC and distributed to all member associations have been being used as training tools and raffle prizes. Members are very interested in future editions of this tool, featuring other common off-flavors.

Acer Grant Update

The Council is working with two of last year's USDA Acer Grant recipients to develop educational tools for sugarmakers. One is an online library of research and resources for the industry, and the other will be a series of 'how-to' articles to be published in the Digest.

Maple Museum

The newly renovated North American Maple Syrup Council Room, housing the International Maple Hall of Fame at the American Maple Museum is being transformed into an interactive experience for visitors to learn about each individual inductee and their contributions to the maple industry. The Council's recent donation will help pay for touch screens that will feature biographical information, and exhibit cases to display artifacts from members of the Hall of Fame.

Research Fund

The RFP process for grants from the NAMSC Research Fund will be changed a bit this year, with applicants being asked to submit a letter of interest in advance of the full grant proposal. More details will be coming in the Spring.

Attend the 2018 International Maple Meetings in New Hampshire!

The New Hampshire Maple Producers Association is excited to host the NAMSC and IMSI meetings in Concord, October 26-29, 2018. Besides the business meetings, this conference will update you on the latest inventions, research and news. It will also include a variety of outstanding technical educational sessions conducted by experts who will give you loads of ideas on how you can improve your maple operation.

There will be competitions in maple syrup, cream, candy, and dry sugar, as well as a photography contest, so be sure to bring your best product or photo to enter into these contests.

We will tour a nearby sugarhouse and other fascinating points of interest. What is there to see in New Hampshire? A lot! Just a short ride north and you'll be in the heart of our towering White Mountains, once called the "Switzerland of America." You may ride the unique Cog Railway to the summit of Mt. Washington, the highest peak in the Northeastern U.S. See where our much-loved Old Man of the Mountains perched for centuries and visit the Flume, Table Rock, or Arethusa Falls. Visit Shelburne's White Birch Forest and take a drive along the wild and scenic Kancamagus Highway, where you may even see moose, deer, or bear.

If you prefer a lower altitude, you can dip your toes into the Atlantic Ocean at one of our beautiful state beaches and tour the historic Strawberry Banke portion of Portsmouth, where homes dating back to the 1600s are preserved.

Concord, the capital city, is steeped in history and has much to offer: Tour the State House, learn all about New Hampshire and see the original chambers where the largest state legislature in the country still meets. Across the street stands the NH Historical Society where you can enjoy our state's historical artifacts. Check out one of the famous Concord Coaches and learn how some carried up to 14 passengers. Over 3,700 of these stagecoaches were built here Visit Pierce Manse, once home to New Hampshire's only President, Franklin Pierce.

Nearby in Canterbury, you may tour the historic Shaker Village, where this entrepreneurial religious sect raised hundreds of orphaned children and contributed numerous inventions to society. In Warner, you may visit the NH Telephone Museum where you'll see the great advancements in communication over the past century. You'll probably even see a phone like one you used as a child! The Mt. Kearsarge Indian Museum offers fascinating displays of artifacts and information about many Native American tribes, and the adjacent Nature Discovery Center is the perfect place to learn things about nature you never imagined.

Some of these places will be included in our tours, others you can visit on your own. Details of the programs and tours are still being worked out, but we're planning to make this one of the best conventions yet. Save the dates, you won't want to miss it! More information will soon be available at: nhmapleproducers.com/2018.

International Maple Syrup Institute News

Dave Chapeskie R.P.F. Executive Director, IMSI

This report will highlight a few of the very important activities the IMSI has been involved with in 2017 and a few activities planned for 2018/19.

A look back to a few important IMSI activities in 2017:

1) The IMSI continued to provide input into United States and Canadian government regulations affecting the maple industry. In the United States, this related primarily to changes in the Nutritional Facts Panel (NFP) requirements for real maple products, including the Added Sugar provision in the new FDA rule. In Canada, IMSI provided input in relation to proposed product labeling changes. Changes to product labeling requirements in both countries will be significant once they are finalized and when compliance is required by the governments. In preparation for changes, the IMSI has facilitated the preparation of proposed NFP Panels for both maple syrup and maple sugar. This has been done with the assistance of maple quality assurance specialists and maple researchers from the U.S. and Canada. The IMSI is very grateful for their collaborative assistance with this project.

2) IMSI launched into the use of social media in the fall of 2017 to help promote real maple to the public and consumers. This includes an IMSI Facebook page with messages to garner consumer interest being posted throughout the year in both English and French. Maple associations and maple producers/processors are strongly encouraged to use this messaging to help support their individual ongoing maple promotion and marketing efforts.

3) The IMSI is supporting development of an application for International Codex Certification for maple syrup. This initiative should ultimately raise awareness about the uniqueness and merits of maple syrup around the globe and should ultimately help with the development of expanded markets overseas.

More detailed information covering the full scope of IMSI activities can be found under News and Events-Meeting Summaries on the IMSI website at www.internationalmaplesyrupinstitute.com (October 2017 Report).

Some Important Activities Planned for 2018/19:

1) More emphasis on discussion and monitoring of the many changes which will, or potentially could, affect the nature and health of the North American maple syrup industry. This includes new product labeling requirements, new food quality and safety requirements, new requirements for exporting real maple products into the U.S. market, implications of NAFTA, maple industry mergers, expanded use of real maple as an ingredient in food products, and other developments. Emphasis will be on information sharing and potentially the development of a strategy to help the maple industry adapt to

the many changes, either real or potential.

2) Liaison and continued input with the federal governments in the U.S. and Canada will continue regarding product labeling changes in the U.S. and Canada.

3) Facilitate and support a formal application for Codex Alimentarius certification for maple syrup.

4) Continue with the implementation of high priority components of the IMSI's Promotion and Marketing Implementation Plan to help promote real maple products. This includes scoping out and renewing promotional and educational materials to help promote and market pure maple products. It will include incorporation of the new international logo for maple syrup as well as refreshing and updating information on the nutritional and potential health benefits of maple syrup published previously by the IMSI. Social media will be an important mechanism to help disseminate information along with more conventional methods utilized in the past.

For further information, contact Dave Chapeskie, Executive Director, International Maple Syrup Institute, at: agrofor@ripnet.com

Research: Tapping

Tree Size Matters

Mark Isselhardt, UVM Maple Extension
Timothy Perkins and Abby van den Berg, UVM Proctor Maple Research Center

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. When using tubing, it is sometimes difficult to observe the impacts each of these has on sap yield, but by conducting controlled research studies it is possible to discern the relationships among certain characteristics and practices. In fact, some of the common sayings in the maple industry such as "strive for five, no more than ten" and "5% more sap for each 1" Hg vacuum" come directly from such research.

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

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 didn't produce so well. It was also easy to observe the effect of tree size on yield. With the prevalence of tubing however, there is the temptation to tap every tree that is reachable, even if it is quite small, because "it's there, so I might as well tap it." However, small trees generally produce fairly modest quantities of sap, and 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, SHOULDN'T) 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 a wide range of tree 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″ 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 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. 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 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

Tree size continued on page 38

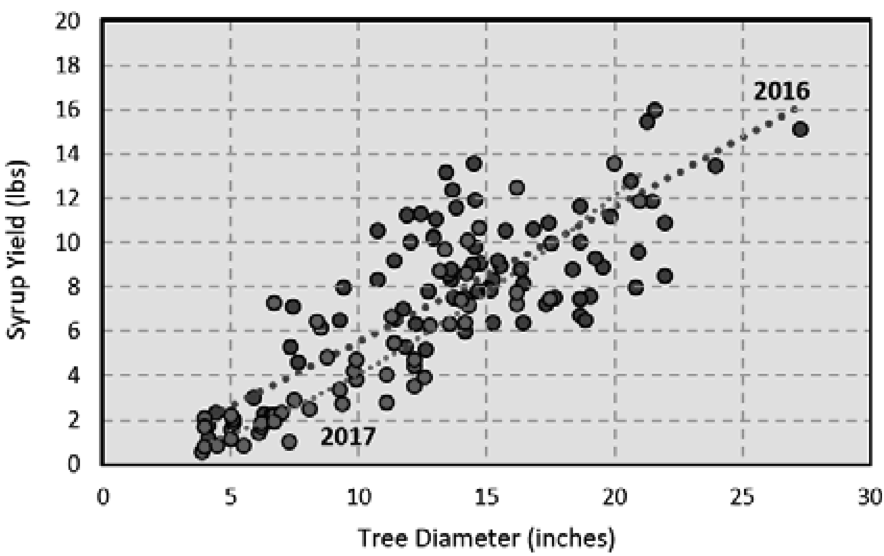


Figure 2. Relationship between tree diameter and syrup yield (lbs) for the 2016 (darker) and 2017 sap flow seasons in Underhill, Vermont. Best-fit trend lines are shown by dotted lines.

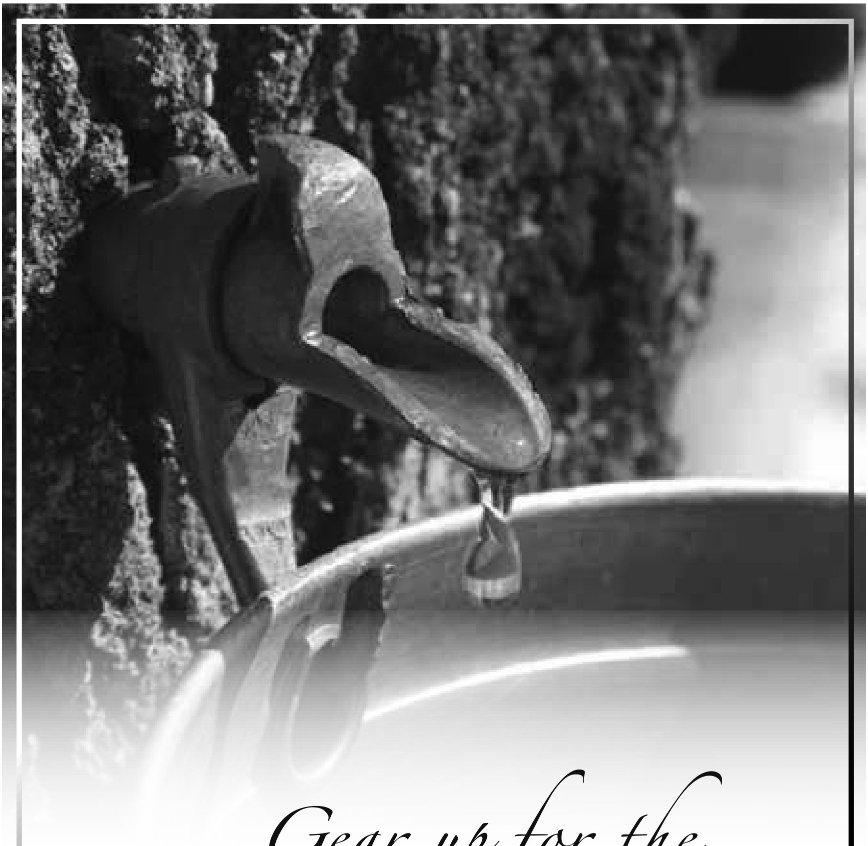
Tree size: continued from page 37

stuck upright in the ground, but filled with a wood matrix filled with 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 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. 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.



43

Season Events in the States

Connecticut

March 17-19: 28th annual Hebron Maple Festival. www.hebronmaplefest.com.

Maine

March 25: Maine Maple Sunday 35th Anniversary.

June 13-16: Maple Mania w/ tour of Golden Road, Greenville, Maine

Massachusetts

March 9: Annual season kickoff celebration, 1:00, Mill Brook Sugar House, Lenox.

March 17-18: Maple Weekend. Details at www.massmaple.org.

New York

April 26: Maple Value Added Products Workshop, Ontario County, Contact: Russell Welser, Cornell Cooperative Extension Ontario County, 480 North Main Street, Canandaigua, NY 14424, Phone: 585-394-3977.

July 15-17: New York State Maple Tour, Upper Hudson. Tour registration will begin starting at 3PM on Sunday afternoon July 15, the trade show displays will be ready for opening at 3:30 PM followed with a reception in the evening. On Monday at 6PM there will be a reception in the trade show area followed by the Annual Maple Tour Banquet. On Monday and Tuesday, July 16 and 17, the tour will feature visits to a variety of maple operations, both larger and smaller. Information is at upperhudsonmaple.com, cornellmaple.com and nysmaple.com.

July 25-28: Cornell Maple Camp, Contact: Stephen Childs, slc18@cornell.edu.

Wisconsin

March 17: Annual First Tree Tapping, 10:00 a.m., Maple Creek Sugar Bush, Barron, WI.

May 5: The Wisconsin Maple Syrup Producers Association Annual Meeting, 10:00 a.m., Hotel Marshfield.

Wisconsin Maple Syrup Producers Cookbook available for Purchase

The WMSPA has published a new maple cookbook with 250 new recipes plus a few old ones from the past editions. The recipes are from various WMSPA members, OMNI hotel, and contest winners from the Wisconsin State Fair Maple Syrup annual cooking contest. The cookbook was made possible by the WMSPA cookbook committee: Alicia Baroun, Theresa Baroun, Heather Durkey, Miriam Durkey, and Dawn Roth.

The cookbooks are available for purchase at various dealers in Wisconsin: The Maple Dude, 715-571-3329; Maple Hollow, 715-536-7251; Roth Sugar Bush, 715-289-3820; and from Executive Director, Theresa Baroun, 920-680-9320. The cost is $10 per cookbook.

Annual Maple Stats

Mark Isselhardt at the University of Vermont has compiled many years of NASS reports on maple production in one, easy to navigate page. Find it at:

https://www.uvm.edu/extension/agriculture/maple-statistics

Michigan's Sugar Maples Will Struggle in a Warmer, Drier Future

University of Michigan, http://ns.umich.edu/new/releases/

Though Michigan's sugar maples benefit from the growth-promoting effects of nitrogen compounds in the environment, those gains will not fully offset the added stresses of growing under a drier climate in the future, according to a new University of Michigan-led study.

Sugar maples, known for their fiery fall foliage and as the main source of maple syrup, are a dominant tree species in the northern hardwood forests of eastern North America. They are found mainly in moist, well-drained soils and are drought-sensitive.

Some climate forecasts for the Upper Great Lakes region in the coming decades call for warmer temperatures and an increased likelihood of summer drought, conditions that could prove stressful for sugar maples and other trees.

But as the climate continues to change, forests worldwide are also being exposed to rising levels of growth-boosting nitrogen compounds generated by motor vehicles, power plants, factories, agriculture and other human sources. This human-derived nitrogen is considered a pollutant but also has a fertilizing effect on trees, promoting growth.

Climate scientists and forest ecologists have long wondered whether the fertilizing effects of human-derived nitrogen would be enough to offset added stresses produced by a warmer,

Michigan: continued on page 42

Thank you to our Research Alliance Partners

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Sunrise Metal Shop
VT Maple Sugar Makers' Association
WI Maple Syrup Producers Association

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NY State Maple Foundation
Ohio Maple Producers Association
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Michigan: continued from page 41
drier climate. It's a difficult question to answer, and previous studies produced contradictory results.

The new U-M-led study, based on 20 years of data from four forest sites in both Michigan peninsulas, concludes that nitrogen deposition from human activities "will not fully compensate for the negative effects of growing under the drier forecasted climates."

In the coming decades, Michiganders should expect decreased growth of sugar maples across the state, according to the study, which is scheduled for online publication in the journal *Ecology* on Jan. 17. And if the most extreme climate predictions for the region prove true, sugar maples will eventually—over a period of centuries—disappear from the state's Lower Peninsula altogether.

"The added nitrogen helps a little bit, but not enough," said U-M forest ecologist Inés Ibáñez, lead author of the study.

"Under extreme climate scenarios, the increase in nitrogen won't be able to compensate for decreased growth of sugar maples due to lack of water," said Ibáñez, an associate professor at the School for Environment and Sustainability and in the Department of Ecology and Evolutionary Biology.

Understanding how various tree species will respond to warmer and drier conditions is essential for producing accurate forecasts of future forest growth. And that's important to know because the world's forests remove about one-quarter of the heat-trapping carbon dioxide emitted into the atmosphere annually through the burning of fossil fuels.

If forest growth slows in response to climate stresses, then those trees will remove less carbon dioxide, which will exacerbate the warming problem. And northern forests around the world are especially important carbon "sinks," removing huge amounts from the air and storing it in tree wood and forest soils.

"The majority of carbon stored on land is in forests," said U-M forest ecologist and study co-author Donald Zak, a professor at the School for Environment and Sustainability and in the Department of Ecology and Evolutionary Biology. "And how forests grow in the future will influence the amount of human-derived carbon dioxide that remains in the atmosphere. That, in turn, will have a feedback effect on global temperatures.

"That's why these questions about forest growth are so important. And the only way to get some of the answers is through the type of long-term ecological research used in this study."

To assess the combined impact of human-derived nitrogen deposition and climate change on tree growth, Ibáñez, Zak and their colleagues used data from a federally funded nitrogen-deposition study at four Michigan hardwood-forest study sites, including one at the U-M Biological Station near Pellston, Mich.

The four sites are separated by 300 miles and span the north-to-south distribution of northern hardwood forests, from the west-central Lower Peninsula to the northwestern Upper Peninsula. The Michigan Gradient Study was established in 1987 to examine the effects of climate and atmospheric deposition on forest growth and ecosystem processes in the Great Lakes region. Zak is one of the project's principal investigators.

Since 1994, project researchers have been adding solid sodium nitrate, a nitrogen compound used in fertilizers, to the soils at some of the Michigan Gradient Study plots to simulate levels of nitrogen deposition expected by the end of this century. Much of the nitrogen emitted into the atmosphere by humans later falls back to Earth in rain, snow and dust.

For the study reported in Ecology, the researchers analyzed the combined effects of nitrogen deposition, summer temperature and soil moisture on the growth of sugar maples. They used records from 1,016 trees collected over the period 1994-2013.

The vast scope of the Michigan Gradient Study, its unusual experimental design, and new statistical tools enabled the researchers to separate the effects of human-derived nitrogen on tree growth from those associated with temperature and water limitation—something previous studies could not do, Zak said.

The results show that, in all cases, added nitrogen boosted measured tree growth, an effect that was accentuated as temperatures increased and soil moisture decreased. In addition, the researchers simulated future growth rates for each tree under two climate scenarios previously developed for the Upper Great Lakes region.

Scenario One envisions moderate changes by 2100: a temperature rise of 1.3 degrees Fahrenheit and a 14 percent increase in summer precipitation. This scenario assumes that global carbon dioxide emissions eventually reverse course and start to decline.

Scenario Two assumes that current carbon dioxide emission levels con-

Michigan: continued on page 44

Michigan: continued from page 43

tinue into the future, resulting in more extreme climatic changes in the region: a temperature rise of about 10 degrees Fahrenheit and a 40 percent decrease in summer precipitation by 2100.

The computer simulations showed that sugar maple growth would be slightly harmed under Scenario One, especially at the warmer southern sites. Results for Scenario Two showed a large and consistently significant decrease in growth for sugar maples at all four sites and for all plots—those treated with the nitrogen fertilizer as well as untreated plots. Threefold decreases in growth rates are possible under Scenario Two conditions.

Under Scenario Two, sugar maples would eventually disappear from Michigan's Lower Peninsula, though the changes would likely occur over several centuries, Ibáñez said. If that happens, the sugar maple and beech-dominated northern hardwood forest might be replaced by oak-hickory forest, which is better adapted to droughty conditions but which doesn't remove as much carbon from the atmosphere.

"Carbon sequestration is a huge service provided to us by forests and is very important for any kind of climate regulation into the future," Ibáñez said. "If droughty conditions reduce the productivity of Michigan forests in the future, their ability to sequester carbon will suffer as well."

In addition to Ibáñez and Zak, the authors of the Ecology paper are Andrew Burton of Michigan Technological University and Kurt Pregitzer of the University of Idaho. The research was supported by grants from the National Science Foundation's Long Term Research in Environmental Biology program and from the Department of Energy.

The full study is available at http://onlinelibrary.wiley.com/doi/10.1002/ecy.2095/full

Pepin Joins Lapierre USA

On November 20, 2017, Mr. Benoit Pepin joined the Lapierre USA team as the US territory manager.

Benoit has worked in the field of maple syrup equipment sales in the US for several years. With his experience and expertise, he will be a major asset to the Lapierre team in the United States.

Benoit is responsible for organizing the network of agents and distributors in the US, and will work in direct collaboration with Mr. Eric Miller and Mr. Steve Bédard.

You can contact Benoit by email at benoit.pepin@elapierre.com or by phone at 802-782-9381.

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