A Decade of Spout and Tubing Sanitation Research Summarized

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More then a decade ago there was a renewed realization that microbial contamination of maple sap collection systems was having a significant detrimental impact on sap yields. Several research studies to investigate ways to improve sap yields from tubing systems were undertaken at both the University of Vermont Proctor Maple Research Center (Underhill, VT) and at the Cornell University Arnot Forest (Van Etten, NY) starting at about the same time and proceeded both as independent and joint projects from 2009-2018. The results of many of these studies have been reported in the past in numerous individual publications and presentations. This article seeks to combine and present this extensive body of work into a single, comprehensive, but concise summary of our results.

Methods

Since this paper is meant to be a broad overview and because methods have been previously described for individual studies (see https://projects.sare.org/sare_project/lne13-326/ for descriptions), the specific approaches used will not be covered here. In general, however, controlled and replicated field trials of different sanitation approaches were investigated for various years using different treatments conducted over several years. In these studies, sap was typically collected and measured from individual trees flowing into small vacuum chambers, groups of 3-5 trees on single lateral lines flowing into larger vacuum cannisters, or larger groups of 60-120 trees on mainlines emptying into calibrated releasers with counters (Figure 1A-C). Regardless of the experimental approach, the average sap yield (gallons of sap/tap) could be determined for each sanitation treatment each season and compared. Using multiple approaches and methodologies provides a check on consistency of findings, provides a level of scalability in the results, and provides a higher degree of confidence in the results.

All the studies presented in this summary were performed with 5/16” tubing on pumped vacuum tubing systems. These results and recommendations do not apply directly to 3/16” tubing systems.

The sanitation approaches tested included: 1) replacement strategies, wherein one or more component of the spout/dropline/tee is/are replaced each year; 2) cleaning strategies in which a chemical sanitizing solution is introduced into the tubing system via injection or by sucking it in under vacuum; and 3) a combination of replacement and cleaning.

Costs are estimated from studies examining the amount of time and materials needed to employ each strategy. Labor costs are based upon $12.00/hr. Chemical sanitizers also included the expense of either rinsing with water after treatment or by allowing the first run of sap to flow on the ground (thus reducing yield).

The specific methods examined were:

- Spout replacement (**SR**), where a new spout was placed on a previously used (age varies, but generally ranged from 1-5 years old) dropline.
- Leader Check-valve use (**CV**), in which a new check-valve type spout or spout adapter/stubby spout combination was placed on a previously used (but not cleaned) dropline.
- New droplines (**ND**), where a new piece of tubing, new spout, and typically a new tee was used.
- Bleach-sanitized (**BS**), in which the spout and dropline were sanitized with a calcium or sodium-based hypochlorite solution. Both short-contact (sucking in a small amount of solution under vacuum) and long-contact time treatments (soaking or injecting a sanitizing solution into the spout and allowing it to remain in the dropline for an extended period, minimum of 10 min) were studied.
- Peroxide-sanitized (**PS**), like the above treatment, but using a hydro-

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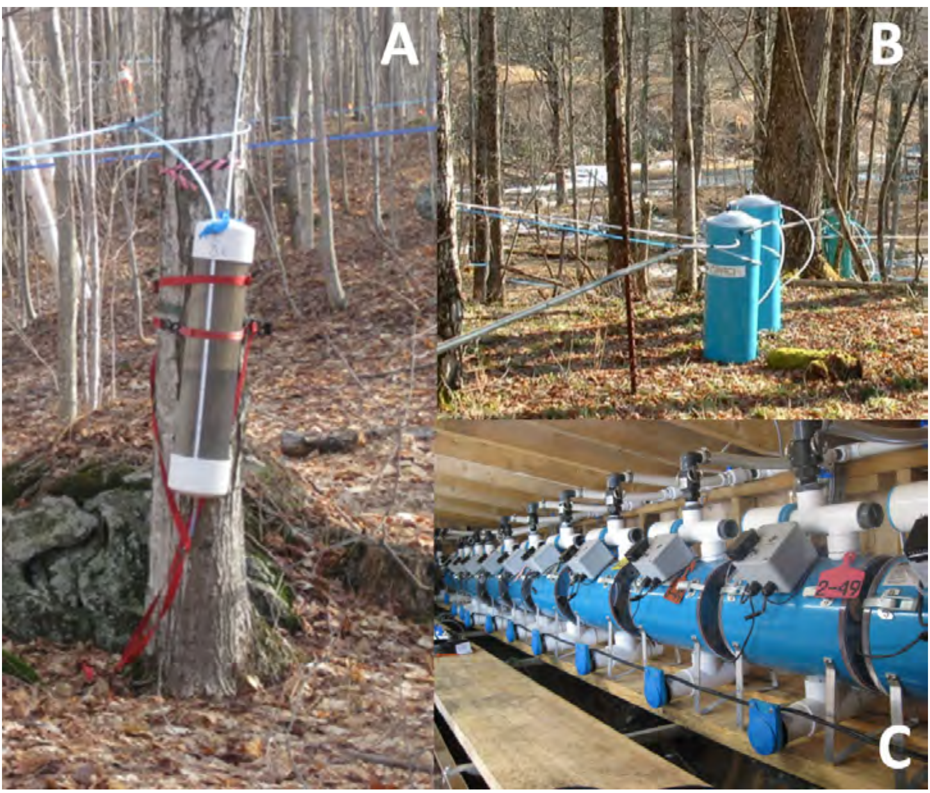


Figure 1. Various methods to measure sap yields from trees under vacuum conditions in sanitation studies. A) Single-tree vacuum chamber, B) Lateral line canisters for multiple trees (typically 3-5), and C) releasers connected to mainlines with 60-120 trees each.

Sanitation: continued from page 9

gen peroxide or hydrogen peroxide + peroxyacetic acid solution under either short-contact or long-contact periods.

- Isopropyl-alcohol sanitized (**IPA**), where IPA is injected into the spout/tubing and allowed to remain for a long period of time (typically until the following flow season). NOTE that IPA, while commonly used in Canada, is not permitted for use in maple tubing systems in the U.S.A.
- Zap-bac use (**ZB**), a spout impregnated with antimicrobial silver, typically used for 3-year period. A new spout is used in year 1, and then reused in years 2-3.

Results

The average annual sap yield improvement (%) for these various sanitation methods compared to control systems (used, but unsanitized) across multiple studies, field sites, and years (Figure 2). The numbers across the top (in the line starting with "N =") represent the number of individual studies which examined that sanitation treatment approach. The values in the boxes just below each bar are the average net profit ($/tap) per year generated by that sanitation regime as calculated for a used system generating 15 gallons of sap/tap with a value of $0.51/gal. Using different sap yields, sap valuations, and costs to calculate estimated profits will provide somewhat different results, but in general, the patterns of yield and net profits remain relatively stable and proportional to sanitation approach, sap yield, and sap value.

Both the **CV** and **ND** approaches automatically incorporate using a new spout each year. However, because multiple overlapping trials of most studies were done each year, we are able to separate out the relative contributions of spout replacement independent of the overall **CV** effect (which combines the **CV**+**SR** effects) and **ND** effect (which includes both the **ND**+**SR** effect). This is represented as a solid intermediate line within the **CV** and **ND** bars.

Dashed lines within the **BS** and **PS** bars show the level of the short-term treatment gained by sucking in sanitizer under vacuum, while the full height of the bar shows the long-term treatment effect, achieved by soaking in sanitizer solution or flooding the system with sanitizer.

In general, over several years across two study sites (Underhill, VT, and Van Etten, NY), annual spout replacement (**SR**) produced an average 31.4% increase each year in sap yield above the profit achieved if no sanitation strategy is used (no replacement and no chemical sanitizer use), producing about $1.03 in net profit. In seven studies, while **SR** generally resulted in only about 1/3 of the sap improvement yield of the best approaches due to the lower cost to implement, it produced nearly 50% improvement in net profit above not using any sanitation strategy.

CV, **ND**, and **BS** (long-contact time) treatments produced similar results to each other, generating about 70-75% more sap [than no sanitation treatment and resulting in a net profit increase around $2.00-2.30. Because these approaches appeared to be the most promising early on, they were also those most intensively examined, with 36, 20, and 9 studies performed respectively. Thus, besides being the treatments found to be most effective, they are also the treatments in which we have the highest confidence.

Looking deeper at the **CV** and **ND** treatments, we see that the new spout alone contributed about 21% of the 69% improvement in sap yield for the **CV** treatment, and about 24% of the 75% improvement from the **ND** treatment, or a little less than one-third of the total sap yield improvement. This clearly indicates that while a new spout is rather important to the overall sanitation effectiveness, replacing the spout by itself does not achieve the highest possible level of sap yield improvement or produce equivalent net profits.

The high net profit presented with **ND** is somewhat artificial in these studies in that older drops were used for comparison each year, which inflates the beneficial results of this treatment. In actual practice, once a drop was replaced, it would age (and build up microbes) slowly over time. By using

Sanitation: continued on page 12

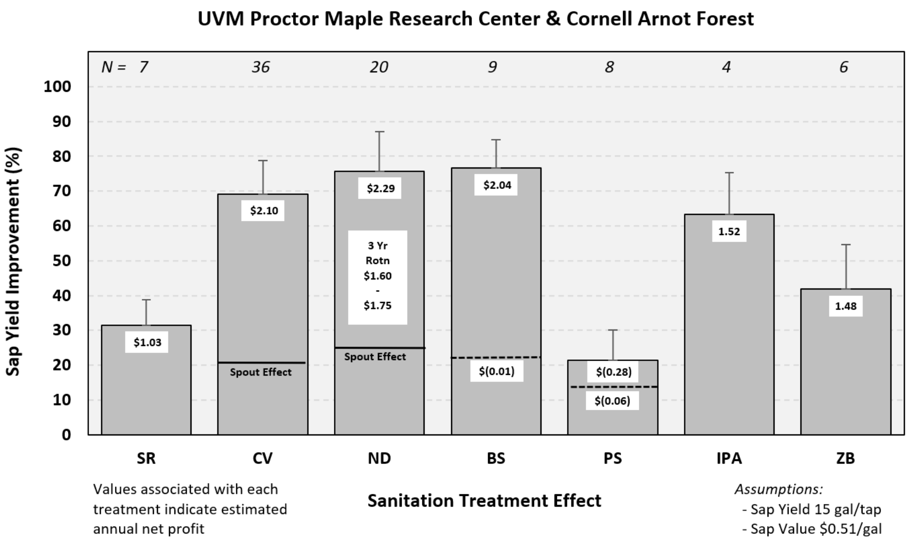
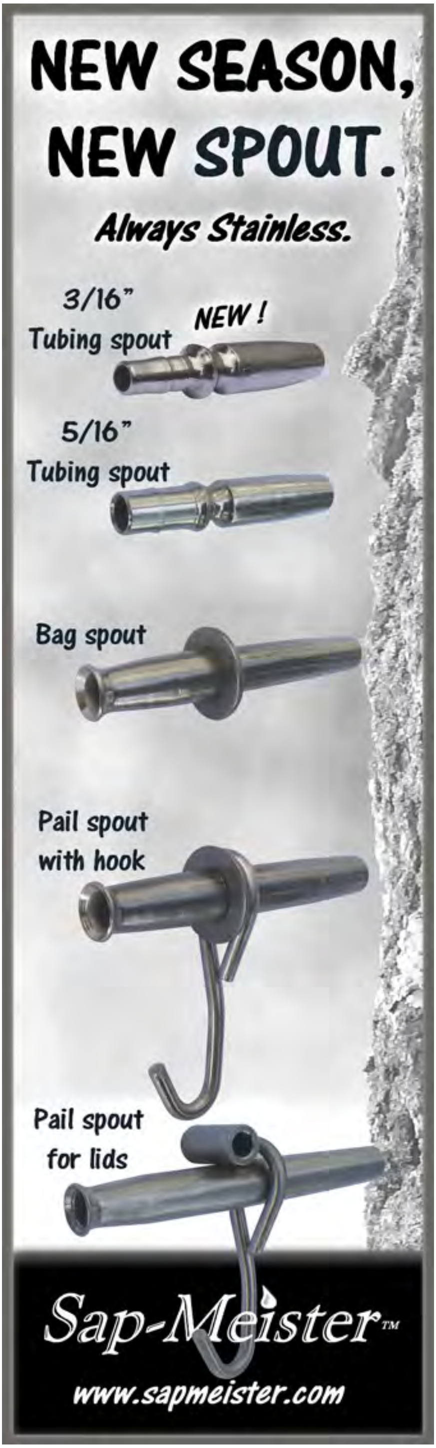


Figure 2. Average annual sap yield improvement (%) for each sanitation treatment in studies conducted at the UVM Proctor Maple Research Center and the Cornell Arnot Forest from 2009-2018. Values within each bar represent the estimated annual net profit above the cost of no sanitation (replacement or sanitizing) with a base sap yield of 15 gal/tap and a sap value of $0.51/gal after subtracting out the cost of materials and labor or lost sap required for each treatment. **SR** = new spouts, **CV** = use of Check-valve spouts or Check-valve adapters, **ND** = new dropline, spout, and tee, **BS** = bleach sanitized, **PS** = peroxide sanitized, **IPA** = isopropyl alcohol sanitized, **ZB** = Zap-Bac spouts or adapters. The solid line within the CV+Spout and Drop+Spout Treatments represents the contributory effect of the new spout alone to the overall effect of the overall treatment. The dashed line in the bleach and peroxide treatment is for short-contact time exposure (sucking solution in under vacuum) while the total bar height is the long-contact time exposure (soaking in sanitizer solution or flooding the tubing system with sanitizer). The text within the **ND** bar represents the estimated net profit range associated with using a 3-year drop replacement interval along with new spouts annually. The total number of research studies conducted for each of the treatments is shown at the top of the figure; error bars represent standard error of the mean for the studies of each treatment.



Sanitation: continued from page 11

older drops for comparison, the baseline level was kept low. This artifact does not affect the results for the other treatments since the drops were the same age as the baseline treatment (no sanitation).

A short-contact time **BS** treatment resulted in a 22% improvement in sap yield, but the cost required to sanitize resulted in a break-even situation, with no gain in net profit realized. Both long-contact and short-contact **PS** produced only modest improvements in sap yield, but due to cost both resulted in a net loss economically.

IPA, widely used in Canada, produced a result intermediate between **SR** and **CV/ND/BS**, with an average improvement of 63% over 6 studies. The higher cost of this approach meant that the net profit was proportionally reduced, producing an average net gain of $1.52/tap. This is intermediate between **SR** and the top three sanitation approaches, economically matching the performance of the **ZB**.

ZB spouts, when averaged out over their intended lifetime of three years, produced nearly a 42% improvement in sap yield, with a net profit of $1.48/tap. While this is nearly a 44% improvement in net profit over **SR** (if a standard spout is employed), it is not as good as other approaches (**CV**, **ND**, **BS**), although it does approach the strategy of a multi-year rotation of drop replacement with annual spout replacement. A possible disadvantage for some maple producers is that the **ZB** is generally not allowed in certified organic maple operations. Because of the small number of studies focused on the **ZB** approach, the multi-year nature of their use, and season-to-season variability in sanitation effectiveness, more research is required to fully understand this system.

The result of all these studies spanning a decade of study is that three approaches appear to be roughly equivalent in producing the best results in terms of the highest net profit: annual use of the Check-valve spout or adapter (**CV**), dropline replacement with new spouts (**ND**), and long-contact time bleach sanitizing (**BS**). Dropline replacement (**ND**) on a three-year rotation, with new spouts (**SR**) each year produces somewhat lower yields and profits, but has gained fairly widespread acceptance in the industry.

The advantage of the **CV** system is that it is simple to implement since it does not require periodic drop replacement until such time as the tubing or associated fittings begin to fail. Since the **CV** system is available both as a spout or as an adapter, producers can choose which style they prefer – the gains in sap yield are similar with either style.

Annual replacement of drops (**ND**) is cost-effective and typically produces excellent results in terms of high sap yields, but can be very time consuming to implement. One advantage of this strategy is that producers have a wide variety of spouts to choose from. It should be noted however, that the yield improvements and net profits as presented here are achieved only when drop replacement is conducted every year. More typically however, drops are replaced (**ND**) on a 2-4 yr rotating schedule with only spouts (**SR**) replaced during intermediate years. Under that approach, sap yields (and net profits) will drop off during each intervening year in which drops are not replaced, so that average net profits over that time period will fall somewhere between that of **ND** and **SR**. Depending upon the drop replacement frequency, a **ND** rotation of every three years with **SR** in intervening years could be expected to produce a net profit in the range of about $1.60-$1.75/tap.

While any type of chemical sanitization is labor intensive, **BS** is something that maple producers are very comfortable and familiar with and is effective in both producing higher yield and good net profits, as long as it is performed in a way that allows long-contact time. It is important to recognize that after bleach cleaning, rinsing of tubing should be performed OR the first run of sap allowed to run on the ground to prevent contamination and off-flavors in syrup. In addition, sodium-based bleach can attract animals, which may damage tubing systems and create leaks. In our testing of calcium-based bleach sanitizers, we did not encounter any such issues, however we cannot (yet) totally discount it. Further research and producer experience is needed.

During these studies, several other observations were noted:

- Systems without replacement or chemical sanitizer treatment display rapid drop off in yield and result in lower net profits than those that employ some sanitation strategy. This drop off occurs fairly rapidly in the first few years before leveling off over a 4-5 year period to about 50% of the sap yield of a new tubing system.
- Sanitizer-based treatments are probably best applied in the late-fall just before the onset of freezing weather. This allows less time for microbes to recolonize tubing systems. Similarly, new spouts, CVs, or new drops should be deployed to the woods

Sanitation: continued on page 14

Sanitation: continued from page 13

only after the return of cold weather for the same reason.

- The older the tubing (especially droplines) the greater the response to any sanitation treatment (replacement or chemical sanitizing).
- Different seasons result in different sanitation-related results. Sanitation approaches in short, cold seasons and short, hot seasons produce modest to highly muted effects. Moderate, long seasons display the best results to good sanitation practices.
- Vacuum pump/releaser systems and management can produce varying results. Leaving the pump running until the tubing system solidly freezes reduces to some degree the negative impacts of poor sanitation. Similarly, using an electric releaser appears to lessen backflow conditions (movement of sap towards the tree) that are common with mechanical releasers. While these management strategies and choices of equipment can lessen sanitation-related issues, they do not totally negate good sanitation as a factor critical in achieving good yields.
- Tighter (higher vacuum) tubing systems show lessened sensitivity to sanitation-related impacts. Conversely, tubing systems prone to

leaks appear to be more susceptible to sanitation issues.

- Sap yield increases due to sanitation treatments consistently tended to be slightly higher at the Cornell Arnot Forest compared to the UVM Proctor Maple Research Center.
- Lateral line sanitation typically has only a minor effect on sap yield, while mainline sanitation has essentially a negligible impact on sap yield.

Summary

Producers should choose what works best in their woods given the advantages and disadvantages of time, labor, and cost in relation to the gains in sap yield in net profit they can expect to experience. The use of **CV** and **BS** (with long-contact time) offer the highest net profits for maple producers with annual net profits estimated to increase by over $2.00/tap compared to no sanitation. While **ND** produces the highest sap yields, the cost of annual replacement is generally prohibitive unless yields are very high (excellent vacuum, large trees). Thus, producers typically replace drops at some interval, typically in a three-year rotation with **SR** each year. This strategy results in somewhat reduced yields, with net profits in the range of $1.60-1.75/tap annually. At minimum, producers should consider annual spout replacement (SR), which achieves an estimated net profit per year of approximately $1.00/tap above the base level of no sanitation. While this approach does not result in the highest sap yields or net profit, it is simple to implement and does provide some amount of benefit, especially when combined with a very tight vacuum system, proper pump management, and an electric releaser.

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