

# CHANGES IN SAP YIELDS FROM TUBING SYSTEMS UNDER VACUUM DUE TO SYSTEM AGING

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## INTRODUCTION

Maple producers who install a new vacuum tubing system in their woods generally experience significantly higher sap production in the first few seasons, with gradually diminishing sap yields evident as tubing systems age. Sap flow reductions are related to microbial contamination of tapholes (Naghski and Willits 1955), which is introduced through contaminated spout/tubing systems via contact of an old spout with a fresh taphole, or through sap backflow into tapholes during periods when vacuum loss occurs (Perkins 2009). The maple industry has attempted to counter microbial contamination impacts on sap yield by using chemicals or air/water introduced under pressure to clean tubing, through the use of annually replaceable spout extensions or spout adapters, via semi-regular replacement of droplines, by occasional retubing sap collection systems, or most recently, by using spouts or spout adapters designed to reduce or limit taphole contamination (Chapeskie and Staats 2006, Heiligmann et al. 2006, Perkins 2009, Perkins 2010, Childs 2010).

However because of year-to-year fluctuations in sap production, the actual loss of sap yield over time has not been well described. Producers know it happens, but are unsure precisely how much sap is lost when using a system of a certain age and contamination level, or how aging of tubing systems affects sap yields over time.

This research was designed to examine age-related losses in sap yield in tubing systems operated under vacuum, and to explore different strategies to reduce tubing microbial contamination induced sap yield losses.

## METHODS

In the fall of 2006 we established 12 treatment plots in the "Red Series" forest management area at the U.V.M. Proctor Maple Research Center in Underhill Center, Vermont. Each plot consisted of an average of 52.6 trees (range 37-69 trees) with an average diameter (dbh) of 14.8" (range 13.5-16.2"), with one tap set per tree regardless of diameter. The stand is predominantly sugar maple, but approximately 39% of the tapped trees were red maple (range in plots 19.6-61.5%). Each plot was serviced by an individual 3/4" maple mainline (Figure 1) and 5/16" lateral lines averaging 5 taps per line. The entire tubing system was installed new in the fall of 2005. During each flow season, the vacuum was pulled on all the mainlines via a common liquid-ring vacuum pump pulling 22-25". Each mainline has an individual vacuum releaser equipped with a counter



**Figure 1. Experimental plot mainlines entering the UVM PMRC “Red Series” sap shed**



**Figure 2. Inside of UVM PMRC “Red Series” sap shed. Each releaser is calibrated and equipped with a counter to measure total sap yield. All releasers and mainlines are connected to a common vacuum pump.**

(Figure 2). Releasers were calibrated to give a known volume of sap for each release.

The sap flow season of 2006 was used as a calibration year to determine the baseline level of sap produced by each treatment plot. Sap yield was calculated on a per tap basis to standardize the results for varying number of taps. Before the sap season of 2007, four treatments (replicated in three plots each) were randomly assigned to the study area:

1. Replacement of all lateral (5/16") lines, fittings and spouts annually (HIGH CONTROL)
2. Cleaning and maintenance of tubing system annually (LOW CONTROL),
3. Use of new spout adapters annually (Leader Evaporator Co. Tree Saver Spout Extensions on Darveau 5/16" spouts) (EXTENSIONS)
4. Various treatments
  - a. Replacement of spouts annually (2007-2008) (SPOUTS)
  - b. Replacement of spouts and dropline (2009) (DROPS)
  - c. Use of Check-valve spouts with replacement of droplines (2010) (CV+DROPS)

All treatments were cleaned each year at the end of the season via an injection of air/water mixture (no chlorine or other chemical sanitizers were used) from the bottom of the system. Spouts were pulled and air/water blown out through each spout for 5-10 seconds. The inside of the spout was cleaned with a small brush and the outside wiped with a sponge. The spout was then capped. After cleaning was complete, replacement of tubing, drops, and spouts was completed as dictated by the treatment regime.

The HIGH CONTROL (replace all) treatment is designed to produce the maximum amount of sap each year due to minimal tubing contamination, and thus represents the most sap a producer could expect to get from those trees if the site was retubed. This treatment, when considered to be 100% each year, also allows us to correct for the year-to-year variations that obscure age-related sap yield changes in the other treatments. The LOW CONTROL (clean/maintain) plots represents the typical situation after a producer retubes a section of their woods, so we would expect to see a reduction in sap yield over time in this treatment. The various other treatments examine the effects of various methods designed to increase sap production above the standard situation of clean/maintain only. More correctly, these treatments allow us to examine approaches to reduce the impact of microbial induced sap yield losses.

## RESULTS & DISCUSSION

During the sap flow seasons of 2006-2010, sap flow was measured from each plot and average sap yields calculated for each treatment. As expected, after the first calibration year, replacement of all lateral tubing and spouts (HIGH CONTROL) produced the highest sap yields, and cleaning/maintenance only (LOW CONTROL) produced the lowest yields (Figures 3 and 4). When compared to the

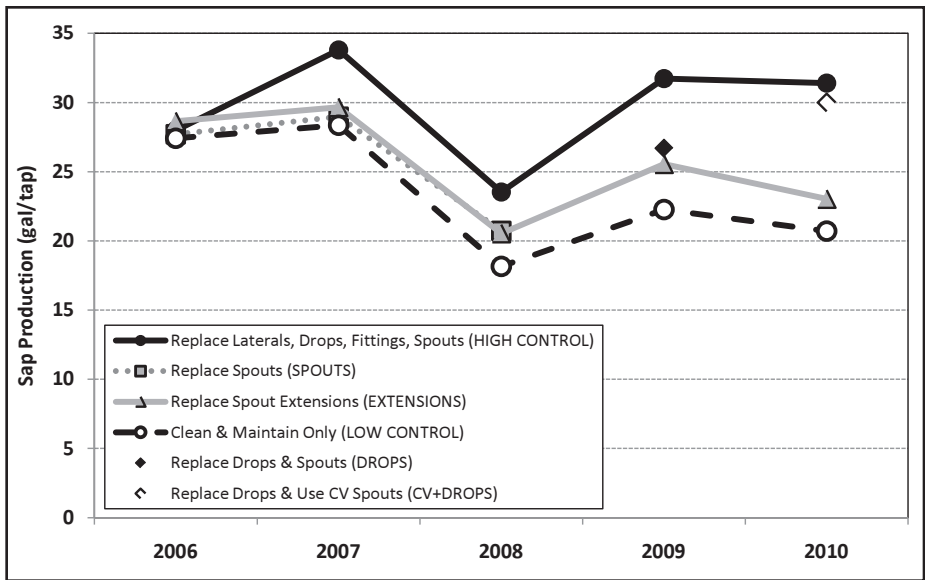


Figure 3. Average sap production (gal. sap/tap) from the various treatments. Each point is the average of 3 mainlines with an average of 53 trees per mainline.

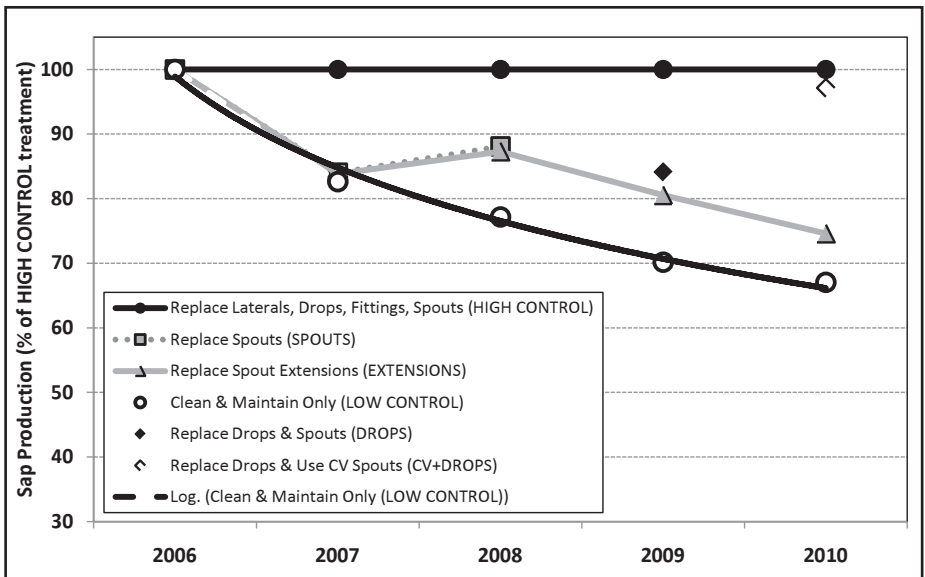


Figure 4. Average sap production expressed as a % of the HIGH CONTROL treatment. Differences between the upper line (HIGH CONTROL) and other treatments show how much microbial contamination impacts sap yields compared to a new tubing installation. Differences from the bottom line (LOW CONTROL) show the expected level of gain due to the use of various maple industry strategies to improve sap yield.

HIGH CONTROL plots, all of the other treatments had lower sap yields every year.

Figure 3 shows the average sap production in gallons per tap from each of the treatments. In 2006, the calibration year, the average yield from plots was very similar at approximately 27.4-28.6 gal/tap. In 2007, sap production in most plots was marginally higher than the previous year, however the HIGH CONTROL plots produced 33.8 gal sap/tap. Sap production was lower in 2008, with the LOW CONTROL plots producing an average of 18.6 gal/tap, and the HIGH CONTROL plots producing 23.5 gal/tap. Sap yield in LOW CONTROL plots was higher in 2009 and 2010, averaging 22.3 and 20.7 gal/tap respectively, but by that time was considerably lower than the HIGH CONTROL treatment yields at 31.7 and 31.4 gal/tap.

After 2007, all of the putative beneficial treatments (EXTENSIONS, SPOUT, DROP, and CV+DROP) showed some degree of improvement in the ability to increase yield above the LOW CONTROL (clean/maintain) treatment. Using new Tree Savers (EXTENSIONS) annually or replacing spouts each year (SPOUT) showed virtually identical responses. In 2009, by which point the systems had been used for 4 seasons, replacing spouts, droplines and tees (DROPS) was only slightly better than using spout extensions (EXTENSIONS), however in 2010 we observed that using Check-Valve Spout Adapters in combination with a new drop (CV + DROPS) resulted in sap yields of 30.0 gal/tap, far higher than the 20.7 gal/tap of the LOW CONTROL, and only slightly below the 31.4 gal/tap found in the HIGH CONTROL treatment.

It is far easier to see how the different treatments differ over time when the results are presented as a % of the HIGH CONTROL treatment (Figure 4). This visualization of the results removes the normal annual fluctuation in sap production, and thus makes patterns far more apparent. When doing this, the HIGH YIELD treatment will always be 100%.

The LOW CONTROL treatment reveals that sap production after the first year of tubing use drops quickly. Sap yield dropped by 17.4% after only one season, and then to a cumulative loss of 22.8%, 29.8, and 32.9% after the second through fourth seasons respectively. This shows that the potential loss of sap is most rapid in the first few years, and although it continues to fall, the rate of decline lessens over time in a logarithmic fashion. Despite this, it is readily apparent that these tubing systems have lost about 1/3 of their potential capability to produce sap after only five seasons of use. To look at it from the other perspective, replacing all lateral lines, droplines, fittings, and spouts after only 5 years time would result in an increase in sap yield of 50% the following season.

If the loss curve of the LOW CONTROL treatment is projected out over 10 years, sap yield falls to 50% that of the HIGH CONTROL treatment, and is still continuing downward. What this means is that retubing a system after 10 years should result in a 100% improvement in sap yield in the same woods.

Strategies to counter this loss in production do show some benefit. Although there is only a small effect of using new spout extensions or new spouts after one year of use (4.4 and 1.0% respectively), benefits are more substantial in

subsequent years as the level of microbial contamination in tubing systems rise. Use of annually replaceable spout extensions produced a gain in sap yield averaging 13.0% in seasons 3-5. Given the cost of a spout extension or spout adapter is about \$0.15-0.20 each, an average gain of 13% on 20 gal of sap/tap will result in an additional 2.6 gal of sap, worth about \$1.30 (with sap at a value of \$0.50). Therefore the average gain on investment with spout adapters is approximately \$1.10-1.15/tap. Although not included in this study, we would expect the Clear-Straight-Through Spouts to exhibit about the same level benefit in terms of sap yield and economic gain. This has been our observation in other ongoing studies (Perkins and Stowe unpublished). In short, putting new plastic in the tree reduces microbial contamination of the taphole, reduces taphole drying, produces higher sap yields, and results in an economic gain for producers.

Replacing the entire dropline assembly (dropline, tees, and spouts) produced only a modest improvement (19.9%) over that observed with spout extensions or new spouts (13.0%) in this study. Childs (2010) reported much larger increases in sap yields with dropline and spout replacement in similar sanitation studies in New York. This difference is likely due to the fact that the NY study looked at far older (and thus more contaminated) tubing systems, therefore the changes made were of greater benefit. The older the tubing system, the higher the level of contamination, and thus the greater benefit expected from making any sanitary changes to the system. The rapidity of the loss in sap yield in an aging tub-



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ing system is likely related to the type and efficacy of the tubing cleaning method employed. The economic calculation becomes far more difficult, as there is added expense of replacing the 5/16" dropline, and tee, as well as the spout, and the added labor cost involved with installing the new drop in the woods. Further research will be necessary to fully determine the cost/benefit relationship of drop replacement.

When dropline replacement was combined with the use of the Leader Check-Valve Spout Adapter (CV + DROPS) the improvement in sap yield was substantial, averaging 44.9%, and nearly reaching the yields produced by replacement of all materials from the mainline to the tree (HIGH CONTROL). Unfortunately the experimental design of this study did not allow us to study the effect of the Leader Check-Valve Spout Adapter (CV) on older laterals and droplines alone, but this will be a subject of study in the 2011 sap flow season. The NY study by Childs (2010), showed an improvement of 114% when using new CV adapters on old drops compared to old spouts on old drops. This equated to a gain of 7.7 gal of sap/tap at a cost of \$0.35/tap, an economic benefit of approximately \$3.50/tap (at \$0.50/gal sap). Based upon that work, as well as our own previous work (Perkins 2009, Perkins unpublished), we anticipate that CV adapters will show significant improvements in sap yields when used on old drops as well as when used in combination with new drops.

It should be noted by producers that these observations were conducted on vacuum tubing systems. Gravity tubing systems show somewhat different results (Childs 2010, Perkins and Stowe unpublished).

## **CONCLUSIONS**

Typical tubing systems (cleaned with air-water injection and maintained) experience rapid drops in sap yields as they age. By the time a vacuum tubing system is five years old, approximately one-third of the potential sap production has been lost. Various strategies to limit these losses have been developed and employed within the maple industry. In general, annual replacement of spouts, use of new spout extensions or spout adapters will increase sap yields by approximately 10-15% in a tubing system that is 3-5 yrs old. Replacement of droplines, tees, and spouts will increase production by 20-25%, however the level of improvement will most likely rise as tubing systems get older. Replacement of droplines in combination with the use of CV adapters resulted in the greatest benefit, although it is likely that use of CV adapters alone on older droplines will also result in significant improvements in sap yield.

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