RELATIONSHIPS BETWEEN TUBING SYSTEM COMPONENT AGE AND SAP YIELD
A Preliminary Assessment

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INTRODUCTION

Although a number of factors affect maple sap flow in vacuum tubing systems, it has become increasingly apparent that sap yields are largely a function of two major influences: vacuum level at the taphole and taphole and tubing sanitation. Vacuum controls sap yield by heightening the pressure differential between the inside of the tree and the inside of the tubing system, therefore causing more sap to flow than otherwise would without vacuum (Heiligmann et al. 2006, Chapeskie and Staats 2006, Wilmot et al. 2007). Good vacuum is primarily a matter of proper tubing system design and installation, vacuum pump capability, and the control of leaks.

Taphole drying, the slowdown or cessation of sapflow, is the direct result of microbial contamination (Naghski and Willits 1955). A multi-year study at the UVM Proctor Maple Research Center demonstrated that tubing systems show fairly rapid reductions in sap yield as they age, and that these reductions are due to the level of tubing system contamination (Perkins, Stowe, and Wilmot 2010). Numerous research studies and abundant maple producer practice have adequately demonstrated that a wide variety of microbes rapidly colonize maple tubing systems (Lagacé et al. 2004, Figure 1), and that changes made in the tubing system aimed at improving sanitation in the immediate vicinity of tapholes (annually changing spout adapters, new droplines, Check-valve adapters, silver antimicrobial spouts) significantly increase sap yield (Perkins 2009, Perkins 2010, Childs 2010).

The objective of this study was to determine the strength of the relationship between the age of the major components of maple tubing systems and sap yield. Eventually a predictive model could be constructed to allow maple producers to evaluate their own tubing systems in order to judge potential improvements and determine the cost versus the benefits of making various changes.

MATERIALS AND METHODS

Maple producers using vacuum tubing systems for sap collection in Vermont and New York were asked to participate in a survey in January - June 2011 describing their tubing systems. A limited geographic area was used in order to limit the impacts of varying weather conditions across a wider area on sap yields. Over 250 surveys were distributed.

For the purposes of this experiment, each individual section of the collection system that was distinctly different (in terms of tubing age, cleaning method, or tap/taphole sanitation practice) and for which sap could be separately measured, was counted as a distinct individual system. Therefore, an individual maple producer could complete a survey for several "different" collection systems. Detailed descriptions of each system were required, including: number of taps, average tree diameter, type of spout used, age of spouts, average number of taps per lateral, vacuum level, type of releaser system, vacuum management style (on all the time, or on/off during season), single or dual-pipe system and sizes, age of mainlines, age of lateral lines, age of droplines, the percentage of droplines or lateral lines changed this year and last year, and sap yield. Producers were also asked to collect 10-20 3" pieces of dropline cut from the spout end of the dropline

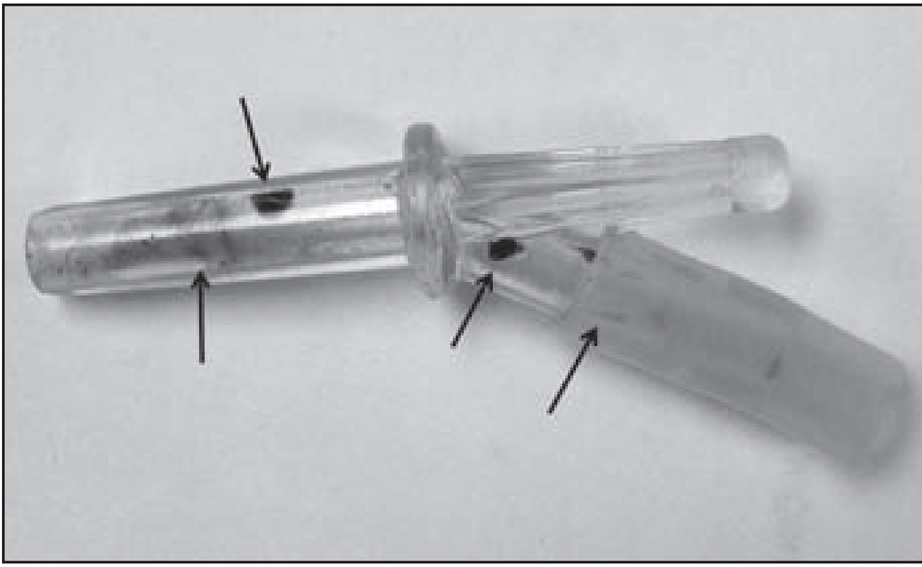

Figure 1. *Microbial contamination in a spout and 5/16" tubing after a single season of use. The recent introduction of clear spouts has made this problem more visible, however it is present even in opaque spouts. Arrows point to large microbial colonies on the inside of the spout and tubing.*

for each different tubing "system" during tapping for the 2011 season. These samples were to be placed into a sealed plastic bag (provided) and shipped via a pre-paid mailer to the UVM Proctor Maple Research Center for microbial analysis with a Charm Sciences© Firefly Luminometer. This device provides a rapid quantitative estimate of the amount of microbial contamination of surfaces based upon the amount of ATP (cellular energy compound in all living things) present, and has been shown to be useful in measuring microbial loads in maple sap (Lagacé et al. 2002).

Data were subjected to simple linear regression analysis to determine the relationships and trends between tubing system attributes and sap yield. The overall goal of this research was to begin to determine the quantitative relationships between tubing system properties and sap yields to help develop a predictive tool for maple producers to evaluate their systems to judge the possible gains in yield that might result from making modifications to their systems. This report is a preliminary assessment of the technique and initial results, and presents only a limited array of early results, focusing primarily on tubing system components (spout, dropline, lateral line, and mainline). A larger survey is planned which should help further develop our quantitative model.

RESULTS

Participation in this survey was relatively modest. A total of 42 surveys with tubing samples were returned. Of these, 33 provided enough complete data to be included in the analysis. The low response rate (over 250 surveys were distributed) precluded a detailed multiple regression analysis due to lack of statistical power, however the data acquired provide some information on general trends, and demonstrates that this technique, with an adequate sample size, might provide a useful approach for quantitative assessment of tubing systems to guide management decisions.

The relationships between individual tubing system component age and sap yield are presented in Figures 2A-2D. For each graph, the individual data points as well as the linear regression between the variables are shown. In addition, the R^2 value and slope are also presented. The R^2 value, or Coefficient of Determination, ranges from 0 to 1, and is an indicator of the strength of the relationship between two variables, with lower values (closer to 0) indicating less of a relationship, and higher values (closer to 1) indicating a stronger relationship. It is important to recognize that the R^2 is not an indicator of causation. In this case, tubing system component age can be used as an indicator or predictor of sap yield, but by itself, tubing system component age doesn't cause changes in yield. More likely, something related to tubing system age and use (probably microbial contamination level) actually causes the observed changes. Slope represents the change in one variable (in this case sap yield) as the other variable (tubing system component age) changes by one unit (in this case 1 year). The steeper the slope, the more rapidly the change occurs.

In addition, there is likely to be substantial interaction among the different tubing system component age variables that makes statistical analysis and interpretation difficult. For example, it is highly unlikely that any maple producer would put old spout and droplines on new mainlines, therefore it is not possible to directly observe and separate all possible (however unlikely) effects. Similarly, the vast majority of survey respondents replaced all or a majority of their spouts or spout adapters each year. Therefore the sample distribution is lower than would be optimal.

In looking at the individual components of a tubing system, we find that spouts/ spout adapters (Figure 2A) has a moderately high R^2 value (0.402). This can be interpreted as meaning that 40.2% of the sap yield can be explained by spout/spout adapter age. In addition, the steep slope of -7.3 (a loss of 7.3 gallons of sap per tap each year) shows that as spouts/spout adapters age, the loss in sap yield occurs quite rapidly. Therefore, if spouts/spout adapters are used for more than one season, there is a strong negative impact on sap yield. The rates observed in this study are considerably higher than those found in another project investigating the loss in sap yields as tubing systems age (Perkins, Stowe and Wilmot 2010), and may be related to the low sample size of spouts older than one year in this survey or may simply be a reflection of the experimental designs. Similar trends of reduced sap yield with tubing system component age are observed in the relationship between dropline age and sap yield (Figure 2B). Nearly half of sap yield (R^2 value of 0.487) is attributable to differences in dropline age. However, the lower slope of this relationship (-2.0 gal/year) indicates that increasing dropline age has a smaller negative impact on sap yield than does increasing spout or spout adapter age.

In contrast, the influence of lateral line age (Figure 2C) on sap yield is less than half as strong as that of spout/spout adapter or dropline age. The consequences of increasing lateral line age are relatively low, with the average loss of only 1.0 gal of sap per tap each year as lateral line ages. Mainline age appears to have very little influence on sap yield (Figure 2D).

A comparison of sap yields from producers using standard small spouts versus the Leader Check-valve spout adapter revealed an 18.9% increase in sap yield for those producers using Check-valve adapters.

Finally, although the range of vacuum level reported fell within a fairly narrow band (minimum 18" Hg, maximum 25" Hg), there was a significant positive relationship such that as vacuum level increased, sap yield increased at a rate of 6.5% for each inch of Hg vacuum pulled, which confirms the approximate magnitude of this relationship in previous findings (Wilmot, Perkins and van den Berg 2007).

DISCUSSION

The results presented in this preliminary assessment are consistent with recent reports

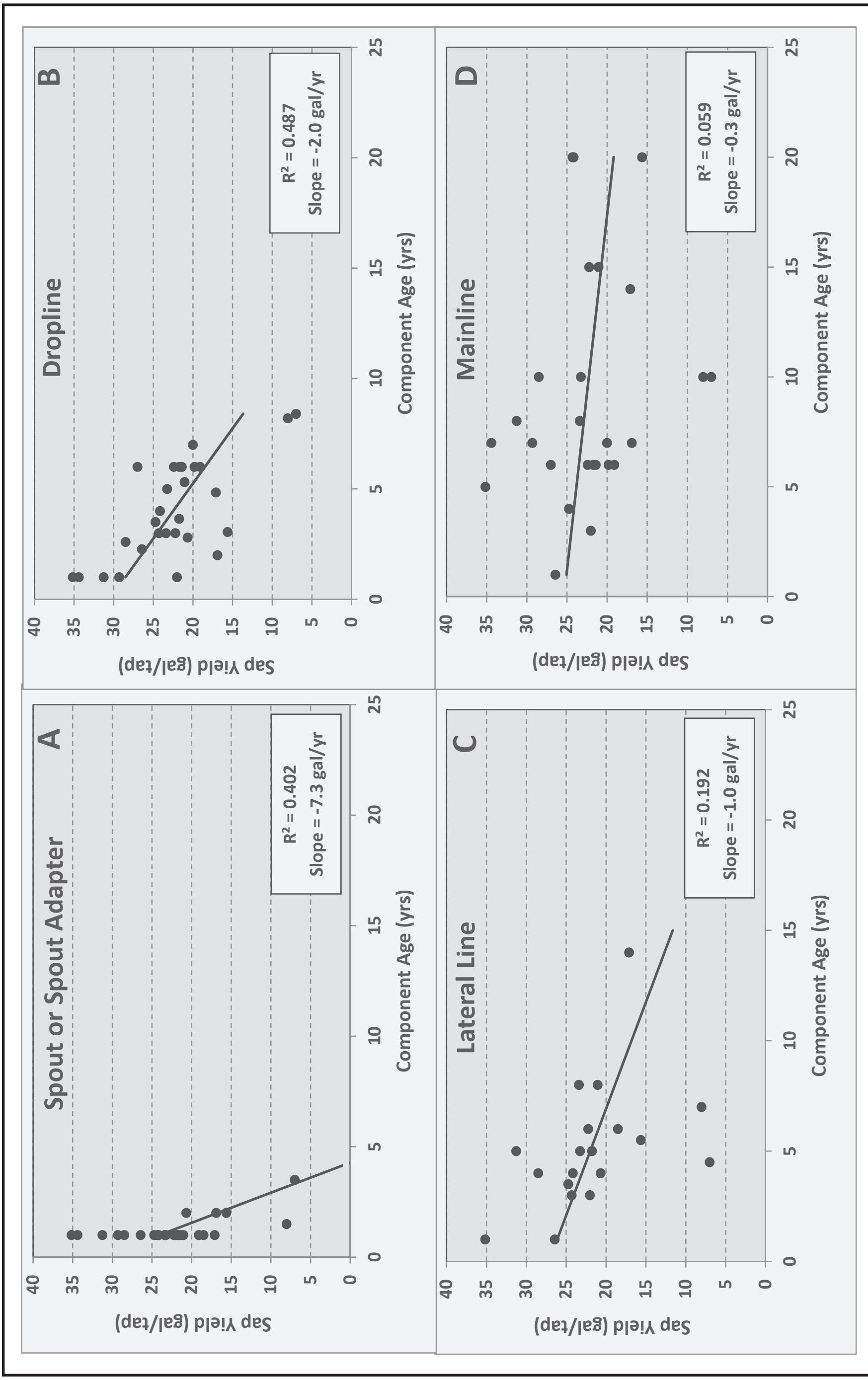

Figure 2. *Relationship between tubing system component age and sap yield (gal/tap) for spouts or spout adapters (A), dropline (B), lateral line (C) and mainline (D).*

that microbial contamination in parts of the vacuum sap collection system nearest the taphole have a strong influence on sap yield. Both spout/spout adapter age and dropline age strongly affect sap yield, although the impact of increasing spout age is 3.7 times greater than that of increasing dropline age (slopes of -7.3 gal/yr versus -2.0 gal/yr respectively).

If we assume the cost of a new spout adapter ranges from $0.15-0.35, it is readily apparent that it is economically advantageous to use a new spout adapter each season, with net profits of $3.30-3.50 per taphole (assuming sap value of $0.50/gallon and negligible costs for installing new adapters). On the other hand, although they have a moderately strong influence on yield, the economic case for installing new droplines is less clear. Given a slope of -2.0 gallons of sap per tap per year, putting in a new dropline each year would have to cost less than $1.00 (2 gallons of sap x $0.50/gallon) in order to simply break even. A dropline cost higher than $1.00 would result in an economic loss. Considering most maple producers replace tees when they install new droplines, it would be hard to justify replacing droplines every year, however the impact is additive, therefore a dropline replacement interval of every 2-3 years would likely result in a marginal profit. If we also factor in the labor cost of making the new drops, bringing them into the woods, their installation, and removal of old drops, then a dropline replacement interval of 4-6 years would likely be required to recoup costs and produce a net profit. The low relationship (R^2) and low impact (slope) of either lateral line or mainline aging and the high cost of replacement of these components strongly argues against replacement as a strategy for increasing sap yields. Instead, it is the useful lifespan of the materials and any breakdown of these components that dictates their periodic replacement.

The use of a new Check-valve spout each year instead of normal spouts changes the economic calculation considerably. If a maple producer can achieve nearly the same result through the replacement of a fairly inexpensive spout as they would through the replacement of both the spout and the dropline (and the tee as is common practice), then replacement of droplines would not be necessary as often, and it may be simpler and more cost effective to only replace drops approximately every 10 years or when an entire system is replaced due to breakdown.

Additionally, this project reinforces previous work that sap yield is linearly related to vacuum level (Wilmot, Perkins and van den Berg 2007). Therefore, in addition to good tubing system sanitation, achieving good vacuum is also important for producers wishing to achieve maximum yields in maple tubing systems.

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