FIELD EVALUATION OF THE SMALL DIAMETER SPOUT FOR MAPLE SAP COLLECTION

By

Lewis J. Staats and Colin A. Campbell
Department of Natural Resources
Cornell University, Ithaca, New York 14853

Abstract. *Beginning in 1999, a newly introduced maple sap spout for use in smaller diameter tapholes was evaluated at Cornell University's Uihlein Sugar Maple Research/Extension Field Station near Lake Placid, New York. After two sap production seasons, no significant differences were found in sap volume yield and sap sugar concentration in maple sap collected with the small diameter spout compared with that of the conventional sap spouts. For tapholes fitted with the small diameter spout, the rate of taphole closure was significantly faster and the amount of discoloration was considerably less. The use of the small diameter spout provides an alternative to traditional diameter spouts by providing comparable sap yield and sap sugar concentration while exhibiting less xylem discoloration with faster taphole closure. In addition, the use of the small diameter spout provides an alternative for the producer to tap with lighter, smaller tapping equipment and to insert the spout into the taphole with less effort reducing the risk of tree damage. (In this report, we have chosen the term "small diameter spout" to identify the spout investigated in this study rather than commercial names commonly used by the maple industry.)*

BACKGROUND

The basic concept of tapping sugar maple trees for collecting maple sap in commercial maple syrup production has remained unchanged for over 100 years (Koelling and Heiligmann 1996). Metal spouts have been used traditionally in bucket operations and plastic spouts are used in more modern plastic tubing sap collection systems. The basic design of spouts used for tapping trees for sap production has remained relatively the same (Staats and Kelley 1996). The traditional procedure is to drill a 7/16 in. (1.11 cm) diameter hole about 2 to 2 ½ in. (5.1 - 6.4 cm) deep into the tree followed with a spout tapped lightly into the taphole with the use of a hammer.

Nearly a century ago, a study of sap yield in relationship to taphole diameter stated larger tapholes provided greater yields of sap (Jones et al. 1903). In contrast Robbins (1965) reported no significant differences in sap yield among 7/16 in. (1.11 cm), 11/16 in. (1.75 cm), and 15/16 in. (2.38 cm) diameter tapholes but found less sap yield from 3/8 in. (0.95 cm) diameter tapholes compared to sap yield from 7/16 in. (1.11 cm) diameter and larger tapholes. Coons (1987) also recommended 7/16 in. (1.11 cm) diameter tapholes stating smaller diameter tapholes produce less sap while tapholes larger than 7/16 in. (1.11 cm) did not increase sap yield. The 7/16 in. (1.11 cm) diameter was chosen for good sap production but small enough to allow taphole closure in an adequate length of time and has remained the traditional diameter for maple industry spouts (Walters and Yawney 1982). A study of spout design among four common commercial metal spouts for use with buckets (Robbins 1965) and comparisons of plastic spout designs for use in plastic tubing sap collection systems (Rye and Walters 1977; Staats and Kelley 1996) did not indicate any significant differences in sap yield or sap sugar concentration among those spout designs studied.

Spouts used for sap production are tapered where they enter the taphole. When inserted into the taphole and tapped lightly, the spout is seated to form a water and airtight seal. If tapped into the taphole with too much force or if the wood at the taphole site is frozen, there is risk of the bark and xylem (sapwood) splitting above and below the taphole which may cause permanent tree damage (Walters 1978). A spout of unique design that did not require force to be inserted into the taphole was found to allow faster closure of tapholes compared to the conventional spout that had to be seated with a hammer (Staats and Kelley 1996). The design and use of spouts that reduce the need for force for seating in the taphole along with proper tapping techniques can reduce the risk of damage to tree tissue adjacent to the taphole. This encourages early closure of tapholes, which is beneficial to the productivity and long-term management of sugar maples for sap production.

During the last forty years, the advent of plastic tubing for sap collection has greatly replaced and reduced the more traditional use of buckets for sap collection. Although buckets still remain present in maple operations, closed-tubing systems serve the maple industry for collection of sap for most producers and for nearly all maple operations with substantial numbers of taps. Along with permanently installed plastic tubing systems, vacuum pumping has been accepted for its benefits of cost-effectiveness, increase in operational efficiency, and well-documented increased sap production (Morrow and Gibbs 1969). Although examination of higher levels of vacuum resulted in significantly higher sap volumes, the application of vacuum at a level of 15 in. (380 mm) Mercury (Hg) at the tap, considered "high-vacuum" in industry terms, was found to be the optimal level of vacuum for sap yield (Kelley and Staats 1989). Because the benefits of vacuum have been clearly demonstrated and applied throughout the industry, further research associated with plastic tubing sap collection system design or installation components, such as spouts, will be best served in collection systems with applied high-vacuum.

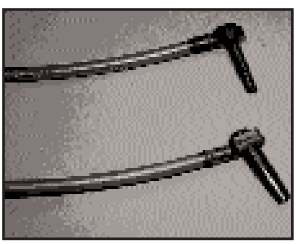

Figure 1. The small diameter spout (top) and control spout (bottom).

The infamous "January 1998 Ice Storm" severely impacted sugarbush stands in several Northeastern states and Canadian provinces (Staats 2001). Producers, uncertain of the benefits and effects of tapping ice-damaged trees but wanting to remain economically viable with continued production, felt tapping more conservatively could help reduce the amount of wound area and, thus, the energy demands on the damaged trees (Connelly et al 1999). During the restoration and replacement of sap collection tubing systems damaged or lost as a result of the ice storm, many producers decided to replace conventional spouts requiring a 7/16 in. (1.11 cm) diameter taphole, with small diameter spouts which utilize a 19/64 in. or 5/16 in. (0.75 cm) diameter taphole, recently introduced for the maple industry. The producers felt the smaller diameter taphole required for the use of the small diameter spout offered a potential for wound reduction even though information regarding performance of the new spout was limited (pers. comm. NENY Maple Producers Assoc.). The interest in the use of the small diameter spout (Figure 1) exhibited by maple producers affected by the 1998 ice storm and encouragement by the maple industry in general for examination of the potential of this new concept prompted the evaluation described in this report.

THE STUDY AREA

The Uihlein Sugar Maple Research/Extension Field Station of Cornell University located near Lake Placid, New York served as the site for this research. The study site is located at an elevation of about 2050 ft. (625 m) on a southeasterly aspect with a slope averaging about 7 percent. The soil series is classified as Becket sandy loam, a deep well-drained soil of glacial till origin (SCS USDA Soil Survey of Essex County, New York 1978). The sugar maples used for this study are located in a natural forest stand that has been under a forest management program for over 20 years. Tree age at the study site is approximate 75 years and trees averaged 15.11 in. (38.4 cm) in diameter at breast height and 70 ft (21 m.) in height. Annual syrup production in this site has averaged .28 gal (1.3 L) /tap for the last 10 years (Cornell Univ. unpublished data).

METHODS

In early winter of 1999, study trees were selected based on current tapping diameter guidelines (Heiligmann and Koelling 1996) to provide 8 tubing lines with 10 taps for each line totaling 80 taps for the study. The tubing lines consisted of Waterloo-Small[1] semi-rigid maple sap collection plastic tubing and fittings throughout the study, and were installed in the winter prior to the 1999 maple production season. Half of the lines were fitted with the recently introduced small diameter spouts and the remaining half of the lines were fitted with conventional spouts. The spout treatments were randomly assigned to lines. Study trees were tapped just prior to first sap flow date for the region using a slow speed power tapper. Tapholes were drilled to a depth of 2 in. (5 cm) for each spout treatment. To reduce the effects of tree variation, the spout treatments assigned to lines for the second year of the study were reversed from that of the first year. For the two years of the sap production phase of the study, sap was collected in 15 gal. (70 L) containers that served as sap collection vessels as well as vacuum chambers. Vacuum was maintained at a minimum of 15 in. (380 mm) Hg at the tap during sapflow trials. Vacuum gauges were installed at each sap collection vessel and vacuum was checked randomly at taps and ends of lines during the duration of the study. The study was designed and installed in a manner for sap to be collected and measured in the collection vessels during daily trials but with an arrangement of valves to allow sap to be transferred into the field station's sap collection system for processing. Following each sap production season, collection vessels were removed from the field, washed with hot water, and reinstalled prior to the following sap production season. Tubing lines for the study remained in place and were washed after each season with a solution consisting of 1 part household bleach in 20 parts water.

Sap flow data were obtained during the 1999 and 2000 sap production seasons. For each daily trial, collection vessels and study lines were activated for vacuum and sap collection at the beginning of each sap flow period and continued throughout the day until nightfall or freezing point, whichever came first. During each sap flow trial period, trial start and stop times, level of vacuum, volume of sap, and sap sugar concentration was recorded for each line. For each sap collection vessel, sap volume was measured to the nearest 0.5 liter and recorded in the field. Sap sugar concentration was determined by collecting a representative sample of sap in a 25 ml vial from each collection vessel and measured with a Reichart Mark II temperature compensating digital refractometer in the field station office.

Taphole closure was measured after the growing season following each sap production season. The width of the taphole (i.e. the distance between the edges of callous tissue forming from annual growth of cambial tissue on the lateral walls of the taphole) was measured to the nearest 0.01 cm using digital calipers. Tapholes were coded by spout

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[1]No endorsement of product by Cornell University is intended nor implied.

treatment and study year with colored tree marking crayons. Percent closure was determined by calculating the amount of formed callous tissue compared to the diameter of the original taphole (i.e. taphole closure).

A representative sample of trees were felled in the fall of 2001 allowing two complete growing seasons to take place after the second sap production trial year. A section containing the tapholes with adequate wood to encompass the discoloration zones was marked for identification and removed from each sampled tree. The discoloration zone formed laterally and vertically relative to the taphole by spout treatment was determined by dissecting the tapping zone section of the tree. Data analyses were performed with MS EXCEL and MINITAB on a Gateway PC computer.

RESULTS

During 1999 and 2000, sap volume and sap sugar concentration measurements were collected from a total of twenty-six daily sap flow trials (13 for each year). For the two years, the average sap volume was 2.32 L/tap for the conventional spout treatment, slightly above the 2.20 L/tap for the small diameter spout . Sap sugar concentration averaged 2.0 percent for both treatments over the two-year period.

No significant differences in sap volume or in sap sugar concentration were found in sap collected with the small diameter spout compared with that of the conventional spout.

The level of vacuum at the tap averaged 16 in. (410 mm) Hg throughout the study and no differences of maintained vacuum level were observed between lines during flow dates.

After two growing seasons, the faster rate of taphole closure for tapholes fitted with the small diameter spout was highly significant (P <0.001). Following one growing season, taphole closure for tapholes fitted with the small diameter spouts averaged 32.44 percent and 53.27 percent for the 1999 trial and 2000 trial, respectively, compared to 26.51 percent and 39.97 percent for tapholes fitted with conventional spouts. Following two growing seasons taphole closure for the small diameter spouts was 89.64 percent and 80.26 percent for the 1999 and 2000 trials, respectively. For the same two-year period, the rate of taphole closure for the conventional spout treatment was 72.21 percent for 1999 and 67.28 percent for the 2000 trial.

After taphole closure measurements were completed following two complete growing seasons, a representative sample of five trees in the study area were selected and felled to provide an examination of the amount of discoloration associated with each spout treatment. For each tree, the lower section of the bole inclusive of the tapping zone of each spout treatment was removed in the field. The tapping zone for each spout treatment in each of the trees was examined to determine the depth, length and width of discoloration zone. Each discoloration zone was cut into smaller sections by band saw and measured to .01 cm using digital calipers. Calculations were made to account for saw kerf. Of the five trees examined, one tree was eliminated because discoloration zones from wounding prior to the experiment interfered with measurements. For the remaining four sample trees the average amount of discoloration associated with the conventional spout was 25.72 cubic in. (422 cubic cm) while the amount of discoloration for the small diameter spout averaged 11.09 cubic in. (182 cubic cm).

DISCUSSION AND MANAGEMENT IMPLICATIONS

This study found maple sap volume yield collected under vacuum 15 - 17 in. (380 - 435 mm) Hg from trees fitted with small diameter spouts to be comparable with that of trees tapped with conventional diameter spouts. Sap sugar concentration in sap collected throughout the study indicated no significant differences between the two spout treatments. The trends of sugar concentration by treatment (spout treatments by lines were reversed for the second year of the study) for each year of the study can be attributed to individual tree characteristics. This illustrates the importance of providing for more than one year of field trials for studies related to maple sap flow and also supports the fact that trees maintain their sap sugar concentration relative to one another year after year (Taylor 1956).

The faster rate of taphole closure associated with the tapholes fitted with the small diameter spout provides a positive effect for maple sap production. The shorter period of time for the formation of callous tissue required for taphole closure allows the tree to begin growing new xylem (sapwood) over an existing taphole. The faster rate of taphole closure may be attributed to the smaller diameter of the taphole, thus, less amount of callous must be formed to close the taphole. The fact that less force is required to set the smaller diameter spout in the taphole may result in less compression of cambium and xylem cells adjacent to the taphole allowing a greater number of uninjured cells to respond in the formation of callous tissue.

In addition to reducing the amount of taphole discoloration zone combined with sap volume yield and sap sugar concentration comparable to that with use of the larger diameter conventional spout, the use of the small diameter spout can allow greater ease during the tapping process. The use of the smaller diameter spout requires a smaller bit, 5/16 in. (0.79 cm) compared to 7/16 in. (1.11 cm) for the conventional spout, which allows producers to use a drill of less power and, thus, often less weight such as a cordless battery pack drill. The spout can be inserted into the taphole by a combined push and twist of the hand with possibly a slight tap with a light hammer. This allows greater efficiency for one man tapping and inserting the spout and virtually eliminates the possibility of tree damage caused by the splitting of cambium adjacent to the taphole. The reduced effort in the tapping procedure as a result in using a tapping unit of less weight combined with the ease of inserting the spout may also contribute to less fatique and therefore provide greater operator safety during the tapping process.

The reduced amount of discoloration zone and faster rate of taphole closure associated with use of the small diameter spout might suggest to some producers that current tree tapping diameter guidelines can be modified to allow a greater number of taps per tree diameter class and smaller trees to be tapped. Based on the information presented at this time and the limited number of years of industry application of the small diameter spout, we strongly encourage maple producers to follow the conservative guidelines established for tapping using conventional spouts. Wounding a tree can impart greater potential impact on tree health than removal of a larger amount of sap. More taps in a tree does not provide a guarantee for a proportionally greater amount of sap yield, and research and industry application illustrates that volume yield of sap per taphole can increase when fewer taps placed on a tree are practiced (Koelling and Heiligmann 1996).

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