RIPARIAN SILVER MAPLE AND UPLAND SUGAR MAPLE TREES SAP SUGAR PARAMETERS IN SOUTHERN ILLINOIS

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ABSTRACT.—Forty two upland sugar maple trees and 59 riparian silver maples were tapped in 2003 to characterize their sap sugar parameters within the southern Illinois region. The mean sap sugar concentration (SSC) among all sugar maple trees was 2.03 percent (1.53 to 3.18 percent range) and the mean sap volume was 133.7 liters per tree or 44.6 liters per tap. Tree basal area was significantly related to total sap volume but not SSC in sugar maples. Sugar maple trees receiving additional taps than recommended guidelines had significantly reduced mean volume per tap but similar total sap volume compared to guideline-tapped trees. Silver maple mean SSC for the season was 1.71 percent (1.10 to 2.53 percent range) and mean total sap volume was 32.6 liters or 23.5 liters per tap. Silver maple total sap volume and sap volume per tap was dependent upon number of taps per tree. Total sap volume and SSC was positively related to basal area of silver maples.

Introduction

A sustainable maple forest resource provides several benefits to the environment and landowners. These benefits include wildlife habitat, timber, carbon sequestration, riparian zone filters, wind and water breaks, and other products. Maple syrup production is an important sustainable forest-based industry within the United States, especially in the northeast. In 2002, the United States production of maple syrup was 5.3 million liters and valued at $38.4 million. The primary maple syrup producers are located in Vermont, Maine, and New York. In 2001, Vermont alone had a maple syrup production value estimated at $8.4 million (Davis 2003). Of the 13 native North American maple species, Sugar maple (*Acer saccharum* Marsh.) and black maple (*Acer nigrum* Michx. f.) are preferred for commercial tapping because of their relatively high sap sugar concentration (SSC) (averaging between 2.0 and 2.5 percent) and long sap collection season (Heiligmann and Winch 1996).

Production of maple syrup is most cost effective if trees produce large volumes of sap with high sugar concentration. This is in part because of the effort, energy, and resources needed to tap trees, collect sap, and produce syrup from sap. While it takes 87.2 liters of sap with a sugar concentration of 1 percent to make one liter of maple syrup, only half the sap is required if SSC is 2% (Willits and Hills 1976). Typically, the sap sugar concentration for sugar maples can range anywhere from 2 to 6 percent, with a tree producing anywhere from 4 to 8 liters of sap per day during peak days (Tyree 1983).

Silver maple (*Acer saccharinum* L.) trees have often been disregarded for tapping because of their shorter collection season due to early budbreak, lower average SSC of 1.5 to 2.0 percent, and higher levels of sugar sand production when processed (Walters 1982, Heiligmann and Winch 1996). However, studies (Larson and Jaciw 1967, Zaczek et al. 2003) have shown considerable variability in sap sugar parameters of individual silver maples, suggesting that progress could be made with tree improvement efforts. Additionally, silver maples grow on a wide range of sites, are flood tolerant, and grow quickly (Hardin et al. 2001). These characteristics may allow maple syrup production on traditionally underutilized bottomland sites, including riparian buffers.

Much of southern and western Illinois is considered outside of the range of commercial maple syrup production (Heiligmann et al. 1996). This may be due in part to an unsuitable climate, a scarcity of maple trees, or poor sap characteristics. Climatic conditions that induce sap flow occur when temperatures oscillate above and below the freezing point anytime during the tree's dormant season (Heiligmann et al. 1996). Although climatic conditions may not be as favorable in this region when compared to others,

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southern Illinois weather conditions include these oscillating periods of freezing and thawing albeit, occurring earlier in the year than areas farther north.

Even though the oak hickory forest type is most common in Illinois there is a considerable existing and currently increasing component of maple in the region (Bretthauer and Edgington 2002, Bretthauer and Edgington 2003). It was reported that the amount of commercial oak-hickory forests dropped 14 percent while maple-beech forests increased by 4,219 percent (10,290 ha to 434,200 ha) from 1962 to 1985, reflecting land use changes and successional processes (Iverson et al. 1989, Fralish 1997, Bretthauer and Edgington 2002, Bretthauer and Edgington 2003).

There is a paucity of information about the sap parameter performance of maple trees in the region. Recent published information (Keeley 2000, Zaczek et al. 2003) has primarily focused on the relative differences among young and small diameter clones from wide-ranging provenances of silver maple that are being grown in southern Illinois. Information on mature larger-sized endemic maple trees is essentially lacking for the region. This study was conducted to provide information and comparisons on the sap performance parameters (SSC and sap volume) of native sugar maple and silver maple trees growing on representative field sites in southern Illinois.

Methods

Study Area

The sugar maple trees used for this study were located on the Buchheit farm near Lick Creek, IL, in Union County, approximately 48 kilometers southeast of Carbondale. The mature forested upland site had variable aspect and rolling topography and was of the oak hickory type with associated sugar maple in the overstory and midstory. Study trees in dominant or co-dominant crown classes were located along a portion of an access trail selected as a fixed population of sugar maple that had been tapped in previous years by the landowner. The site was used as part of a low intensity rotational cattle pasture. Silver maple trees were located along a relatively narrow riparian zone adjacent to open agriculture row crops and grassland within 10 meters of Little Crab Orchard Creek, bounded by Chautauqua and Rowden Roads on Southern Illinois University property near Carbondale, IL, in Jackson County. The site was composed primarily of early successional tree species trees with tapped silver maples in the dominant or co-dominant crown classes.

Field Procedures

Tapping procedures and equipment were similar for both sugar maple and silver maple. Starting in mid-January 2003, 42 sugar maples and 59 silver maples were tapped using a cordless power drill with a 7.9 mm in diameter drill bit. Holes were drilled 3.8 cm deep with a slight upward slope. This is the recommended depth for 7.9mm diameter spiles (personal communication from Timothy Perkins on February 3, 2004 based on research at the Proctor Maple Research Station, University of Vermont). Tree Saver food grade nylon spiles, (Sugar Bush Supplies Co. Mason, MI) were then hammered into the holes using a rubber mallet. These spiles are smaller in diameter at 7.9 mm and purportedly allow the tree to heal-over tapholes more quickly than more traditionally-sized spiles with diameters of 11.1 mm (Perkins 1999). Polyethylene tubing was run from the spile end to 19 liter plastic food grade buckets to collect sap.

The number of taps for each sugar maple tree (ranging from 2-6) was established by the landowner. This was done in previous years by estimating tree size and increasing the number of taps as tree size increased. These estimates did not strictly follow traditional tapping guidelines for the number of taps per tree of a given diameter at breast height (DBH) as recommended in the North American Maple Sugar Producers Manual (NAMSPM) (Heiligmann et al. 1996). Tapping silver maple trees also did not strictly follow NAMSPM tapping guidelines and included some trees slightly smaller in DBH than recommended. Since an unknown response of silver maple to tapping guidelines using smaller diameter taps exists, a comparative analysis of the sap parameters was performed for trees categorized as; guideline-tapped (guideline recommended number of tapholes per tree DBH); undertapped (fewer tapholes per tree DBH); and overtapped (greater numbers of tapholes per tree DBH).

The data collection period for SSC analysis and sap volume of the sugar maple trees was from January 29 to March 2, 2003. There were six sap collections for SSC analysis and there were eight volume measurements. For silver maple, there were four collection periods for SSC analysis and four volume measurements, starting January 31 and ending on March 5.

Diameter at breast height in centimeters was measured on July 22, 2003. Basal area (cm^2) was determined for each tree by calculating the cross-sectional area for each stem forking below breast height (Π *(1/2 DBH) ^{2}) and summing the total for each stem of the tree.

Laboratory Procedures

To determine SSC, samples were collected from each tree directly from the tubing with 1.5ml polypropylene microcentrifuge tubes (Fisher Scientific Pittsburg, PA) while sap was actively flowing. The sap samples were brought back to the lab, refrigerated (1.1°C to 4.4°C), and analyzed within 48 hours. SSC was measured using a temperature compensated refractometer (Fisher Scientific Pittsburgh, PA). The refractometer was initially calibrated and periodically recalibrated using distilled water. Sap sugar concentration was determined by placing a drop of sap from sample tubes onto the lens of the refractometer, exposing it to a fluorescent light, and reading the scale to the nearest tenth of a percent. The lens was cleaned between each sample. Sap volume (ml) was determined by measuring the depth of the sap in the bucket in the field to the nearest 0.1 cm using a ruler. The bucket depth to volume conversion was determined by calibrating the buckets with known volumes of water and measuring depth, producing a linear regression equation with a R^2=0.99 ($p<0.0001$).

Analysis Method

Mean DBH, basal area (BA), SSC, total sap volume, and sap volume per tap were determined for each species to provide baseline information on sap parameter performance and general comparisons between the two species. Variance analysis using JMPIN software (SAS institute, Cary, North Carolina) at alpha=0.05 compared stem basal areas of each tree between species to determine if the sample populations of each species differed in stem size. Comparing the two species for sap parameters was not warranted. This is because the species did not co-occur on each site and sites were considerably different physically and developmentally potentially confounding species to species comparisons. Analysis of variance was used to determine if differences existed among silver maple and among sugar maple trees using individual tree SSC for each collection period. Analysis of total sap volume and sap volume per tap was made for each species by tapping categories (undertapped, overtapped, and guideline-tapped). Since there were only two sugar maple trees that were considered undertapped according to NAMSPM guidelines, this category was omitted when analyzing sugar maple by tapping guidelines. For each species, linear regression was used to determine if significant relationships existed between SSC and BA, SSC and sap volume, and BA and sap volume. Basal area was used in regression analyses to sap parameters instead of DBH because previous studies have shown stronger relationships (Keeley 2000, Zaczek et al. 2003).

Results

The mean DBH of sugar maple trees was 56.6 cm with a range from 26.2 to 122.3 cm. Mean basal area of sugar maple trees was 1823.8 cm^2 with a range from 539.1 to 5229.6 cm^2. Silver maple mean DBH was 43.3 cm (range 22.4 to 101.1 cm) and mean BA was 1622.2 cm^2 (range 394.1 to 8027.7 cm^2). Basal area of the trees was similar for both species (p=0.4961).

Sugar maple mean SSC was 2.03 percent ranging from 1.53 to 3.18 percent for individual trees. The season high SSC for a single tree during an individual collection date was 3.70 percent. Among sugar maple trees there was no significant relationship between SSC and basal area (p=0.5243).

Silver maple mean SSC was 1.71 percent ranging from a season-wide 1.10 to 2.53 percent for individual trees. The highest SSC among silver maple trees for a single collection date was 2.70 percent. Among silver maples there was a significant but weak relationship between a tree's basal area and SSC (R^2=0.07, p=0.0386).

Table 1.—Sap sugar concentration (SSC) characteristics of upland sugar maple and riparian silver maple trees growing in southern Illinois.

Species	Number of trees	Mean SSC (%)	Range SSC (%)	% Trees with a SSC at or above 2.00
Silver Maple	59	1.71	1.10-2.53	27%
Sugar Maple	42	2.03	2.53-3.18	60%

Sap volume produced from the population of 42 sugar maple trees totaled 5614.4 liters for the season (a mean of 133.7 liters per tree or 44.6 liters per tap). One individual tree produced 338.6 liters of sap for the season. There was a significant positive linear relationship between total sap volume of sugar maples and their basal area (R^2=0.69, p<0.0001) but this may be confounded by larger trees having more taps in general. In order to eliminate this, an analysis for trees with only 2 taps (n=27) determined that the total sap volume of a tree was still positively related to its basal area (R^2=0.28, p=0.0049). Accounting for variable number of taps by determining a tree's sap volume per tap, regression analysis also determined that there was a significant but weak positive relationship of sap volume per tap to basal area (R^2=0.15, p=0.0101). No relationship existed between a sugar maple's SSC and total sap volume for the season (p=0.4222).

The 59 silver maple trees produced 1925.3 liters of sap over the season (mean per tree 32.6 liters, and a mean of 23.5 liters per tap) with the highest total volume produced by a tree being 141.9 liters of sap. There was a significant positive linear relationship between total sap volume per tree and BA (R^2=0.30, p<0.0001). This may have been related to the number of taps per tree generally increasing with increasing tree size. Considering this, the sap volume per tap and BA were not significantly related (R^2=0.07, p<0.0584). However, a significant positive relationship existed between SSC and total sap volume (R^2=0.29, p<0.0001) and between SSC and volume per tap (R^2=0.16, p<0.0015).

Total sap volume examined according to tapping category per tree (Table 2) showed no significant difference among guideline-tapped and overtapped sugar maples (t=0.6680). Considering sugar maple sap volume per tap with regard to tapping categories, guideline-tapped trees tended to produce more sap per tap (48.8 liters) than overtapped trees (38.9 liters) (R^2=0.12, t=0.0265).

Silver maple total sap volume (Table 2) was significantly greater for overtapped and undertapped trees compared to guideline-tapped trees (R^2=0.16, p=0.0089). Among silver maples, sap volume per tap was greater for undertapped trees compared to guideline-tapped or overtapped trees (R^2=0.15, p=0.0098).

Discussion

Within each maple species there was considerable variation in sap volume production as well as SSC. Sap sugar concentration is a very important factor in production efficiency and cost. Sugar maple SSC (mean 2.03 percent) in our study fell into the range 2.0 to 2.5 percent expected in other regions and may vary due to genetics, site and environmental conditions such as weather (Heiligmann and Winch 1996). Silver maple SSC was 1.71 percent which is in the range expected for the species in other regions (Walters 1982, Heiligmann and Winch 1996). However, a previous study of woodlot-grown silver maples found that mean SSC was higher at 2.6 percent and ranged from 1.7 to 5.1 percent (Larsson and Jaciw 1967). In the current study study, 27 percent of the 59 silver maple trees tapped, had a SSC at or above 2.0 percent whereas 60 percent of the sugar maples had SSC at or above 2.0 (table 1). Sap sugar concentrations of individual sugar maple trees have been found to be relatively consistent from year-to-year (Taylor 1956, Kriebel 1960). A two year examination of silver maples also showed a year-to-year consistency (Keeley 2000). Therefore, trees with lower SSC may be culled out, leaving only those trees that have a higher SSC.

Sugar maple SSC was not related to total sap volume. A study done by Blum (1971) also found no significant relationship between SSC and total sap volume among three sugar maple stands. Additionally no relationship was found between SSC and basal area, indicating that larger sugar maple trees are not necessarily sweeter trees. However, when considering all sugar maples, higher DBH trees produce more

Table 2.—Comparisons of basal area (BA), total volume, total volume per tap, and sap sugar concentration (SSC) for sugar maple and silver maple trees receiving the recommended number of taps (guideline-tapped), more taps (overtapped) or fewer taps (undertapped) than guidelines published in the North American Maple Syrup Producers Manual (Heiligmann and Winch 1996).

Silver Maple

Tapping categories	Number of trees	Mean BA (cm^2)	Mean total sap volume (L)	Mean sap volume/tap (L)	SSC (%)
Guideline	33	1250.4	22.6 (b)	18.7 (b)	1.60 (b)
Overtapped	7	1531.4	54.9 (a)	16.7 (b)	2.03 (a)
Undertapped	19	2301.5	41.8 (a)	30.9 (a)	1.81 (a)
		NS	*	*	*

Sugar Maple

Tapping categories	Number of trees	Mean BA (cm^2)	Mean total sap volume (L)	Mean sap volume/tap (L)	SSC (%)
Guideline	13	1897.0	125.2	48.8 (a)	2.12
Overtapped	27	1766.8	138.1	38.9 (b)	1.99
		NS	NS	*	NS

Note: Means by species in a column followed by the same letter are not significantly different alpha=0.05 using LSD mean separation procedures
NS = Not Significantly Different
* = P<0.05 (Silver maple, F-test with 2 degrees of freedom; Sugar maple, t-test with 1 degree of freedom)

total sap volume although this may be a result of larger trees tending to have more tapholes or having larger root systems. There was a significant relationship between tree basal area and total sap volume of sugar maples. Accounting for this and examining the 27 individual sugar maple trees with just two taps, it was still found that as the basal area increased so did the total sap volume. Sugar maple trees totaled 5614.4 liters of sap for the season or a mean of 133.7 liters per tree or 44.6 liters per tap. In other studies sugar maple total sap volume was found to be relatively consistent from year to year (Marvin et al. 1967), suggesting that this can be used to select for tree with desirable sap volume production.

Contrary to sugar maple, silver maple SSC was positively related to both total sap volume and basal area. This indicates that larger silver maple trees tend to be sweeter and also produce more sap volume. Silver maple is one of the fastest growing hardwoods and the fastest growing of the North American maple species (Dirr 1975, Heiligmann and Winch 1996). Since it may be possible to select for sweeter silver maples by selecting larger silver maples, their fast growth rate would be a positive species characteristic to consider. Silver maples have been found to grow from 1.3cm to approximately 2.5cm in DBH each year (Gabriel 1990); this would mean that they would reach a large enough size for tapping between 15 to 20 years compared to the 40 to 60 years for sugar maples to reach a size appropriate for tapping (Heiligmann and Winch 1996). Silver maples, unlike sugar maples, can be readily clonally propagated (Preece et al. 1991). A study done by Kriebel in 1989, indicated that SSC among sugar maple grafted clones was relatively consistent over the years. Therefore there may be potential to select for silver maple trees with desirable sap characteristics, and receive similar results from their propagated clones when grown in comparable environments.

Environmental influences and species differences, probably affected sap volume yields in this study. In addition, a tapping depth of 3.8cm and the use of relatively smaller 7.9 mm diameter spiles may have also influenced sap volume yield. Tapping depth has been shown to be related to sap volume yield, with deeper tapholes resulting in higher volume yields (Cope 1949, Perkins 1999). While past research has shown taphole diameter did not affect sap yields (Robbins 1965). A more recent study found that using smaller diameter spiles sap volume yield was 80-100% the sap volume yield of standard-sized spiles (Perkins 1999). The potential effect on the sap volume yield for this study from reduced tapping depth and smaller diameter spiles, would be a reduced sap volume yield.

Examination of NAMSPM tapping guidelines was done to understand more clearly whether guidelines established for maple tree tapping in the northeastern U.S. are appropriate for southern Illinois using silver and sugar maple tree species. In earlier research, volume of sap collected per taphole has been found to be independent of the number of tapholes per tree (Willits 1967). However, in the current study, both silver and sugar maple sap volume per tap was dependent on the number of taps per tree producing greater sap volume per tap on trees with fewer taps. This is in accordance with Heiligmann et al. (1996) who reported that using fewer tapholes can substantially increase the yield of sap per taphole. In sugar maple, overtapping trees did not produce greater total volumes than guideline tapped trees as a result of reduced sap volume per tap. In addition, overtapping trees is a concern because wounding from tapholes can influence tree health more than harvesting too much sap (Heiligmann et al. 1996).

Undertapped silver maple trees produced more volume per tap than both guideline-tapped and overtapped trees. Overtapped and undertapped trees had a significantly higher SSC and total sap volume than guideline-tapped trees. This agrees with silver maple SSC being positively related to total sap volume, (as shown earlier) regardless of guidelines. This may suggest that the traditional guidelines recommended in the NAMSPM (1 tap for 25-38cm, 2 taps for 38-51cm, 3 taps for 51-64cm, and 4 taps for tree bigger than 64cm) should be reconsidered when tapping. More research is needed to determine if tapping guidelines are appropriate for silver maple.

Conclusion

This study has characterized maple sap sugar parameters of sugar and silver trees in southern Illinois. Both species had a mean SSC that was within the expected range reported in other regions. With past research showing SSC and total sap volume of sugar maple to be relatively consistent over time, there is potential to select for just those trees with desirable SSC and total sap volume production (Taylor 1956, Kriebel 1960, Marvin et al. 1967). Silver maple SSC was positively related to total sap volume and BA. Silver maple SSC has been shown to be consistent from year-to-year (Keeley 2000). Selecting silver maple trees with desirable SSC, may include relatively high total sap volume production. The number of tapholes per tree was shown to influence the amount of sap volume per tap of both species. Each species' sap sugar parameters showed a different response to tapping guidelines. Sugar maple guideline-tapped trees produced as much total sap volume as overtapped trees with similar SSC. Silver maple had a different response with both undertapped and overtapped trees producing more total sap volume with higher SSC. This was unexpected, and reflects the potential need for further research on tapping guidelines.

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