Future Generations University

MAPLE INITIATIVE

Research, Learning, Action for Inclusive & Sustainable Change Worldwide

Research into Designing a Walnut Specific Spile

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INTRODUCTION

Over the years, people have been working to perfect the ideal spile or spout for tapping maple trees. Wooden spouts preceded metal spouts; 5/16-inch spouts have largely replaced by 7/16-inch spouts. Some people like check-valve spouts and some like non-check valve spouts; you can use nylon spouts or polycarbonate spouts, and today, if you are feeling patriotic, you can get them in red, white, or blue. Each of the spouts on the market has advantages and disadvantages; each has advocates and detractors, but they all are catering to the specific anatomical features of sugar maple (*Acer saccharum*) wood, and the environment where a particular maple sugar bush is located.

Black walnut (*Juglans nigra*) is another species that can be tapped, and the sap boiled down to make syrup. Wood anatomists classify black walnut as a semi-ring porous wood, as opposed to the diffuse porous maple species. As a semi-ring porous species, black walnut wood has large and small pores, also called vessels, distributed throughout its xylem (Panshin and Zeeuw, 1970). Walnut wood is relatively soft when compared to sugar maple and its sap flow physiology relies on root pressure as well as stem pressure (Ewers, et.al.,2001). Walnut trees are shade intolerant, fast growing, and abundant in the mid-Atlantic and Midwestern states (USFS, 1990). All of which is to say that black walnut is very different from sugar maple and that what we know about tapping sugar maple trees may not necessarily apply to walnut trees.

The volume of sap flow from black walnut is much less than what is expected from maple. In this 2020 walnut sap flow study, we collected an average of 2 gallons of sap per tap using a bucket collection system. Sugar maple is expected to produce up to 10 gallons of sap per tap on buckets. Given the paucity of sap flow, it would be reasonable to ask, “Why bother?” The answer has to do with the market price of the syrup made. The bulk price for walnut syrup this year was between $150 and $250/gallon, which is close to 10 times the 2020 bulk price of maple syrup. Tonoloway Farm in Highland County Virginia sold all the walnut syrup they made this season retail, in small quantities, and as a maple/walnut blend at prices ranging from $560 to $800/ gallon (Tonoloway Farm, 2020). In addition to a high price for its syrup, black walnut is an abundant tree on abandoned agricultural lands in Virginia and West Virginia and, therefore, presents a syrup making opportunity where sugar maples are less abundant.

2019 SAP SEASON WALNUT SPOUT OBSERVATIONS

During the 2019 sap season, Future Generations University, with funding from the West Virginia Department of Agriculture, began a series of tapping studies on tree species other than maple. We tapped and made syrup from black walnut, sycamore (*Platanus occidentalis*), and black birch (*Betula lenta*) trees. The walnut sap was collected with a 3/16-inch tubing system using 5/16” clear polycarbonate spouts and in sap bags with 7/16” maple spouts. Because of the

thickness of the bark and the softness of the wood, we found that we were often driving the less tapered 5/16-inch spouts all the way into the tree before getting a good seat. Prior research at Future Generations and the Proctor Maple Research Center showed that overdriving spouts in maple sealed off xylem to sap flow, greatly reducing sap yield (Future Generations, 2019). In 2019, we also had trouble developing the expected natural vacuum on the 3/16-inch lines, even though they had plenty of slope. We assumed that the problem was related to vacuum leaks associated with a poor seal in the soft wood with the minimally tapered spouts.

2020 SAP SEASON WALNUT STUDIES

Going into the 2020 sap flow season, we knew we had two problems with commercially available spouts. First, the spout needed a longer barrel to accommodate the thicker bark on walnut trees. Second, there was the presumed issue of vacuum leaks at the tap hole. Working with the Robert C. Byrd Institute of Advanced Manufacturing (RCBI) in Charleston, WV, we had stainless steel spouts manufactured with a 3/4-inch longer barrel and a taper similar to commercially available 7/16-inch maple spouts. They were stainless steel because that is the material they could machine to manufacture the spouts. We decided on 7/16- inch spouts instead of the more commonly used 5/16-inch health spouts and the greater taper because:

- Although not shown to make a significant difference in maple (Wilmot et al., 2007), there seemed to be logic to exposing more xylem through the larger diameter spout would increase sap flow. Maple develops 10 or more psi of stem pressure during sap flow events. Walnut, on the other hand, seems to have low levels of stem pressure during sap flow events; walnut sap has been observed flowing with no measurable build-up of pressure. With less pressure to move sap through the xylem, you may need a bigger hole.
- Walnut is a faster growing tree than sugar maple. We felt that with the faster growth the trees would increase in diameter quickly enough to replace lost xylem without sacrificing area in the tapping zone. The issue with 7/16” in maple is that, given the slow growth of the tree, new wood is not added to the tree fast enough to tap over previous holes within the tapping zone. (**Note:** In a separate study, we are looking at the size and shape of the dead zone associated with both sizes of spout.)
- We wanted the higher taper of the 7/16” spouts to reduce the presumed vacuum loss and ensure a better seal in the tap hole.

Prior to the sap flow season, we did a study on the depth to which various types of spiles penetrated walnut wood before reaching proper seating. Proper seating being defined by the less-than-scientific parameters of (1) the pitch of the blow from the tapping hammer rising, and (2) the hammer bouncing off the spout when hit.

The results of this study are shown in Table 1. The four 5/16-inch maple spouts tested had an average taper of 0.05-inches and seated at an average depth of 0.72 inches. The 7/16 -inch spout, had taper of 0.15-inches and seated at 0.41-inches depth. The more shallowly seated 7/16-inch spouts exposed 0.31 more inches of xylem from which to collect sap. With more exposed wood and a longer barrel to get through the thick bark, it looked like we had a spout more appropriately designed for use in walnut. It is worth noting that when tapped into the harder sugar maple, the 5/16-inch spouts seated at a depth of 0.44-inches, or approximately the same as the more highly tapered 7/16-inch spout in walnut wood.

Depth to seating (inches)	**Spouts tested**	**Barrel taper** (inches)
0.81	5/16 - Polycarb stubby adapter	0.07
0.66	5/16 - Nylon stubby adapter	0.02
0.62	5/16 - Polycarb CDL	0.04
0.79	5/16 - White plastic CDL	0.07
0.41	7/16 - Stainless Steel spout	0.15

Table 1. *Depth of seating for various sap collection spouts in walnut wood*

PARTNERSHIP STUDIES

The amount of exposed xylem is a factor of how far the spout is driven into the tree and how deep the tap hole is in the wood. Maple tap holes under vacuum are typically drilled 1.5 inches deep. This is mostly to avoid tapping into dead wood, which results in a reduced volume of sap. Older tapping guidelines recommended drilling between 2 and 2.5 inches deep. A walnut sap flow study by Gary Naughton et al. (2006) found that sap flow was positively correlated to the thickness of the sapwood. In their study, they drilled through the sapwood, stopping only when dark heartwood shavings came off the drill bit.

During the 2020 sap flow season, we set up a series of trials, partnering with walnut syrup producers, to determine whether we could increase walnut sap flow through the use of more highly tapered spouts with less penetration and drilling a deeper tap hole.

Partnering farmers were: (1) Chip Matheny, Palestine, WV, (2) Christoph Herby (Tonoloway Farm), McDowell, VA (3) Elton Bowers, Upper Tract, WV, (4) Karen Milnes (The Sweetwater Farm), Sugar Grove, WV (Figure 1).

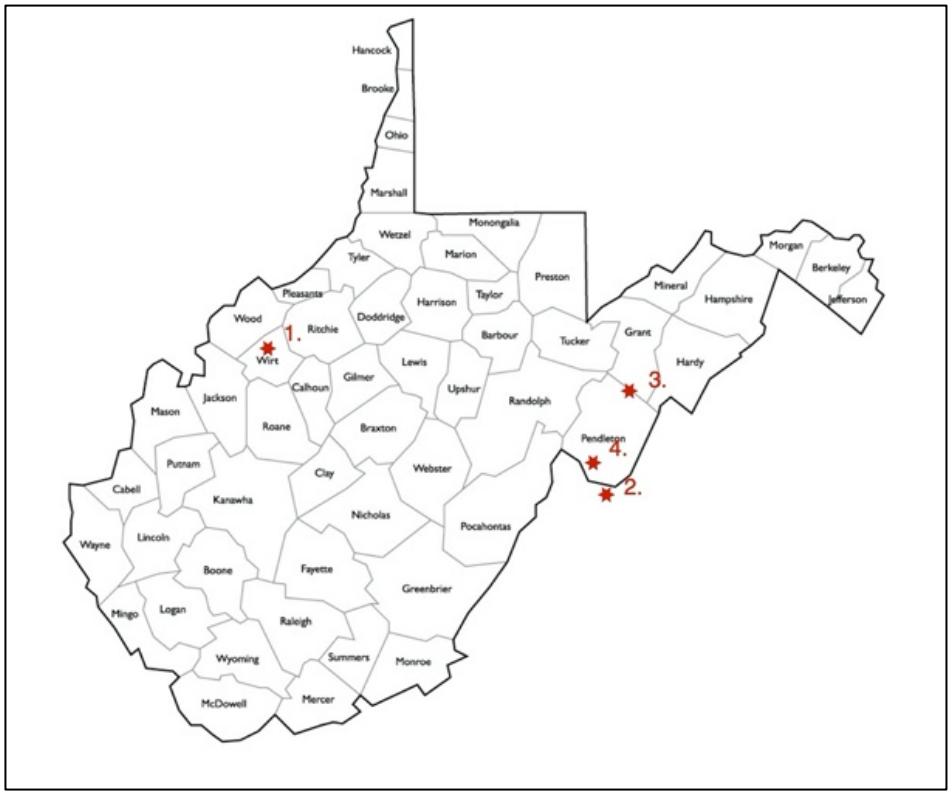

Figure 1. *Locations of participating farms*

METHODOLOGY

Each partnering farmer identified 10 black walnut trees large enough to support 2 taps each. Each tree was tapped with whatever style spout the farmer had used in past years. The farmer was instructed to tap the trees using the same procedures they had used in the past. This most often resulted in drilling 1.5-inch tap holes and tapping in almost the full barrel of the spout.

At Tonoloway, taps were placed on alternating sides of the tree (mostly north & south) so that an equal number of test taps and maple taps were placed on north and south sides of the trees, to eliminate the potential impact of sun exposure and temperature on sap flow.

We then went back to each tree, and I drilled a hole attempting to cross the entire sapwood zone and tapped in one of our 7/16-inch stainless-steel spouts. This most often resulted in drilling holes 2 to 2.5 inches into the wood. Both spouts had 5/16-inch tubing that ran into separate 5-gallon buckets. Participating farmers were also collecting sap from other trees as well to make walnut syrup. They were asked to collect sap from the study trees at the same time as they were gathering sap from their other trees. Each partnering farmer was provided with a refractometer, instruction on its use, and asked to periodically measure the sugar content of each tree's sap.

RESULTS

A summation of the data from each participating farm is provided in Table 2. As you can see, the data is inconsistent.

Table 2. *Summary data of comparative tapping procedures on the 4 study farms*.

Farm no.	Farmer	Season length (days)	Gallons, maple spout*	Gallons, Walnut spout*	t-Test p-value	Ave gal/tree	Ave Brix
1	Chip Matheny	35	15	32	0.000002	2.35	1.1
2	Christoph Herby	28	15	27	0.00018	2.15	1.5
3	Elton Bowers	22	20	19	0.34	2.1	1.0
4	Karen Milnes	19**	9	13	0.032	2.1	1.9
	Average	28 (1-3)				2.17 (1-4)	

* Maple spouts are what the farmer used in past years, and walnut spouts were 7/16-inch stainless steel.
** Karen Milnes had a shorter season and collected less sap because she joined the study later in the season when another participating farmer had to drop out of the study.

What is consistent is the amount of sap expected from a walnut tree. Under gravity flow, study trees, on average, produced 2.2 gallons of sap. In another 2020 sap flow study, we showed that even low levels of vacuum can double sap flow (*The Effect of Vacuum on Walnut Sap Flow*, Future Generations University, 2020).

Where the data interpretation gets interesting is looking at sap flow from the maple spouts and the walnut spouts (Table 2). These deserve individual attention.

FARM NO.1, CHIP MATHENY: At Chip's, because of more exposed xylem provided by the deeper tap holes and the larger diameter, the 7/16" stainless-steel walnut spouts that seated sooner outperformed the smaller (5/16") diameter less tapered maple spouts. A paired sample analysis t-test gave a probability, or p-value, of .000002. Anything less than 0.05 is considered statistically significant, meaning there is a statistically significant difference in amount of sap from each spout type. Chip's walnut spouts and tapping procedures produce 128% more sap than the maple spouts and procedure. The average per tree sap flow in the season was 2.2 gallons of sap/tree. Using the new spouts and the new tapping procedure, Chip got an average of 3.2 gallons/tree.

FARM NO.2, CHRISTOPH HERBY: Christoph also saw a significant increase (p=0.00018) in sap flow on the walnut spouts. Going from 15 gallons to 27 gallons was an 80% increase in sap flow. On Christoph's trees, both spouts used were 7/16-inch. One spout was our stainless-steel walnut spout and the other a CDL 7/16-inch nylon spout. Both should have seated at the same depth in the wood and, having the same diameter tap hole, would have exposed the same internal surface area of xylem. That leaves only the added depth of the tap hole to account for the increased sap flow.

FARM NO.3, ELTON BOWERS: At Elton's farm, there was no significant difference between the two spout types. In fact, on average, the maple spouts out produced the stainless steel walnut spouts. Looking at individual data pairs, in 22 out of 39 measurements, or 56% of the time, the walnut spouts out produced the maple spouts. In 3 trees, the maple spouts consistently out produced the walnut spouts. In the rest of the measurements and the rest of the trees, it was "all over the map."

FARM NO.4, KAREN MILNES: Karen again saw a statistically significant (p=.032) increase in sap flow with the walnut spouts and deeper holes. Her increase was 40% over the standard 5/16" maple spouts.

ANALYSIS

With Elton's data not following the trend of increased sap flow we saw in the other 3 study sites, it is hard to conclusively state that deeper holes and the larger diameter, more tapered spouts yielded more sap. However, with 3 out of 4 cases indicating it does, if I were tapping walnut trees and using a bucket collection system, I would certainly use the larger diameter spouts and the deeper tap holes.

Some related questions are whether 7/16-inch spouts are creating significantly more dead xylem as the tree compartmentalizes the microbes invading through the injury and whether the trees are growing fast enough for the 7/16-inch spouts to be sustainable. We are looking into those concerns in an ongoing study (waiting for this year's tap holes to heal over) and hope to have the answers before the next tapping season.

All this work was done using bucket sap collection systems. If, however, you are using a tubing collection system and applying vacuum to increase sap flow, there is another problem. In our vacuum studies, we found that the commercially available, and more highly tapered, 7/16" maple spouts led to excessive vacuum leaks at the tap hole and were found to actually back-out of the tree. Although we did not gather enough data to quantify how much they backed-out, Christoph Herby, at Tonoloway Farm, found it necessary to reset at least 25% of his taps on a daily basis to maintain vacuum on both 3/16" and 5/16" lines. So, although commercially available 7/16-inch maple spouts may yield more sap, they do not stay put in the tree, making them totally impractical for anything more than just a few trees. The search for the ideal maple spile or spout has been going on for more than 100 years; the search for the ideal walnut spile or spout is just starting.

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