Quarter-Inch Tubing: Is it a Better Option for Gravity Sap Collection?

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The industry standard for maple tubing has long been 5/16" internal diameter with sufficient capacity to allow sap flow along with air being pulled from the vacuum pump to be evacuated from the tubing. Although vacuum pumps increase yields, elaborate vacuum systems are expensive, require additional mainline tubing, and require a significant amount of energy to run. When 5/16" diameter tubing is applied in a gravity system (no vacuum pump), sap can easily be collected from maple trees, but yields are typically diminished.

Ten years ago, 3/16" diameter tubing was introduced to the marketplace as an alternative tubing to 5/16" diameter tubing. The smaller inner diameter of 3/16" tubing easily allows a full column of sap to form through capillary action. When the weight of the full column of sap drops in elevation, natural vacuum is achieved if the tubing is airtight. With every foot of drop this type of system can achieve 0.88 inHg (Wilmot 2018). When applied in a natural gravity system, under appropriate topographical conditions, 3/16" tubing can achieve maximum potential vacuum (often better than a vacuum pump) and even has capability to pull sap over a hill. This maximum yield is achieved without the need for high-priced vacuum pumps or the energy needed to run them, and 3/16" diameter tubing is cheaper to install.

However, recent research shows that sap production in 3/16" tubing drops off as soon as the second year after installation due to microbial growth. With a small inner diameter, bacteria and yeast grow within the tubing and over time cause clogging, especially within any fittings where the inner diameter is less than 3/16" (Childs, 2019). This plugging restricts sap flow and diminishes potential yield. Despite the initial gains from 3/16" diameter tubing, by year three of using the tubing, production diminishes to significantly less than using 5/16" tubing without vacuum unless the tubing is sanitized.

A replacement for 3/16" diameter tubing in gravity systems could be 1/4" tubing. With almost twice the aperture of 3/16" tubing (0.049 sq inches compared to 0.0275 sq inches), 1/4" inch tubing is less likely to plug from microbes yet is still able to create a full column of sap for gravity vacuum. Quarter-inch tubing is currently not available for maple producers but can be procured from other industries and, with modifications, will work for maple production.

Methods

Thanks to funding from the Northern NY Agriculture Development Program, we were able to test the effectiveness of 1/4" tubing at the Cornell University Uihlein Maple Research Forest in Lake Placid, NY during the

2020, 2021, and 2022 maple seasons. Four replicate blocks were established on a slope of at least 50 feet drop in elevation. Each replicate block contained a 3/16" lateral line, 1/4" lateral line, and 5/16" lateral line with the same length, number of taps, and elevation drop. Trees were matched in elevation across the three lateral lines per block. Each tree had only one tap. Block one had eight taps per lateral, block two had ten taps per lateral line, block three had 18 taps per lateral line (added in 2021), and block four had 30 taps per lateral line (added in 2021). Each lateral line flowed into its own tank where sap volume could be measured. All lines were on gravity without the use of a vacuum pump. Vacuum gauges were attached to the top of the lateral line at the highest elevation point.

Additionally, a fifth replicate block was established to compare production yields of 3/16", 1/4", and 5/16" tubing when vacuum is applied with the use of a vacuum pump. There was minimal elevation drop from the end of the lateral to the collection vessels. In this scenario, the minimal gravity vacuum could help boost the vacuum at the tap hole (especially the distance of the dropline), but most of the vacuum was initiated by the vacuum pump. Two lateral lines of the same diameter flowed into one vacuum chamber with three taps per lateral line. Each tubing replication was never cleaned. New spouts were used each year.

Volume of sap per replicate was measured from each collection vessel during each sap flow event. Vacuum levels were read from the top of each lateral during sap flow events. All sap production data was normalized to show an increase or decrease in yield over 5/16" tubing with the 5/16" tubing set at 100% of the yield. This allowed for equal comparison across years and removed the noise of season-to-season variability.

Results

Gravity Tubing Results. In the first year of testing with just 8 and 10 taps per lateral, 3/16" tubing achieved consistently high vacuum at the top of the lateral and produced over three times the amount of sap per tap than 5/16" tubing (figure 1, panel A & B). Quarter-inch tubing did achieve vacuum at the top of the lateral (as high as 25 in/Hg) but the vacuum was not consistent throughout the season (figure 2), yet still produced more than twice the amount of sap per tap than 5/16" tubing (figure 1, panel A & B). The 5/16" tubing produced little to no vacuum at the top of the lateral line. In the second season spouts were replaced but droplines and laterals were not cleaned. Similar results were observed during the second season with no significant plugging on 3/16" tubing (figure 1, panel A & B). Production in the 3/16" tubing was significantly lower by year three but still held the highest production (figure 1, panel A & B). Quarter-inch tubing saw a slight drop in production in year two and three but still maintained higher production than 5/16" tubing. Fittings that we were able to acquire for the 1/4" tubing had minimal barbs and did not fit as tightly on the tubing. These fittings most likely created micro vacuum leaks in the tubing system which

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is most likely the cause of the drop in production over time. This can be seen throughout the experiment. By year two and three, some of the 1/4" tubing replicates even pulled off the fittings, creating challenges in data collection.

With more trees per lateral, the results were extremely different. With 18 taps per lateral, all three tubing types produced essentially equal amounts of sap in year one but 5/16" outperformed 3/16" and 1/4" tubing by over 20% in year two (figure 1, panel C). In 30 taps per lateral, 1/4" tubing had significantly higher sap production in year one but in year two 5/16" tubing outperformed the 3/16" and 1/4" tubing (figure 1, panel D). The large drop in production in year two is most likely a result of the previously mentioned microleaks within the tubing. The 30 taps per lateral 1/4" line separated multiple times throughout the 2022 season. Data from the 3/16" and 5/16" comparison replicate was thrown out on these days to keep equal production but the loose fittings most likely impacted production. However, with more taps per lateral, 5/16" tubing (and 1/4" tubing if in a tight system) can create vacuum and higher yields than 3/16" tubing (figure 2). With 18 or more trees per lateral, the 3/16" tubing is restricted in volume space and production drops. This confirms previous research that when more trees are added to larger diameter tubing, vacuum can be created (Morrow, 1972). However, it can be challenging to find this many trees unless a very large slope is available.

Vacuum Tubing Results. In the small trial of all three tubing sizes on

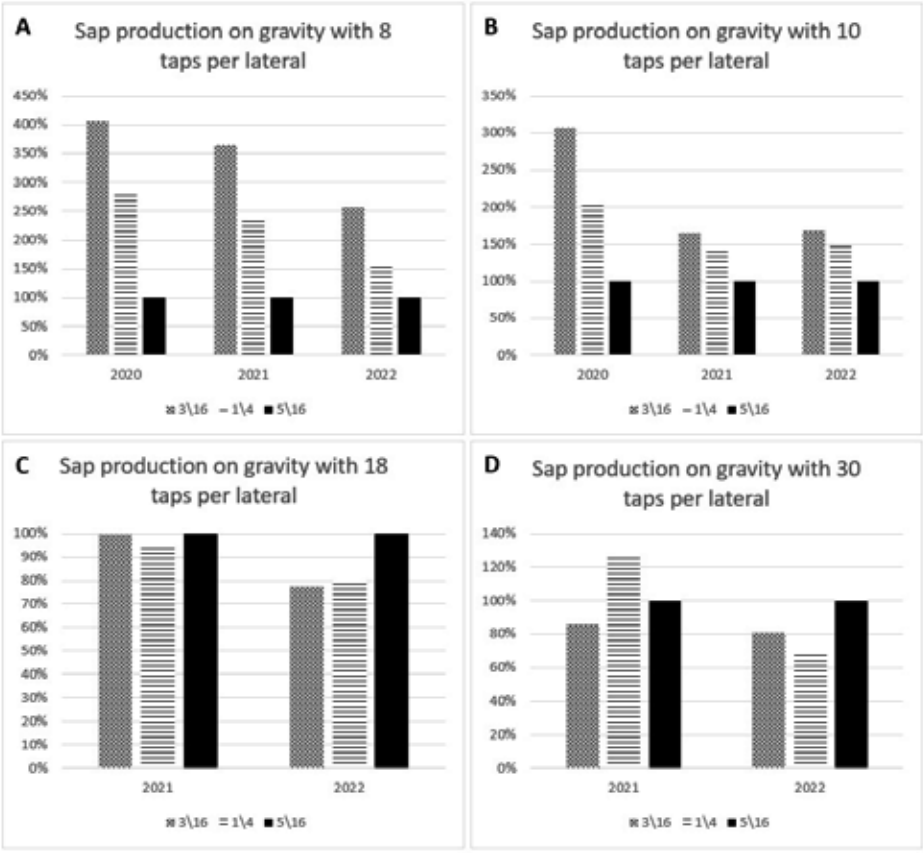

Figure 1: Sap yields on gravity tubing of three different diameters: 3/16", 1/4", and 5/16". Each replication had at least 50 feet in elevation drop. Within each replication, 5/16" tubing was considered 100% of production while 3/16" and 1/4" tubing is shown to be a percentage above or below of 5/16" tubing. Panel A shows gravity production with 8 taps per lateral and panel B represents 10 taps per lateral across three seasons. In all three years, 3/16" tubing yielded higher production, but production dropped in year 2 and 3. Quarter-inch tubing did create vacuum and increased yield over 5/16" tubing but did not have as high of yields as 3/16" tubing. Quarter inch tubing did drop in production in years 2 and 3 but did not drop as much as 3/16" tubing. When more taps were added to a lateral (18 taps per lateral – panel C, and 30 taps per lateral – panel D) the highest yielding tubing size is completely different. With enough taps per lateral, 5/16" tubing does create vacuum and yields comparable or greater than 3/16" and 1/4" tubing. With more taps, the smaller 3/16" diameter tubing is not able to handle the volume of sap. With 30 taps per lateral 1/4" tubing showed the highest production in 2021 but the lowest in 2022. This is most likely a result of fittings, not made for maple production, having minimal barbs and thus creating microleaks.

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a commercial vacuum pump, 1/4" tubing performed equal to 5/16" in year one and slightly less in years 2 and 3 (figure 2). The drop in production was most likely a result of poor fittings that created microleaks in the lateral lines. Testing production of 1/4" tubing on a vacuum pump was not replicated nor were different numbers of taps per lateral. Not surprisingly, 5/16" tubing still appears to be the ideal tubing when a vacuum pump is used. More testing is necessary although resources would be better focused on the effectiveness of 1/4" tubing in a gravity system.

Conclusions

Quarter-inch tubing was shown to be an effective option for sap collection, especially when at least 18 taps per lateral were used. On laterals with more taps, 1/4" tubing had the higher yields per tap, while with fewer taps per lateral, vacuum was not as high and 3/16" tubing had higher yields. However, 1/4" tubing produced significantly more sap than 5/16" tubing and after three years of comparing yields on 3/16", 1/4", and 5/16" tubing, significant plugging was not observed in either of the sizes of tubing. It is expected that the 3/16" tubing will continue to plug and 1/4" tubing will outperform all the tubing. We will be repeating the study during the 2023 sap season for a fourth year on 8 and 10 taps per lateral, and the third season on 18 and 30 taps per lateral.

A lot of research is still needed to determine the effectiveness of 1/4" tubing but it is showing promising results. However, with larger hillsides with a greater number of trees, 5/16" tubing may be a better option for gravity tubing systems. The smaller volume of the 3/16" tubing is not recommended for laterals with more than 18 trees. We don't want to rush into promoting 1/4"

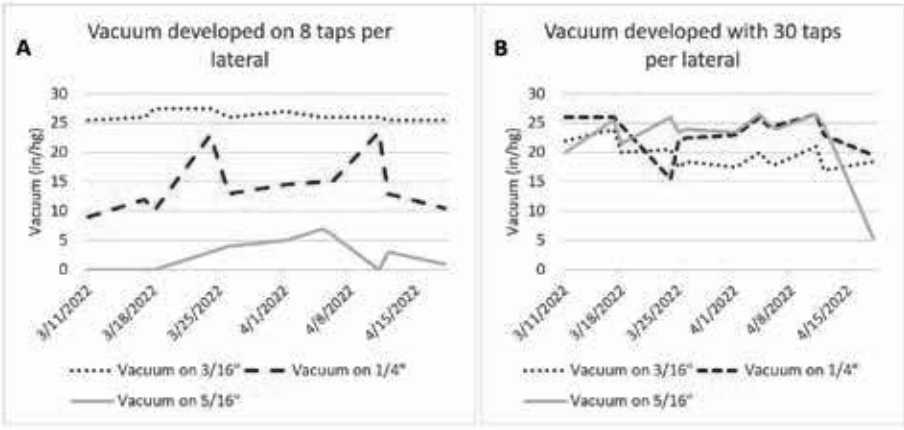

Figure 2: Vacuum created at the top of lateral lines in a gravity tubing system with 8 taps per lateral (A) and 30 taps per lateral (B) across the 2022 maple season. With only 8 taps per lateral, little to no vacuum is created on 5/16" tubing while higher vacuum is created when enough taps create enough volume of sap to create a full column of sap. With only 8 trees per lateral 1/4" tubing can create moderate vacuum that reached higher levels on bigger sap flow events.

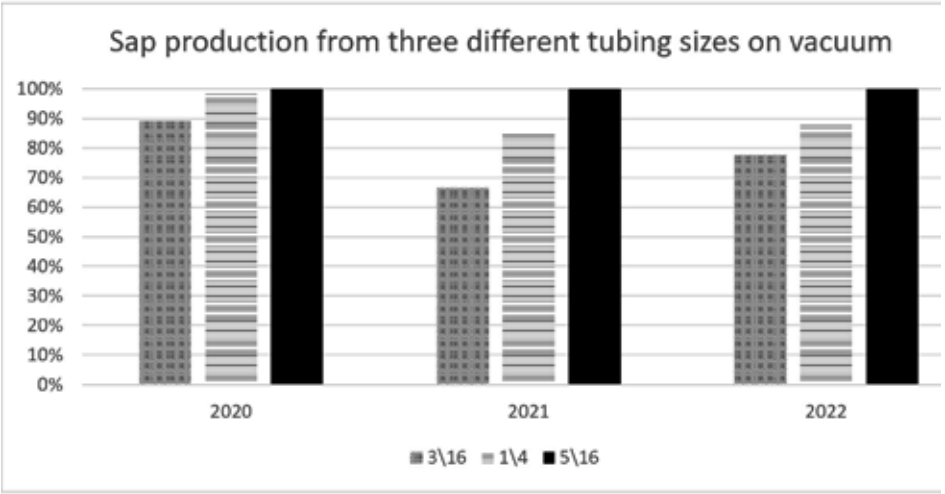

Figure 3: Sap yields on 3/16", 1/4", and 5/16" tubing across three maple seasons using a vacuum pump. Each lateral line had 3 taps per lateral and high vacuum was maintained throughout the season. Droplines were not replaced or sanitized. Yields were normalized to 5/16" tubing production at 100%. New spouts were used each year. Not surprising, 5/16" tubing had the highest production. The drop in production of quarter inch tubing in year two and three is likely due to poor fittings causing microleaks.

Taps per lateral	Gallons of sap per tap: 3/16" tubing			Gallons of sap per tap: 1/4" tubing			Gallons of sap per tap: 5/16" tubing		
	2020	2021	2022	2020	2021	2022	2020	2021	2022
8 taps, gravity	26.5	16.9	27.8	18.6	10.9	16.6	6.5	4.6	10.8
10 taps, gravity	27.9	9.7	15.4	18.4	8.2	13.5	9.1	5.8	9.1
18 taps, gravity		12.2	18.5		11.5	19.2		12.2	24.0
30 taps, gravity		10.6	22.9		15.5	X		12.3	26.4
Vacuum pump	18.5	14.1	19.2	20.5	18.0	21.6	20.7	21.2	24.7

Table 1: Sap yields from three years on three different tubing diameters in a gravity system with different number of taps per lateral along with production on the three different tubing sizes when a vacuum pump is incorporated. When the vacuum pump was incorporated, each lateral had three taps. Data is not shown for the 1/4" tubing with 30 taps per lateral in 2022 because the lateral line separated compromising the data. Comparison data was able to be created but not realistic yield data.

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tubing until we are confident plugging will not be an issue, but it's anticipated not to be an issue as it can be with older 3/16" tubing that has not been sanitized. Finding tubing with fittings that do not create vacuum leaks and hold tight to the tubing is key. If so, 1/4" tubing may be an alternative tubing option for gravity sap collection systems.

For More Information

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