# A Comparative Analysis of Sugar Concentrations in Various Maple Species on the St. Johns Campus

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**Abstract**

*It is well known that many varieties of Maple trees produce sugar containing sap in the springtime. The average concentration of Sucrose in Sugar Maple sap is estimated to be approximately 2% in concentration. The purpose of this study is to tap maples present on the St. Johns campus and obtain samples to compare their sugar concentrations to those of the sugar maples in the St. Johns Sugar bush. By obtaining samples from numerous species of maples around campus a comparison can be conducted regarding the sugar concentration of the saps of these various maple species. This study found a gradient in sap concentrations of the five species sampled that proved to be significant.*

# Introduction

Many species of the maple family, *Aceraceae,* possess a unique characteristic that distinguishes the group from all other species of trees. This characteristic is the ability to produce edible sap that can be collected and processed into maple syrup in the springtime when sap runs from these trees. The Sugar Maple, *Acer saccharum,* is the most well know and targeted species for its abilities in this area. However, there are other varieties of maples which have sap producing capabilities. But many of these species are not as widely used and well known for their sap producing capabilities; partially due to varying sap quality and sugar concentration. In this project we will explore the various saps of other maple species in an attempt to compare their sugar concentrations to one another and to the sugar maple ultimately determining the success in which they can produce maple syrup.

## Maple Syrup: An Early History

The production of maple syrup is a very old practice in North America and is one that predates the establishment of both the United States and Canada. It was not the white settlers of these countries but the Native Americans who discovered the unique attributes of these species. There were many names used for maple syrup including the Ojibwa name of sheesheegummavvis, meaning "sap flows fast."(Green Mountain Sugar Refining, 2003). There are many legends that exist in Native American cultures that indicate how well known and important this process was for its many uses. One such legend entails how an angry chief threw his tomahawk at a maple tree striking it and causing sap to run form the wound. His wife thought this sap was water and tried to cook with it only to discover it produced a sweet tasting substance (Maple Syrup Producers Manual, 2006).

A reason why the product was so highly valued was that it provided a quick source of energy and was a sweet supplement to a bland diet. Native Americans in New England used maple sugar as gifts, for trade, and to mix with berries as a good tasting meal. In the summer they would make up a special drink, a sort of treat, in which sugar was mixed into water (Massachusetts Maple Producers Organization). Native Americans relished the product so much that they would even move in to camps near maple tree in the spring to allow for harvest of the relished commodity.

It is a common opinion among historians that Indians first introduced white settlers to the process of Maple Syrup production. No matter the first seeds of its introduction into to European settlers, maple syrup production would become a tradition that has deep roots in North American culture both in the past and today. The early use of this product was largely for subsistence by early colonial farmers. Maple syrup was a supplemental commodity that could be traded for goods or sold for money as a way of obtaining objects that could not be found on the farm.

The practice eventually became widespread enough to evolve into a seasonal pattern practiced throughout the country where maples were found. Settlers prepared in the winter for the upcoming spring by cutting wood and acquiring necessary tools. In early spring before planting, when there was a lull in farm activity, farmers could focus their activities on syrup pursuits. In many areas this was a collective effort in which people would work together to take part in this early event. The process even developed a type of festive or social connotation in many areas.

The product eventually became more important as it was a sugar source that was alternative to sugar cane in the West Indies that was often in short supply. It eventually caught on as a luxury product and was used as a sweetener and preservative to many foods. And Soon maple sugar was a staple product in the colonies. Sugar demand continued to be a localized pursuit for many years but all of this changed in the advent of World War II. As other types of sugar were in short supply maple syrup became in high demand for maple sweetener. Since this era their have been many advances that have allowed for faster and more widespread production of this product. Due to these demands and innovations professional maple syrup producing operations can be observed in addition with the more traditional family operations.

**Maple syrup: A St. Johns Legacy**

The *Rule of St. Bennedict* is a code by which the monks of St. Johns have lived by long before their initial pursuit of syrup production in 1942. Anyone familiar with the rule knows that it calls the individual to live a balanced life in regards to spiritually, the practical pursuit of self subsistence, and life in a community. The production of maple syrup embodies all these efforts and is lived out every spring when members of the St. John's monastery work together in these self-sustaining efforts (Saupe, 2006). In many ways the process of maple syrup production resembles the vitality and communal gathering that it had in the earliest communities of North America. Early on in St. Johns history it was observed that a high concentration of maples existed on campus that would be suitable "for a large scale operation"(Saupe, 2006). Sugar maple trees as well as all sort of other types of maples have been present on the campus even prior to the settlement by the monks in 1857.

Throughout its beginning the maple syrup operation has been run by various individuals with one prominent member, Brother Kiefer, being involved in the operation since 1962. Today the syrup production facility at St. Johns is run by Stephen Saupe, Sarah Gainey, and Linda and Bill Mock. The sugar bush at St. Johns is 29 acres consisting of maple trees upwards to 130 years old (Saupe, 2006). The stand of trees is managed by standard maple management techniques. Non syrup producing trees are routinely cut to make way for sugar maples to ensure production is at its highest. Around March 11$^{th}$ the trees are tapped by drilling a hole in which a spile is placed and on about March 19$^{th}$ there is enough sap to collect.  On average St. Johns puts out 1397 spiles per season. However, this number has not been as high in recent years.  The sap is collected by the bucket method and then transferred to the Sugar house for processing. The concentration of sugar in the sap at the St. Johns sugar maple stand is about 2.2% .

**Sap Flow**
The sap flow in maple trees is temperature dependent. Towards the spring or at certain times in the winter when the temperature rises above 32º F sap can be seen flowing from the trees. Fluctuation of temperature such as cold nights followed by warm days cause the maple to develop strong or positive sap pressure that is higher than atmospheric pressure (Maple Syrup Producers Manual, 1997). One theory that attempts to explain this phenomenon suggests that when temperature falls below zero pressure becomes negative within the tree as it freezes causing it to draw liquid form the trees roots and this process replenished the sap pressure within the tree. Condensing of gases such as $CO_2$ also aid in this negative pressure during cold snaps. This is especially pronounced in a prolonged period of cold weather and upon warming periods high amounts of sap can begin to flow (Massachusetts Maple Producers Organization).

Sap flows from out of the tree when the tree is wounded provided there is a positive sap pressure within the tree. This period of sap flow can vary greatly in length sometimes up to 20 hours. The temperature fluctuations that are the driving process for sap flow will need to continue throughout the season or otherwise the process will not continue.

**Tapping/Production of maple syrup**
Typically a tree mature enough for tapping is larger than 12 inches in diameter at 4 feet off the ground. Only healthy trees should be tapped that are capable of producing higher quantities of sap. Tapping of unhealthy trees will cause lengthier period or time for the sap hole to close causing increased chances of microbial infection and insect invasion ultimately defecting health of the tree. A good tapping technique will look to create small tap hole damage and attempts to prevent contamination of sap by microbes. Microorganisms are a large threat to sap quality and are the biggest factor in poor sap quality and tree health.

There are five basic necessities for tapping a tree: bit for drilling whole; taper; spiles; some sort of collecting apparatus; and a mallet to pound a spile. A power drill with a 7/16 inch drill bit should be used for fastest tapping and cleanest holes. The drill bit should be cleaned before use to prevent microbial contamination as should all equipment coming into contact with the tree. Once the hole is drilled a spile or spout is pounded into the tree. The function of the spile is to allow sap to travel from the tap hole into the container or bucket that hangs from the spile. The spile will also be a means to protect the tap hole from microorganism contact. Tools and technique need to be sterile in order for best quality of syrup and to protect the tree.

When to tap depends on geographic location. However the late winter season is the general time in which most maples are taped ranging from February to April. In the St. Johns area tapping is typically done around March 10$^{th}$. Tapping too early or late can also be a factor. Too early taping will allow for increased microbial growth and too late of taping will cause sap runs to be missed. Journals are often kept to determine the best time to tap trees based on previous year’s results.

Number and location of tap holes can also be a factor. In smaller trees of less than 47 inches in circumference only 1 tap hole is sufficient. In trees larger than 78 inches in circumference 4 tap holes can be used. Generally taps should be at least 10 inches apart. When trees are tapped in each successive season the new holes should be 6 inches form old ones in an alternating pattern. The general health of the tree should be noted before each tapping for disease, trunk wounds, insect problems etc. It the tree is not healthy enough to individual should not be tapped.
See Table 1.

**Table 1:** Tapping numbers for different tree sizes. Data taken from Maple Syrup Producers Manual 2006.

| Tree circumference (inches) | Number of taps (inches) |
|---|---|
| 31-47 | 1 |
| 47-63 | 2 |
| 63-78 | 3 |
| Over 78 | 4 |

Collected sap in buckets is then transferred into larger holding tanks until sap build up is high enough for processing. The sap is then transferred to the sugar shack for processing. It is important that sap be processed soon after collection to prevent microbial build up.

**Production of Syrup**

Syrup is produced by the simple method of boiling excess liquid of sap off in order to get a highly concentrated syrup. For typical sugar maple sap concentration is about 2%. It takes high amounts of about 40-50 gallons to make one gallon of syrup. This is done through the evaporation method. The earliest example of this technique was the Native American method of putting the sap in a hollow log and drop a heated stone in it in order to complete the evaporation process. European settlers also had primitive evaporators often kettles hung over fires. These methods were crude and produced poor syrup quality that can be observed when syrup is dark in color. Modern day evaporators are much more elaborate in design. They are divided into a sap pan and a syrup pan. Raw sap is placed in the syrup pan and as the sap increases in sugar concentration it flows through tubes connected to the syrup pan where it is removed. The larger the evaporator the more sap it will be able to process and hour. The St. Johns evaporator is 4 feet wide and 16 feet long with a 4x4 wood box a heat source. These systems are often very elaborate and are contained in a sugar house. Often the process is completed on a cooking pan to allow for a greater degree of precision. These processes produce maple syrup of much higher quality and light color.

On average St. Johns produces around 250 gallons of sap but recently production has been around 100(Saupe, 2006). The season is around 22 days long and normally begins around March 10th. When the tree quits producing sap the spiles are removed.

**Trees That Produce Sap**

There are three other main species of maples, besides sugar maple, that are commonly used for maple syrup production in commercial syrup regions. *Acer nigrum* (black maple), *Acer rubrum* (red maple), and *Acer saccharium* (silver maple) are common commercial supplements to sugar maple sap. All four edges of the ranges of the Maple tree are all around Central Minnesota. All of these in addition to *Acer negundo* boxelder and *Acer genala* amer maple are found on the St. Johns campus. These maples are not commonly used in commercial operation like the others due to lower abundances in commercial regions. Other maples that produce sap but are not commonly tapped are *Acer pennsylvanicum (*striped maple) and *Acer spicatum (*mountain maple). However, these maple ranges do not occur in Central Minnesota.

Of all the Maples it is reported that *Acer saccharium*, *Acer negundo*, and *Acer rubrum* to be commercially productive species. Although they do not produce as high of concentrations of sap they sap can be processed to produce syrup. A study done in southern Illinois showed that Acer saccharium produced on average 1.71 percent sugar concentration (1.10 to 2.53 percent range) and they indicate that concentrations may average even closer to 2 percent (Crum et. al 2004). *Acer rubrum* is another alternative species producing concentrations around the value of that of Acer saccharium. *Acer negundo* is a commonly tapped maple along more moist riverside operations and is also commonly tapped.

However both *Acer rubrum* and *Acer saccharium* are not able to produce the abundance of sap over the course of a season. They bud earlier than *Acer saccharum* and therefore do not produce as much overall sap per season. This combined with lower sugar concentrations makes them a less desirable species in regards to syrup production.

The sugar and black maple are very similar to one another in regards to overall appearance as well as sap production capabilities. They are often very difficult to distinguish form one another and can easily hybridize. In Central Minnesota Blach Maples are not very common. So they will be ignored in this study. The region in which sugar maples occur naturally is mainly in the northeastern region of the United States. The is probably the reason why most commercial syrup production occurs in this region The sugar maple likes sites that are not excessively too dry or too wet. The tree produces buds that are blackish/brownish and have a sharp point to them. This can be a giveaway when comparing immature trees to red maple or silver maple. When the tree is young the bark will be silvery or smooth, however; often the young tree will possess bumps protruding through the bark (lenticles). As the tree gets older the bark will become highly furrowed with thick vertical plates. These trees will often still have a warty appearance when older. The most objective way to distinguish this tree is through bud appearance which is pointy brownish buds.

The red maple is another tree that is commonly tapped southern portions of the maple range. They extend up and down the entire eastern coast and go as far west as Minnesota. They are typically tapped in the south and often prefer to live in drier sites. Overall these trees have a smoother bark than sugar maples and this is especially noted in younger trees. However, young sugar maples tend to have smooth silvery bark making distinction difficult. As they mature they too develop furrows and long plates. It can be difficult to compare mature red maple to a sugar maple. However, the furrows in mature red maples often has hint of red in it. One tell-tail sign of this species is again the buds. Red maples have round reddish buds that often encircle the twig. There is also a bunch at the end of the stem. The twigs of these trees are also a bright red at the end (or more recent years growth). These are probably the best indicators for the species.

The silver maple is the most rapidly growing of all maples and is not as commonly tapped by syrup producers. When it is tapped it will typically be on road sides. The silver maple is probably the most easily distinguishable of all maples at maturity due to its silvery appearance and highly pealing bark. The poor form of the tree, which often has a short trunk that is highly branched, has an overall shaggy looking appearance in conjunction with its bark. The silver maple produces red buds like the red maple but they are much larger and rounder, very large when compared, and more irregularly clustered than in red maples. One easy way to tell a young silver maple from a red maple is to scratch the bark of a twig. The silver maple will produce a sharp almost unpleasing odor while the red maple will produce no odor. The twig of the maple is red.

The boxelder is easily distinguishable from other maples. Often the form in the wild will be fairly poor as the tree braches highly at the base. They do not grow as tall as other maples and have a more stunted form. They like water and are often found growing near to a source. The twigs have a greenish or purple color of a combination of both. Another key distinction is that the buds are white and hairy (glaucus). The trees possess another unique trait in that they often they hold their V-shaped samaras in the winter which many maples in Central Minnesota do not do. Glaucus buds, green/purple twig, and V-shaped samaras are the best way for objectively identifying the tree.

The amur maple is easily mistaken for the boxelder. It is a relatively short tree that has a irregular form, often multi stemmed branching from the base. The bark also has a scaly has a grayish brown appearance like that of the boxelder. And like the boxelder the samaras are often held in the winter, however they are smaller than the boxelder. The buds are reddish-brown in color and are normally smaller than 1/8 inch in length.

## **Methods**

Overall there were five species of maples included in the study; *Acer saccharum*, *Acer rubrum*, *Acer genala*, *Acer saccharium*, and *Acer negundo*. Each tree was identified using winter tree identification techniques. Traits such as bark appearance, twig color, bud shape, and overall tree form were some of the different ways used to distinguish each species. There were twenty trees of species *Acer saccharum* (sugar maple) and twelve trees of species *Acer rubrum* (red maple) sampled. All the trees sampled for these two species were located in the St. Johns sugar bush. There were fourteen *Acer genala* (amur maple), fifteen *Acer saccharium* (silver maple), and ten *Acer negundo* (box elder). The silver maple and amur maple were found on campus proper existing as ornamentals. The box elder were found on the Arboretum on the edge of *Lake Stmpf*. Each tree was identified and labeled according to its species.

After each tree was located it was tapped using a 1/8 inch drill bit and cordless drill. For trees with thinner bark the required was less than an inch in depth in order to reach the xylem. For trees such as sugar maple and red maple in which the bark was thicker the drill hole was approximately two inches. The sampling was done over a two day period in early April.

After a hole had been drilled in each sample tree a 2 mL micropipette was used to collect approximately 0.5-1 mL of sap from each sample tree. Sap protruded from the hole quite rapidly and could easy be collected by suction. Each pipette was then labeled according to tree species and was given a sample number. The samples were then frozen to preserve for later analysis.

To determine the percent sucrose in each sample a *Baush and Lomb* spectrometer was used. Varying amounts of sucrose were dissolved in water to create 6 sample solutions. The test solutions consisted of a .5%, 1%, 2%, 5% and 10% sucrose dissolved in water. These five sample solutions along with pure water were analyzed with the spectrometer. By obtaining the refractive index values (RI) for these six solutions a standard curve was calculated (see fig. 1). Each sap sample (a total of 73) taken from each tree was then analyzed under the same refractometer to determine an RI value for each sample. By comparing this RI value to the standard curve it was possible to than approximate the concentration of sucrose each sample.

## Results

Based on these methods it was found that *Acer saccharum* had the average overall sucrose concentration at approximately 4.5 %. *Acer rubrum* was the next closest as 4% followed by *Acer genala* at 3.9 %. *Acer saccharium* and *Acer negundo* were significantly lower at 3.4% and 3.5% respectively (see Fig. 2). The maximum values also followed this trend with *Acer saccharium* and *Acer negundo* being the only exceptions.

The values were significantly higher than expected with *Acer saccharum* having a concentration of 4.5% which was about double the expected concentration of 2.2%. The observed percentages of each tree therefore was much higher than expected with *Acer negundo* being even higher than 2.2%.

An ANOVA test was run comparing the concentrations for each tree species. From this a p value was obtained of .0001. This indicated that there was a significant difference overall among the data sets further validating that the relationships between these concentrations were correct.

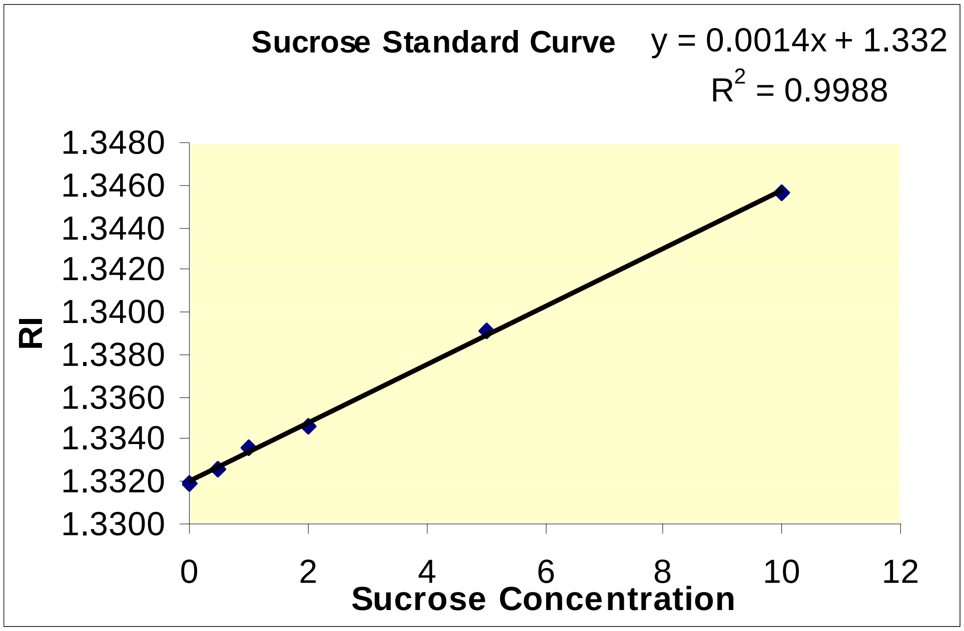


**Fig. 1**- a standard curve of known sucrose concentrations. Sucrose concentration of plotted vs. refractive index (RI).

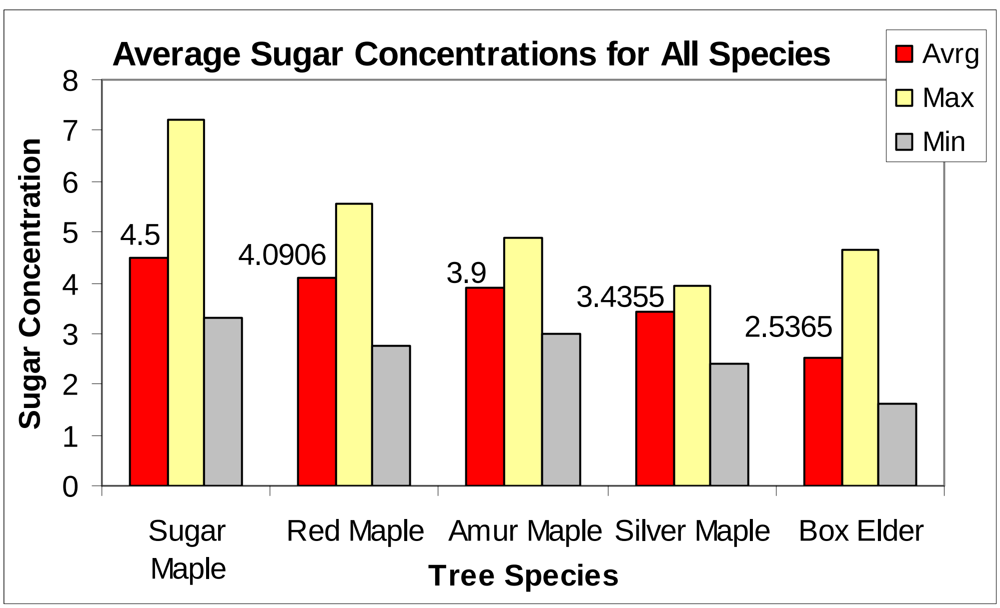

**Fig. 2**- Bar graph showing average sucrose concentrations of all species as calculated using the standard curve. Figure also shows maximum and minimum values for each species.

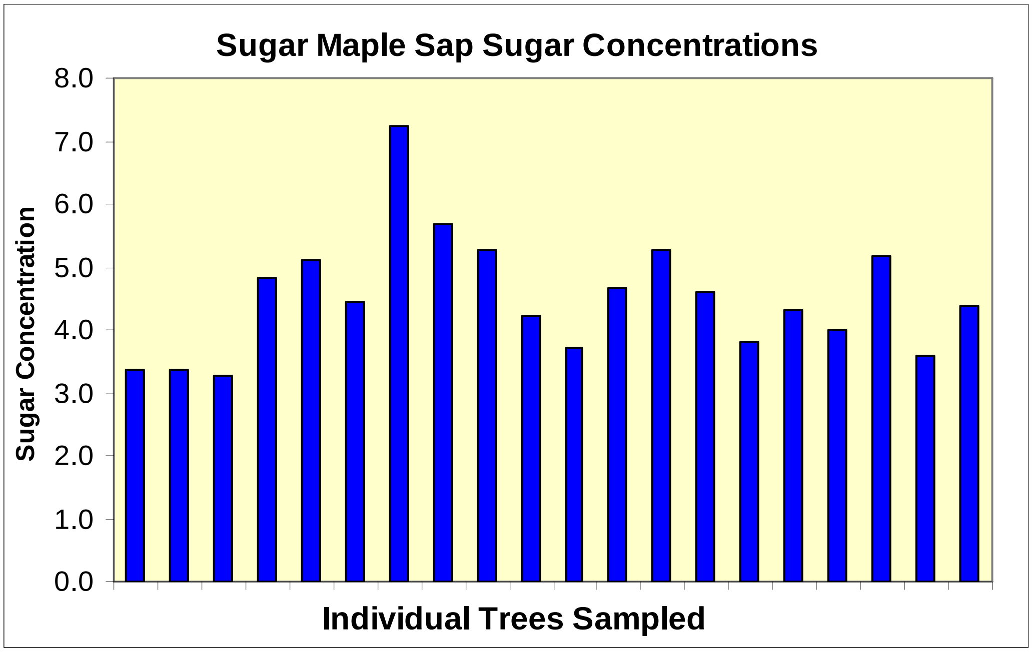


**Fig. 3**- A bar graph showing sucrose concentration of each sample taken per tree.

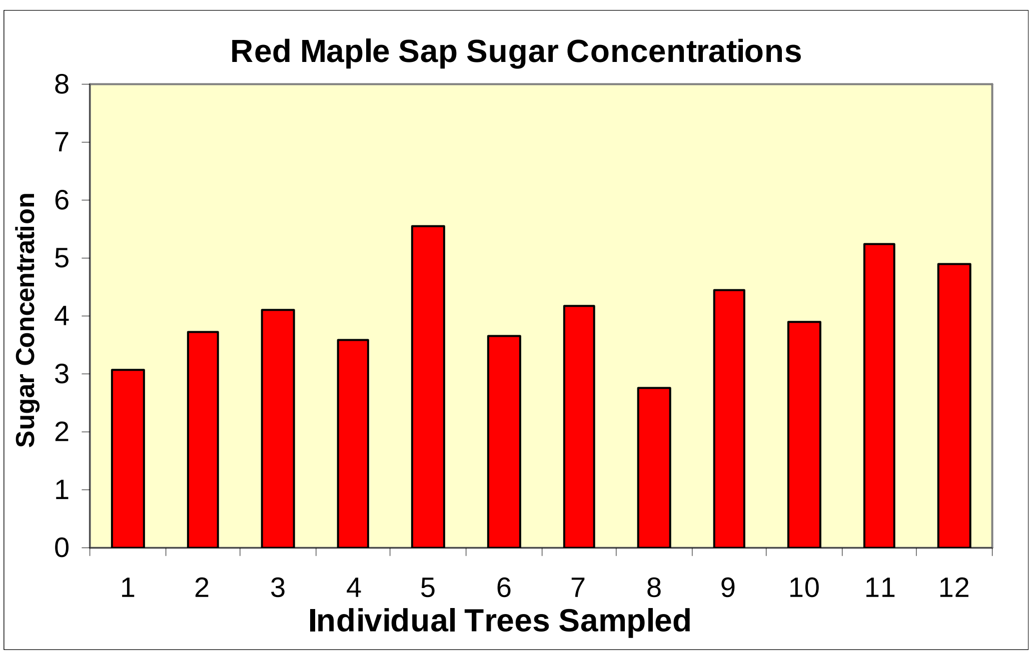


**Fig. 4**- A bar graph showing sucrose concentration of each sample taken per tree.

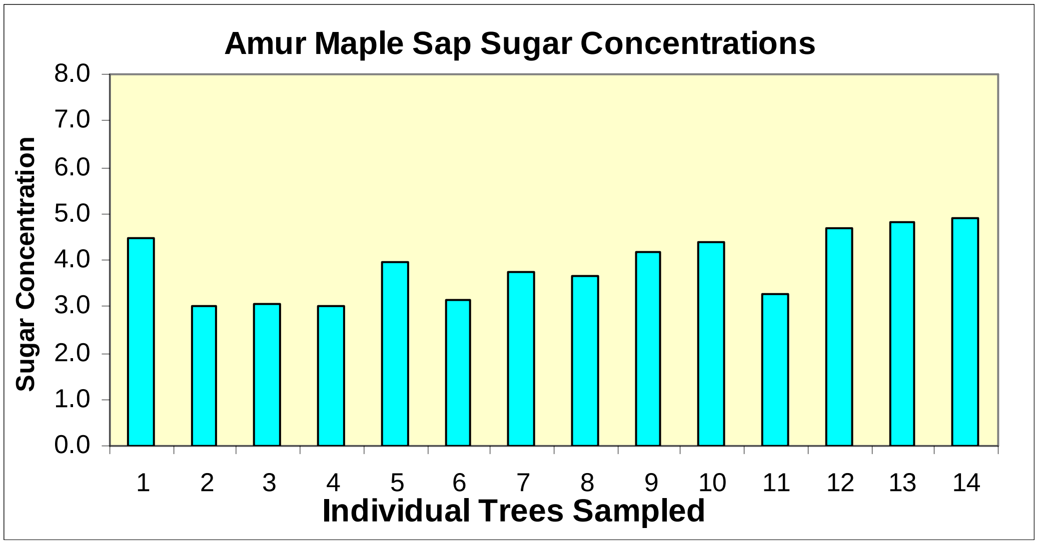


**Fig. 5-** A bar graph showing sucrose concentration of each sample taken per tree.

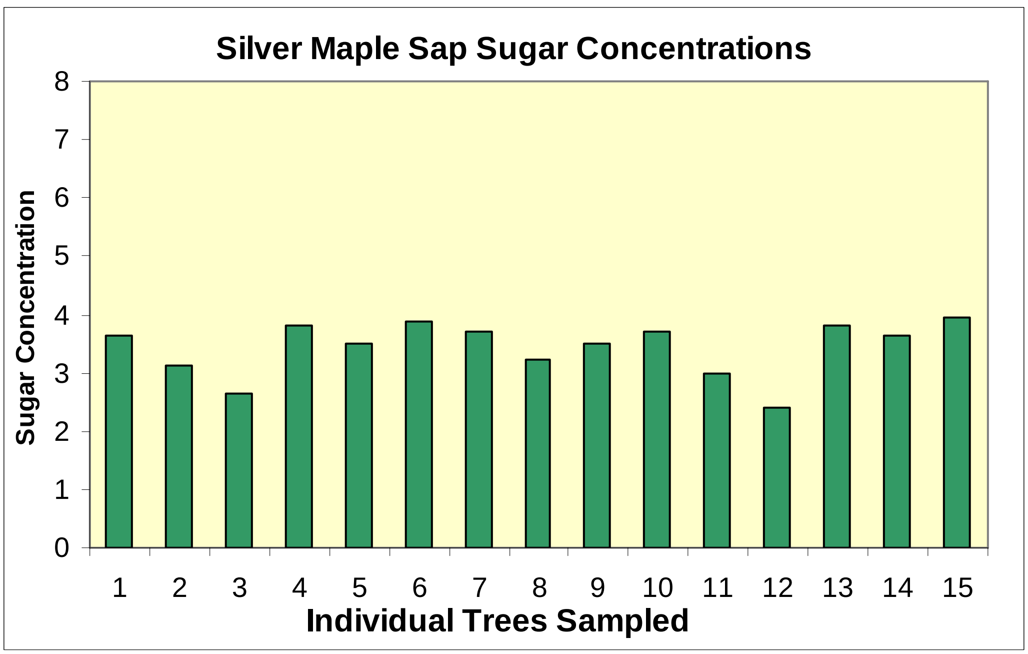


**Fig. 6-** A bar graph showing sucrose concentration of each sample taken per tree.

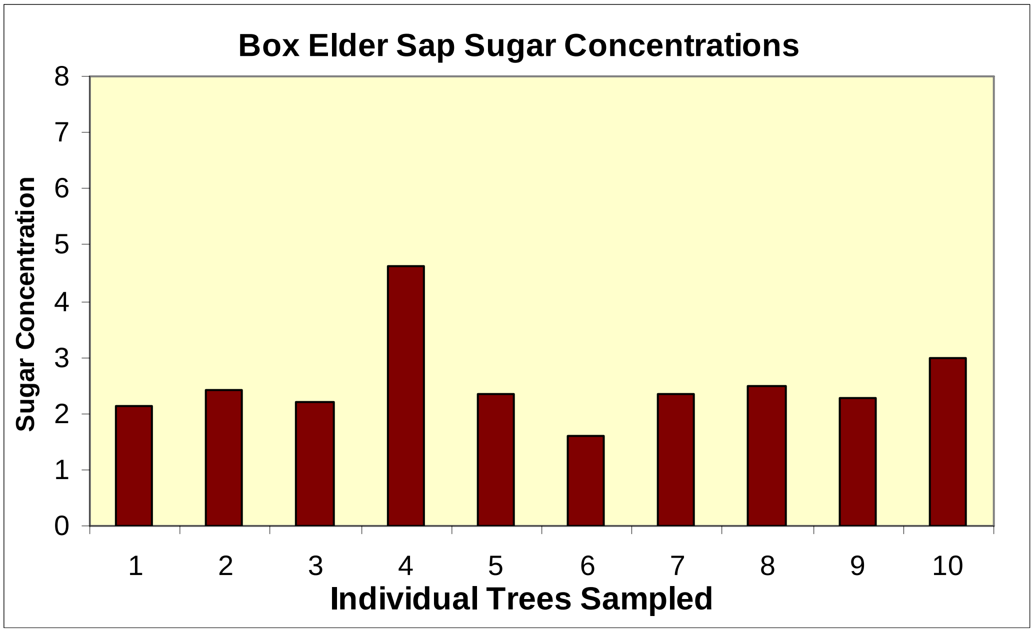


**Fig. 7-** A bar graph showing sucrose concentration of each sample taken per tree.

## Discussion

Typically we would expect sugar concentrations *Acer saccharum* to be around 2 percent or slightly higher. A study conducted in southern Illinois showed annual concentrations of sugar maple to be 2.03 percent with values ranging from 2.53 to 3.18 percent (Crum et. al. 2004) . On the St. Johns campus this value is reported to be slightly higher. In a previous study Steve Saupe in 1994 the sugar concentration was found to be about 2.5 percent (Barr, 2002). In this study the average concentration was 4.5percent (ranging from 3.2 to 7.1 percent). These values were therefore much higher than expected and were far outside the normal range. The low values were even higher than the higher than the expected range.

Since sugar maples are expected to have the highest sugar concentration this also makes concentrations for each other species relatively high. The lowest average was for that of *Acer negundo* at 2.53 percent. In conclusion all sap concentrations were much higher than expected.

However, the comparison of relative concentrations of each species to another seems to be valid. We expected sugar maple to have the highest concentrations and this was certainly true. This species showed a significantly higher average concentration and maximum and minimal value than any other species. *Acer rubrum* had the second highest concentration being close 4.1%. This tree was the most physiologically similar to is the a common supplement to the sugar maple. *Acer genala* was not as predicted. This species exists as a more stunted from of a tree and is seldom large enough to be tapped. Information regarding sap concentrations in these species were fairly limited because tapping is not extensive. Acer saccharium was expected to have a lower concentration that *Acer rubrum* and a higher concentration than *Acer negundo* and this is what was observed

ANOVA test indicated a p value of .0001. This value was relatively low and verified that there was an overall statistical difference between overall concentrations of each species. This statistic shows that our results are reasonable. We can therefore conclude that we indeed saw a valid gradient when comparing the concentrations of each species to one another. The actual values of sap concentration were high; however, the relative values in comparison of each species was significant.

High sap concentrations may have been due to the fact that each tree was analyzed shortly after is first tapping of the season. These trees may produce higher sugar concentrations than they would after they had been allowed to run for longer. Sap was usually collected from each tree only minutes after tapping. If the tree had been allowed to run for hours or even days concentrations may have been lower. Furthermore, estimates regarding sap concentrations are often produced over the course of an entire season. In this study each species was only tapped once. Had subsequent samples been taken at multiple intervals over an entire season we may have found these values to have been lower.

## Conclusion

This study indicated much higher than normal sugar concentrations in these maple species. These concentrations could have been due to a variety of different physiological factors. Analysis over a season is more reliable for predicting average concentrations in normal conditions. However, this study was successful in demonstrating the differences in relative sugar concentrations in maple species of the St. Johns campus.

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