Sugar Content of Maple Sap after N, P, or Ca Fertilization

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By choosing sites with higher soil N or by adding N to the soil, maple producers may be able to collect sweeter sap, which reduces the energy needed to boil sap into syrup. Rooted sugar maple cuttings have consistent sap sweetness within clones and could provide a means to propagate sweet sugar maple trees.

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http://www.nsrcforest.org

Project Summary

Maple syrup is an important non-timber forest product in the northeastern United States and southeastern Canada. Sugar maples (*Acer saccharum* Marsh.) that are healthier and have higher growth rates often have higher sugar concentration in their sap. Soil N mineralization and soil base cations have been shown to be important to sugar maple health. However, the relationship between soil nutrients and sap sweetness is not well understood. Sap sweetness is economically important because it affects the amount of sap and the amount of fuel required to produce a gallon of syrup.

This study looked at what specific soil and foliar nutrients affect the sugar concentration of maple sap and whether addition of N, P, or Ca increases sap sweetness. We sampled 309 sugar maple trees for sap sweetness in five sites with N, P, and Ca additions in the White Mountains of New Hampshire using a digital refractometer.

Trees with higher sugar concentrations in their sap were growing in sites with higher soil N mineralization ($p = 0.01$). Foliar P had a negative correlation with sap sweetness ($p = 0.02$). The foliar N:P ratio had a strong relationship with sap sweetness ($p < 0.001$). Higher foliar N increased the potential photosynthetic rate in leaves ($p = 0.001$), presumably allowing the trees to produce more sugars. Nitrogen addition increased sap sweetness ($p = 0.09$).

Replicates of ten clones of sugar maples propagated by rooted cuttings in Heiberg Memorial Forest, Tully NY, were sampled for sap sweetness. Unpublished sap sweetness data from the 1980's and data collected in 2014 showed that sap sweetness differed by clone ($p < 0.001$).

By selecting sites with higher soil nitrogen or fertilizing with N, maple syrup producers may be able to collect maple sap with higher sugar concentration and reduce the energy needed to boil sap into syrup. Genetically sweeter sugar maples can be replicated through rooted cuttings.

Background and Justification

- Maple syrup is produced by boiling sap from maple trees to concentrate the sugars
- Maple sap is typically around 2% sugar
- Sweetness of maple sap determines the amount of sap necessary to produce maple syrup
- Sweetness of maple sap is influenced by the genetics of the tree and the environment

↑ Sugar % = ↓ Energy Needed to Boil Sap ↓ Labor Required to Produce 1 Gallon

↑ Profit ↑ Syrup Production

Background and Justification

- Faster growing trees and trees with larger canopies have sweeter sap (Morrow 1955, Taylor 1956)
- Sugar maples deficient in nutrients or growing on sites with low soil nutrients are often unhealthy and have slow growth rates (Sullivan et al. 2013)
- Adding calcium has increased the canopy health and growth of sugar maple trees (Long et al, 1997; Battles et al, 2013)
- Sugar maples growing on sites with higher N have higher growth rates (Thomas et al. 2010)
- The role of native soil nutrients in determining the sweetness of maple sap is unknown
- Past fertilization trials to increase sap sweetness have not isolated the effects of specific nutrients.

Battles, J.J., Fahey, T.J., Driscoll, C.T., Blum, J.D. and Johnson, C.E. 2013. Restoring soil calcium reverses forest decline. Environmental Science & Technology Letters

Long, R.P., S.B. Horsley and P.R. Lilja. 1997. Impact of forest liming on growth and crown vigor of sugar maple and associated hardwoods. Canadian Journal of Forest Research 27: 1560–1573.

Morrow, R.R. 1955. Influence of tree crowns on maple sap production. Cornell University Agricultural Experiment Station Bulletin 916:5-30.

Sullivan, T.J., G.B. Lawrence, S.W. Bailey, T.C. McDonnell, C.M. Beier, K.C. Weathers, G.T. McPherson and D.A. Bishop. 2013. Effects of acidic deposition and soil acidification on sugar maple trees in the Adirondack Mountains, New York. Environmental Science & Technology 47:12687-12694.

Taylor, F. H. 1956. Variation in Sugar Content of Maple Sap. University of Vermont and State Agricultural College, Bulletin 587.

Thomas, R.Q., C.D. Canham, K.C. Weathers and C.L. Goodale. 2010. Increased tree carbon storage in response to nitrogen deposition in the US. Nature Geoscience 3:13-17.

Background and Justification

- Sugar maple sweetness may be genetically controlled
- Replicating genetically sweet trees would allow maple syrup producers to plant sweeter trees
- Propagating sweet trees by grafting cuttings onto rootstock fails because the root stock influences sap sweetness (Demeritt 1985)
- Biparental breeding requires long generation times and the results are unpredictable (Kriebel 1990)
- Propagating sugar maples through rooted cuttings is the most reliable way to replicate sweet trees
- Sap sweetness from rooted sugar maple cuttings has never been tested

Demeritt, M.E. 1985. Sap-sugar content of grafted sugar maple trees. USDA Forest Service, Northeastern Forest Experiment Station Research Note NE-328.

Kriebel, H.B. 1990. Genetic improvement of sugar maple for high sap sugar content. II. Relative effectiveness of maternal and biparental selection. Canadian Journal of Forest Research 20:837-844.

Methods – Nutrient Effect on Sap Sweetness

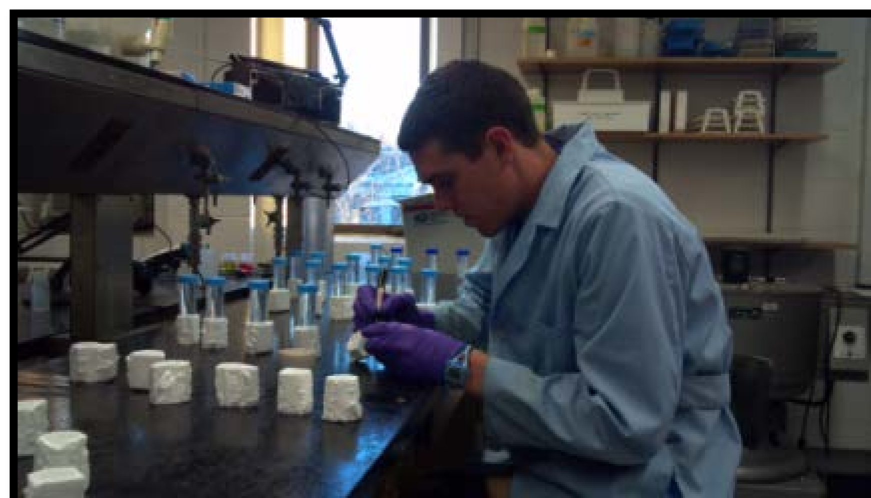
- 298 sugar maple trees from multiple stands in the White Mountains of New Hampshire with separate calcium, nitrogen, phosphorus, nitrogen and phosphorus, and control plots were sampled for sap sweetness four times in the winter of 2013 using a digital refractometer
- Soil nutrient availability was previously measured
- Canopy health and stem growth were measured for all trees
- Photosynthesis, conductivity, and foliar nutrients were measured for 4 trees in each of the 21 plots

Follow the link below for a video of the sap sampling methods

http://youtu.be/jbsum_3qqxg

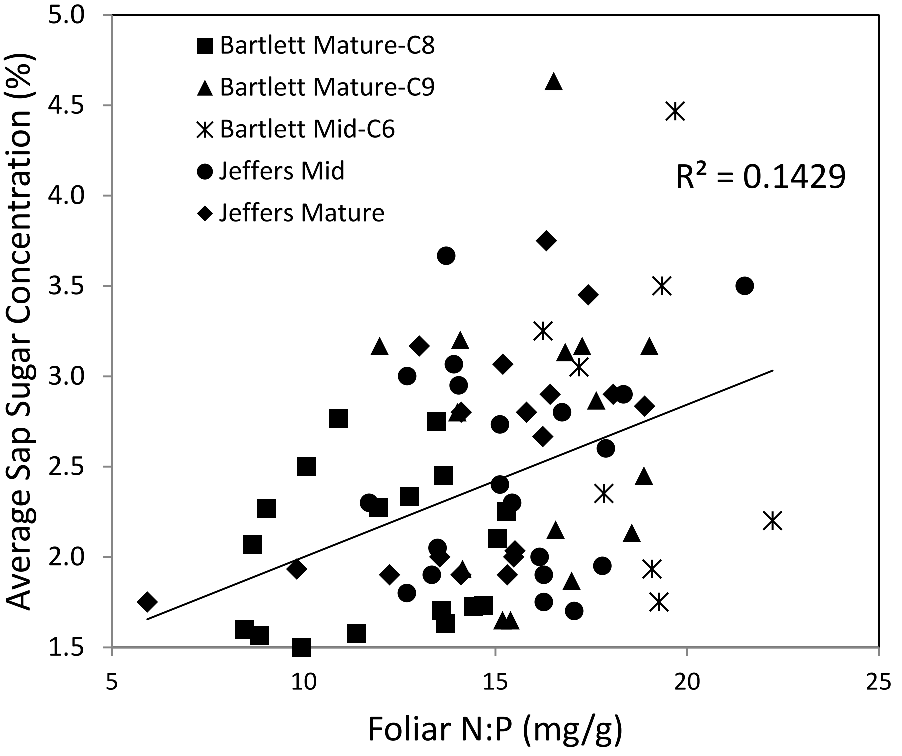
Methods – Nutrient Effect on Sap Sweetness

- Sap sweetness was averaged across the season for each tree and correlated with foliar nutrients, canopy health and growth
- Sap sweetness was averaged for each plot and correlated to soil nutrients and sap nutrients
- Effect of treatment on sap sweetness blocked by stand was analyzed using analysis of variance and analysis of covariance with pretreatment soil N mineralization as a covariate



Nutrient Effect on Sap Sweetness

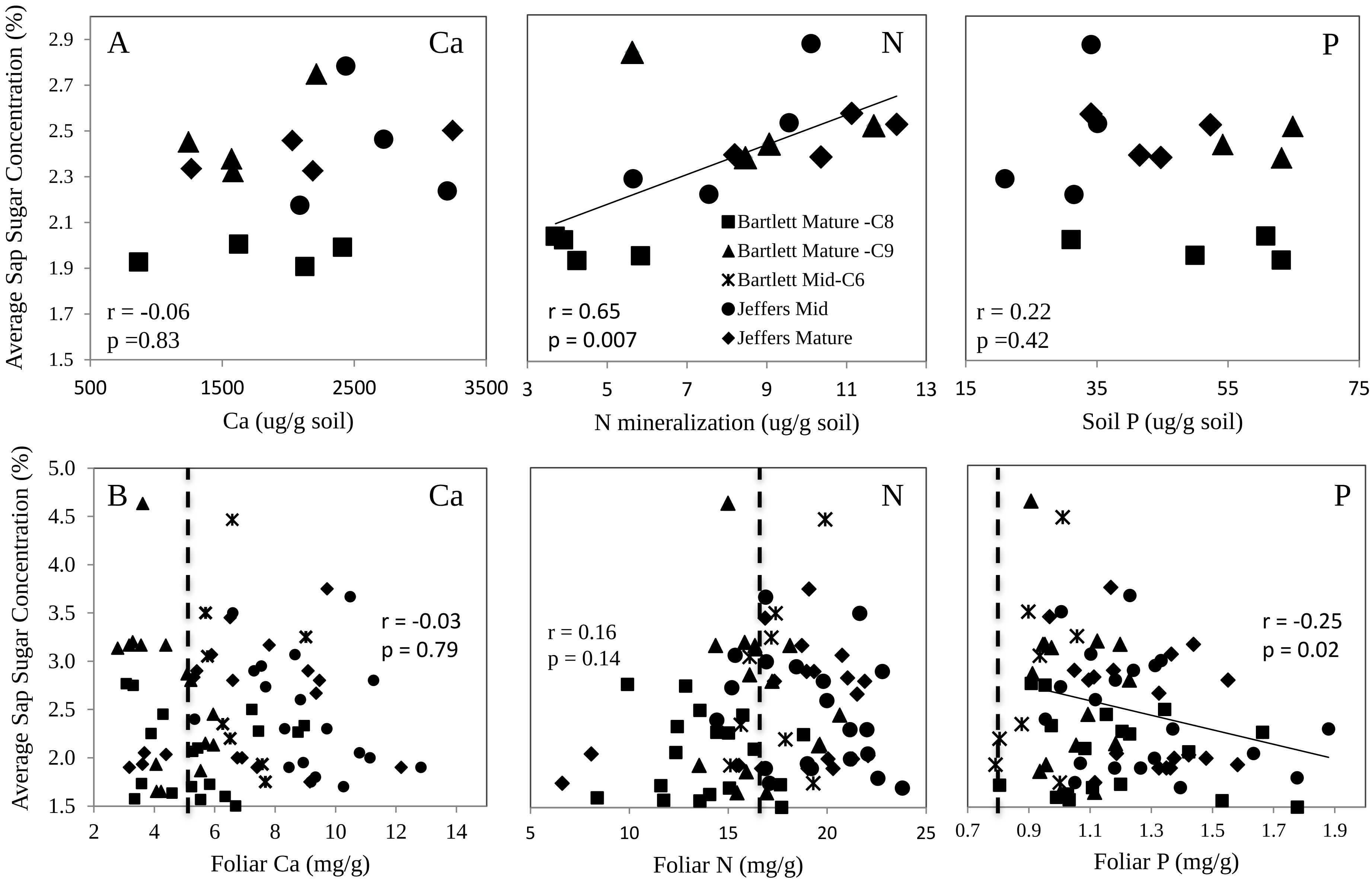
- Foliar N:P was highly correlated with sap sweetness
- Foliar P was negatively correlated with maple sap sweetness
- Sites with higher soil N mineralization had sweeter sap
- Neither soil Ca nor P was correlated with sap sweetness



- Canopy health did not correlate with sap sweetness
- Growth rate correlated weakly with sap sweetness
- Photosynthetic rate correlated weakly with sap sweetness while stomatal conductivity was not significantly related to sap sweetness
- Sap nutrients were variable and not correlated with sap sweetness

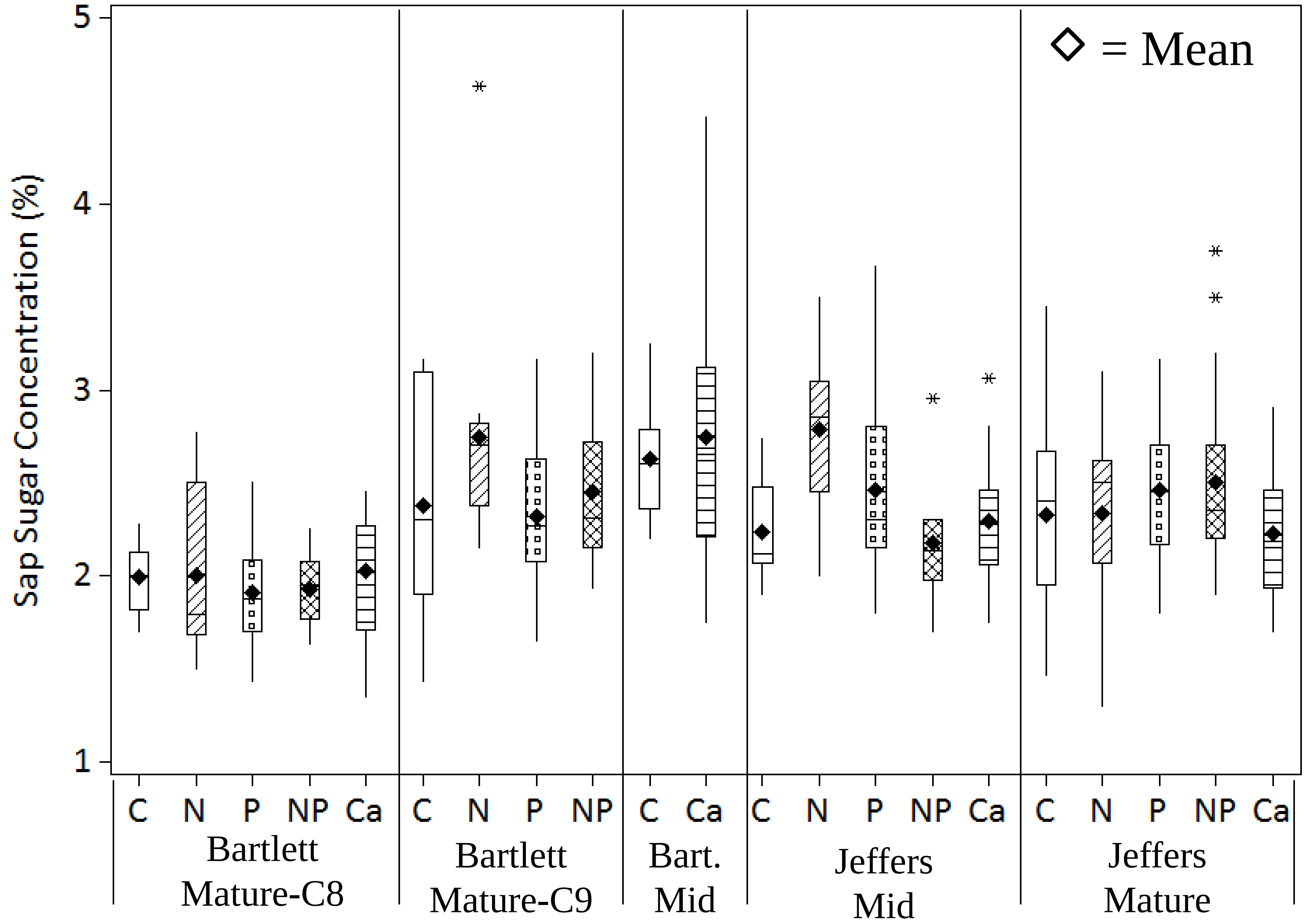
Nutrient Effect on Sap Sweetness

Sap sweetness was correlated with soil nutrients (A) and foliar nutrients (B).



Nutrient Effect on Sap Sweetness

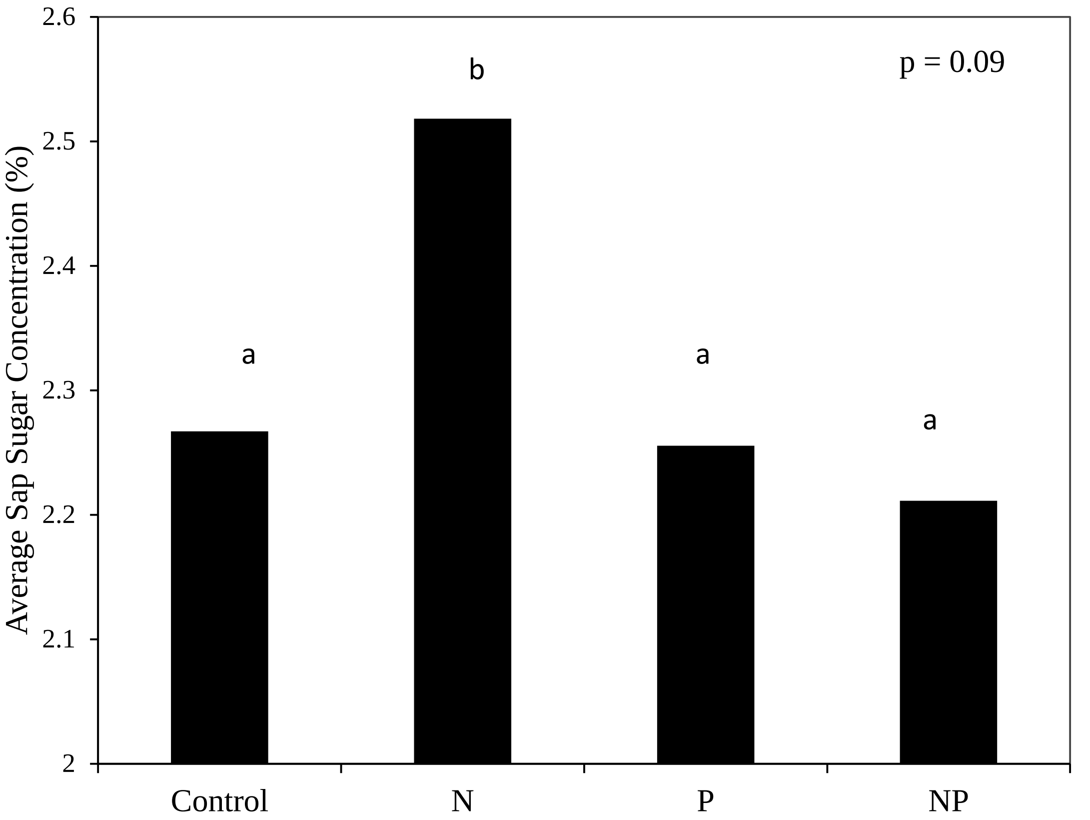
Sap sweetness response two years after a nutrient addition without accounting for variation in pretreatment soil nutrients



Nutrient Effect on Sap Sweetness

- Addition of N increased sap sweetness 11% using pretreatment soil N mineralization as a covariate

- Addition of N and P together did not increase sap sweetness
- Nor did addition of P or Ca increase sap sweetness



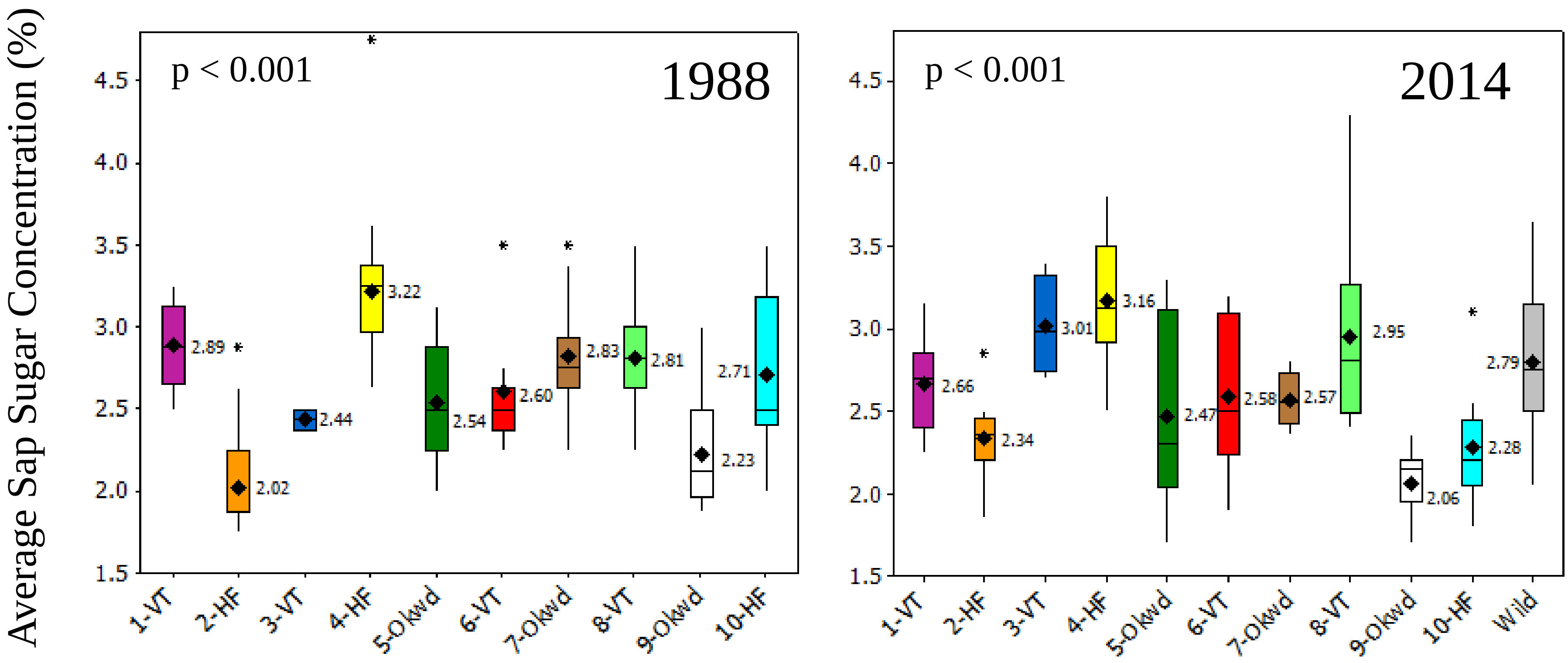
ls means of sap sweetness from an analysis of covariance

Methods – Genetic Control of Sap Sweetness

- Sap sweetness was sampled using a digital refractometer for10 clones of sugar maples propagated by rooted cuttings in the 1970s
- Each clone was replicated at least 3 times in a randomized complete block design at SUNY-ESF's Heiberg Memorial Forest
- DBH was measured and the stems were mapped to determine stand edge effects and competition from surrounding stems
- Unpublished sap sweetness data from the 1980s was also analyzed to test for a genetic difference in sap sweetness
- Difference in clones was determined through analysis of variance.

Genetic Control of Sap Sweetness

- Sap sweetness is genetically controlled. Sap sweetness differed significantly among clones.
- Propagating sugar maples through rooted cuttings is an effective way to replicate sweet trees. Variability within clones was low.



Results/Project outcomes
Genetic Control of Sap Sweetness

- Clone ranking by sap sweetness was similar between 2014 and the 1980s when the trees were saplings
- Increased light from the edge of the stand did not increase sweetness of maple sap

Sugar Concentration of Sugar Maples in 2014

Sugar Concentration	
1.7-2 (10)	2.75-3.0 (14)
2-2.3 (24)	3.0-3.4 (20)
2.3-2.5 (30)	3.4-4.3 (8)
2.5-2.75 (17)	

Darker symbols represent sweeter trees.

Implications and applications in the Northern Forest region

- By choosing sites with higher soil N or by adding N to the soil, maple producers may be able to collect sweeter sap, which reduces the energy needed to boil sap into syrup.
- Stands deficient in N could benefit from an addition of N to increase sap sweetness
- Sites high in P could have a negative effect on sap sweetness
- N is the most important nutrient for explaining sap sweetness

Implications and applications in the Northern Forest region

- Genetically sweeter sugar maples can be replicated through rooted cuttings and maintain rather consistent sap sweetness

- Propagating sweet trees through rooted cuttings would allow sugar maple producers to replicate sweeter trees

Future directions

- Nitrogen was applied at a low rate (30 kg/ha/yr). Future work is needed to determine whether adding N at a higher rate would further increase sap sweetness

- More time maybe needed to determine whether Ca has an affect on sap sweetness

- Testing sap sweetness across a broader range of soil variation and tree health would better explain how soil nutrients effect sap sweetness

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List of products

PRESENTATIONS:

- Wild, A.D. April 2014. “Soil Nutrients Affect Sweetness of Maple Sap” Masters Capstone, SUNY ESF. Video of presentation: http://youtu.be/wOkiQsHvPGI
- Wild, A.D. and Yanai, R.D. April 2014. "First Signs of a Foliar Treatment Response in the Multiple Element Limitation in Northern Hardwood Forest Ecosystem Study“ Hubbard Brook Committee of Scientist Spring Meeting.
- Wild, A.D. and Yanai, R.D. January 2014. "Do Nutrients Make Maple Sap Sweeter?“New York Society of American Foresters.
- Wild, A.D. and Yanai, R.D. November 2013. **"**Project Sweeter Sap: Do Soil Nutrient Make Maple Sap Sweeter?" Rochester Academy of Science Fall Paper Session.
- Wild, A.D. and Yanai, R.D. July 2013. "Sweet Times in the MELNHE Plots: Do Soil Nutrients Make Maple Sap Sweeter” Hubbard Brook Cooperators Meeting.

List of products

POSTERS:

- Wild, A.D., Maynard, C.A., Yanai, R.D. and Callahan, T.E. April 2014. "Is Sap Sweetness of Sugar Maples Genetically Controlled?" SUNY ESF Research Spotlight.
- Wild, A.D. and Yanai, R.D. January 2014. "Do Nutrients Make Maple Sap Sweeter?" New York Society of American Foresters.
- Wild, A.D. and Yanai, R.D. March 2013. "Project Sweeter Sap: Increasing the Sugar Concentration of Sugar Maple Sap Through Nutrient Additions" Syracuse University Life Sciences Research Showcase.

Theses

- Wild, A.D. April 2014. “Soil Nutrients Affect Sweetness of Maple Sap.” Masters Thesis, SUNY ESF.

Publications in Preparation

- Wild, A.D. and Yanai, R.D. “Soil Nutrients Affect Sweetness of Maple Sap.”
- Wild, A.D. Maynard, C.A., Pafka, D., Yanai, R.D. and Callahan, T.E. “Rooted Sugar Maple Cuttings Maintain Similar Sap Sweetness Within Clones”