FERTILIZATION OF SUGARBUSHES PART I. PHYSIOLOGICAL EFFECTS

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BACKGROUND

Liming and fertilization have long been used in agricultural crop production. Although some work has been conducted investigating the effects of fertilization on the growth of trees, primarily for timber production, and generally on sites with known deficiencies, relatively little effort has been focused on crop tree management, and especially on the use of fertilization as a tool in maple sugarbush management.

During the 1980's and 1990's, researchers examined whether maple decline symptoms could be ameliorated by liming and fertilization of maple stands. Studies at the UVM Proctor Maple Research Center (Wilmot et al. 1995, 1996, Liu et al.1997) and elsewhere (Ouimet and Fortin 1992, Long et al. 1997, Horsley et al. 1999, Moore et al. 2000) showed that soil nutrition strongly affected tree vigor and growth of mature sugar maple. A recent survey of maple nutrition in Vermont (Wilmot 2002) found that soil and foliar calcium levels were positively correlated with diameter growth. More recent work conducted in Ontario after the January 1998 ice storm was aimed at improving health and survival of storm damaged maple trees (Lautenschlager et al. 2003). Finally, research underway at the University of Monkton (New Brunswick) shows some promise in improving sugar production by fertilization (Barry and Robichaud 1996).

The goal of this project was to examine the effects of liming and fertilization on tree physiology, growth and sugar production of a moderately fertile maple stand. In this first report, we describe, in general terms, the study area, treatments, and results of liming and fertilization on tree physiology and growth. This report is not intended to be a comprehensive discussion of all the changes observed, but rather is meant to indicate some of the more important aspects of fertilization on maple tree physiology and function as they relate to health, vigor, and growth of trees. Subsequent reports will describe the effects of liming and fertilization on sugar production and regeneration of sugar maple.

STUDY AREA AND FERTILIZATION TREATMENT

The primary study site (Clark) was adjacent to the Proctor Maple Research Center in Underhill Center, Vermont with a western exposure on the slope of Mount Mansfield in the Green Mountain foothills at approximately 1350 ft. elevation. The site was a former sugarbush that had been abandoned several decades ago. While the majority of the stand was comprised of sugar maple, some yellow birch, beech, and hemlock also occupied the site. The majority of trees were mature and visibly healthy, with > 75% intact crowns.

Ten irregular plots consisting of 10-14 taps each were delineated within the study area and randomly assigned to one of five treatment groups, with two replicate plots per treatment. A buffer strip of varying width encircled each plot. Treatments consisted of: 1) control plots (no fertilization), 2) a commercial 10:10:10 NPK (nitrogen, phosphorus, potassium) at a rate of 270 lbs/acre, 3) a cation mix, consisting of potassium sulfate, calcitic lime, and Epsom salt (designed to supply the soil with potassium, calcium and magnesium) at combined rate of 400 lbs/acre, 4) cations + 10:10:10 at the rates given above, and 5) cations plus supplemental liming at 3000 lbs/acre. All treatments were applied in May 1999 by hand as a single dose spread evenly throughout the plots.

A second study site was set up in the PMRC Progeny plantation for additional studies. These trees were planted in 1960, and are currently pole-sized. The site is fairly shallow and droughty. Ten 20 ft wide plots were laid out parallel to the slope, with 15 ft buffer strips between plots. Four treatments were set up in May 1998. These were: 1) control plots (no fertilization), 2) lime at 3000 lbs/acre, 3) lime at 3000 lbs/acre + 10:10:10 at 270 lbs/acre , and 4) lime at 3000 lbs/acre + manure at 1600 bushels/acre.

METHODS

Foliage was collected from sun leaves in the upper half of the crowns of five dominant or codominant trees within each treatment plot on two occasions (June and August) during the growing season of 2001. Soil samples were obtained using a soil corer in October/November 2001. For each plot, five soil samples were taken from the Oa horizon (depth of approximately 1 inch) and bulked and one sample was taken from the A/B horizon (depth of approximately 5 inches).

Several measures were taken to assess the effects of treatment on tree physiology. Chlorophyll content was determined using a Minolta SPAD502 chlorophyll content meter. Dark-adapted chlorophyll fluorescence was determined using an Opti-Sciences OS-FL1 fluorometer. Both chlorophyll content and fluorescence are indicators of the efficiency at which trees can capture solar energy and convert it into sugars, and are typically affected by the nutrient status of the plants. Foliage and soil samples were analyzed for nutrient content via standard procedures at the UVM testing laboratory.

In October 2001, wood cores were taken from five trees within each of the plots using an increment borer. Cores were taken from the south side (Clark site) or the north side (Progeny site) of the trunk at breast height. Cores were glued into wooden mounts, dried, then cut and sanded until thin enough to see through when illuminated from below with strong light. Tree ring widths were measured to the nearest 0.01 mm using an optical measuring bench interfaced to a computer. Tree diameter was used to calculate basal area increment for each year from 1995-2001.

Due to the low level of replication, a Kruskal-Wallis nonparametric analysis was used to compare treatment ranks. When significant differences were detected at the $p < 0.10$ level, a Bonferroni adjusted test was used to compare treatment means using SAS statistical software.

RESULTS

In general, liming treatment increased soil pH and soil calcium levels in the organic horizon, with much smaller effects in the A/B mineral soil horizon (Figure 1). Low soil pH impedes uptake of beneficial soil nutrients, and makes detrimental elements (iron, aluminum) more readily available. An increase in pH is generally beneficial to plants growing in forest soils of the northeast region. Minor addition of calcium in the cation mix had no real effect on soil pH.

All treatments at both sites had substantial effects on soil A/B calcium levels in relation to control soil calcium levels (Figure 2). Addition of one or more of the nutrients supplied in

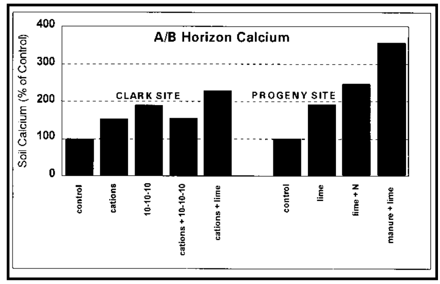

Figure 2. Soil A/B horizon calcium.

the treatment may have hastened litter and soil organic matter breakdown, or caused faster root turnover, resulting in higher soil calcium levels.

At both study sites, foliar calcium and nitrogen levels measured at the end of the growing season (August) increased compared to controls under all treatments (Figure 3). Foliar calcium increased by over 50% in some treatments. Nitrogen increased in most cases, but to a far lesser degree than calcium.

In general, the increased uptake of nutrients improved the photosynthetic

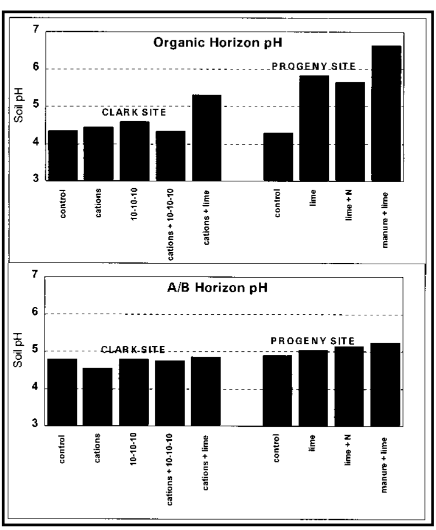

Figure 1. Soil organic horizon (top) and A/B Horizon (bottom) pH.

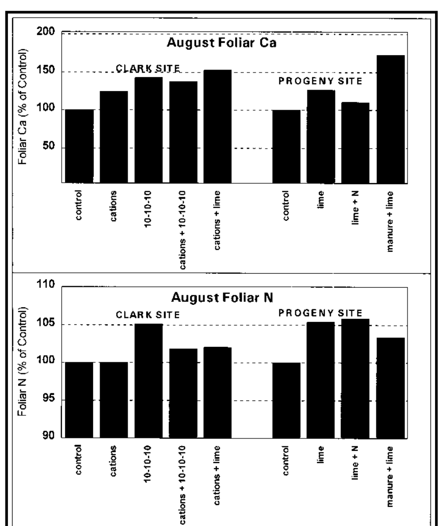

Figure 3. Foliar calcium (top) and foliar nitrogen (bottom) in August.

apparatus of the maple trees within the treatment plots (Figure 4). Because chlorophyll is the primary pigment responsible for capture of solar energy and conversion to chemical energy (sugars) within leaves, any increase in chlorophyll content or efficiency (fluorescence) would represent an enhanced ability of the trees within these plots to convert light energy into sugars. Chlorophyll content of trees within treated plots at both sites tended to increase, although only very slightly in some cases. Chlorophyll fluorescence, or the photochemical efficiency of the photosynthetic light reaction, also increased. Although the increase was slight, averaging only an 0.8% increase, when this small increase is multiplied over the millions of leaves in a tree over an entire growing season, it can result in a substantial increase in sugar acquisition.

Fertilization and liming generally increased basal area growth in these sites. The Progeny Site, which is considerably younger than the Clark site, responded to a much higher degree. When supplied with a nitrogen source in combination with liming, trees in the Progeny Site had almost twice the growth rate of untreated plots. Although liming alone had the maximum effect on chlorophyll content, the growth response with this treatment was unexpectedly small; similar treatment at other sites has yielded a much greater growth response. At the Clark Site, the growth response was considerably less. The cations + 10:10:10 treatment showed no change in growth. The other treatment plots averaged nearly 15% additional growth in comparison to control plots over the three year study period.

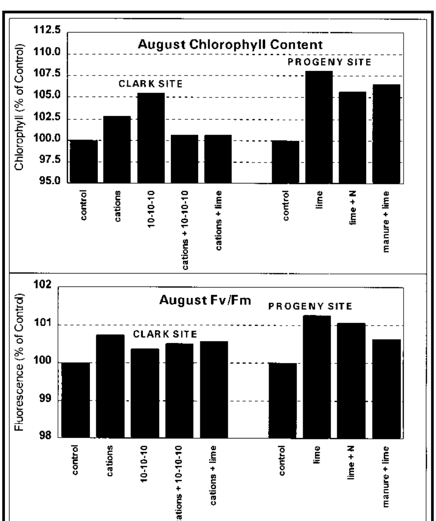

Figure 4. Foliar chlorophyll content and chlorophyll fluorescence in August.

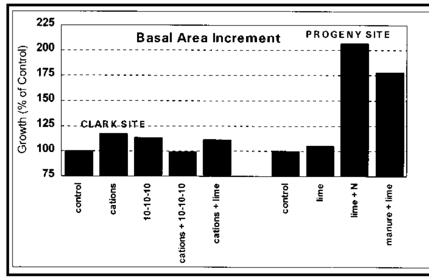

Figure 5. Basal area growth of trees in plots.

DISCUSSION

Good sugarbush managers utilize a suite of forest management tools. Although fertilization is by no means recommended for all maple stands, in areas of known deficiencies or where nutrient limitations may restrict physiological function of trees, fertilization and/or liming may improve vigor and growth of maple trees. In this study, we demonstrated that fertilization and liming can induce changes in soil nutrients and nutrient availability that subsequently affect foliar nutrient levels, photosynthetic physiology, and ultimately, growth.

A subsequent article will detail the effects of fertilization and liming on sugar (sap volume and sweetness) in the Clark study area.

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