FOLIAR NITROGEN VARIABILITY AND RESORPTION DURING AUTUMN LEAF SENESCENCE IN SUGAR MAPLE

Eveline Leon
Timothy Scherbatskoy
University of Vermont
School of Natural Resources

ABSTRACT

Resorption in plants represents an important mechanism for reducing nutrient loss during autumn leaf senescence. This study examined nitrogen resorption in sugar maples in the Stevensville Brook Watershed on Mt. Mansfield, VT. Percent resorption can be calculated as the maximum nitrogen pool in green leaves minus the nitrogen pool in leaf litter and the nitrogen leached by rain, all divided by the maximum nitrogen pool. During July and August of 1993 green leaves were collected from the canopies of sugar maple trees to obtain the maximum nitrogen pool. Nitrogen lost during leaf fall and from leaching was estimated from leaf litter and throughfall samples collected in the autumn of 1993. The green leaf tissue, leaf litter and water samples have been analyzed for nitrogen content. Statistical analysis of the resultant data has not yet been completed.

INTRODUCTION

The resorption of inorganic nutrients from senescing leaves in autumn represents an important nutrient conservation mechanism for the plant. There is substantial evidence that trees can reduce nutrient loss during leaf fall through withdrawal of nutrients from senescing leaves before abscission (Bukovac and Wittwer 1965; Ryan 1979; Ostman and Weaver 1982). The evidence for nutrient resorption from tree leaves is suggested by a decrease in absolute amounts of N, P, and K in leaves during senescence (Woodwell 1974). Measurements of resorption rely on the assumption that all nutrients lost from the leaves are resorbed, or leached by rain and appear in throughfall (Eaton et al. 1973).

Nitrogen is an essential plant nutrient often limiting to forest production (Birk and Vitousek 1986), and resorption represents an important mechanism for reducing nitrogen loss during leaf fall. Nutrients resorbed and reused within trees are not subject to mineralization and potential loss from the ecosystem in drainage water. Resorption, storage, and remobilization also allows trees to be somewhat independent of soil supplies of critical nutrients during periods of high demand, such as during springtime flush. Resorption may also dampen fluctuations in annual growth and may provide more uniform growth from year to year (Ryan 1982). The pattern of changes in foliar nitrogen concentration has been reported by Ryan (1979) and Ostman and Weaver (1982) to reach a constant peak level during mid-summer and then to undergo a sharp decrease in concentration during leaf senescence. Resorption can account for most of this decrease in nitrogen and is a key process by which plants achieve maximum efficiency in the use of this element. Ryan (1982) found that resorption during senescence can contribute 34% of nitrogen used annually by trees.

The present study investigated nitrogen resorption in sugar maple on Mt. Mansfield, VT. Previous resorption studies have all been at the stand level, pooling samples from individual trees to obtain a single measure of resorption per hectare. The purpose of this study is to clarify discrepancies found in previous studies (Chapin and Kedrowski 1983; Birk and Vitousek 1986) in determining the relationship between the amount of resorption and leaf nitrogen content. This is done by characterizing tree to tree variability in nitrogen content and resorption within a stand. The objectives of this research are:

1. Establish a relationship between foliar nitrogen content and the amount of nitrogen resorbed.

2. Characterize variation in resorption efficiency of nitrogen during senescence between individual sugar maple trees.

3. Develop a data-set of nitrogen levels in leaf tissue, leaf litter, throughfall, and soil which can be used as baseline information for longterm ecological monitoring.

METHODS

A stand, composed predominantly of mature sugar maple trees, was located off the Butler Lodge trail on the west face of Mount Mansfield at an elevation of 1700 feet. Twenty sugar maple trees were randomly selected on the site for sampling. The average dbh of trees sampled is six inches, and the average height is 63 feet. Included in the understory is sugar maple, striped maple, beech, yellow birch, elderberry, and hobble bush. The site is in the drainage of Nettle Brook, a small tributary to the north branch of Stevensville Brook, with a continuous stage recorder and regular water chemistry measurements. The location of the site is within the planned area for experimental silvicultural treatment in 1996.

Samples of attached leaves were collected once in mid-July and once in mid-August to obtain a measure of the maximum nitrogen pool. Foliar nutrient concentrations are most stable from mid-July to mid-August. Using a combination of pole pruners, ladders and rope climbing techniques, six samples of green foliage from each tree were obtained on each sampling date. One sample each was collected from the north and south sides of the tree, from the lower, middle and upper portions of the canopies.

Leaf litter was collected throughout the leaf drop period, September 20 to October 22, 1993. One litter trap was placed under each tree, positioned so that minimal litter would fall in from surrounding trees. Leaf litter was collected twice a week.

Estimates of resorption should be corrected for nutrient loss in throughfall during the resorption period; however, both Tukey (1970) and Chapin and Van Cleve (1991) found that leaching of nitrogen during resorption is minimal except under high nitrogen concentrations and might be ignored. However, since little information exists on the nutrient cycling of this stand and to evaluate whether correcting for leached nitrogen is important, throughfall was collected under five trees. Two funnel collectors were placed under each tree, one on the north and one on the south side of the tree. The collectors were placed half way between the bole and the canopy drip line and positioned to minimize other tree contributions to throughfall. Stemflow was not collected since it is not important to this study. Two funnel collectors were placed in an open area in close proximity to the site to collect rain as a control.

After each sampling, leaf tissue was run through a leaf area meter, assigned a thrips damage index number, oven dried at 70^{0}C to a constant weight, and ground in a Wiley mill. Total nitrogen was determined with a Leeman Laboratories CHN CE440 Elemental Analyzer. Throughfall and rain samples were weighed for volume and tested for pH. Chloroform (100 ul in 100 ml of sample) was used to preserve the samples which were then refrigerated at 4^{0}C until analysis. Nitrate was analyzed with a Dionex Ion Chromatograph Model 2010i, and ammonium was tested colorimetrically using a Lachat Quick Chem AE flow injection analysis.

Nutrient resorption is the proportion of the leaf nutrient pool that is withdrawn prior to leaf abscission (Chapin and Van Cleve 1991). Nitrogen resorption will be calculated as:

$$\%\text{ N resorbed} = 100 \times \frac{(\text{max. N mass/leaf area})-(\text{litter N mass/leaf area})-\text{NTF}}{\text{max. N mass/leaf area}}$$

NTF = net throughfall, (Fahey and Birk 1991

Only those individuals for which throughfall is collected will have net throughfall subtracted from the numerator. Net throughfall is estimated as the nutrient content of precipitation under the canopy, throughfall, minus that of bulk precipitation in the open, rain.

RESULTS

Although statistical analysis has not been completed, data from the green leaf tissue analysis indicate that some degree of variability does exist in nitrogen content between sugar maple trees on the site (Figure 1). The mean nitrogen content for July is 129.47 $\pm$ 18.05 ug/cm^2 leaf area and for August it is 132.95 $\pm$ 14.99 ug/cm^2 leaf area.

These data also indicate that foliar nitrogen content increases with height in the canopy (Figure 2). No difference is discernable between the north and south sides of the trees. However, figure 2 suggests that the maximum foliar nitrogen content might be in August.

All green leaf samples were assigned a pear thrips damage index number, 0 meaning no visible damage through 5 meaning the highest visible damage. Foliage with a higher nitrogen content appears to have more pear thrips damage than foliage with lower nitrogen content (Figure 3).

Results from data on leaf litter and throughfall nitrogen have not yet been analyzed. Therefore, at this time it is difficult to discuss the ecological significance of these data. Further data analysis is also underway for resorption calculations.

FUTURE PLANS

Immediate plans include completion of chemical analysis on rain and throughfall samples and statistical data analysis. In the spring of 1994 soil samples will be collected to gain an indication of site quality and soil nutrient availability. During the summer of 1994 I plan to write and complete my thesis. The site will be marked for future use as a long term monitoring study area. In addition to providing important data on nitrogen resorption processes, these data will also be useful for long term studies.

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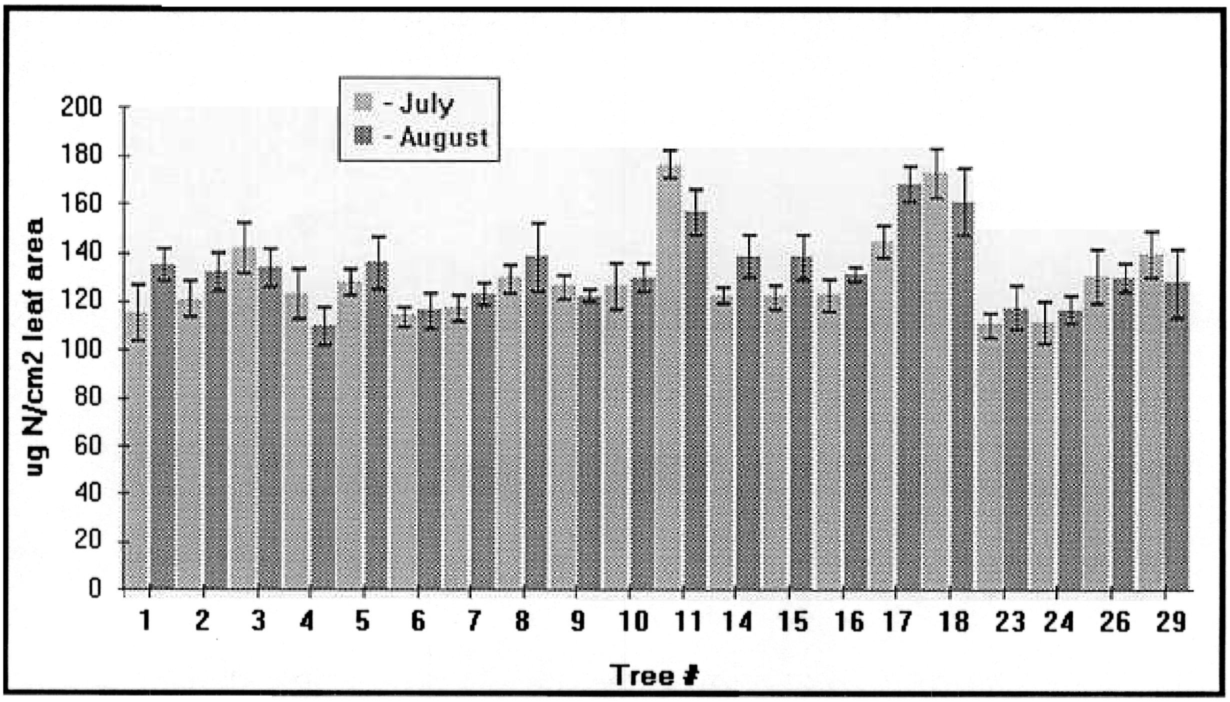

Figure 1. Foliar nitrogen content of individual sugar maple trees for July and August 1993.

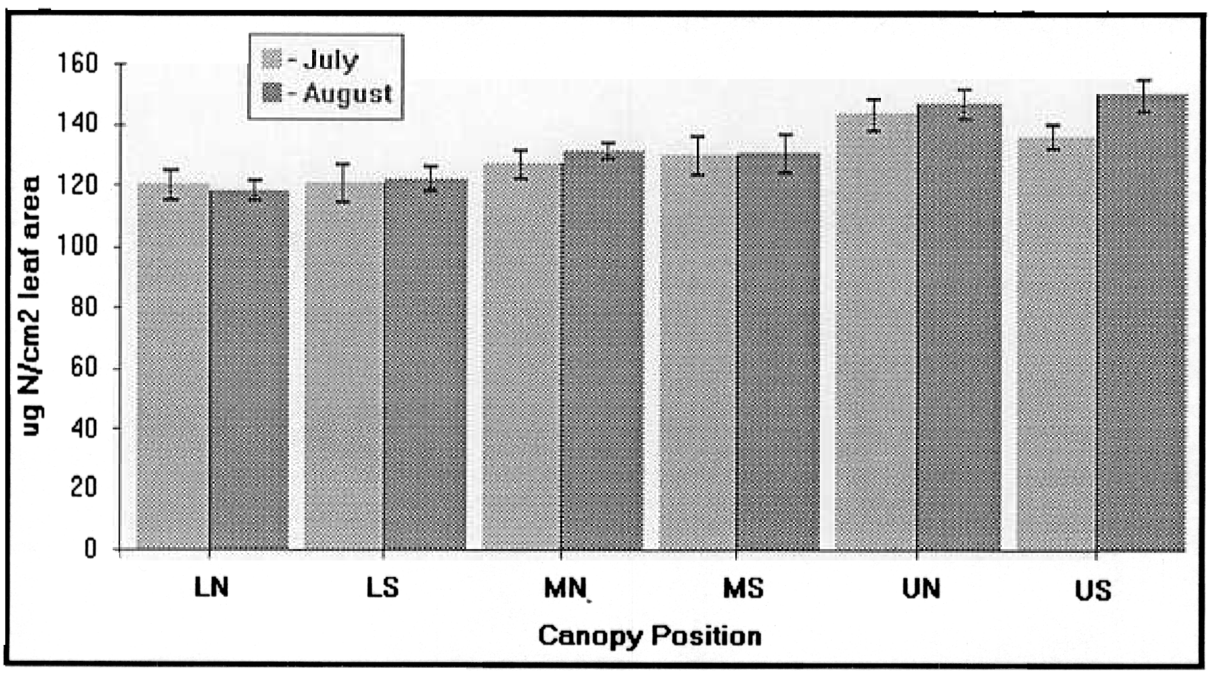

Figure 2. Foliar nitrogen content for different canopy positions in sugar maple during July and August 1993. LN = lower north, LS = lower south, MN = middle north, MS = middle south, UN= upper north, US = upper south.

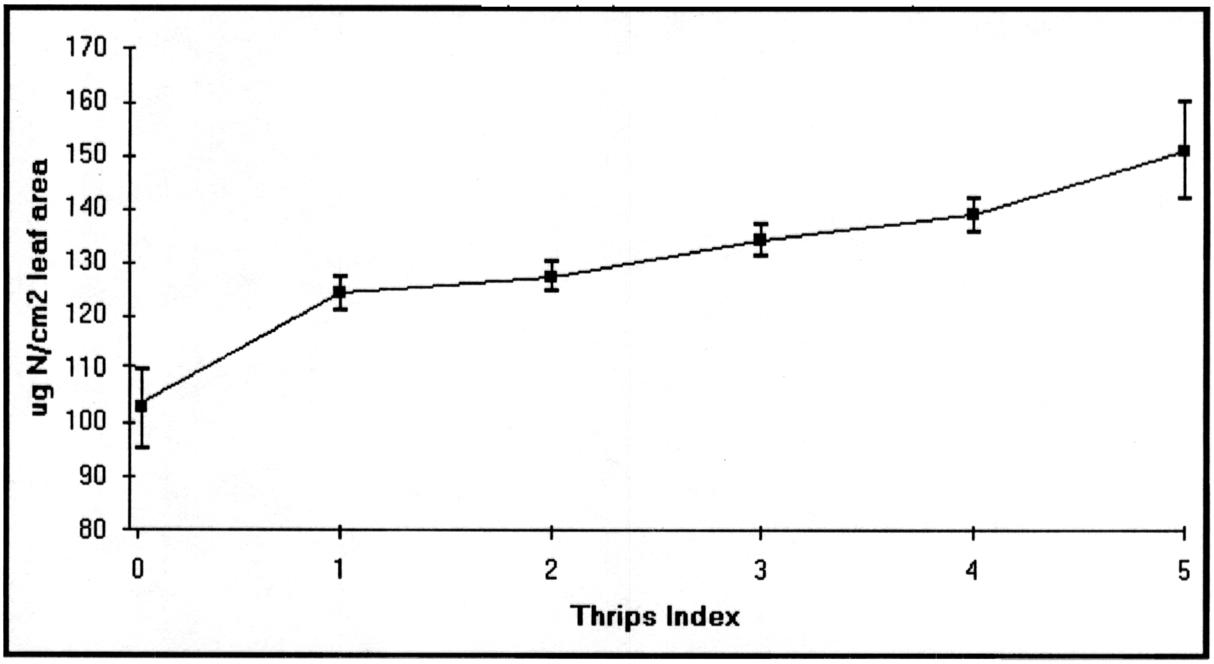

Figure 3. Foliar nitrogen content in relation to pear thrips damage in sugar maple. 0 = no thrips damage and 5 = highest damage.