CANOPY ION EXCHANGE MECHANISMS

Tim Scherbatskoy
School of Natural Resources
University of Vermont

Cooperators

Gary Lovett, Institute of Ecosystem Studies, Millbrook NY

Objectives

The broad goal of this work is to better understand mechanisms controlling foliar ion exchange (foliar leaching and uptake) in forest canopies. This is important in order to properly assess effects of changing atmospheric chemistry and climate on nutrient cycling processes in forests. Specific objectives of this project include: (1) characterizing the ion exchange rates in sugar maple during artificial precipitation events, (2) identifying the relative importance of possible sources of and sinks for exchanging ions, (3) relating tissue ion concentrations to ion exchange rates, and (4) develop a mechanistic model predicting canopy ion exchange rates.

Methods:

Integrated field and laboratory experiments are being conducted with sugar maple during two growing seasons. In 1991, the objective was to identify the relative importance of foliage *vs*. stems in canopy ion exchange. This was done by comparing the chemistry of foliar leachate from normal and artificially defoliated branches, and evaluating the kinetics of ion exchange in each.

Multiple paired branches were selected to receive treatments on two replicate open-grown trees. One branch per pair was manually defoliated in early July. Branches were pre-rinsed to remove surface deposits. Artificial precipitation at pH 4.4 was applied for three hours in branch chambers and foliar leachate collected every 15 min. Foliage and leachate samples were analyzed for all major nutrient cations and anions. Laboratory studies examined the ion transport properties of isolated leaf cuticles from the field foliage in order to calculate ion permeability rates.

Significant Findings

Analysis of this work is still underway, including evaluation of the exchange kinetics from the field studies and cuticular ion permeability analyses. Preliminary analysis of the field work indicates that stems are very important contributors to canopy ion exchange processes such as foliar leaching. When expressed on a leaf and stem surface-area basis, stems released as much as 18 times more of an ion than foliated branches. This is summarized in the following table as the relative proportion of stem leaching to foliated branch leaching over the entire three hour precipitation event.

RATIO OF STEM/WHOLE-BRANCH LEACHING ON A SURFACE-AREA BASIS

Na	K	Ca	Mg	NO_3	SO_4	Cl
10.2	17.3	2.93	15.7	1.23	18.4	17.5

Thus, on a unit-area basis stems alone leach 2.93 times more Ca than whole foliated branches, 17.3 times more K, etc. This result incorporates several factors: the relatively small surface area of stems (6% of the total surface area of stems plus leaves), the relatively small amount of water that actually contacts the stems, and the relatively high "leachability" of stems compared to leaves. The first two factors tend to work toward a small contribution from stems; thus, the third factor - a high leaching rate for bark - counteracts these factors significantly. This finding is important new information about the canopy ion exchange process, and has not been documented before.

The relatively small surface area of stems, however, limits their contribution to nutrient flux in throughfall. The fractional contribution of stem leaching to total branch leaching is shown in the following table.

RATIO OF STEM/WHOLE-BRANCH ION QUANTITY IN THROUGHFALL

Na	K	Ca	Mg	NO_3	SO_4	Cl
0.69	1.03	0.16	0.92	0.03	0.96	1.06

Thus, for the total quantity of ions contributed to a throughfall sample, stems contribute 16% of the Ca, all the K, etc. The conclusion from this observation is again that stems are important contributors to the ion exchange process in canopies, particularly for some ions such as K, Mg, SO_4 and Cl.

NH_4 showed consistent uptake by foliage and leaching by stems. Here again, stem leaching was about 17.8 times greater on a surface-area basis than (the absolute value of) foliated branch uptake.

Future Plans:

In 1992, the objective is to evaluate the contribution of leaf surface deposits to canopy exchange. Using similar procedures to 1991, the chemistry of foliar leachate from acid-washed, distilled water-washed, and un-washed foliage will be compared, and the kinetics of ion exchange within each component will be evaluated by sequential leachate sampling. Branches will be pre-washed in branch chambers with pH 3 or deionized water, and a third set of branches will not be rinsed to serve as the control. Artificial precipitation will be applied at pH 3.8 and 5.4, and foliar leachate collected for analysis. Leaf and branch tissues will also be analyzed for major ions, and relationships between tissue and leachate ion concentrations evaluated.

Funding Sources

Funding for this research comes from a grant from the USDA Cooperative State Research Service Forest Biology Program.