Response of Northern Hardwood Forests to Nutrient Perturbation

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Abstract

Substantial amounts of calcium have been depleted from the soils of northern hardwood forests in northern New England over the past 50 years. Portions of this depleted calcium have been incorporated into the biomass of the aggrading forests; however, significant amounts have been leached into drainage waters and lost from the ecosystem. The depletion of base cations from the soil exchange pool combined with the acidic conditions of most northern hardwood soils results in increased levels of exchangeable Al. Elevated levels of Al can inhibit the uptake of Ca by sugar maple (*Acer saccharum* Marsh.) and may adversely affect the health of other species. The objectives of this field experiment are to: 1) determine if sugar maple productivity is limited by the declines in calcium pools, 2) evaluate the response of sugar maple to changes in soil Ca:Al ratios, and 3) determine the effect of changes in Ca and Al availability on nutrient cycling. Twelve 45m x 45m plots were established in an 80 year old sugar maple dominated stand located at an elevation of about 750m at Hubbard Brook Experimental Forest (HBEF) in New Hampshire. Four plots received a total of 10 g m^{-2} Ca applied as $CaCl_2$, 4 plots received a total of 4.5 g m^{-2} of Al applied as $AlCl_3$, and the remaining 4 plots were untreated controls. Treatments began in October 1995, with additional applications in May 1996, November 1996 and May 1997. The following attributes are being measured: tree growth, tree health, sugar maple wood chemistry, sugar maple foliar nutrient content, concentration and mass, litterfall amount and chemistry, soil chemistry, soil solution chemistry, and throughfall chemistry.

Prior to treatment the soils at the site had low exchangeable base cations (A horizon Ca = 0.68 cmol × kg^{-1} and Mg=0.17 cmol × kg^{-1}) and high exchangeable Al (A horizon Al=5.82 cmol × kg^{-1} from 1M NH_4Cl extraction). These values are similar to other sites at HBEF and are some of the more base-poor values found in the White Mountains. Soil water is collected from three nests of 3 tension lysimeters on each plot. At each nest, lysimeters are located beneath the organic horizon, and at 25 cm and 50 cm below the top of the forest floor. A goal of the study is to increase the concentration of inorganic monomeric Al (Al*i*) in soil solution in the upper soil horizons to at least 100 μmol L^{-1}, a concentration that inhibits the uptake of Ca by sugar maple. Table 1 shows the average soil solution concentrations for Ca, Mg , Al*i*, and Cl and the average Ca:Al*i* ratio for the 1997 growing season. The calcium treatment increased the concentration of Ca at all depths. Other cations, including Al, were elevated relative to the control plots, but not to the degree of Ca. The Ca:Al*i* ratio was increased to a level well out of the range that would be potentially harmful to sensitive plants. The aluminum treatment increased Al concentration to near the target level in the organic horizon and to almost 50% of the target level for the B horizon (25 cm depth). The aluminum treatment also substantially increased the concentration of Ca at all depths; consequently, there was only a minimal change in the Ca:Al*i* ratio compared to the control plots. Multi-cation response suggests that changes in soil water chemistry are due to both added cations as well as native cations contributed from soil exchange sites. Foliar samples for chemical analysis were collected in August of each year from sapling and overstory sugar maple, hobble bush (*Viburnum alnifolium* Marsh.), and wood fern (*Dryopteris spinulosa* (Muhl.) Underw.). There has not been a significant response of foliar concentrations of Ca in sugar maple saplings or overstory trees; however, the trends are in the expected directions with higher concentrations of Ca in the calcium treatment plots and lower in the aluminum treatment plots relative to the control. Wood fern showed the most dramatic response to treatments with the foliar concentration of Ca doubling in the calcium treatments compared to controls and a trend toward reduced Ca in the aluminum treatments.

Table 1.—Average soil solution concentrations and the Ca:Al*i* ratio for the 1997 growing season at three depths

Treatment	Depth	Ca	Mg	Al*i*	Cl	Ca:Al*i*
		(μmol L^{-1})				
Calcium	O	135.8	32.6	25.9	371.0	4.3
	25cm	43.0	13.1	19.4	132.3	2.3
	50cm	43.2	14.1	15.1	113.6	3.1
Aluminum	O	103.4	27.2	89.6	492.7	1.4
	25cm	48.0	16.0	40.0	218.7	1.3
	50cm	39.4	13.7	18.8	112.7	2.5
Control	O	23.0	6.8	15.0	25.1	1.5
	25cm	15.0	4.7	13.6	12.6	1.1
	50cm	17.4	5.8	8.5	11.3	2.1

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