Do the competitions among calcium, aluminum and hydrogen ion for organic binding sites determine soil pH and aluminum solubility in Adirondack Forest soils?

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Abstract: Long-term acid deposition has resulted in a decrease in soil pH, the depletion of labile calcium (Ca) and the mobilization of aluminum (Al) in Adirondack forest ecosystems. In acidic soils, the labile Al is highly toxic to most organisms, affects the growth of plants, and can displace base cations [such as Ca (II), Mg (II), K, Na] on the exchange sites of soil organic matter (SOM). Liming is generally applied to mitigate soil acidity and to improve soil base status. After liming, the acid cations (Al3+, H+) may be neutralized by base cations (Ca2+), and the soil pH may be improved, suggesting that the competition between Ca2+ and Al3+ binding on SOM is the key process controlling soil pH and Al solubility. However, some researchers have noted that the fraction of exchangeable base cations and Al ion exchange capacity (CEC) is correlated with soil pH, and it has been suggested that Al3+ might act as a base cation. Furthermore, researchers have hypothesized that the composition of hydrogen ions (H+) and Al3+ adsorbed to the SOM determines the soil pH and Al solubility. The goal of this project is to explore the relationships between Al3+, Ca2+ and H+ bound to the organic exchange sites of SOM, and to improve understanding of the key acid-base processes determining the soil pH and Al solubility in the acidic forest ecosystem. We have conducted experiments to determine the acid-base chemistry of thirty-six samples from three horizons (Oe, Oa and mineral) of two limed subcatchments (II and IV) and two control subcatchments (III and V) for the Woods Lake watershed in the Adirondack Region.

Objectives

- Comparisons of soil chemistry of Woods lake subcatchments between pre-liming in 1989 and post-liming in 1991 and 2008
- Exploration of the relationships between Al3+, Ca2+ and H+ bound to organic exchange sites from three soil horizons

Sampling Sites

Woods Lake Watershed (43°52′00″ N 75°57′30″ W)
Sampled in 2008
6 sites from limed subcatchments: II and IV
6 sites from control subcatchments: III and V
Each pit has 3 horizons: Oe, Oa, and mineral

Methods

- Soil pH Measured in deionized water and 0.01 M CaCl2
- Exchangeable Ca Measured in 1 M KCl extracts
- Exchangeable Al and acidity (EA) Measured in 1 M KCl extracts
- Exchangeable H Difference between EA and exchangeable Al
- Base cations (BC) Summation of Ca, Mg, K, and Na measured in 0.5 M CaCl2 extracts
- Effective CEC (CECef) Summation of BC and EA
- Total C and N Measured by elemental analysis
- Organically bound Al Measured in 0.5 M CaCl2
- Total acidity (TA) Measured in 0.5 M BaCl2, TEA buffered at pH 8.2
- Total CEC (CEC) Summation of BC and TA
- Effective base saturation (BS) Percentage of BC divided by CEC

Conclusions

- Exchangeable Ca, CEC, and BS have experienced a large increase in organic horizons of limed sites, compared to reference sites.
- Exchangeable Al and acidity decreased after liming.
- The model of cation exchange reactions among H+, Al3+ and Ca2+ and the pH-dependent solubility of Al hydroxide should be both considered while determining soil pH and Al solubility.
- The indicator H+/CEC produces a better relationship with pH than BS, when the soil pH is less than 4.0.
- Competition between H+ and Al3+ are more important for mineral horizons than for Oe and Oa horizons.

References


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