THE EFFECTS OF LIME, FERTILIZER, AND HERBICIDE ON FOREST SOIL SOLUTION CHEMISTRY AND NORTHERN RED OAK RADIAL GROWTH FOLLOWING SHELTERWOOD HARVEST

Angela M. Happel and William E. Sharpe[1]

Soil acidity, nutrient deficient soils, lack of light penetration, herbivory, and understory competition are the major obstacles encountered in regenerating and sustaining northern red oak. Changes in soils that may occur during soil acidification include: reduced soil pH, increased availability of aluminum (Al) and manganese (Mn), loss of base cations due to leaching; and competition between base cations and Al for exchange sites in the fine roots (Robarge and Johnson 1992).

Cronan and Grigal (1995) proposed that a calcium/aluminum (Ca/Al) ratio of 1.0 or less in soil solution posed at least a 50 percent risk of adverse impacts on tree growth and a ratio of 0.2 (or less) a 100 percent risk. Soil acidity increases Al concentrations in the soil and has been implicated in oak regeneration failure in Pennsylvania (Lyon and Sharpe 1995). Northern red oak (*Quercus rubra* L.) is sensitive to Al toxicity (Cronan and Grigal 1995, Demchik and Sharpe 1999). Standard red oak regeneration practice in Pennsylvania requires a shelterwood cut to provide seeds for the new forest and allow enough light penetration to promote seedling growth. In addition, herbicides, such as sulfometuron methyl (Oust®), are used to reduce competition. Applications of lime and fertilizer have the potential to ameliorate soil acidity; therefore, their use could be very beneficial in the establishment of new seedlings The objectives of this study were to determine the effects of shelterwood harvest with herbicide application on soil and soil solution chemistry; to test the efficacy of liming and fertilization as an acidity remediation treatment; and to determine the effects of these treatments on red oak tree growth.

Three sites with extremely acidic soils, forest floors dominated by hay-scented fern (*Dennstaedtia punctilobula*), and predominately northern red oak (*Quercus rubra* L.) overstories were selected for study in southwestern Pennsylvania. Soil solution samples were taken bi-weekly using tension lysimeters for three growing seasons, from plots receiving herbicide (Oust®, sulfometuron-methyl, 2.0 ounces per acre) (H); lime and fertilizer (LF) (Dolomitic lime - 1.5 tons per acre and 10-20-20 Nitrogen-Phosphorus-Potassium (NPK) fertilizer - 0.5 tons per acre); and a combination of the herbicide, and lime, and fertilizer (HLF) treatments. Two plots served as controls (C). All plots were previously shelterwood harvested (within the year) to leave a residual basal area of 4.9 m^2 – 11.1 m^2. Northern red oak tree diameters at breast height (d.b.h.) were measured and basal area increment (BAI) was calculated.

Median soil solution data indicated calcium (Ca), magnesium (Mg), potassium (K), and pH increased with the addition of lime and fertilizer. Soil solution from plots receiving lime and fertilizer had increased Ca/Al and base cation/aluminum (BC/Al) ratios above critical levels. The addition of herbicide alone caused increased soil solution Al and H+ concentrations and reduced Ca/Al ratios to critically low levels. Within the HLF treatment plot, the addition of lime and fertilizer counteracted the acidifying effects of herbicide treatment, while still providing hay-scented fern control.

Northern red oak measurements indicated that under normal moisture conditions trees in the HLF plot had significantly increased radial growth over all other treatments. Both the LF and H treatments had significantly increased radial growth over the control treatment. The improved soil solution chemistry conditions on all plots receiving lime and fertilizer seemed to increase red oak radial growth.

Soil solution results indicated that even with the relatively modest lime and fertilizer application rates used, important soil chemistry improvements were produced. Sulfometuron-methyl herbicide application by itself lowered Ca/Al and BC/Al ratios well below critical levels implicated in Al toxicity to red oak, decreased soil solution pH, and increased plant available Al. Liming and fertilization with hay-scented fern control ameliorated soil acidification effects associated with sulfometuron-methyl application and resulted in Ca/Al and BC/Al ratios above critical levels and significantly improved plant available Ca and Mg concentrations. Based on the unfavorable soil chemical changes observed and their amelioration by lime and fertilizer application, sulfometuron-methyl herbicides should not be used to promote northern red oak regeneration on extremely acidic soils without accompanying lime and fertilizer treatment.

LITERATURE CITED

Cronan, C.S.; Grigal, D.F. 1995. Use of calcium/aluminum ratios as indicators of stress in forest ecosystems. Journal of Environmental Quality. 24: 209-226.

Demchik, M.C.; Sharpe, W.E. 1999. The effect of calcium/aluminum ratio on root elongation of twenty-six Pennsylvania plants. p. 211 – 217. In The Effects of Acidic Deposition on Pennsylvania's Forests. Sharpe, W.E. and Drohan, J.R. (eds.). Proceedings of the 1998 PA Acidic Deposition Conference, Vol. 1, ERRI, The Pennsylvania State University, University Park, PA. Chapter 18.

[1] Research Assistant and Professor of Forest Hydrology, Environmental Resources Research Institute and School of Forest Resources, The Pennsylvania State University, University Park, PA 16802 respectively.

Citation for proceedings: Spetich, Martin A., ed. 2004. Upland oak ecology symposium: history, current conditions, and sustainability. Gen. Tech. Rep. SRS–73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 311 p.

Lyon, J. 1995. The impacts of soils, herbaceous competition, and soil liming on the growth and nutrition of northern red oak (*Quercus rubra* L.) seedlings. University Park, Pennsylvania, U.S.A.:The Pennsylvania State University. [Not paged]. Ph.D. dissertation.

Robarge, W.P.; Johnson, D.W. 1992. The effects of acidic deposition on forested soils. Advances in Agronomy. 47: 1-83.