Sugar Maple Seedling Anatomy and Element Localization at Forest Sites with Differing Nutrient Levels

Carolyn J. McQuattie, Robert P. Long, and Thomas J. Hall[1]

Abstract

Sugar maple (*Acer saccharum* Marsh.) seedlings often have poor survival on acidic unglaciated portions of the Allegheny Plateau. Greater survival is found after lime treatment of unglaciated sites or on glaciated areas of the Plateau. The difference in survival rate may depend in part on the acidity or chemical composition of the soil. From a 1993 seedling cohort, survival after 2 years was 70 percent on limed plots (surface mineral soil pH=5.4) compared with 35 percent on more acidic unlimed plots (surface mineral soil pH=3.8) (Horsley and Long, unpublished data). A third site, Dodge Hollow (DH), on nearby glaciated soils had an abundant 1993 sugar maple seedling cohort and surface mineral soil pH was 4.0. Comparison of foliar nutrient levels showed significantly higher concentrations of base cations in foliage from seedlings on limed plots but significantly higher Mn and a lower Ca:Al ratio in foliage from unlimed plots (Horsley and Long, unpublished data). At DH foliar base cation concentrations were similar to those from the limed plot, but high foliar Mn concentration and a low Ca:Al ratio was comparable to foliage from the unlimed plot. An anatomical study was conducted to compare differences in mycorrhizal colonization, root and foliar anatomy, and the location of potentially toxic elements (Mn, Al) in seedlings from these 3 forest sites with differing soil chemical characteristics. In June and August 1996, 10 seedlings each from limed, unlimed, and DH sites were collected. Root and foliar tissues from each seedling were chemically processed for examination by light and transmission electron microscopy, and by energy-dispersive x-ray microanalysis. Remaining root systems (>80 percent of total) were chemically preserved in the field for later mycorrhizal assessment. Roots and foliar tissues for transmission electron microscopy and x-ray analysis were thin-sectioned and examined in a JEOL transmission electron microscope coupled with a Link Systems x-ray analyzer. In June, mycorrhizal colonization of roots was highest at the limed site, lowest at the unlimed site, and intermediate at DH (66, 21 and 45 percent, respectively). In August, colonization at the unlimed and DH sites was similar (approximately 35 percent) but lower than colonization at the limed site (61 percent). By light microscopy, roots from the unlimed site had an irregular outline and contained increased amounts of dense compounds in endodermal and stele cells compared to roots from the other sites. Dense staining is often associated with accumulation of phenolics or defensive compounds. Precipitates analyzed by x-ray analysis in root xylem and cortical cells (June collection) from the unlimed site were composed of Mn, and dense material observed by transmission electron microscopy in leaf chloroplast membranes was similar to Mn toxicity injury observed in sugar maple seedlings under controlled conditions (McQuattie and Schier, unpublished data). Aluminum was detected in mycorrhizal fungal hyphae (associated with P) in roots from the unlimed site and occasionally at DH. Precipitates containing Al in petiole and midvein vascular cells were found in foliage collected from the unlimed site only. In contrast, Ca and/or Si precipitates were found in foliar and root cell walls in seedlings from all sites, indicating a common chemical composition in these cellular sites. By transmission electron microscopy, starch grains were observed in leaf chloroplasts from all sites in June, whereas in August starch was prominent only in leaf blades from the unlimed site. In August, large starch grains were seen in roots of seedlings from DH. Starch grains were not observed in roots from limed and unlimed plots possibly indicating starch storage had not commenced for these seedlings. Overall, potential indicators of stress were most often seen in seedlings from the unlimed site: low early-season mycorrhizal colonization, Mn compounds in root cells, Al precipitates in leaf cells, and altered patterns of starch accumulation in leaves and roots.

[1]Research Plant Pathologist, Project Leader/Research Plant Pathologist, Northeastern Research Station, U.S. Department of Agriculture, Delaware, OH, and Forest Pathologist, Pennsylvania Bureau of Forestry, Division of Pest Management, 34 Airport Road, Middletown, PA, respectively.