

Root Dynamics and Nutrient Allocation in Sugar Maple

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Abstract

My colleagues, Kurt Pregitzer and Andy Burton, and I have been studying root dynamics in sugar maple forests in Michigan for the past 10 years. We have used a combination of traditional soil cores, minirhizotron video images and physiological techniques in an effort to understand patterns of carbon and nutrient allocation to roots, particularly the ephemeral, small diameter roots.

With respect to the role of roots in ecosystem annual net primary production (NPP), roots <2.0 mm in diameter account for about 60% of ecosystem NPP. These same roots account for about 50 – 60% of the total amount of N returned through above and below ground litterfall. Foliage production and litterfall account for about 1/3 of NPP and N returns, respectively. About 85% (numbers) of the roots are less than 0.50 mm in diameter (70% of biomass and 80% of length), and less than 2% exceed 1.0 mm. The average diameter of sugar maple fine roots is about 0.35 – 0.37 mm. In addition to their overall importance to the C and N economy of sugar maple forests, we have measured a substantial degree of simultaneity in root production and mortality throughout the year. Traditional approaches that rely on measurements of temporal biomass changes to quantify root production and mortality would yield estimates about 50% too low in these forests. Combined with the tendency to use a relatively coarse (1.0 – 2.0 mm) screen through which to wash and recover roots, we believe that the importance of very fine roots has been underestimated in at least some previous root studies.

We have used minirhizotrons to follow the appearance and fate of individual roots as a measure of root longevity. In sugar maple forests, about 40% of all annual root production occurs prior to and coincident with canopy expansion. Most mortality occurs after leaf fall and over winter. Root mortality rates for any time period during the year are the same for all roots produced that year, regardless of when they first appeared. However, mortality rates drop dramatically over

winter, and remain low for roots surviving into their second growing season. However, roots produced the subsequent year die off at the same, higher mortality rates as did roots produced the previous year.

Based upon the above data, it appears that changing environmental conditions during the growing season do not affect mortality rates. However, we have measured substantial differences among sites arrayed along a north-south gradient of about 400 km. In earlier studies we observed that root mortality rates were highest at our warmest, most southern site, suggesting that higher rates of root respiration might be associated with shorter root life spans. However, we subsequently measured equally high root mortality rates at the coolest, most northern site. Root chemistry assays and soil nutrient dynamics data revealed that root nitrogen content, and ultimately root nitrogen supply potential, explain the differences. Contrary to observations from other forests, high levels of soil N increase sugar maple root lifespan, regardless of soil temperature regime. Greater tissue N concentrations were associated with higher respiration rates at all temperatures, but high rates of respiration do not appear to be shortening root lifespans.

Further studies of the relationship between root dynamics and soil temperature, matric potential and site water balance showed that there are no strong effects of the soil environment on the dynamics of fine roots at our sites. There is some tendency for periods of abundant water to be associated with lower mortality and higher production rates, but the relationship is weak. There does appear to be a temporal correspondence between the onset of periods of high, midsummer water demand and the production of deep (80 – 100 cm) roots, and between autumn leaf fall and the death of the deep roots, but it is highly variable spatially.

Our current efforts are focused upon better understanding the role that soil N, mycorrhizae, and root physiology play in regulating root dynamics, and how controls over root dynamics in sugar maple forests compare with a variety of coniferous and deciduous forests across North America.

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