Belowground phenology at Harvard Forest

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*What relationships exist between shoot and root phenology? Generating hypotheses from metaanalysis and testing them at HF.*

Roots are hidden from view and heterogeneously distributed making them difficult to study in situ. As a result, the causes and timing of root production are not well understood. Researchers have long assumed that above and belowground phenology is synchronous; for example, most parameterizations of belowground carbon allocation in terrestrial biosphere models are based on allometry and represent a fixed fraction of C uptake. However, using results from metaanalysis as well as empirical data from oak and hemlock stands at Harvard Forest, we are finding that synchronous root and shoot growth is the exception rather than the rule.

We collected root and shoot phenology measurements from studies across four biomes (boreal, temperate, Mediterranean, and subtropical). General patterns of root phenology varied widely with 1-5 production peaks in a growing season. Surprisingly, in 9 out of the 15 studies, the first root production peak was not the largest peak. In the majority of cases (32/47) maximum shoot production occurred before root production. The number of days offset between maximum root and shoot growth was negatively correlated with median annual temperature and therefore differs significantly across biomes (ANOVA, F3,43=9.47, p<0.0001). This relationship may reflect earlier root growth relative to shoot growth due to higher soil temperature during spring in warm biomes. The difference between biomes may also be explained by differences in species composition.

To explore the range of phenological relationships within woody plants in the temperate biome, we focus on above and belowground phenology in three stands each dominated by a common northeastern tree speices, *Quercus rubra, Fraxinus americana,* and *Tsuga canadensis*. Relative greenness, root growth, and mortality were measured beginning in April 2012 through August 2013 at the Harvard Forest in Petersham, MA, USA. Relative greenness was extracted from the Phenocam mounted on the EMS tower. Root growth and mortality were measured using a minirhizotron camera (n=10 for each stand). Greenness was highest in late May and early June with one clear maximum growth period. In contrast, root growth was characterized by multiple production peaks in 2012 and to some extent in 2013. *Q. rubra* root growth peaked in mid-summer with high mortality over winter and early spring. *F.americana* root growth also peaked mid-summer with moderate mortality throughout the season. *T. canadensis* root growth peaked later in the season with early spring mortality. *T.canadensis* has a notably longer lag between greenness maximum and peak root growth when compared to the deciduous *Q.rubra* and *F.americana.* Despite large spatial and inter-annual heterogeneity, it appears that deciduous *Q. rubra* and *F.americana* allocate more C to root growth earlier in the year and overall during the growing season. The storage pool of nonstructural carbohydrates experiences a mid-summer drawdown in all stands in 2012, but with large inter-annual variability. My goal for this meeting is to go over the data I have just described and think about what kinds of conclusions I can draw from the patterns that I see, given the variability of the data and lack of previous work looking at the relationship between above and belowground phenology. As you can see, I have my own ideas, but am struggling to explain all of patterns that fall out of this dataset and would like to invite feedback from the group.

*(Root growth and) death is just the beginning…*

If time and interest, we can also talk about patterns in root respiration and Q10 over the growing season that I’ve measured on severed roots in the LiCor, and root exudation as it (doesn’t appear to) change over the growing season. I would also like to test the hypothesis that the same amount of rhizosphere inputs into the soil (as root turnover or root exudates) at different times of the year feeds back into microbial decomposition to produce different annual C fluxes out of the soil. I have some preliminary data on this that we could look at using my root exudation data fed into the DAMM model of enzyme kinetics (Davidson et al. 2012). Because plant roots supply substrate to microbial communities, their production feeds back to other plant and soil processes that affect ecosystem C fluxes, so I think explicitly looking at this feedback is an important next step.