Eissenstat, D.M. and Yanai, R. 1997. Ecology of Root Lifespan. Advances in Ecological Research, 27: 1-62.

Summary

Theories of plant evolution and adaptation have posited relations between tissue deployment and environmental conditions which have yet to be substantiated belowground. Root production is quantitatively important, exceeding aboveground productivity in a range of ecosystems. In addition, carbon expended for root maintenance often exceeds that used for root production. Root production and turnover have consequences for carbon and nutrient cycling, water and nutrient acquisition, competition between plants and the survival and reproduction of species under changing environmental conditions. Despite its importance, relatively few studies have examined factors controlling root lifespan.

This review identifies some competing theories of root lifespan and reviews the evidence available to support them. New methods of root observation and analysis produce data appropriate to testing these theories, but the results to date are few and often conflicting. Tentative generalizations include a suggestion that small diameter roots with low tissue density tend to have short lifespans. Root lifespan appears to be longest in cold environments, but data are lacking for tropical species. There is a strong seasonal variation in lifespan, with roots produced in the fall surviving longest, at least in temperate climates. Species differences are difficult to quantify, due to seasonal and interannual variation, but root lifespans of deciduous fruit crops seem to be shorter than those of temperate deciduous forest trees or citrus, a broadleaf evergreen.

Until more data are available on root lifespan, simulation modeling offers an approach to developing testable hypotheses and identifying research needs. We applied a cost-benefit analysis to determine the lifespan that would maximize root efficiency, defined as the amount of nutrient acquired per unit of carbon expended. The analysis suggests that roots should have long lifespans if they have low maintenance respiration or are located in favorable patches of nutrient-rich soil. Shedding roots in dry soil may not be necessary to root efficiency if reductions in maintenance respiration can match reductions in uptake. Accurate predictions of optimal root lifespan are presently limited by insufficient information on the changing C costs and nutrient uptake capacity of roots with age. The costs and benefits of root hairs, root exudates and mycorrhizal fungi also need to be included.

The current model of root efficiency omits some important factors that may exert controls on root lifespan. Fine roots have other functions besides absorption, including transport of water and nutrients. Seasonality of climate and the need for carbon and

nutrient storage could constrain the root lifespan that optimizes plant fitness to differ from that which maximizes root efficiency. Roots compete for carbon and nutrients with other plant organs; roots may be shed when demands of roots are low relative to reproductive demands or to the demands of new leaf production. Death of roots may not entail the loss of all the C and nutrients they contain, if material is resorbed from senescing tissues or if nutrient cycling is tight and the lost material eventually benefits the plant.

Finally, root herbivory and parasitism are probably much greater than generally appreciated. Young roots generally lack structural defenses and are at high risk of attack by soil organisms. The lifespan of stressed roots with low carbohydrate reserves is probably affected by weak pathogens and primary saprophytes that reside in the rhizosphere. Plant-animal (including plant-fungus) interactions are likely a dominant factor influencing the lifespan of roots.

More long-term studies are needed, both to detect existing patterns of root lifespan with resource availability and plant strategy, and to progress beyond short-term responses to treatments, which may be misleading. Factors that should be included in studies of root lifespan in addition to resource availability include root age, plant C status, and pathogen pressure. Because root lifespan differs from leaf lifespan in many species, better knowledge of root lifespan may result in revision of current theories regarding plant adaptation and growth strategies.