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Plant hydraulic traits govern forest water use and growth

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Biophysical controls at the leaf, stem, and root levels govern plant water acquisition and use. Suites of sometimes co-varying traits afford plants the ability to manage water stress at each of these three levels. We studied the contrasting hydraulic strategies of red oaks (Q. rubra) and red maples (A. rubrum) in northern Michigan, USA. These two species differ in stomatal regulation strategy and xylem architecture, and are thought to root at different depths. Water use was monitored through sap flux, stem water storage, and leaf water potential measurements. Depth of water acquisition was determined on the basis of stable oxygen and hydrogen isotopes from xylem water samples taken from both species. Fifteen years of bole growth records were used to compare the influence of the trees' opposing hydraulic strategies on carbon acquisition and growth. During non-limiting soil moisture conditions, transpiration from red maples typically exceeded that of red oak. However, during a 20% soil dry down, transpiration from red maples decreased by more than 80%, while transpiration from red oaks only fell by 31%. Stem water storage in red maple also declined sharply, while storage in red oaks remained nearly constant. The more consistent isotopic compositions of xylem water samples indicated that oaks can draw upon a steady, deep supply of water which red maples cannot access. Additionally, red maple bole growth correlated strongly with mean annual soil moisture, while red oak bole growth did not. These results indicate that the deeper rooting strategy of red oaks allowed the species to continue transpiration and carbon uptake during periods of intense soil water limitation, when the shallow-rooted red maples ceased transpiration. The ability to root deeply could provide an additional buffer against drought-induced mortality, which may permit some anisohydric species, like red oak, to survive hydrologic conditions that would be expected to favor survival of more isohydric species, like red maple. Advanced plant hydrodynamic models, including the FETCH2 model, are able to capture the effects that traits regulating water loss (e. g. isohydry/anisohydry, conductivity of woody tissue, and rooting depth) impose upon transpiration at scales of a single tree to a whole forest. The integration of detailed knowledge of species-specific hydraulic traits, available through the TRY Global Plant Trait Database, provides biologically relevant constraints for the governing parameters within these modeling systems. By incorporating the effects of plant hydraulic traits at the leaf, stem, and root levels, with mechanistically based predictions of transpiration, growth, and mortality, we can improve simulations of the surface energy budget and global carbon and water balances.