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Carbon translocation patterns associated with new root proliferation during episodic growth of transplanted *Quercus rubra* seedlings†

JOSHUA L. SLOAN[1] and DOUGLASS F. JACOBS[1,2]

[1] *Hardwood Tree Improvement and Regeneration Center, Department of Forestry and Natural Resources, Purdue University, 715 West State Street, West Lafayette, IN 47907-2061, USA*

[2] *Corresponding author (djacobs@purdue.edu)*

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Summary Patterns of carbon allocation in northern red oak (*Quercus rubra* L.), characterized by episodic growth through recurrent single-season flushing, vary by growth stage. To examine post-transplant timing and carbohydrate sources for new root growth, dormant, bare-root, half-sibling northern red oak seedlings were transplanted to pots and placed in a favorable growth chamber environment. Unlabeled seedlings were harvested at transplant and at the bud swell stage. After leaf emergence, seedlings were exposed to $^{14}CO_2$ at the linear shoot, linear leaf or lag growth stages. Seedlings were then placed in a growth room for 48 h to allow for translocation of ^{14}C-labeled current photosynthate and its stabilization in sink component plant parts. Seedlings were subsequently harvested and tissue ^{14}C:^{12}C ratio analyzed. New root growth began during the linear shoot growth stage. However, no increase in ^{14}C:^{12}C ratio was found in new roots until the linear leaf and lag growth stages, indicating a downward shift in translocation of current photosynthate to fuel new root growth. In old roots, ^{14}C:^{12}C ratio increased at the lag stage. Our results indicate that both stored carbohydrates and current photosynthate contribute to new root growth of transplanted northern red oak seedlings; stored carbohydrates promote initial new root proliferation, whereas current photosynthate assumes a greater role as new leaves mature and the flush terminates. Optimizing nursery practices to increase carbohydrate reserves may reduce the time required to establish root–soil contact and facilitate early post-planting survival.

Keywords: carbohydrate reserves, carbon allocation, Quercus morphological index, root growth.

Introduction

Relatively few studies have examined carbon allocation in temperate deciduous forest tree species exhibiting episodic growth patterns (Dickson et al. 1990, 2000*a*, 2000*b*). True episodic flushing, as exhibited by northern red oak (*Quercus rubra* L.), is characterized by the endogenously controlled recurrent development of flushes throughout the growing season during periods of suitable environmental conditions; such growth involves the expansion of new stem and leaf material from a resting bud before formation of a new resting bud (Dickson 1994).

To faciliate studies examining the association of physiological status and activity with physical growth of *Quercus* seedlings, Hanson et al. (1986) developed the *Quercus* morphological index (QMI). The QMI divides a flush of growth into stages that are readily identifiable by a series of simple morphological measurements. Several studies have successfully used the QMI in conjunction with ^{14}C labeling techniques to quantify allocation and partitioning patterns of current photosynthate at various developmental stages and across a number of flushes (Dickson et al. 1990, 2000*a*, 2000*b*). Patterns of allocation of current photosynthate in northern red oak seedlings vary greatly across QMI growth stages, with the greatest downward translocation to roots typically occurring during the lag stage when the resting bud is set at the end of a flush (Dickson et al. 2000*a*).

Research on northern red oak has focused on the carbon allocation patterns during the first growing season growth flushes (Dickson et al. 1990, 2000*a*, 2000*b*). Several studies have been conducted with coniferous species to examine post-transplant allocation of current photosynthate (van den Driessche 1987, Philipson 1988, Maillard et al. 2004). New root growth following transplanting depends at least partially on current photosynthate in Douglas-fir (*Pseudotsuga menziessii* (Mirb.) Franco), Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and Corsican pine (*Pinus nigra* Arn. ssp. *laricio* var. *corsicana*) (van den Driessche 1987, Philipson 1988, Maillard et al. 2004). Despite information relating seedling root morphology to planting success of *Quercus* spp., few studies have examined physiological aspects of root growth in relation to transplanting. Andersen et al. (2000) hypothesized that loss of coarse roots before transplanting had a more negative effect on post-transplant root growth than loss of fine roots, and that new root growth following transplanting is likely reliant on nonstructural carbohydrates and nutrients stored in coarse roots. To test the hypothesis that new root growth following transplanting relies on stored carbohydrates, and to assess the degree to which current photosynthate contributes to new root

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