From Forest Nursery Notes, Winter 2012

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Forest Ecology and Management 262 (2011) 791–802

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Growth, foliar nutrition and $\delta^{13}C$ responses of red alder (*Alnus rubra*) to phosphorus additions soon after planting on moist sites

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ARTICLE INFO

Article history:
Received 30 November 2010
Received in revised form 2 May 2011
Accepted 6 May 2011
Available online 1 June 2011

Keywords:
Alnus rubra
Red alder
Phosphorus nutrition
Stable carbon isotope
$\delta^{13}C$
Growth

ABSTRACT

In south-coastal British Columbia, a low availability of phosphorus (P) may limit the early growth of young red alder (*Alnus rubra* Bong.), even on sites classified as productive for red alder. However, it remains unclear as to what P addition rates best alleviate P deficiencies on such sites and how long effects of P additions on growth persist.

We applied P 1–3 months after planting at rates up to 60 g P tree^{-1} and assessed growth and foliar elemental contents over three growing seasons at three sites with site productivity classed as good for red alder. Foliar $\delta^{13}C$ was also determined in year 1 in the two sites on Vancouver Island and in year 2 in the site on the British Columbia mainland coast in order to better understand the relationships among foliar nutritional status, leaf water use efficiency (WUE), and growth.

P additions at planting significantly increased height (11–15%), diameter (26%) and stem volume (62–64%) through 3 years. Maximum growth rates were achieved at P addition rates of 30 g tree^{-1} and at foliar P concentrations of 2.2–2.5 g kg^{-1}. Growth did not increase further at addition rates of 60 g P tree^{-1}. Stem growth increases were accompanied by increased individual leaf mass, first-year foliar concentrations of N, P, Ca, Mg, and S, and foliar $\delta^{13}C$, the latter suggesting that WUE increased with P additions. Foliar concentrations of P in unfertilized trees were at deficient levels, based on earlier studies, and increases in first-year foliar P concentrations and stem growth through year 3 were consistent with responses in earlier single-tree plot experiments. Longer-term measurements are required to define the duration of growth response to P additions in these otherwise-productive sites.

1. Introduction

Red alder (*Alnus rubra*) is the most common hardwood species in early-successional low elevation forests of coastal northwestern North America, aggressively colonizing sites following disturbance. Red alder has potentially rapid growth rates (Harrington, 1990), is immune to laminated root rot, *Phellinus weirii*, a major pathogen of coastal Douglas-fir (Thies and Sturrock, 1995), fixes significant amounts of atmospheric nitrogen (N) (Binkley et al., 1994) in forests which are generally considered N-limited (Chappell et al., 1991), and has wood properties suitable for a variety of products that add to the diversity of the region's forest economy. However, alder has also been considered a formidable competitor of more highly-desired conifers and was targeted for elimination from conifer plantations during the past four decades. Development of the hardwood industry in the Pacific Northwest United States and in British Columbia has led to increasing demand for alder and, given past eradication efforts, to concerns that the current inventory of alder is insufficient to meet projected demands (Mason, 2003). Plantation management may be a key to ensuring a sufficient supply of high value alder logs. Careful site selection and stand density management, combined with potentially rapid growth rates of alder, may result in the production of high-value clear logs in as little as 25–30 years (Bluhm and Hibbs, 2006).

Understanding the nutritional requirements of red alder is important for selecting plantation sites, maximizing the growth potential of plantations, and determining when fertilization is ecologically and economically appropriate. Various studies have suggested that deficiencies of phosphorus (P) may limit growth of red alder. In Oregon and Washington, site index increased with soil phosphorus (P, Bray-extraction) to ca. 30 mg kg^{-1} (Harrington and Courtin, 1994). On Vancouver Island, site index of mature alder increased with foliar P concentrations in lower pH soils (Courtin, 1992). In short-term glasshouse experiments and in single-tree plot field experiments where trees were fertilized within a year of planting, growth was limited more often and to a greater degree

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doi:10.1016/j.foreco.2011.05.013