From Forest Nursery Notes, Winter 2012

155. © Do limited cold tolerance and shallow depth of roots contribute to yellow-cedar decline? Schaberg, P. G., D'Amore, D. V., Hennon, P. E., Halman, J. M., and Hawley, G. J. Forest Ecology and Management 262:2142-2150. 2011.

Forest Ecology and Management 262 (2011) 2142–2150

Contents lists available at SciVerse ScienceDirect

Forest Ecology and Management

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

Do limited cold tolerance and shallow depth of roots contribute to yellow-cedar decline?

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ARTICLE INFO

Article history:
Received 24 June 2011
Received in revised form 27 July 2011
Accepted 2 August 2011
Available online 8 September 2011

Keywords:
Yellow-cedar
Western redcedar
Western and mountain hemlock
Sitka spruce
Root freezing injury

ABSTRACT

It has been proposed that yellow-cedar (*Callitropsis nootkatensis*) decline is initiated by the freezing injury of roots when soils freeze during times of limited snowpack. To explain the unique susceptibility of yellow-cedar in contrast to co-occurring species, yellow-cedar roots would need to be less cold tolerant and/or more concentrated in upper soil horizons that are prone to freezing. We measured the root cold tolerance and used concentrations of foliar cations as an assay of rooting depth for five species in one forest in Ketchikan, Alaska. Species evaluated were yellow-cedar, western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), mountain hemlock (*Tsuga mertensiana*), and Sitka spruce (*Picea sitchensis*). Roots were collected in November 2007 and January, March and May 2008; foliage was collected in January 2008. Soil samples from surface and subsurface horizons were analyzed for available calcium (Ca) and aluminum (Al) to compare with foliar cation concentrations. Across all dates the sequence in hardiness from the least to most cold tolerant species was (1) yellow-cedar, (2) western redcedar, (3) western and mountain hemlock, and (4) Sitka spruce. Yellow-cedar and redcedar roots were less cold tolerant than roots of other species on all sample dates, and yellow-cedar roots were less cold tolerant than redcedar roots in January. Yellow-cedar roots were fully dehardened in March, whereas the roots of other species continued to deharden into May. Yellow-cedar roots exhibited the highest electrolyte leakage throughout the year, a pattern that suggests the species was continuously poised for physiological activity given suitable environmental conditions. Yellow-cedar and redcedar had higher foliar Ca and lower Al concentrations, and greater Ca:Al ratios than the other species. Yellow-cedar had higher foliar Ca and Ca:Al than redcedar. Soil measurements confirmed that the upper horizon contained more extractable Ca, less Al and higher Ca:Al than the lower horizon. Considering the distribution of Ca and Al in soils, we propose that concentrations of Ca and Al in yellow-cedar and redcedar foliage reflect a greater proportional rooting of these species in upper soil horizons compared to other species tested. Greater Ca and Ca:Al in the foliage of yellow-cedar suggests shallower rooting compared to redcedar, but broad similarities in foliar cation profiles for these species also highlight some overlap in rooting niche. Our data indicate that both limited root cold tolerance and shallow rooting likely contribute to the unique sensitivity of yellow-cedar to freezing injury and decline relative to sympatric conifers.

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1. Introduction

Yellow-cedar (*Callitropsis nootkatensis* (D. Don) Florin ex D.P. Little) is an ecologically, economically and culturally important tree species that has an extensive native range from the northern Klamath Mountains of California to Prince William Sound in Alaska (AK). The species is limited to high elevations throughout most of its range, except in northern regions where it grows from near timberline down to sea level (Harris, 1990). Yellow-cedar is a slow-growing tree that tolerates poor growing sites, and which diverts considerable resources toward protection from biotic stressors (Hennon and Shaw, 1997). Despite this protection, yellow-cedar has experienced dramatic mortality (Hennon and Shaw, 1997; Hennon et al., 2005) now estimated to extend over 200,000 hectares in AK (Lamb and Winton, 2010) and nearly 50,000 hectares in British Columbia (Westfall and Ebata, 2009). The extensive mortality of this species, referred to as yellow-cedar decline, is a classic example of forest declines, which are generally recognized as wide-spread, long-term, and having either complex or unresolved etiologies (Manion and Lachance, 1992). Consistent with the defensive niche of the species (e.g., being relatively free from insect damage with its wood remarkably durable to fungal attack; Harris, 1990), yellow-cedar decline is not believed to be associated with

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0378-1127/$ - see front matter Published by Elsevier B.V.
doi:10.1016/j.foreco.2011.08.004