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Relationships between frost hardiness, root growth potential, and photosynthesis of nursery-grown white spruce seedlings

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Abstract

• **Context** Root growth is a characteristic to which nursery personnel is particularly attentive. The increase in root growth of white spruce seedlings in the autumn relies on the current season's photosynthates. Needle hardening or a decrease in the mass of photosynthetically active foliage as a result of early frost may negatively affect the seedling's photosynthetic capacity and its ability to fuel root growth.
• **Aims** This study evaluated the relationship between cold hardiness, root growth potential, and photosynthesis of 2-year-old white spruce seedlings.
• **Methods** At the end of their second growing season under standard cultural practices in a forest nursery, seedlings were hardened under natural conditions of photoperiod and temperature. After being subjected to artificial freezing tests on four sampling dates during the fall, the seedlings were compared for cold tolerance and recovery of gas exchange.
• **Results** The effect of artificial freezing treatments on seedling photosynthesis varied with frost intensity and degree

of needle hardening. The mass of new roots formed over a 21-day cultivation test period following the freeze tests was positively related to the photosynthetic capacity of the seedlings and negatively related to the proportion of damaged needles.

• **Conclusion** These results imply that autumnal cold damage to needles directly affects seedling root growth and emphasize the importance of maintaining seedlings in an environment favorable for photosynthesis during the fall to promote root growth.

Keywords *Picea glauca* · Cold damage · Hardening · Root growth · Photosynthesis

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1 Introduction

Seedling quality is generally determined by outplanting performance (Landis 2010) and is linked to a seedling's capacity to rapidly establish good contact between its roots and the surrounding soil (Grossnickle 2005). Therefore, root system development is a characteristic to which nursery personnel must be particularly attentive. In Quebec, seedlings must meet 25 rigorous quality standards before being shipped to plantation sites (Veilleux et al. 2010). According to the first of these criteria, root systems of containerized seedlings must be sufficiently developed and possess adequate root plug cohesion to permit handling and transporting of the seedlings with minimal or no root damage (Veilleux et al. 2010). Boreal climate is characterized by a short growing season and extremely cold winter temperatures (Müller 1982). Since they are not produced under greenhouse conditions, large white spruce (*Picea glauca* [Moench] Voss) seedlings must, therefore, meet strict morphological criteria within two short growing seasons as per official guidelines in Quebec (Margolis 1987). Moreover, since they are kept outside during winter, shoots and roots of containerized white spruce