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An operational method for estimating cold tolerance thresholds of white spruce seedlings in forest nurseries

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ABSTRACT

Cold damage leads to the rejection of millions of seedlings each year in northern forest nurseries. Nursery managers need a procedure to estimate the degree of hardening at a specific time in order to make decisions to avoid seedling loss. Estimates based on variables that are quick and easy to measure such as thermal time, a variable quantifying the cumulative effect over time of temperatures below a given threshold, and apical dry mass ratio (DM/FM) hold particular promise. In this study, two-year-old white spruce containerized seedlings were subjected to artificial freezing tests. The progression of DM/FM during the fall was determined and the thermal time was quantified by calculating hardening degree days (HDD) based on air temperature and a specific threshold for white spruce. Results establish that cold tolerance thresholds are associated with easily identifiable specific DM/FM and HDD values for nursery × species × seed source combinations.

Key words: *Picea glauca*, cold damage, hardening, apical dry mass ratio, hardening degree days

RÉSUMÉ

Les dommages causés par le gel sont à l'origine du rejet annuel de millions de semis dans les pépinières forestières nordiques. Les pépiniéristes ont besoin d'une procédure pour estimer le degré d'endurcissement à un moment précis pour prendre des décisions qui permettront d'éviter la perte de semis. Des estimations basées sur des variables facilement et rapidement mesurables, telles que le temps thermique, une variable permettant de quantifier l'effet cumulé dans le temps de températures en deçà d'une température seuil donnée, ou le ratio de matière sèche des apex (MS/MF) semblent particulièrement prometteuses. Dans cette étude, des plants d'épinette blanche de deux ans, et produits en récipients, ont été soumis à des tests de gels artificiels. L'évolution du MS/MF en automne a été déterminée et le temps thermique a été quantifié en calculant des degrés jours d'endurcissement (DJE) basés sur la température de l'air et une température seuil spécifique à l'épinette blanche. Les résultats établissent que les seuils de tolérance au gel sont associés à des valeurs de MS/MF et de DJE facilement identifiables et spécifiques à chaque combinaison « pépinière × essence × provenance ».

Mots clés : *Picea glauca*, dommages causés par le gel, endurcissement, ratio de matière sèche des apex, degrés jours d'endurcissement

Introduction

Cold damage is one of the principal reasons that millions of seedlings are rejected each year in northern forest nurseries (Colombo 1997). In Québec, containerized seedlings are grown under unheated polyethylene tunnels during their first growing season. The tunnel is removed in October and a thick layer of natural snow covers the seedlings during the winter. During the second growing season and subsequent winter, the containerized seedlings are left uncovered and exposed to natural environmental conditions (Margolis 1987). Annual rejection rates due to frost damage can range from 5% to 30% (Lamhamedi *et al.* 2005). Irrigation is the most common method of protecting containerized seedlings from damage when air temperatures approach and drop below 0°C before the seedlings are fully hardened (Rose and Haase 1996). The formation of ice around the shoot tissue liberates heat, thus ensuring that the tissue does not freeze. Irrigation must be continued until the risk of frost has passed. This abundant application of water saturates the substrate. Unfortunately, seedlings are unable to use the majority of this water because physiological processes slow down in the fall, thus reducing water uptake and transpiration. The surplus water, along with any dissolved solutes it contains, may leach from the growing medium into the groundwater system (Lamhamedi *et al.* 2001, Stowe *et al.* 2010). If the cold hardiness level was known, the need for irrigation during hardening could be reduced and optimized.

In most of Canada, cold hardiness of conifer seedlings is operationally determined using the freeze-induced electrolyte leakage technique (Colombo 1997, Colombo *et al.* 2001). This technique quantifies cell membrane damage by measuring the increase in electrical conductivity of a bathing solution after artificial freezing of plant tissue (Colombo *et al.* 1984). The main disadvantages of this approach are that the tests take several days to carry out and expensive equipment is required (Colombo *et al.* 2001). When freezing temperatures are forecast, nursery managers need to be able to estimate the level of seedling cold hardiness immediately. They

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