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Effects of thermal model and base temperature on estimates of thermal time to bud break in white spruce seedlings

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Abstract: To improve the predictability of bud burst and growth of boreal trees under varying climate, the thermal time for bud break in white spruce (*Picea glauca* (Moench) Voss) seedlings was evaluated under a range of temperature conditions in controlled environment chambers. Thermal time requirements were calculated as the sum of growing degree days or growing degree hours above base temperatures ranging from –1 to 5 °C. The results indicated that the common modeling approach, which uses a high base temperature of 5 °C and growing degree days, may not be appropriate for future climatic conditions. Estimates of thermal time requirements using a base temperature of 5 °C varied considerably among temperature treatments and thus would reduce the predictability of bud burst under changing climate. In contrast, estimates of thermal time requirements with lower temperatures closer to 1 °C were relatively consistent among treatments. Growing degree hour models were less sensitive to base temperature than degree day models. These results should help in the selection of appropriate base temperatures and thermal time models in quantification of thermal time for bud burst modeling in other boreal trees.

Résumé : Dans le but d'améliorer la prévisibilité du débourrement et de la croissance des arbres en milieu boréal sous diverses conditions climatiques, le temps thermique nécessaire au débourrement chez l'épinette blanche (*Picea glauca* (Moench) Voss) a été évalué dans différentes conditions de température dans des chambres à environnement contrôlé. Le temps thermique requis a été calculé par le cumul des degrés-jours de croissance ou degrés-heures de croissance au-dessus de températures de base allant de –1 à 5 °C. Les résultats indiquent que l'approche commune de modélisation qui utilise une température de base élevée de 5 °C et les degrés-jours de croissance n'est peut-être pas appropriée pour les conditions climatiques futures. Les estimations du temps thermique requis en utilisant une température de base de 5 °C varient considérablement parmi les traitements de température et, par conséquent, réduiraient la prévisibilité du débourrement sous un climat qui est en train de changer. Par contre, les estimations du temps thermique requis avec des températures de base plus près de 1 °C étaient relativement consistantes parmi les traitements. Les modèles qui utilisent les degrés-heures de croissance étaient moins sensibles à la température de base que ceux qui utilisent les degrés-jours. Ces résultats devraient aider à choisir les températures de base et les modèles de temps thermique appropriés pour quantifier le temps thermique et modéliser le débourrement chez d'autres espèces boréales d'arbre.

[Traduit par la Rédaction]

Introduction

The annual cycle of growth and dormancy in temperate and boreal trees is controlled by seasonal changes of the environment (Saxe et al. 2001). Termination of tree growth in late summer is thought to be induced by shortening photoperiod, while a period of chilling temperatures (–4 to 5 °C) during the subsequent fall and winter is required for buds to break dormancy (Kramer 1994; Saxe et al. 2001). Once chilling requirements are met, trees are ready to resume growth, beginning with bud burst, which occurs following a species-specific accumulation of thermal time above a base temperature (Fuchigami et al. 1982; Hänninen 1995; Hannerz 1999; Tanja et al. 2003; Søgaard et al. 2008). In boreal regions, winter is long and chilling requirements are readily met (Heide 1993; Myking and Heide 1995; Colombo 1998; Hannerz et al. 2003; Linkosalo et al. 2006), and the start of growth therefore depends largely on the critical cumulative thermal time in the spring. The increase of temperatures with climate change will therefore affect bud burst and growth through different timing of bud break and duration of growing season

The time required for bud burst to occur decreases with increasing temperatures, following a sigmoidal response pattern between the minimum base temperature of 0 °C and a maximum at about 35 °C (Hänninen 1990; Kramer 1994). Within the dominant range of temperatures for bud burst in spring (between 10 and 25 °C), the relationship can be approximated using a linear model (Bloomberg 1978). Thus, the thermal time required for bud burst is often expressed as the sum of degree days or degree hours above a base temperature (Cannell and Smith 1983; Hannerz 1999; Bailey and Harrington 2006). The degree day model is used more commonly than the degree hour model mostly because hourly temperature data are often unavailable and bud burst data are collected over a fairly long time interval. However,

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