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Modeling the effects of winter environment on dormancy release of Douglas-fir

Constance A. Harrington [a,*], Peter J. Gould [a,1], J. Bradley St.Clair [b,2]

[a] USDA Forest Service, Pacific Northwest Research Station, 3625 93rd Ave. SW, Olympia, WA 98512, USA
[b] USDA Forest Service, Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331, USA

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ABSTRACT

Most temperate woody plants have a winter chilling requirement to prevent budburst during mid-winter periods of warm weather. The date of spring budburst is dependent on both chilling and forcing; modeling this date is an important part of predicting potential effects of global warming on trees. There is no clear evidence from the literature that the curves of chilling or forcing effectiveness differ by species so we combined our data and published information to develop new curves on the effectiveness of temperature for chilling and forcing. The new curves predict effectiveness over a wide range of temperatures and we suggest both functions may be operating at the same time. We present experimental data from 13 winter environments for 5 genotypes of Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) and use them to test various assumptions of starting and stopping dates for accumulating chilling and forcing units and the relationship between budburst and the accumulation of chilling and forcing units. Chilling started too early to be effective in one treatment but the other 12 environments resulted in budburst from many combinations of chilling and forcing. Previous reports have suggested benefits or cancellations of effects from alternating day/night or periodic temperatures. Our simple models do not include these effects but nevertheless were effective in predicting relationships between chilling and forcing for treatments with a wide range of conditions. Overall, the date of budburst changed only slightly (+1 to −11 days) across a wide range of treatments in our colder test environment (Olympia, WA, USA) but was substantially later (+29 days) in the warmest treatment in our warmer environment (Corvallis, OR, USA). An analysis of historical climate data for both environments predicted a wide range in date to budburst could result from the same mean temperature due to the relative weightings of specific temperatures in the chilling and forcing functions. In the absence of improved understanding of the basic physiological mechanisms involved in dormancy induction and release, we suggest that simple, universal functions be considered for modeling the effectiveness of temperature for chilling and forcing. Future research should be designed to determine the exact shape of the curves; data are particularly lacking at the temperature extremes. We discuss the implications of our data and proposed functions for predicting effects of climate change. Both suggest that the trend toward earlier budburst will be reversed if winter temperatures rise substantially.

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1. Introduction

Many temperate zone woody plants have a chilling requirement which prevents budburst during a warm period mid-winter. The chilling requirement is usually described as some time period (i.e., days or hours) of temperatures in a specific range (e.g., $\geq$0 °C and $\leq$5 °C) that is necessary for budburst or reduces the time to budburst in the spring. Past researchers have studied chilling for many species; some have tested models with long-term phenological records and others have conducted controlled experiments. In spite of great interest in this topic for more than 100 years, the biological mechanisms involved in perceiving and "remembering" temperatures effective for releasing winter dormancy (bud dormancy, seed dormancy, flowering and vernalization) and forcing (warm temperatures that accelerate budburst) are not well understood (Amasino, 2004; Sung and Amasino, 2005). There have been several recent advances in physiology, biochemistry and molecular markers which may hold promise for understanding the underlying mechanisms (cf. recent reviews by Horvath et al., 2003; Arora et al., 2003; Rohde and Bhalerao, 2007). Currently, however, empirical studies and modeling are necessary for addressing questions of how plants respond to warmer winter environments

* Corresponding author. Tel.: +1 360 753 7670; fax: +1 360 753 7737.
E-mail addresses: charrington@fs.fed.us (C.A. Harrington), pgould@fs.fed.us (P.J. Gould), bstclair@fs.fed.us (J.B. St.Clair).
[1] Tel.: +1 360 753 7677; fax: +1 360 753 7737.
[2] Tel.: +1 541 750 7294; fax: +1 541 758 7760.

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