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From Forest Nursery Notes, Summer 2009

**164. © Frost hardening and dehardening in *Abies procera* and other conifers under differing temperature regimes and warm-spell treatments.** Nielsen, C. C. N. and Rasmussen, H. N. Forestry 82(1). 2009.

# Frost hardening and dehardening in *Abies procera* and other conifers under differing temperature regimes and warm-spell treatments

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## Summary

Frequent bud frost damage in cultivation of *Abies procera* Rehder and pending climate changes are the background for this study of cold hardiness under varying acclimation regime (in closed-top chambers) and experimental warm spells during the cold season. LT<sub>50</sub> values were established by freezing tests at different times of year. Damage and deaths were assessed on leader buds, subapical lateral buds, needles and cambium. Minor parallel experiments involved *Abies nordmanniana*, *Picea abies* and *Picea sitchensis*. Lower acclimation temperatures resulted in deeper frost hardiness during late autumn but less during spring, compared with ambient temperature controls. Elevated temperatures resulted in less deep frost resistance. Apical buds generally developed deeper frost hardiness than lateral buds but less deep than the cambium, varying with species, however. Frost damage in buds ranged from death over partially destroyed bud contents resulting in distorted shoots to buds seemingly remaining dormant. Responses to warm spells differed with duration, timing and species, ranging from dramatic decrease in frost hardiness with or without subsequent recovery to no reaction. Furthermore, the reactions did not show any clear relation to dormancy level. For *A. procera*, exposure to fluctuating temperatures appeared to be particularly problematic. This explains why this species develops best in coastal climates, and in sites sheltered from temperature extremes either by hedging, a winter snow cover, or topography. The Christmas tree production will suffer severely on sites with harsh temperatures due to losses of lateral and terminal buds, which destroy the crown symmetry. Clipping of greenery is less influenced by frost damages, although the development of normal branch whorls is often disturbed.

## Introduction

Phenology and dormancy patterns of trees are adapted to the conditions of their natural habitat (Chuine and Cour, 1999). Hence, species and provenances that are cultivated far from their origin may display problems in seasonal timing, which can lead to irregular bud breaking, poorly formed

shoots or loss of buds. Successful cultivation requires a deeper analysis of the critical environmental stimuli that are needed to carry trees through the annual cycle, such as dormancy and cold hardiness. The topical interest in climate change further emphasizes the relevance of such knowledge.

Noble fir (*Abies procera* Rehder) is native to the Cascade Mountains, north-western USA, and