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Research article

Effect of bud burst forcing on transcript expression of selected genes in needles of Norway spruce during autumn

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ABSTRACT

Expression of selected genes in needles of Norway spruce (*Picea abies* [L.] Karst) was investigated by following their transcription levels during late autumn. Transcription was assessed in mature needles which likely serve as sensor of environmental cues that enable trees in the temperate and boreal regions to change between stages of growth, frost tolerance and bud dormancy. Samples were collected from grafts kept under outdoor conditions and after bud burst forcing in greenhouse at 20 °C (12 h darkness) for one week. Transcription was assayed with real-time RT-PCR. During the sampling period, chilling requirement was partially fulfilled, and time to bud burst after forcing was decreased. Of the 27 transcripts studied, expression of 16 was significantly affected either by forcing, sampling time, or interaction between them. *PaSAP*, *PaACP*, *PaSGS3*, *PaWRKY*, *PaDIR9*, *PaCCCH* and dehydrin genes responded drastically to forcing temperatures at all sampling points, showing no correlation with readiness for bud burst. Expression patterns of some vernalization pathway gene homologs *PaVIN3*, and also of *PaMDC*, *PaLOV1* and *PaDAL3* had a clear opposite trends between forcing and outdoor conditions, which could imply their role in chilling accumulation and bud burst regulation/cold acclimation. These genes could constitute putative candidates for further detailed study, whose regulation in needles may be involved in preparation towards bud burst and chilling accumulation sensing.

1. Introduction

In forest trees adapted to the temperate and boreal regions, growth is synchronized with the seasonal climatic cycle. Bud burst in the spring and growth cessation, bud set, and induction of endodormancy in the autumn are essential features of this adaptation. Timing of these processes is related to the risk of frost damage.

Effects of environmental stimuli like temperature, photoperiod, and light quality on bud burst have been widely studied [3,4,22,27,38,42]. Even though timing of vegetative bud burst is influenced principally by temperature, photoperiod and light quality may have modifying or subordinate roles. Bud dormancy is induced during late summer and early fall. During late fall and early winter the dormant buds are subjected to chilling, and when enough chilling has been met, the buds are ready to resume growth in response to warmer temperatures in the spring [32] even in short days [38 and references therein]. With increasing chilling period, time to bud burst after a transfer to higher temperature is gradually reduced [15,19,25]. In fact, temperature ranges for chilling and for heat sum accumulation are overlapping, making it difficult to separate between these two effects, and challenge our ability to experimentally study dormancy induction, cold acclimation, heat accumulation and deacclimation. Long photoperiod can also promote bud flushing, for example, in *Betula pendula*/*Betula pubescens* [15], and *Picea abies* [38]. But in these species the effect of daylength is limited, and, particularly in *Picea*, is nullified by sufficient exposure to chilling temperatures. Exposure to low temperatures during the autumn also results in enhanced cold acclimation, which can be reversed (deacclimation) by high temperatures [30].

Timing of bud burst is under moderate to strong genetic control [2,11]. However, molecular mechanisms underlying bud burst are still unclear. Recently, Yakovlev et al. [44] reported significant

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