Tree Genetics & Genomes (2016) 12:109
DOI 10.1007/s11295-016-1070-3

ORIGINAL ARTICLE

Single nucleotide polymorphisms in two *GID1* orthologs associate with growth and wood property traits in *Populus tomentosa*

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Received: 6 January 2016 / Revised: 14 October 2016 / Accepted: 17 October 2016

Abstract Gibberellic acids (GAs) have multiple functions in various stages of plant growth and wood development, and GA receptor *GIBBERELLIN INSENSITIVE DWARF 1* (*GID1*) is a key player in GA signaling. Here, we used association studies to examine the allelic variation within *PtoGID1a* and *PtoGID1b* associated with growth and wood properties in a natural population of *Populus tomentosa*. We isolated two full-length PtoGID1a and PtoGID1b cDNA by reverse transcription PCR, and both of these two genes had an open reading frame with the same length (1035 bp) and encoded a protein of 344 amino acids. Analysis of tissue-specific expression profiles indicated that these two genes had similar transcription patterns, being expressed predominantly in leaves. Nucleotide diversity and linkage disequilibrium (LD) analysis showed that *PtoGID1a* and *PtoGID1b* harbor high single nucleotide polymorphism (SNP) diversity (π_T = 0.08237 and 0.00921, respectively) and low LD ($r^2 > 0.1$, within 350 and 1000 bp, respectively). SNP- and haplotype-based association tests identified that six single SNPs ($Q < 0.05$) and six haplotypes ($P < 0.05$, $Q < 0.10$) were significantly associated with growth and wood properties, explaining 0.99–10.28 and 3.10–5.39 % of the phenotypic variance, respectively. Therefore, isolation of *PtoGID1a* and *PtoGID1b* and dissection of their allelic polymorphisms open an avenue to understand the regulation of *PtoGID1* in the growth and wood formation in trees.

Keywords GA receptor · GIBBERELLIN INSENSITIVE DWARF 1 · Single nucleotide polymorphisms (SNPs) · *Populus tomentosa*

Communicated by P. Ingvarsson

Electronic supplementary material The online version of this article (doi:10.1007/s11295-016-1070-3) contains supplementary material, which is available to authorized users.

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Introduction

The gibberellin (GA) phytohormones function as important endogenous growth regulators in plants. The bioactive GAs (e.g., GA_1, GA_3, and GA_4) modulate diverse physiological and developmental processes including stem elongation, leaf expansion, seed germination, pollen maturation, and the induction of flowers and fruits (Olszewski et al. 2002; Sun and Gubler 2004). In some species, bioactive GAs also play a major role in stimulating early stages of xylem differentiation during wood formation and ultimately in determining wood quality (Israelsson et al. 2005). The accumulating evidence that GAs stimulate these processes indicates a close link between GA metabolism and GA response pathways to maintain GA homeostasis in plants. The precise mechanisms of GA perception and signal transduction have remained longstanding questions that are central to the regulation of gene expression and plant phenotype. Extensive studies showed that the components of GA signaling pathways include the transcriptional regulators DELLA proteins and the soluble GA receptor encoded by *GIBBERELLIN INSENSITIVE DWARF 1* (*GID1*). DELLAs act as repressors,

Published online: 09 November 2016