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Genome-Wide Association Studies to Improve Wood Properties: Challenges and Prospects

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Wood formation is an excellent model system for quantitative trait analysis due to the strong associations between the transcriptional and metabolic traits that contribute to this complex process. Investigating the genetic architecture and regulatory mechanisms underlying wood formation will enhance our understanding of the quantitative genetics and genomics of complex phenotypic variation. Genome-wide association studies (GWASs) represent an ideal statistical strategy for dissecting the genetic basis of complex quantitative traits. However, elucidating the molecular mechanisms underlying many favorable loci that contribute to wood formation and optimizing GWAS design remain challenging in this omics era. In this review, we summarize the recent progress in GWAS-based functional genomics of wood property traits in major timber species such as *Eucalyptus*, *Populus*, and various coniferous species. We discuss several appropriate experimental designs for extensive GWAS in a given undomesticated tree population, such as omics-wide association studies and high-throughput phenotyping technologies. We also explain why more attention should be paid to rare allelic and major structural variation. Finally, we explore the potential use of GWAS for the molecular breeding of trees. Such studies will help provide an integrated understanding of complex quantitative traits and should enable the molecular design of new cultivars.

Keywords: GWAS, omics, functional genomics, wood formation, systems biology

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INTRODUCTION

Wood, the secondary xylem of long-lived perennial plants, is produced via cell division from the vascular cambium, cell expansion, cell wall thickening, programmed cell death, and heartwood formation (Plomion et al., 2001; Mellerowicz and Sundberg, 2008). In general, the chemical and ultrastructural properties of wood depend on the components of the secondary cell walls, allowing wood to fulfill highly specialized functions that are essential for tree growth and development (Du et al., 2013a; Mizrachi and Myburg, 2016). Wood also represents a major carbon sink that plays a crucial role in carbon cycling in the terrestrial ecosystem, serving as an important renewable resource for the production of lumber, pulp, paper, and biofuels (Mellerowicz and Sundberg, 2008).