Compensatory plasticity of lignification in poplar

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Background

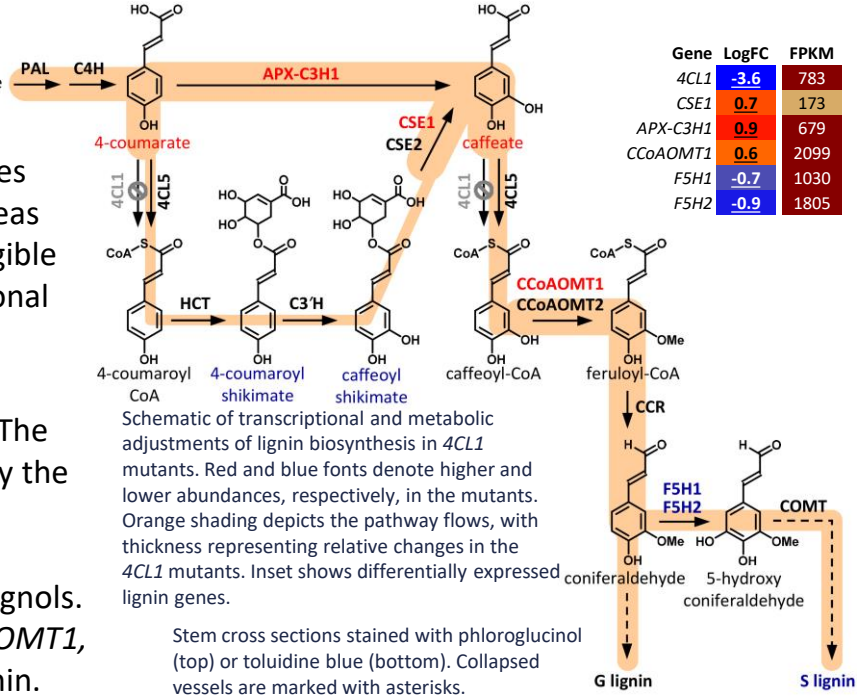
- The lignin biosynthetic pathway is highly conserved in angiosperms, yet pathway manipulations give rise to taxon-specific outcomes.
- Knockout (KO) of 4-coumarate:CoA ligases (4CLs) in herbaceous species mainly reduces G lignin and enhances cell wall saccharification, whereas CRISPR-KO of *4CL1* in poplar preferentially reduces S lignin with negligible effects on biomass recalcitrance. Such discrepancies hinder translational research.

Conclusions

- *4CL1* and *4CL5* paralogs are the only xylem-expressed *4CLs* in poplar. The *4CL1* mutants accrue 80% WT lignin levels which must be sustained by the minor 4CL5.
- *4CL1*-KO results in elevated levels of caffeic acid and various phenolic conjugates at the expense of lignin pathway intermediates and oligolignols.
- Compensatory changes in other key enzymes (*CSE1, APX-C3H1, CCoAOMT1,* and *FSH)* shift fluxes toward caffeic acid, lignification and G over S lignin.
- The decreased S/G ratio along with widespread down-regulated biosynthesis of all major cell wall glycans, and up-regulation of cell wall remodeling and detoxification processes, likely offsets the potential economic gain in enzymatic hydrolysis brought about by reduced lignin in the *4CL1* mutants.

Significance

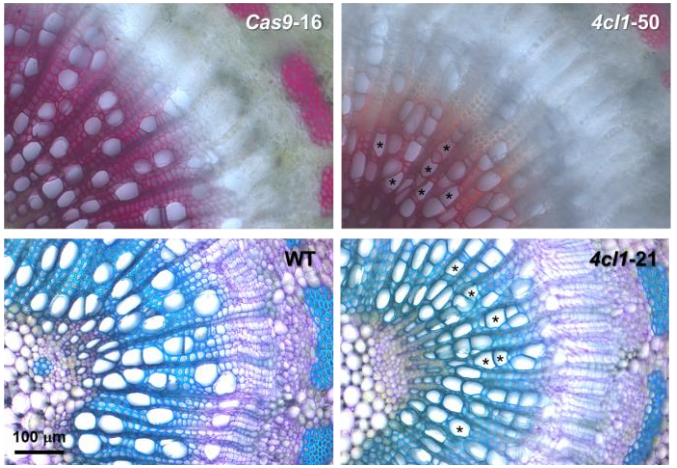
- Transcriptional, metabolic, and biochemical coordination of the 4CL5 compensatory pathway underscores poplar-specific lignin perturbation responses.
- Understanding tree-specific molecular mechanisms and compensatory plasticity of gene duplicates will enable us to fine-tune feedstock engineering strategies.



Gene	LogFC	FPKM
4CL1	-3.6	783
CSE1	0.7	173
APX-C3H1	0.9	679
CCoAOMT1	0.6	2099
F5H1	-0.7	1030
F5H2	-0.9	1805

Schematic of transcriptional and metabolic adjustments of lignin biosynthesis in *4CL1* mutants. Red and blue fonts denote higher and lower abundances, respectively, in the mutants. Orange shading depicts the pathway flows, with thickness representing relative changes in the *4CL1* mutants. Inset shows differentially expressed lignin genes.

Stem cross sections stained with phloroglucinol (top) or toluidine blue (bottom). Collapsed vessels are marked with asterisks.



Tsai C-J, et al. 2020. Compensatory guaiacyl lignin biosynthesis at the expense of syringyl lignin in *4CL1-knockout* poplar. *Plant Physiology* 183:123-136. https://doi.org/10.1104/pp.19.01550

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