

# QTL mapping for wood chemical properties and saccharification potential in black poplar (*Populus nigra*)

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## Background

Lignocellulosic biomass from short-rotation coppice (SRC) poplar is a renewable resource of interest for producing second generation biofuels. However, current poplar varieties have not been bred for this purpose. In order to optimize their biomass conversion into simple sugars (saccharification), we need to gain understanding into the genetic architecture of wood chemical properties. In this context, several genetic studies have been carried out over the last 5 years in various poplar species. Genomic regions controlling lignin content and composition, and 5- and 6-C sugar contents from cellulose and hemicellulose have also been identified either through QTL mapping in biparental crosses (1, 2) or association mapping in more complex crosses (3) or natural populations (4).

## Methods

Near Infrared Spectroscopy (NIR) has been used as a high throughput phenotyping technique for predicting 12 phenotypes related to the chemical properties and saccharification potential of 479 *P. nigra* samples, from calibration models developed in a subset of 100 samples. From these predicted values a genetic analysis was carried out in order to evaluate their broad sense heritability. Afterwards, we used a recently developed genetic map (8) to identify loci that control the genetic variability of phenotypes related to chemical properties and saccharification potential.

## Results

NIR spectra allowed the prediction of all phenotypes in the entire mapping population (Table 1). Predicted values displayed a significant variation within the mapping population, with for instance lignin and holocellulose contents ranging between 21 and 28 % and 51 and 73 %, respectively. Further genetic analysis revealed that a significant proportion of the phenotypic variability was controlled by genetics with medium (0.47) to high (0.76) broad sense heritabilities for all phenotypes (Table 1).

As a result, a total of 10 QTLs located on 6 linkage groups were detected (Table 2). In addition, two genomic regions involved in an epistatic interaction were identified (Table 2). These QTLs marginally explained between 2.2 and 16% of the phenotypic variance. Noticeably, one of them had opposite effects on lignin and solubilized sugars contents, and harbored genes from lignin and cellulose pathways (Figure 1a). Another QTL, identified in the present study for the proportion of hydrolyzed glucose, collocated on linkage group XIII with a QTL previously detected in hybrid poplar for 5- and 6-C sugars (Figure 1b, 1).

## Conclusion

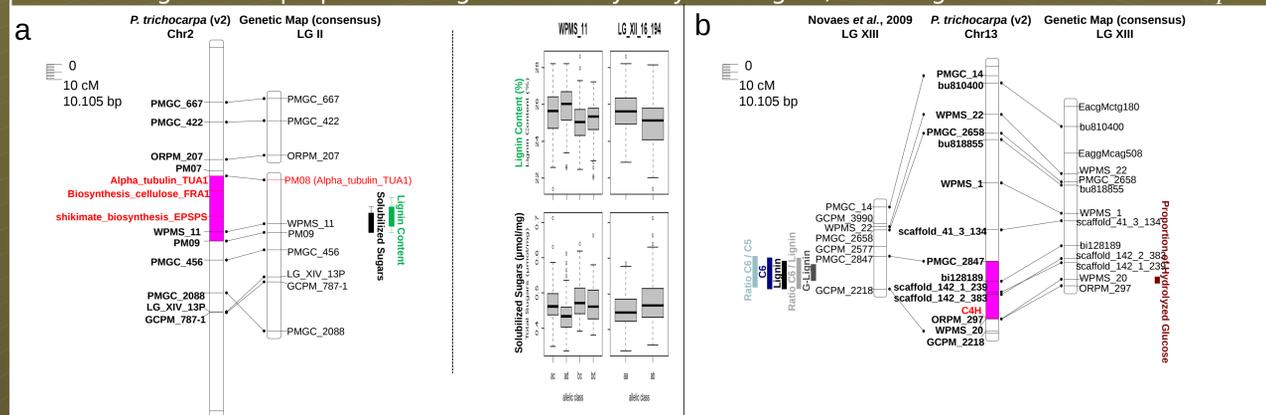
The present work shows that significant genetic variability exists in *P. nigra* for saccharification potential. As a result, several loci controlling this variability were detected, some of which being also detected for wood chemical properties. These QTLs deserve further investigation in order to decrease their confidence intervals for example by increasing the number of progenies or through association mapping in natural populations.

Despite the established relationships between wood chemical properties and saccharification yield (5, 6), the impact of loci affecting chemical properties onto biofuel production has not been assessed. In willow, one study has reported several QTLs controlling saccharification yield but their relationships with wood chemical properties were not assessed (7). The present work aimed at specifically addressing this point by studying jointly the genetic variability of wood chemical properties and saccharification potential and mapping the corresponding loci in a biparental cross of *P. nigra*.

**Table 1.** Descriptive statistics, NIR calibration models and broad sense heritability estimates for 12 phenotypes related to the chemical composition and saccharification potential of wood samples from a *P. nigra* F1 mapping pedigree

Trait	Calibration set (n=100)									NIR Predictions (n=479)		
	mean	(sd)	R <sup>2</sup> tra	R <sup>2</sup> cv	RMSEcv	RPDcv	Nb. Comp	Nb. Outliers	Nb. Lambda a	mean	(sd)	H <sup>2</sup> (se)
<b>Chemical properties</b>												
Extractives content (%)	8.88	(2.74)	0.87	0.83 (0.01)	1.12 (0.03)	2.46 (0.07)	5	3	131	9.18	(2.33)	0.56 (0.05)
Lignin content (%)	25.11	(1.60)	0.86	0.83 (0.01)	0.63 (0.02)	2.42 (0.06)	5	10	505	25.35	(1.35)	0.56 (0.05)
Holocellulose content (%)	66.00	(2.49)	0.88	0.84 (0.01)	0.97 (0.03)	2.49 (0.08)	6	13	279	65.90	(2.44)	0.67 (0.04)
<b>Saccharification Potential</b>												
<i>Soluble Sugars</i>												
Total Sugars (μmol mg <sup>-1</sup> )	0.16	(0.08)	0.91	0.88 (0.01)	0.03 (0.001)	2.92 (0.09)	5	0	72	0.16	(0.06)	0.58 (0.05)
Glucose (μmol mg <sup>-1</sup> )	0.07	(0.02)	0.87	0.85 (0.01)	0.01 (0.0002)	2.60 (0.06)	4	0	46	0.08	(0.01)	0.54 (0.05)
Proportion of Glucose	0.54	(0.14)	0.89	0.84 (0.01)	0.06 (0.002)	2.52 (0.10)	6	1	262	0.49	(0.13)	0.56 (0.05)
<i>Solubilized Sugars</i>												
Total Sugars (μmol mg <sup>-1</sup> )	0.50	(0.08)	0.83	0.78 (0.01)	0.03 (0.001)	2.17 (0.07)	5	20	251	0.47	(0.06)	0.60 (0.04)
Glucose (μmol mg <sup>-1</sup> )	0.27	(0.05)	0.86	0.80 (0.02)	0.02 (0.001)	2.27 (0.09)	6	9	105	0.25	(0.05)	0.67 (0.04)
Proportion of Glucose	0.55	(0.09)	0.89	0.85 (0.01)	0.03 (0.001)	2.63 (0.09)	5	1	80	0.53	(0.08)	0.56 (0.05)
<i>Hydrolyzed Sugars</i>												
Total Sugars (μmol mg <sup>-1</sup> )	0.35	(0.06)	0.82	0.77 (0.02)	0.02 (0.001)	2.10 (0.07)	6	27	262	0.31	(0.05)	0.76 (0.03)
Glucose (μmol mg <sup>-1</sup> )	0.20	(0.05)	0.87	0.83 (0.01)	0.02 (0.001)	2.41 (0.08)	6	9	67	0.18	(0.06)	0.54 (0.05)
Proportion of Glucose	0.56	(0.07)	0.85	0.80 (0.01)	0.03 (0.001)	2.26 (0.07)	5	15	360	0.56	(0.06)	0.47 (0.05)

**Figure 1.** Schematic representation of the QTLs detected on (a) LGs II and (b) XIII for lignin content, soluble sugars and proportion of glucose in hydrolyzed sugars, and alignment on *P. trichocarpa*



**Table 2.** QTLs associated with phenotypes related to the chemical composition and saccharification potential of wood samples from a *P. nigra* F1 mapping pedigree

Trait	LG	Effec t	Individua l p-value	Individua l R <sup>2</sup>	Global p-value	Global R <sup>2</sup>
<b>Chemical properties</b>						
Extractives content (%)	IV	F	2.09E-03	3.6	9.18E-04	13.2
	NA	M	9.96E-03	2.7	1.20E-04	
	IV*	F * M	NA	NA	2.94E-03	
	NA					
Lignin content (%)	II	F & M	1.66E-04	7.4	1.45E-03	11.3
	XII	F	4.49E-05	6.6	2.29E-04	
Holocellulose content (%)	I	M	9.09E-04	6.5	2.83E-04	15.6
	I*IV	F * M	NA	NA	1.20E-04	
<b>Saccharification Potential</b>						
<i>Soluble Sugars</i>						
Total Sugars (μmol mg <sup>-1</sup> )	I	M	1.63E-05	9.4	1.63E-05	9.4
<i>Solubilized Sugars</i>						
Total Sugars (μmol mg <sup>-1</sup> )	II	F & M	1.90E-04	7.3	2.93E-04	14.7
	IX	M	1.58E-02	2.2	1.55E-03	
	XII	F	4.06E-04	5.0	1.63E-03	
Proportion of Glucose	I	M	1.07E-05	9.8	1.07E-05	9.8
<i>Hydrolyzed Sugars</i>						
Proportion of Glucose	XIII	F & M	2.36E-04	15.9	2.36E-04	15.9

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