PHENOTYPIC AND GENOTYPIC CORRELATIONS FOR WOOD PROPERTIES OF HYBRID POPLAR CLONES OF SOUTHERN QUEBEC

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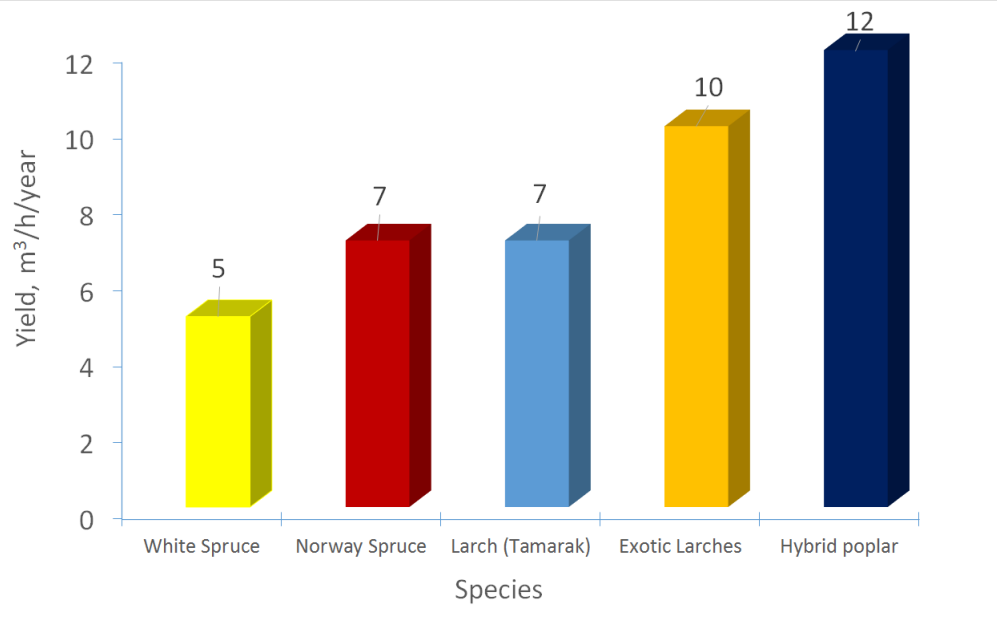
CONTENT

- Introduction
- Objectives
- Material and methods
- Results and discussion
- Conclusions

INTRODUCTION

Poplars in Canada

- Canadian forests are among the most valuable resources and most extensive in the world.
- Poplar is one of the top components of this resource.
- Since 1969, Quebec's MNR has been actively breeding and selecting hybrid poplar clones for growth, adaptability to the climatic conditions, and wood quality.
- Quebec's genetic improvement program of poplar emphasized on hybridized populations using 5 species: *P. balsamifera*, *deltoides*, *maximowiczii*, *nigra*, *trichocarpa* (Périnet et al. 2007)
- Hybrid poplars showed the greatest potential for fast growth & biomass production compared to other species
- Anticipated yields (Messier et al. 2003):
  - Best sites 20 m^3/ha·yr
  - Average sites: 14 m^3/ha.yr
  - Boreal sites10 m^3/ha·yr
- Their ability to rapidly produce fiber is a significant economic contribution.

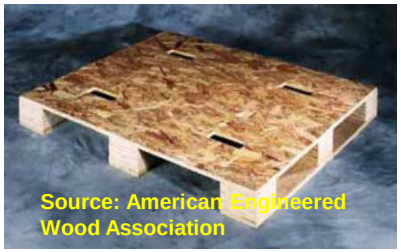


INTRODUCTION

Hybrid poplars in the wood industry

- Poplars are important species as fiber for pulp and paper and as solid wood for lumber and engineered wood products.
- Poplar wood is well suited for fiber particle, flake, and strand-based composites due to its low density, ease of cutting, low processing cost and availability.
- Hybrid poplar wood showed high potential as raw material for all these applications and other applications namely:
  - Pulp and paper
  - Oriented Strand board (OSB),
  - Oriented Strand lumber (OSL),
  - Veneer, plywood, laminated veneer (LVL)
  - Pallets and packaging materials
  - Furniture
  - Wood polymer composites.

Photo 14) Furniture made from 1" and 2" hybrid poplar lumber.



INTRODUCTION

Hybrid poplar wood quality

- Wood quality is defined in terms of specific end-uses and involves several properties.
- Selection for wood quality is important for any tree improvement / breeding program.
- Wood density, a commonly used quality indicator, is related to other wood properties as well as processing. However, it is not the only property involved in strength development and processing.
- In a breeding program, knowledge of genetic correlation plays a vital role in the prediction of correlated responses and the development of effective selection indexes.
- Several studies have focused on the fiber morphology, density, and growth properties of poplars. However, there is no available study on the phenotypic and genotypic correlations among anatomical, physical, and mechanical properties of hybrid poplar clones.

OBJECTIVES

The general objective of the present study was to investigate the genetic and phenotypic relationships among wood properties of hybrid poplar.

The specific objectives of this study were:

1) To estimate the genotypic and the phenotypic correlations among wood anatomical, physical, and mechanical properties;

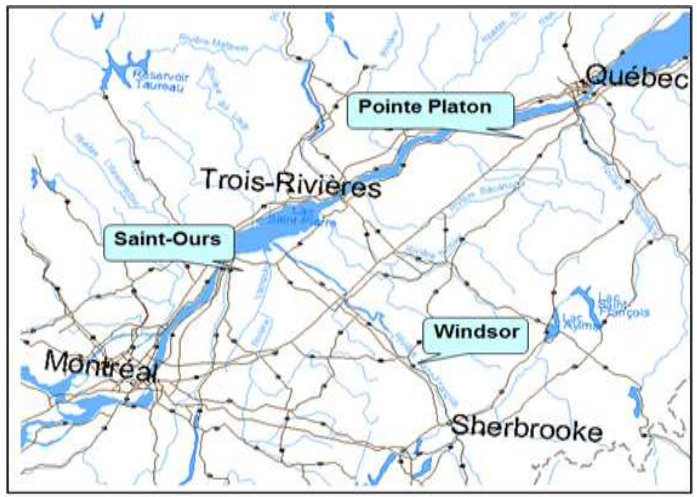
2) To evaluate the implication of these relationships in hybrid poplar breeding programs for wood quality.

MATERIAL AND METHODS

Sampling

Investigated hybrid poplar wood

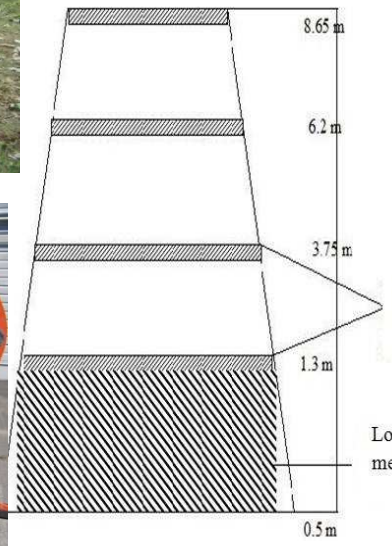
Clones code	Species cross
131	*Populus deltoides x P. nigra*
3230	*P. trichocarpa x P. deltoides*
3565	*P. deltoides x P. nigra*
3570	*P. deltoides x P. nigra*
3586	*P. deltoides x P. nigra*
4813	*P. deltoides x P. nigra*
915508	*(P. deltoides x P. nigra) x P. maximowiczii*



- 3 sites from Southern Quebec
  - Pointe Platon
  - Saint-Ours
  - Windsor
- 7 clones of 15 years of age
- 5 trees per clones were sampled

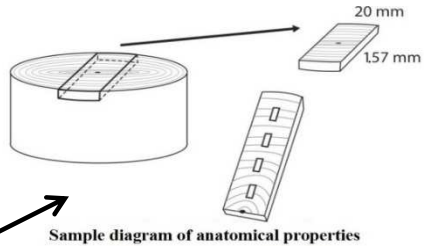
MATERIAL AND METHODS

Samples preparation

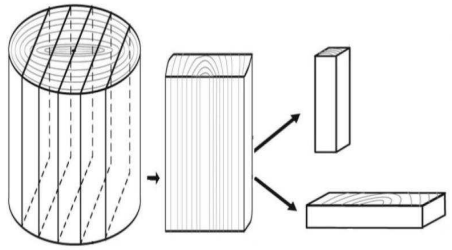


Discs for anatomical and physical properties

Log for physical and mechanical properties



Sample diagram of anatomical properties



Sample diagram of physical and mechanical properties

Schematic diagram illustrating the procedures of sample preparation

MATERIAL AND METHODS

Measurements

Anatomical properties

- Leica compound microscope (DM 1000) with image analysis stem WinCell 2004a was used to measure fiber and tension wood proportion

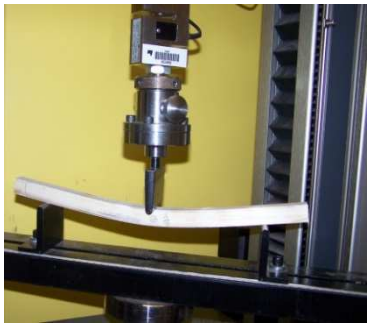
Physical properties

- Density and volumetric shrinkage (ASTM D 143-94)

Mechanical properties

- Flexural strength (ASTM D 143-94)
- Compression strength (ASTM D 143-94)

Anatomical properties measurement



Mechanical properties measurements

Physical properties measurement

MATERIAL AND METHODS

Statistical data analysis

The SAS mixed linear model was used to estimate variance components:

$$X_{ijk} = \mu + S_{i+} C_j + (S \times C)_{ij} + \varepsilon_{ijk}$$

Phenotypic correlations

The Pearson's correlation coefficients were used as phenotypic correlations coefficients. SAS CORR procedure was used .

Genetic correlations

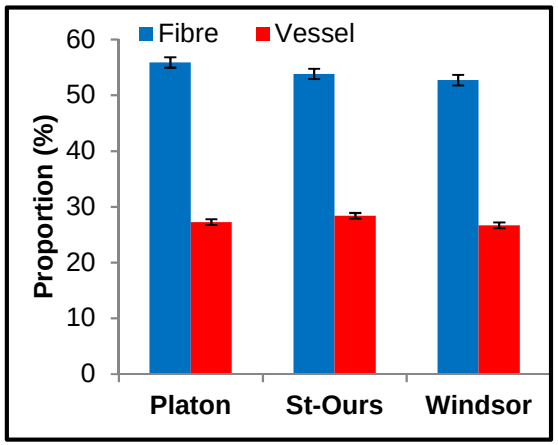
Genetic correlations were performed with MANOVA option using the GLM procedure in SAS. Standard errors associated with the genotypic correlations were also estimated.

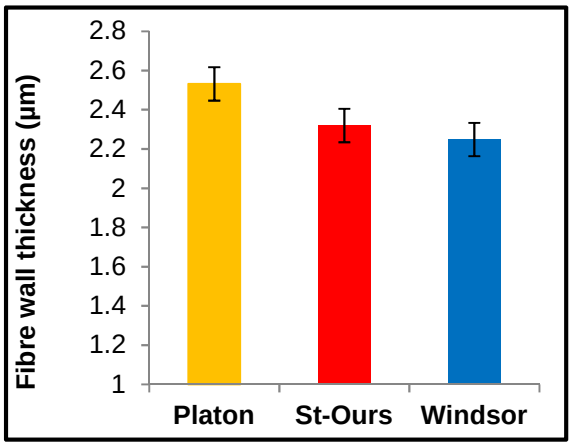
$$r_A = \frac{\sigma_{c(xy)}}{\sqrt{\sigma^2_{c(x)} \times \sigma^2_{c(y)}}}$$

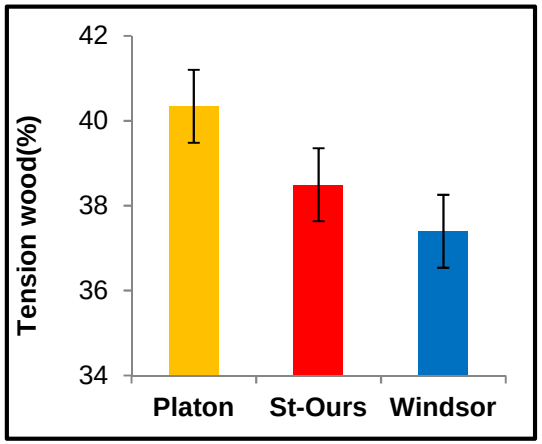
RESULTS AND DISCUSSION

- Site variation
- Clonal variation
- Phenotypic correlations
- Genetic correlations
- Comparisons between phenotypic & genetic correlations
- Heritability and genetic gains

SITE VARIATION: ANATOMICAL PROPERTIES

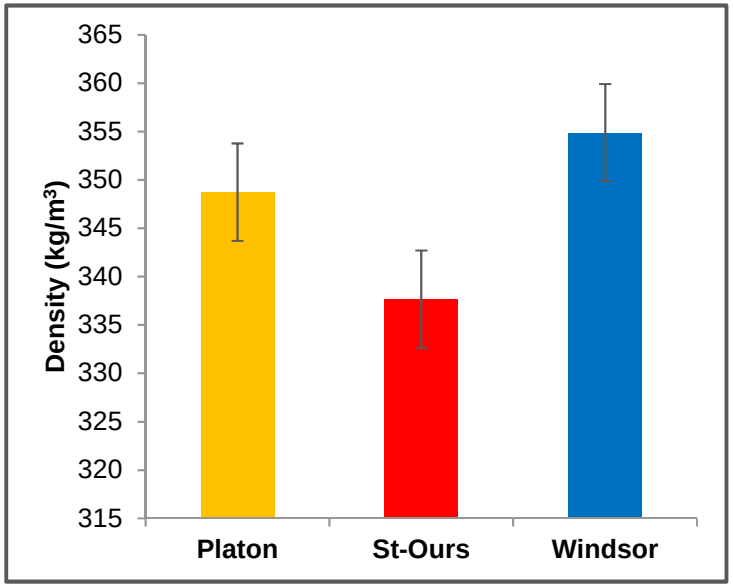


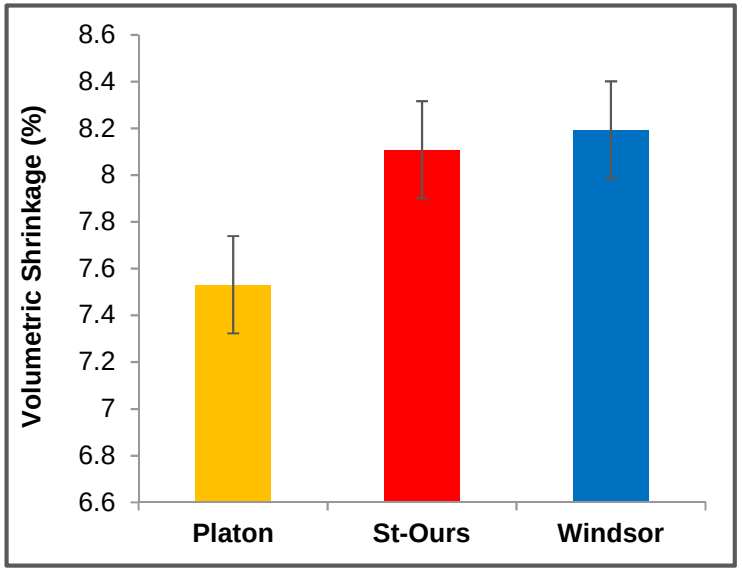




All Anatomical wood properties of hybrid poplar clones varied with site.

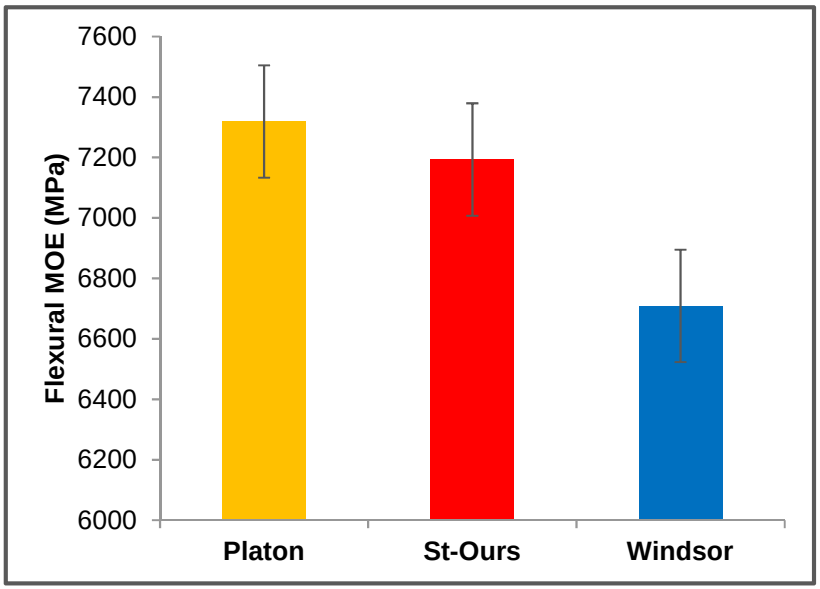
SITE VARIATION: PHYSICAL PROPERTIES

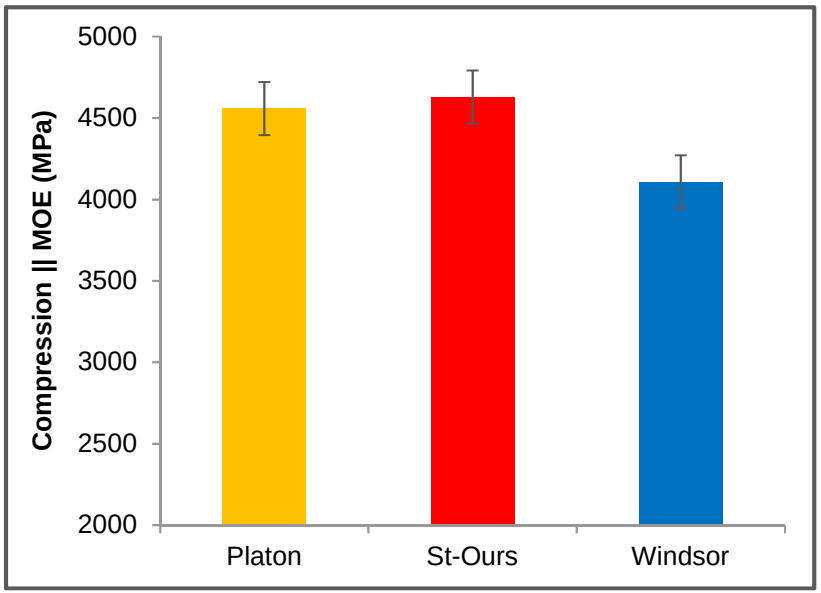




Density and volumetric shrinkage varied with sites.

SITE VARIATION: MECHANICAL PROPERTIES





Site showed significant effect on wood strength properties of hybrid poplar clones.

CLONAL VARIATION

Clone	Anatomical properties				Physical properties		Mechanical properties	
	FP (%)	VP (%)	FWT (µm)	TW (%)	Density (kg/m^3)	VSH (%)	F. MOE (MPa)	// C. MOE (MPa)
131	55.3^{C}	26.2^{D}	2.4^{C}	36.2^{C}	340^{B}	8.3^{B}	7007^{AB}	4352^{C}
3230	51.7^{E}	29.3^{B}	2.1^{E}	37.1^{C}	338^{B}	8.3^{B}	7023^{AB}	4205^{D}
3565	*59.7^{A}*	*24.1^{F}*	*2.5^{B}*	*44.1^{B}*	*368^{A}*	*7.9^{BC}*	*7483^{A}*	*4754^{A}*
3570	52.7^{D}	30,0^{A}	2.2^{E}	35.1^{C}	344^{B}	7.4^{CD}	6965^{AB}	4458^{B}
3586	51.6^{E}	28.9^{D}	2.5^{BC}	35.7^{C}	329^{B}	7.6^{CD}	6597^{B}	4327^{C}
4813	*57.0^{B}*	*24.5^{E}*	*2.7^{A}*	*47.8^{A}*	*378^{A}*	*8.9^{A}*	*7523^{A}*	*4692^{A}*
915508	50.8^{F}	29.4^{B}	2.3^{D}	35.8^{C}	332^{B}	7.2^{D}	7289^{AB}	4273^{CD}
Average± se	**55.9± 4.8**	**27.3± 4.1**	**2.5 ± 0.5**	**38.8 ± 7.1**	**347 ± 26**	**7.8 ± 0.8**	**7131 ± 817**	**4441 ± 530**

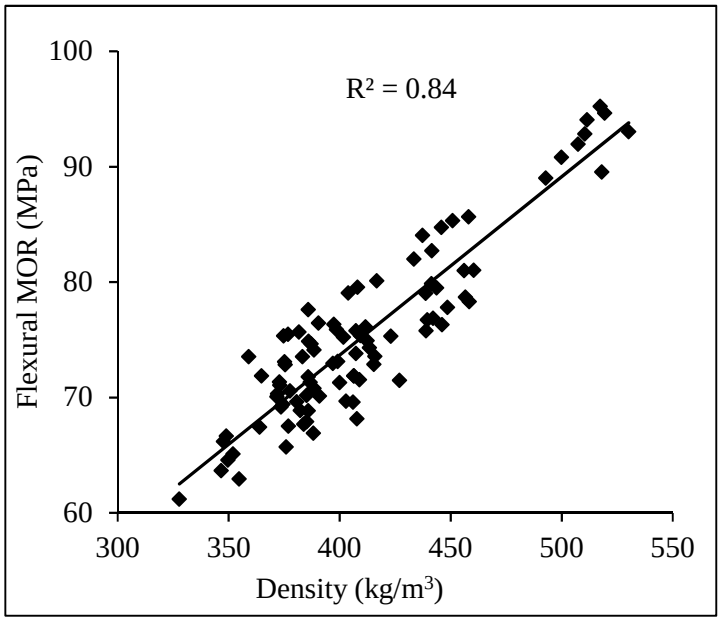
The clone effect was highly significant for all studied properties

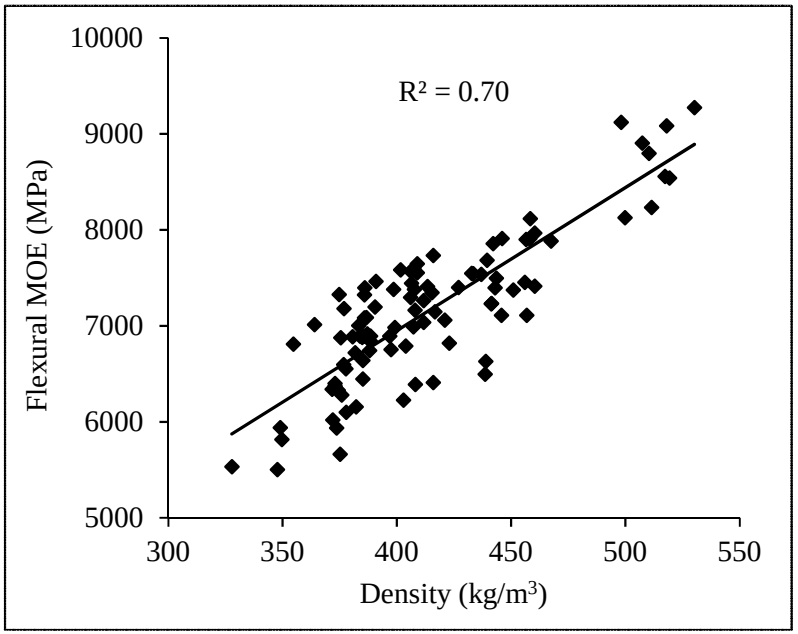
PHENOTYPIC CORRELATIONS

	FP	VP	FWT	TW	BD	VSH	F. MOE	F. MOR	// CS σ
FP	1	*-0.70***	*0.53***	*0.30***	*0.44***	*0.19*^{ns}	*0.31***	*0.53***	*0.41***
VP	-0.75**	1	*-0.38***	*-0.39***	*-0.41***	*-0.27***	*-0.17*^{ns}	*-0.47***	*-0.38***
FWT	0.55**	-0.47*	1	*0.30***	*0.34***	*0.17*^{ns}	*0.15*^{ns}	*0.37***	*0.33**
TW	0.43^{ns}	-0.51*	0.47*	1	*0.35***	*0.19*^{ns}	*0.23**	*0.53***	*0.38***
BD	0.57**	-0.52*	0.48*	0.78**	1	*0.36***	*0.42***	*0.61***	*0.80***
VSH	0.32^{ns}	-0.39^{ns}	0.33^{ns}	0.41^{ns}	0.45*	1	*-0.08*^{ns}	*0.24***	*0.30***
F. MOE	0.52**	-0.29^{ns}	0.30^{ns}	0.44*	0.71**	0.06^{ns}	1	*0.73***	*0.51***
F. MOR	0.66**	-0.57**	0.49*	0.75**	0.90**	0.34^{ns}	0.78**	1	*0.69***
// CS	0.57**	-0.43*	0.47*	0.73**	0.88**	0.31^{ns}	0.83**	0.90**	1

Upper Italic tree averages, Lower Clone averages

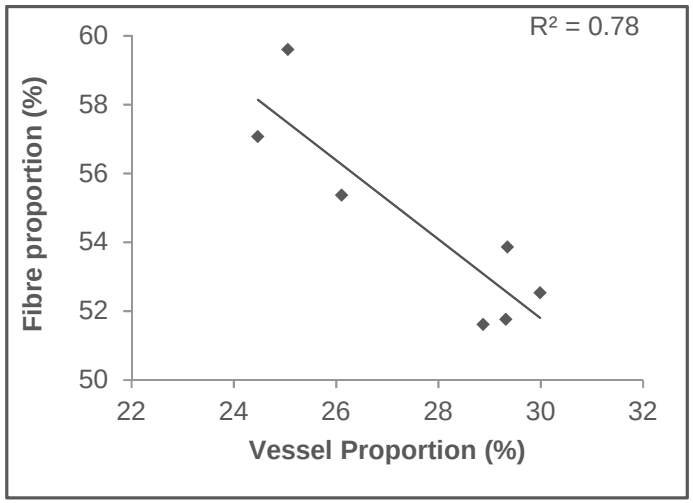
PHENOTYPIC CORRELATIONS

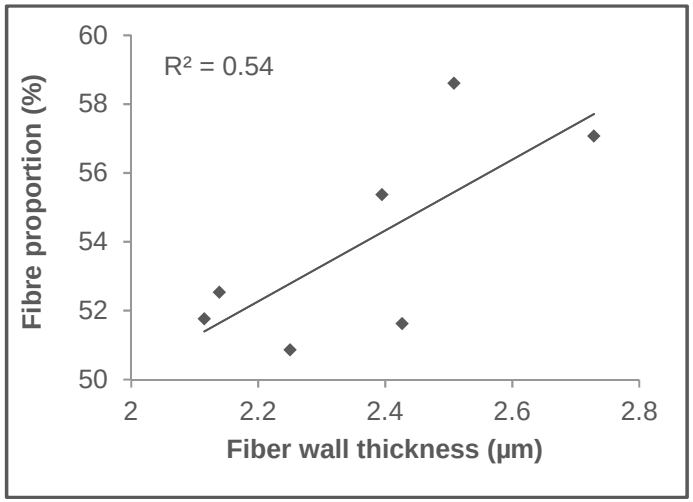


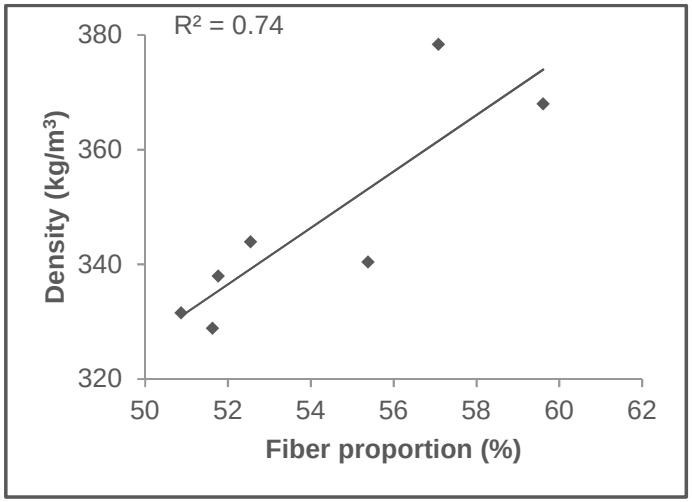


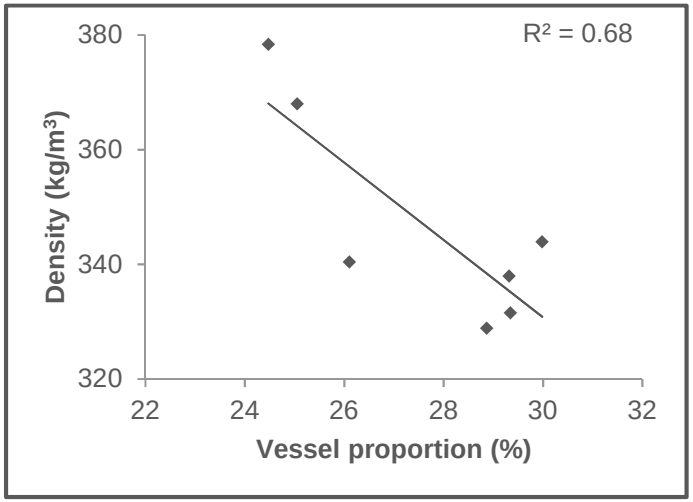
Relationship between the density and flexural strength and elasticity of hybrid poplar clones.

PHENOTYPIC CORRELATIONS



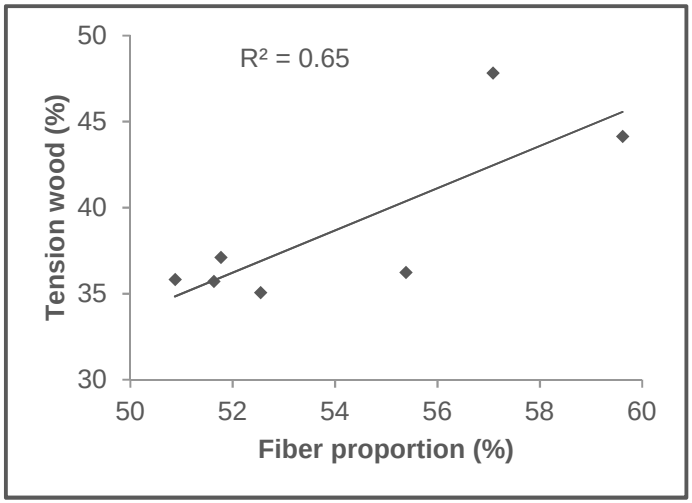


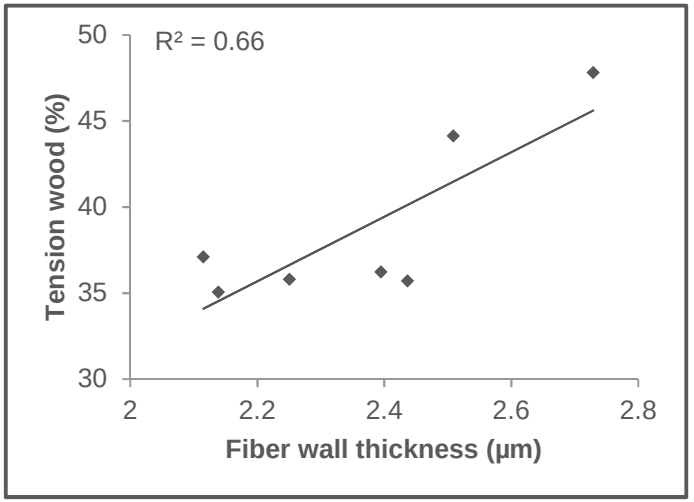


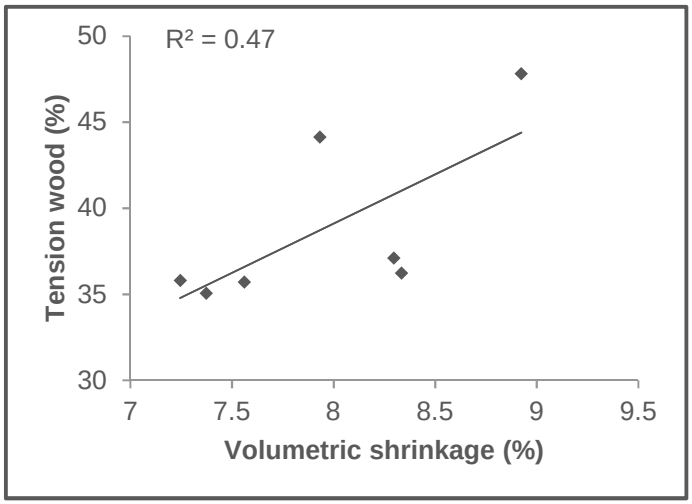


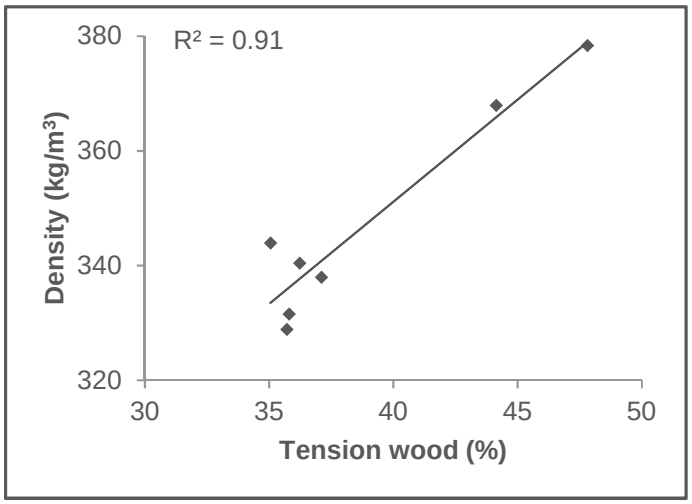
Relationships between anatomical properties of hybrid poplar clones

PHENOTYPIC CORRELATIONS









Relationship between tension wood proportion to other anatomical properties

GENETIC CORRELATIONS

	FP	VP	FWT	TW	BD	VSH	F. MOE	F. MOR	// CS σ
FP	1	*0.18*	*0.07*	*0.23*	*0.01*	*0.05*	*0.04*	*0.16*	*0.04*
VP	**-0.97**	1	*0.18*	*0.15*	*0.01*	*0.36*	*0.23*	*0.13*	*0.20*
FWT	0.74	**-0.90**	1	*0.18*	*0.14*	*0.39*	*0.12*	*0.07*	*0.06*
TW	0.87	**-0.91**	**0.88**	1	*0.07*	*0.14*	*0.08*	*0.01*	*0.03*
BD	**0.90**	**-0.92**	**0.84**	**0.86**	1	*0.21*	*0.12*	*0.17*	*0.10*
VSH	0.62	-0.76	0.69	0.73	0.53	1	*0.36*	*0.21*	*0.28*
F. MOE	0.78	-0.77	0.72	0.88	**0.97**	0.46	1	*0.28*	*0.01*
F. MOR	0.90	-0.84	0.77	0.76	**0.97**	0.73	0.68	1	*0.14*
// CS	0.64	-0.74	0.73	0.81	**0.93**	0.53	1.00	0.83	1

Upper *Italic standard error*, Lower Genetic correlations

COMPARISON BETWEEN PHENOTYPIC & GENETIC CORRELATIONS

	FP	VP	FWT	TW	BD	VSH	F. MOE	F. MOR	// CS s
FP	1	*-0.70***	*0.53***	*0.30***	*0.44***	*0.19*^{ns}	*0.31***	*0.53***	*0.41***
VP	-0.97	1	*-0.38***	*-0.39***	*-0.41***	*-0.27***	*-0.17*^{ns}	*-0.47***	*-0.38***
FWT	0.74	-0.90	1	*0.30***	*0.34***	*0.17*^{ns}	*0.15*^{ns}	*0.37***	*0.33**
TW	0.87	-0.91	0.88	1	*0.35***	*0.19*^{ns}	*0.23**	*0.53***	*0.38***
BD	0.90	-0.92	0.84	0.86	1	*0.36***	*0.42***	*0.61***	*0.80***
VSH	0.62	-0.76	0.69	0.73	0.45*	1	*-0.08*^{ns}	*0.24***	*0.30***
F. MOE	0.78	-0.77	0.72	0.88	0.97	0.46	1	*0.73***	*0.51***
F. MOR	0.90	-0.84	0.77	0.76	0.97	0.73	0.78**	1	*0.69***
***//* CS**	0.64	-0.74	0.73	0.81	0.93	0.53	1.00	0.83	1

Upper italic phenotypic correlation, Lower genetic correlations

Environmental impacts weaken the phenotypic correlation

HERITABILITY AND GENETIC GAIN ESTIMATES*

	Broad sense heritability	Genetic gain
	Anatomical properties	
Fiber length	*0.59*	5.11
Wall thickness	*0.73*	6.02
Lumen diameter	*0.57*	2.77
Fiber diameter	0.23	1.31
Vessel diameter	*0.59*	4.04
Fiber proportion	*0.62*	5.11
Vessel proportion	*0.58*	3.82
Ray proportion	0.37	2.92
Cell wall area	*0.76*	4.67
	Physical properties	
Density	*0.72*	6.65
Volumetric Shrinkage	0.39	4.77
Longitudinal shrinkage	*0.53*	*13.53*
Radial shrinkage	0.19	2.02
Tangential shrinkage	0.40	6.52
	Mechanical properties	
Flexural MOE	0.37	2.07
Flexural MOR	*0.76*	*9.52*
// Compressive strength	*0.74*	*9.43*

* Data from Huda et al. 2014, 2014

CONCLUSIONS

Anatomical, physical, and mechanical properties of hybrid poplar clones were measured and results were analyzed for phenotypic genetic parameters estimations:

- Hybrid poplar properties varied with sites and clone effect was highly significant.
- Variation in anatomical properties explained that of density: Clones with higher density had higher fiber proportion, thicker cell walls, and lower vessel proportion.
- Phenotypic & genetic correlations between fiber properties and density were strong.
- Correlations between wood density and mechanical properties were moderate at the phenotypic level and strong at the genotypic level.
- Genotypic correlations for all wood components were higher than the corresponding phenotypic correlations
- The highest broad sense heritability values were found for fiber properties and mechanical properties
- The highest genetic gains could be achieved through proper clones selection for longitudinal shrinkage and mechanical properties

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- Fonds de recherche du Québec – Nature et technologies (FQRNT)
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