Near infrared reflectance (NIR) spectroscopy: dialing stem chemistry for optimal root disease resistance and forest products – CAFS Project Update

Brian K. Via
Lori Eckhardt

Rational & Problem Identification

Forest Products

- Important for us to know the ***chemical composition*** which relates to ***stiffness*** for these genetically superior families.
- Important to pick families that have a combination of good forest product and tree health characteristics.

Forest Health

- Pine Decline/Disease has been on the rise.
- There is a need to rapidly screen trees for disease resistance
- There is a need to identify genetic families with superior disease resistance.

Forest Products Development Center

Key Objectives for CAFS (Year 1)

- Develop NIR calibrations for wood chemistry of loblolly pine (*Pinus taeda*).
- Take these NIR calibrations and screen 14 genetic families from 2 sites for differences in:

  Lignin, Cellulose, Hemicellulose, Extractives
- Relate wood chemistry to disease resistance and small clear wood stiffness.
- Pick families forecasted to have good disease resistance and small clear wood stiffness.
- Validate the “forecast” works!

Forest Products Development Center

Timeline and Expected Deliverables for Short and Long term

Expected Deliverables for Year 1 (2014)

Finish development of NIR models for wood chemistry: extractives, lignin, cellulose, hemicellulose.

Expected Deliverables for Year 2 (2015)

Determine and validate relationships between wood chemistry and disease.

Expected Deliverables for Year 3 (2015-2016)

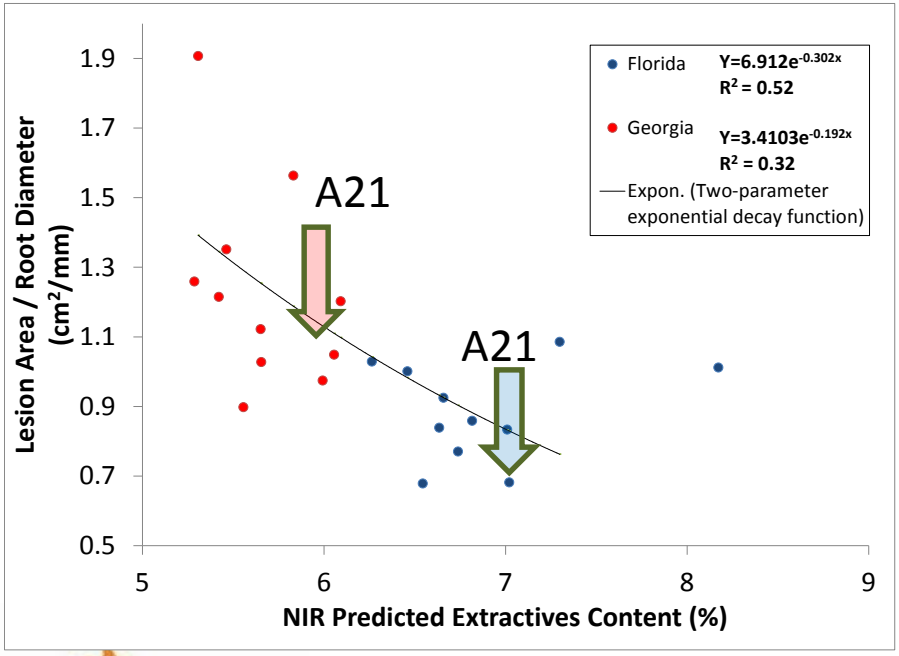
Perform more detailed examination of wood chemistry to determine underlying mechanism causing disease. Choose families with superior health with acceptable stiffness.

Forest Products Development Center

Key Hypothesis

- An increase in low molecular weight phenolics (present in extractives) will result in better disease resistance of genetic families.
- By breeding trees for better disease resistance through increased extractives production, we may be inadvertently decreasing wood stiffness.

Recent IGP Auburn University Funding: Update on Dialing Chemistry for Disease Tolerance



- Money was obtained from Auburn grant for intensive sampling.
- Need to obtain more data regarding extractives to lesion morphology.

Forest Products Development Center

Why Measure Fiber to Product Performance?

What happens if you:	Paper Burst	Paper Tensile	Paper Tear	Cardboard Compression	Clear Lumber MOE	Pulp Yield	Lumber Longitudinal Shrinkage
Decrease fibril angle from 40 to 30 degrees	?	↑ 2.5%	↑	↑ 3%	↑ 100%	No effect	↓ 66%
Increase cell length by 10%	↓ 10%	↓ 6%	↑ 15%	↓ 3%	↑	No effect	No effect
Increase cell wall thickness by 10%	↓ 6%	↓	↑ 15%	↓ 19%	↑	↑ 1%	No effect
Increase % latewood by 10%	↓ 3%	↓	↑ 7%	↓	↑	↑ 1%	No effect
Decrease lignin by 1 percentage point	No effect to small reduction	No effect to small reduction	↓ 4-10%	↓	↓	↑1-1.5 percentage point	Small improvement
Increase cellulose by 1 percentage point	No effect	No effect	↑ 7.5%	No effect	↑ 10%	↑0.5 percentage point	No effect

Many references: Available by Request

What about Fiber to Bioenergy Performance?

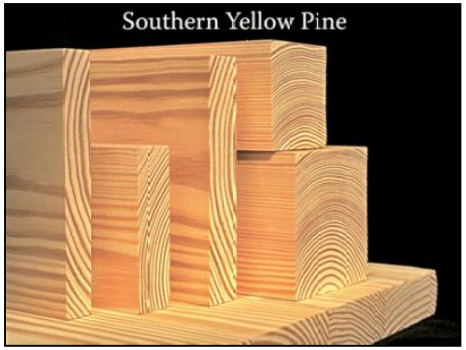
Family	Mean NIR Chemistry (%) and Crystalline Index (%)					HHV (Btu/lb)		Youngs modulus (GPa)
	Lignin	Cellulose	Hemicellulose	Extractives	Crystallinity Index	Demirbas Model	White Model	Rong et al. Model
Low Lignin	26.6	51.5	27.2	4.2	58.5	8256	8503	11.3
Medium Lignin	27.2	49.4	25.3	4.0	61	8299	8570	12.7
High Lignin	28.3	50.4	27.4	2.4	62	8342	8611	14

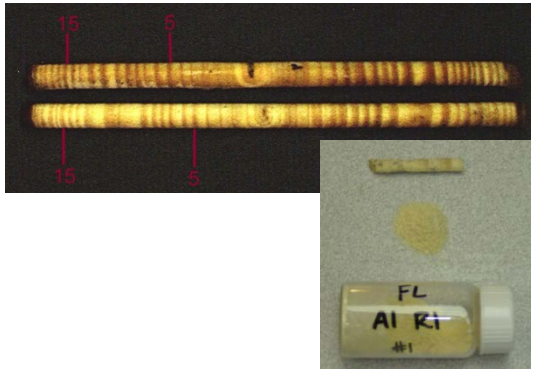
References for Models: Available by Request

Near Infrared Spectroscopy: Characterization of Southern Pine Chemistry

Table 1 Results of NIR models before and after wavenumber selection

Chemistry	Pretreatment	Before wavenumber selection			After wavenumber selection		
		r^2	RMSEP	RPD	r^2	RMSEP	RPD
Extractives	FD	0.96	0.62	1.19	0.91	0.37	2.00
Lignin	FD	0.90	0.53	1.98	0.99	0.19	5.53
Holocellulose	FD+MSC	0.95	0.85	2.08	0.96	0.27	6.56
Cellulose	FD	0.96	1.34	1.13	0.95	0.68	2.22
Hemicellulose	FD+MSC	0.90	1.12	1.40	0.82	1.05	1.50





Forest Products Development Center

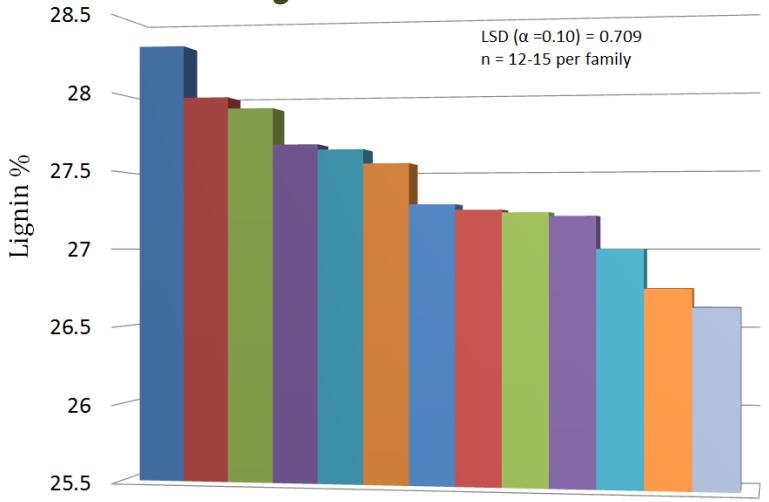
Near Infrared Spectroscopy: Characterization of Wood, Bark, & Needle Chemistry

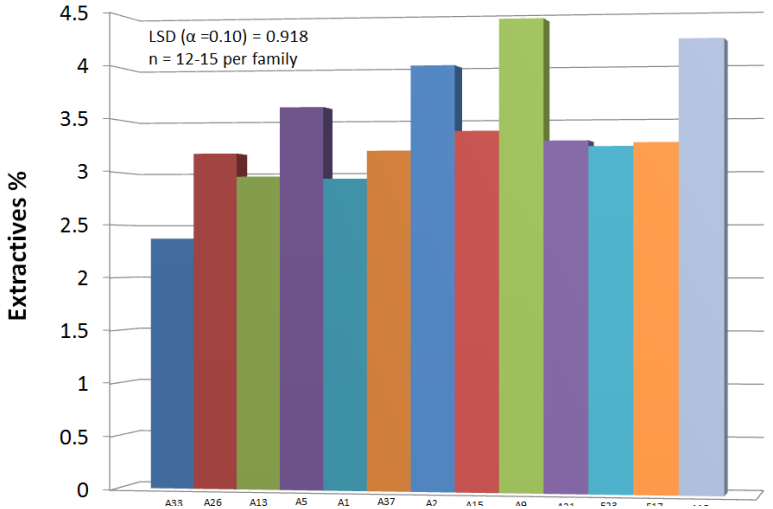
Table: PLS1 model statistics for the chemical properties of forest biomass using raw spectra

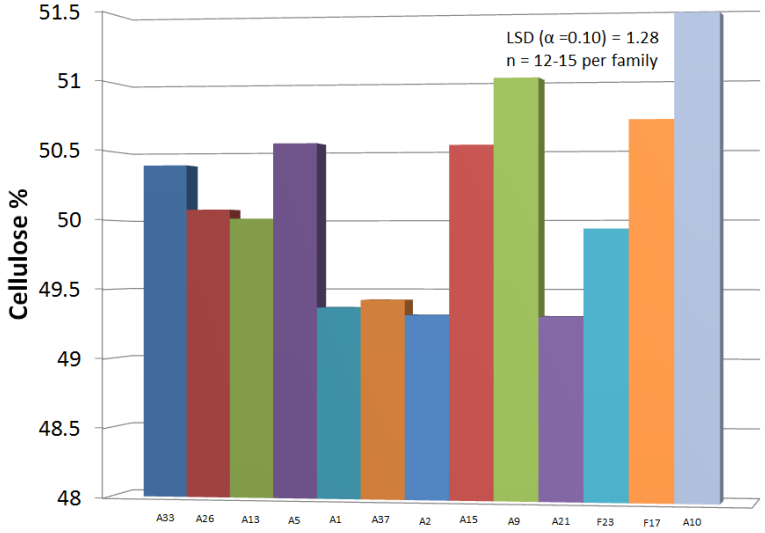
Property	Pretreatment	SEC	Bias	PCs	SECV	R^2
Extractives	1st derivative	0.99	0.03	2	1.23	0.92
Lignin	Raw	1.55	0.07	4	1.75	0.87
Glucose	1st derivative	3.30	-0.12	2	3.95	0.82
Mannose	1st derivative	0.63	-0.10	3	1.60	0.84
Galactose	1st derivative	0.97	0.00	3	2.05	0.71
Arabinose	1st derivative	0.36	0.00	2	0.42	0.77
Xylose	1st derivative	0.73	0.05	3	1.23	0.71
Cellulose	1st derivative	3.40	-0.14	2	4.09	0.80
Hemicelluloses	1st derivative	1.78	0.00	3	3.40	0.68
Holocellulose	1st derivative	3.73	-0.15	2	4.44	0.75

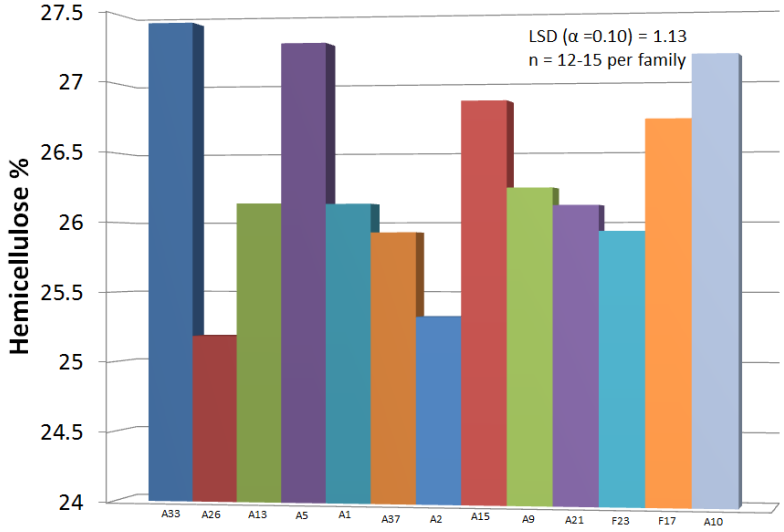
Forest Products Development Center

Near Infrared Spectroscopy: Characterization Loblolly Pine Families for Forest Health Coop.

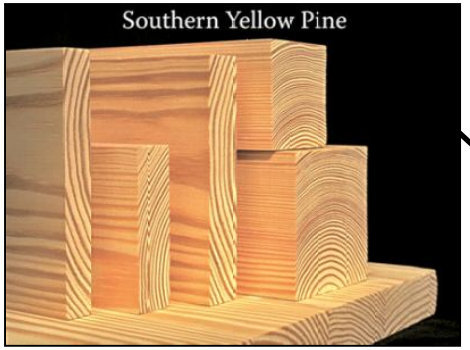


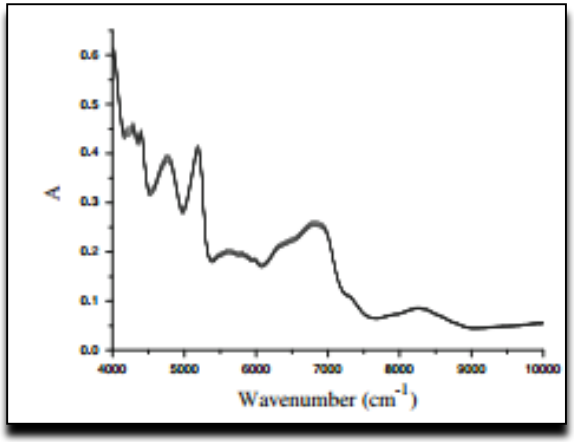




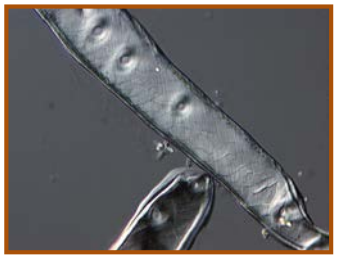


Near Infrared Spectroscopy: Predicting Multiple Traits from One Measurement





Seedling Freeze Tolerance

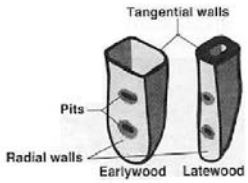


Microfibril Angle?

Forest Health

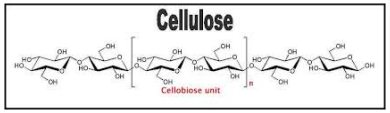
Build Models

Solid R^2=0.9

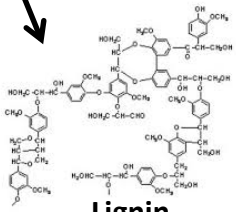


Solid R^2=0.76 to 0.9

Powder R^2=0.9 – 0.96



Powder R^2=0.96-0.99



Lignin

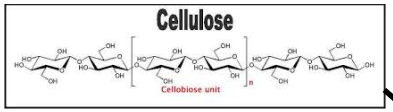
Powder
Volatiles (R^2=0.92),
HHV (R^2=0.7), Ash (R^2=0.7)

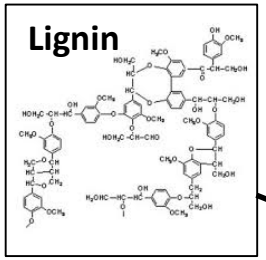
Forest Products Development Center

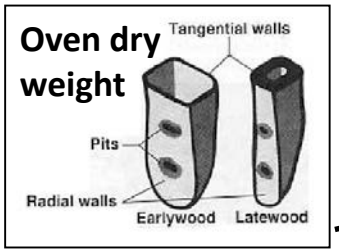
Additional Deliverables not Promised to CAFS or Coop

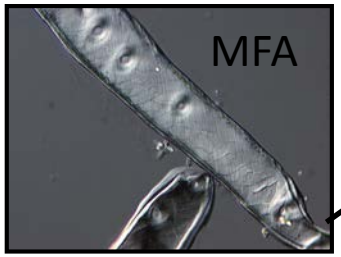
- Acoustic measurement of 15 families.
- Answer the Question: Can Acoustics really measure true MOE?

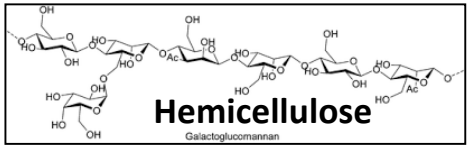
Acoustics: Is it sensitive to the same underlying mechanisms as true wood stiffness?







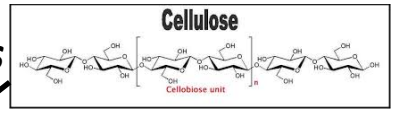


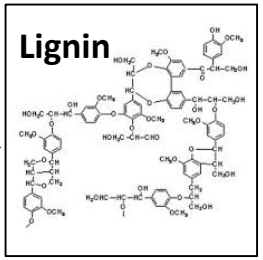


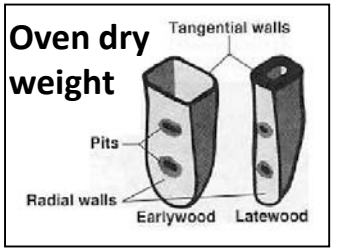
Lab Data *15 yr*
Pinus taeda

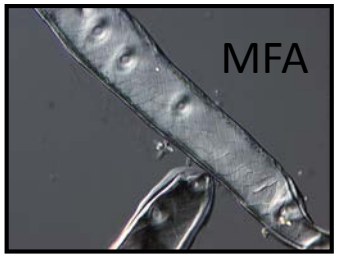
Published Data
16yr - Pinus palustris

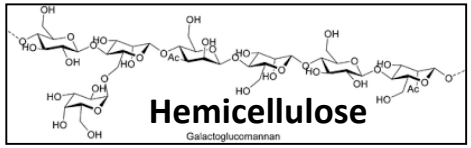
R^2=0.78	R^2=0.81
Acoustics	True Stiffness
p<0.0001	p<0.01
p<0.12	p<0.05
p<0.01	p<0.01
p<0.06	p<0.05
p<0.101	p<0.10





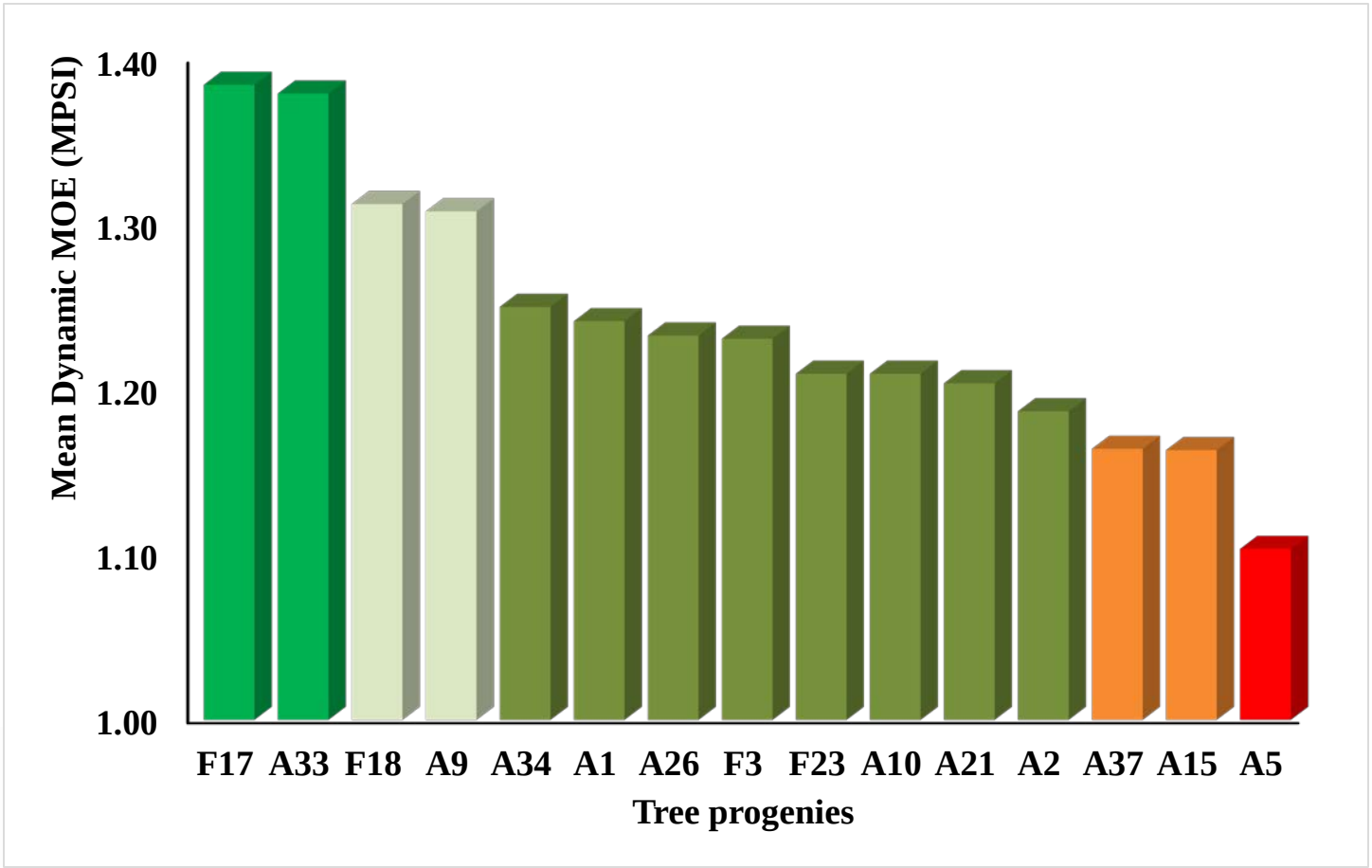




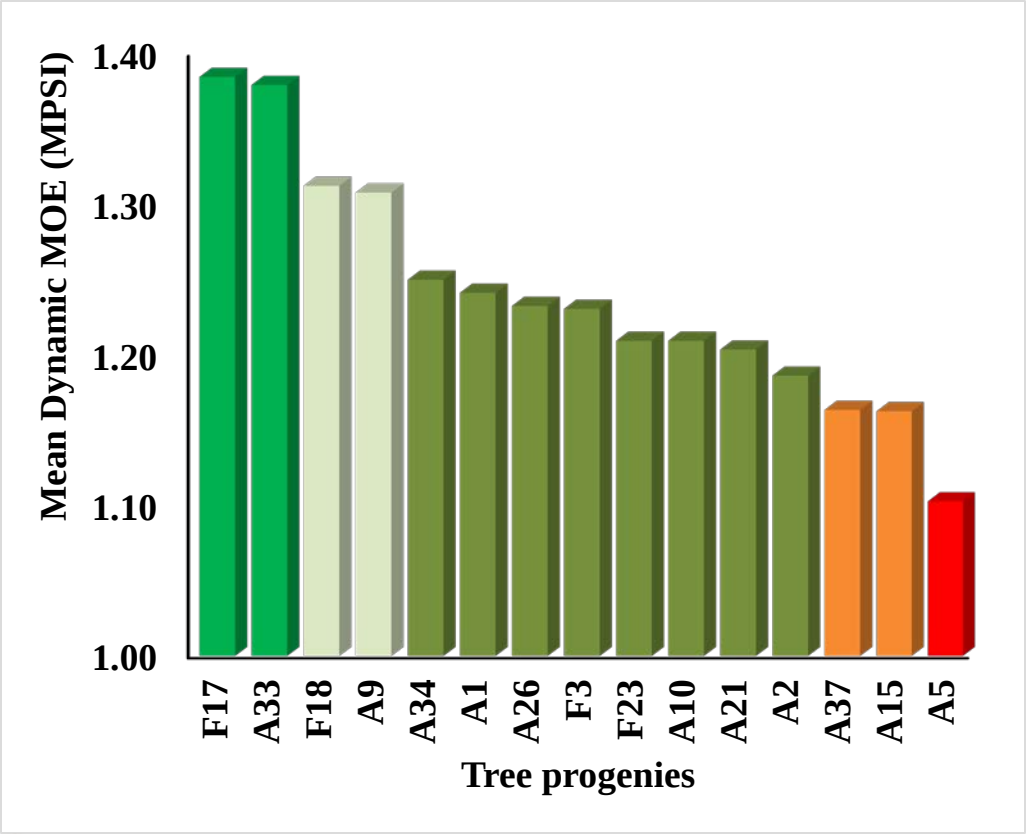


Via, B. K. et al. (2009). Composites Part A: Applied Science and Manufacturing, 40(1), 60-66.

Acoustic Stiffness Estimate of 15 genetic families from Rayonier Site



Projected Samples Necessary to See Statistical Differences?



Difference (MOE) psi (95% confidence)	Sample Size Per Family
0.05	314
0.1	79
0.15	35
0.2	20
0.25	**13**
0.3	9
0.35	6
0.4	5
0.45	4
0.5	3

Note: Actual statistical difference (LSD) was 0.25 at 90% confidence for this study

Maximizing Stiffness & Extractives/Disease Tolerance

	Rayonier, Yulee, FL		
	Lignin	Extractives	Acoustic Stiffness
A1	28.4	6.6	1.24
A2	29.2	6.5	1.19
A5	29.1	6.3	1.10
A9	**28.7**	**6.5**	**1.31**
A10	28.8	6.7	1.21
A15	28.9	6.5	1.16
A21	28.1	7.0	1.20
A26	29.1	6.5	1.23
A33	**28.9**	**6.9**	**1.38**
A34	28.3	6.7	1.25
A37	29.3	7.3	1.16
F17	**29.2**	**8.2**	**1.38**
F23	28.8	6.8	1.21

Acknowledgements

IGP “Good To Great Grant”
Regions Bank
Forest Products Development Center
Forest Health Coop
Rayonier and Plum Creek

Forest Products
Development Center