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Populus Hybridization for the Renewable Transportation Fuels Industry: Integration of Genomic Tools into a Varietal Development Program

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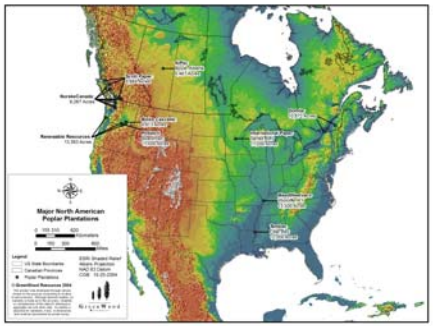
Hybrid Poplar in the Pacific Northwest: Biomass Production



1. 13,000 hectares

2. *P. ×generosa, P. ×canadensis*

3. Eight year pulp wood rotations at 1,540 trees per hectare

4. Biomass yield up to 18 MT ha^{-1} yr^{-1}

Hybrid Poplar in the Pacific Northwest: Management for Multiple Markets

Pulp and Paper

Environmental Services

Sawn Wood Products

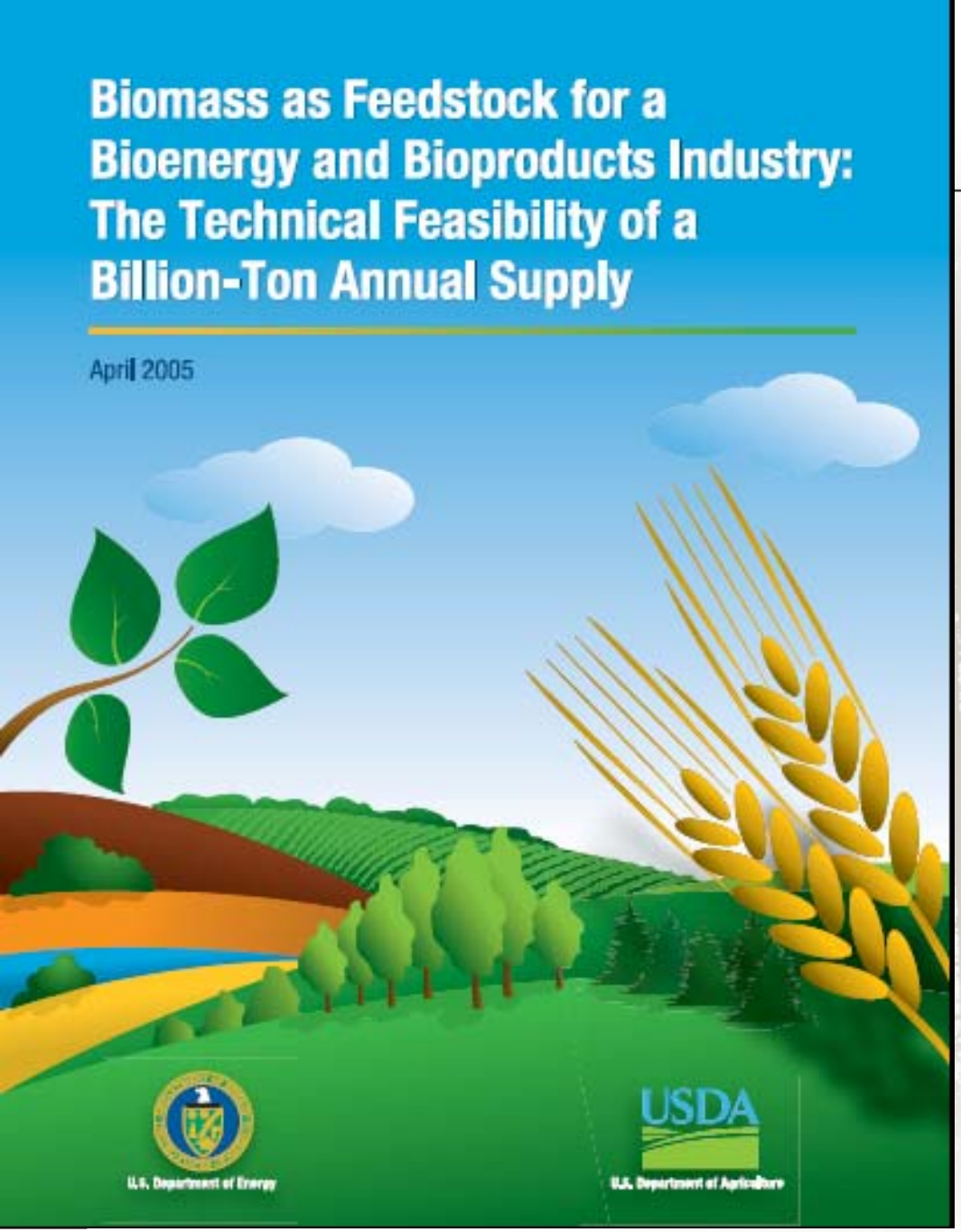
Cellulosic Ethanol

- 1980s - Pulp and paper industry.
- 1990s – Environmental services.
- 2000s - Sawn wood markets.
- Future - Cellulosic ethanol industry

Poplar Biomass for Ethanol Production

- Pacific Ethanol Cellulosic Facility
- 115 million liters per year
- 50 % of feedstock from hybrid poplar
- 400 – 700 metric biomass tons per day

- GreenWood Resources Poplar Farm
- Two year coppice rotation
- Harvest rate of 12 to 20 hectares per day



The Billion Ton Study

The United States National Goal:

1. Displacement of 30% of the country's present petroleum consumption with a sustainable supply of biomass.

2. Requirement of one billion tons of biomass per year.

3. 38% from dedicated perennial energy crops grown on 22 million hectares.
   - *Panicum virgatum, Miscanthus ×giganteus*
   - *Populus, Salix*

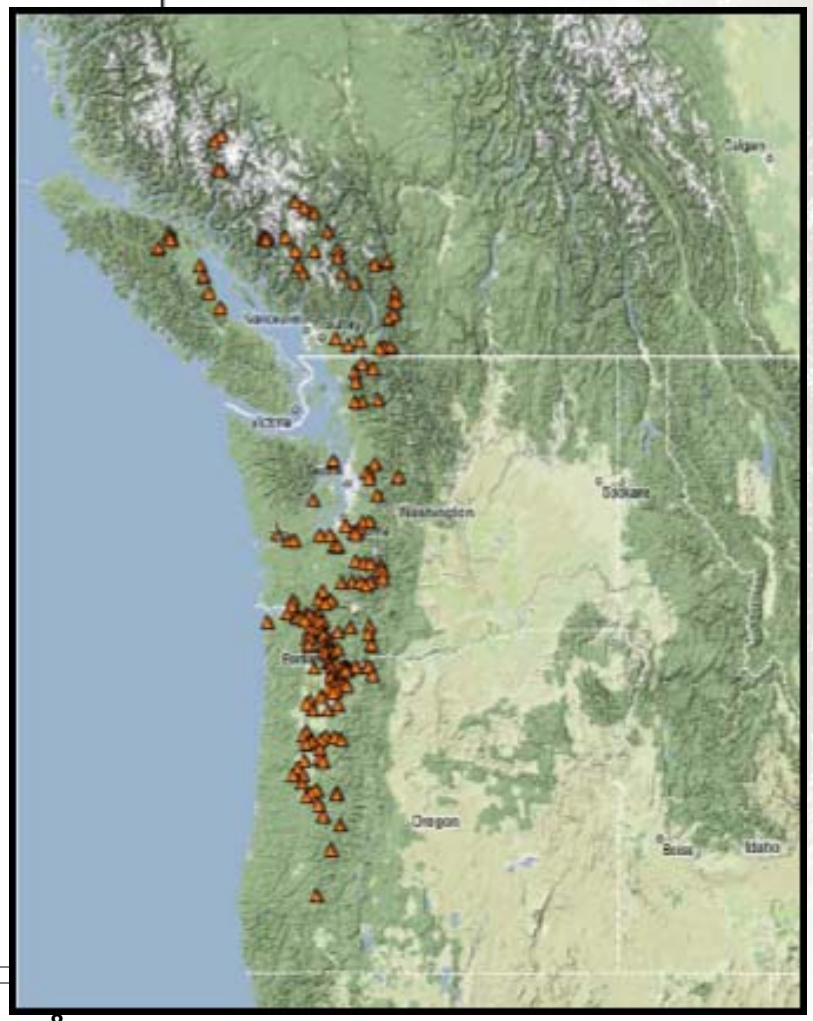
Hybrid Poplar's National Strategic Position

1. **Proven production systems**
   - **Elite varieties**
   - **Wood handling/storage**
2. **Superior environmental benefits**
   - **Lower energy inputs**
   - **Reduced CO_2 / NO_2 emissions**
3. **Excellent opportunity for improvement in biomass yield and quality**
   - **Conventional approaches**
   - **Novel approaches**

Conventional Approach: The SunGrant Initiative

- National program to coordinate/integrate *Populus* breeding and varietal development
- Goal is elite germplasm of regionally-adapted hybrid taxa for renewable bio-energy feedstock industry.
- Focus on:
  - North Central - *Populus ×canadensis*, *P. nigra* × *P. maximowiczii*
  - Pacific Northwest - *P. ×generosa*, *P. ×canadensis*
  - Southeast - *P. deltoides*.

Novel Approach: Association Genetics

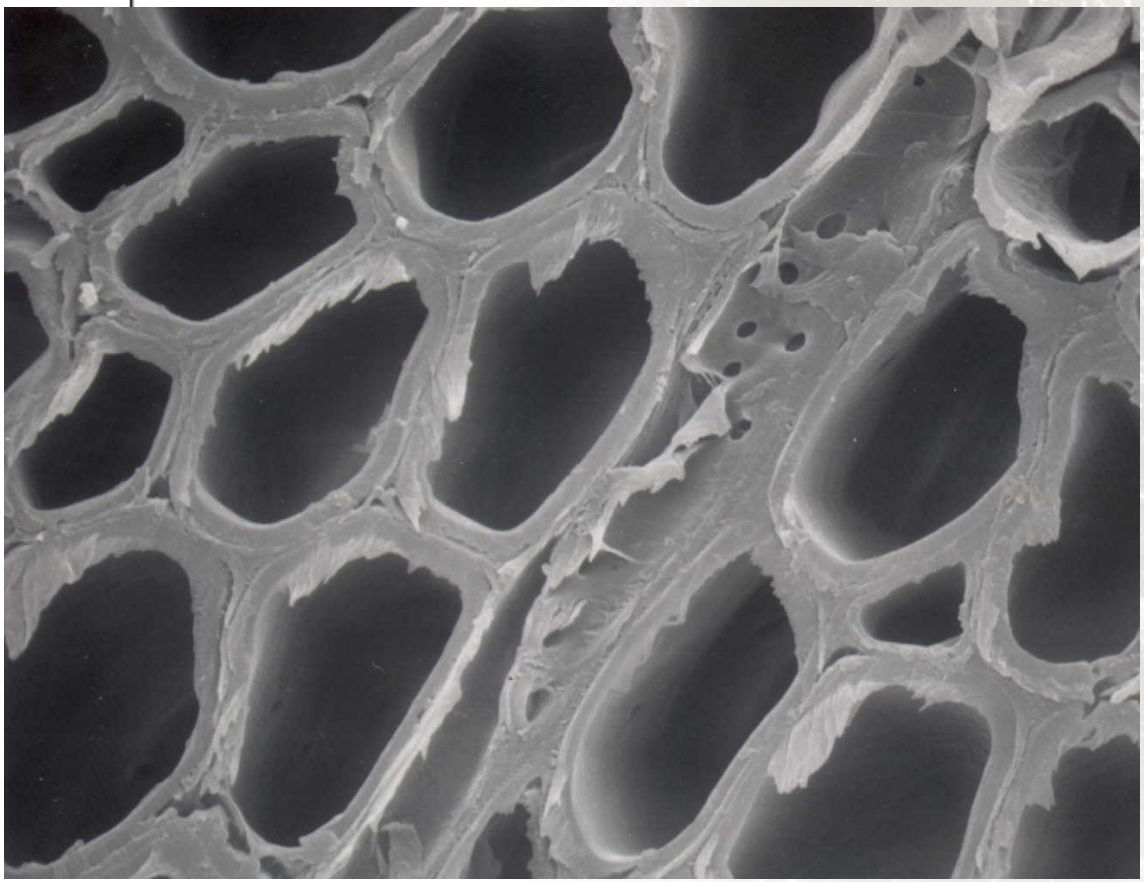


- Goal is the identification of markers associated with genes involved in lignin bio-synthetic pathway
- Two studies of the association between molecular markers (single nucleotide polymorphisms) and biomass compositional traits in *Populus trichocarpa*
- Bioenergy Science Center Oak Ridge National Lab, West Virginia University

BESC
BioEnergy Science Center

- University of California, GreenWood Resources, Michigan Tech, National Renewable Energy Lab

UCDAVIS PLANT SCIENCES
NREL
GREENWOOD RESOURCES
MichiganTech
Chevron



1. **Phenotyped a replicated collection of 456 clones for lignin and cellulose composition.**

2. **Genotyped SNP sequence variation in 40 candidate genes believed associated with lignin and cellulose**

3. **Presently establishing statistical associations in SNP variation with variation in lignin and carbohydrate chemistry.**

Association Genetics of *P. trichocarpa*

Syringyl-to-Guaiacyl Lignin Ratio

Statistic	S/G Ratio
Number of Clones	456
Mean	1.70
Minimum	1.35
Maximum	2.12
Range (% of Mean)	47.80
Phenotypic Standard Deviation	0.16
Clonal Repeatability	0.76

SNP Marker – Trait Associations

The Syringyl-to-Guaiacyl Lignin Ratio

Gene	SNP	R^2	Gene	SNP	R^2
4CL1	06-252	0.0310	**F5H1**	01-653	0.0262
C4H1	04-219	0.0498	**LAC1a**	03-98	0.0354
C4H2	09-135	0.0270		05-218	0.0386
	12-151	0.0280		11-493	0.0372
CESA1A	12-223	0.0218		11-70	0.0334
	12-40	0.0218	**LAC90a**	07-72	0.0333
	16-100	0.0218	**PAL2**	01-116	0.0584
	16-280	0.0218		01-33	0.0300
	16-506	0.0218	**SHMT1**	08-428	0.0271
	20-226	0.0218	**SUSY1**	02-108	0.0214
	16-193	0.0218	**gdcH1**	05-382	0.0235

Closing
Integration of Novel and Conventional Approaches

A U. S. Initiative in Translational Genomics

1. **A national program of government, university, and private companies currently being organized.**

2. **Adaptation of information derived from genome technologies to applied *Populus* improvement programs.**

3. **Extend SNP markers developed in *P. trichocarpa* to other *Populus* species.**

4. **Molecular marker-assisted selection (MAS) to increase the selection efficiency of conventional improvement approaches.**