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2015 DOE Bioenergy Technologies Office (BETO)
Project Peer Review

Regional Feedstock Partnership: Woody Crops

(Award # GO85041; WBS 7.6.2.5)

March 24, 2015
Terrestrial Feedstocks

Bill Berguson, Poplar Team Lead
Univ. of Minnesota-NRRI

Tim Volk, Willow Team Lead
State University of New York – ESF

Tim Rials, SGA Coordinator
The University of Tennessee

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Quad Chart Overview

Timeline

- Start date – 1/15/2007
- End date – 12/31/2015
- 90% complete

Barriers

- Ft-A: Resource availability & cost
- Ft-B: Sustainable production
- Ft-C: Crop Genetics

	Total Costs FY07-FY12	FY 13 Costs	FY 14 Costs	Total Planned Funding
DOE Funded	$1,804,279	$558,829	$457,929	$435,274
Cost Share (Comp.)*	$380,229	$251,594	$194,533	

Partners

- Collaborations: ArborGen, Inc., Cornell Univ., GreenWood Resources, Michigan State Univ., Middlebury College, Mississippi State Univ., ORNL, Sun Grant Initiative, SUNY-ESF, Univ. of Connecticut, Univ. of Minnesota-NRRI, USDA-Forest Service

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Project Overview – Woody Crops

- DOE and the Sun Grant Initiative formed the **Regional Biomass Feedstock Partnership** in 2007
- Regional Biomass Feedstock Workshops
- Conduct a literature review to establish the current state of technology for major woody crop candidates
- Establish field trials to evaluate new varieties on representative sites around the country
- Produce new, elite genotypes for improved process performance
- Assess yield data, including long-term production patterns
- Provide data to the KDF for public consumption

Wood Resources

Sun Grant Lead: The University of Tennessee

Agency Lead: Oak Ridge National Laboratory; Department of Agriculture

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Approach

1. Advance genetics & breeding program
2. Establish replicated field trials for new varieties (poplar & willow)
3. Incorporate existing field trials for current baseline yields
4. Populate the KDF with current yield data

Poplar Development Team

Bill Berguson, Lead
Univ. of Minnesota-NRRI

Mike Cunningham/Bijay Tamang ArborGen
Randy Rousseau, Mississippi State University
Brian Stanton/Rich Shuren GreenWood Res.
Bernard McMahon, Univ. of Minnesota-NRRI

Willow Development Team

Tim Volk, Lead
State Univ. of New York-ESF

Ray Miller, Michigan State University
Lawrence Smart, Cornell University
Julia Kuzovkina, University of Connecticut
Tom Corbin, Middlebury College

Advisory Team

Bryce Stokes, CNJV, LLC
Marilyn Buford, USDA-Forest Service
Jim Perdue, USDA-FS, Southern Research Station
Don Riemenschneider, USDA-FS, Northern Research Station (retired)

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Relevance

Crop Development

Woody crops (poplar & willow) offer significant genetic variation to draw on for advancement

Presents the prospect of tailoring crops for optimal conversion

Harvest Systems

Woody crops fulfill the need for a portfolio of feedstock sources to:

1) Address varied landowner interests

2) Maximize ecological and environmental benefits

Logistics

Woody crops provide an important approach to address annual supply issues

The supply chain infrastructure is in place due to FPI

Sustainable Production

Woody crops provide material for diverse markets

Flex management targets the range of landowner interests and objectives

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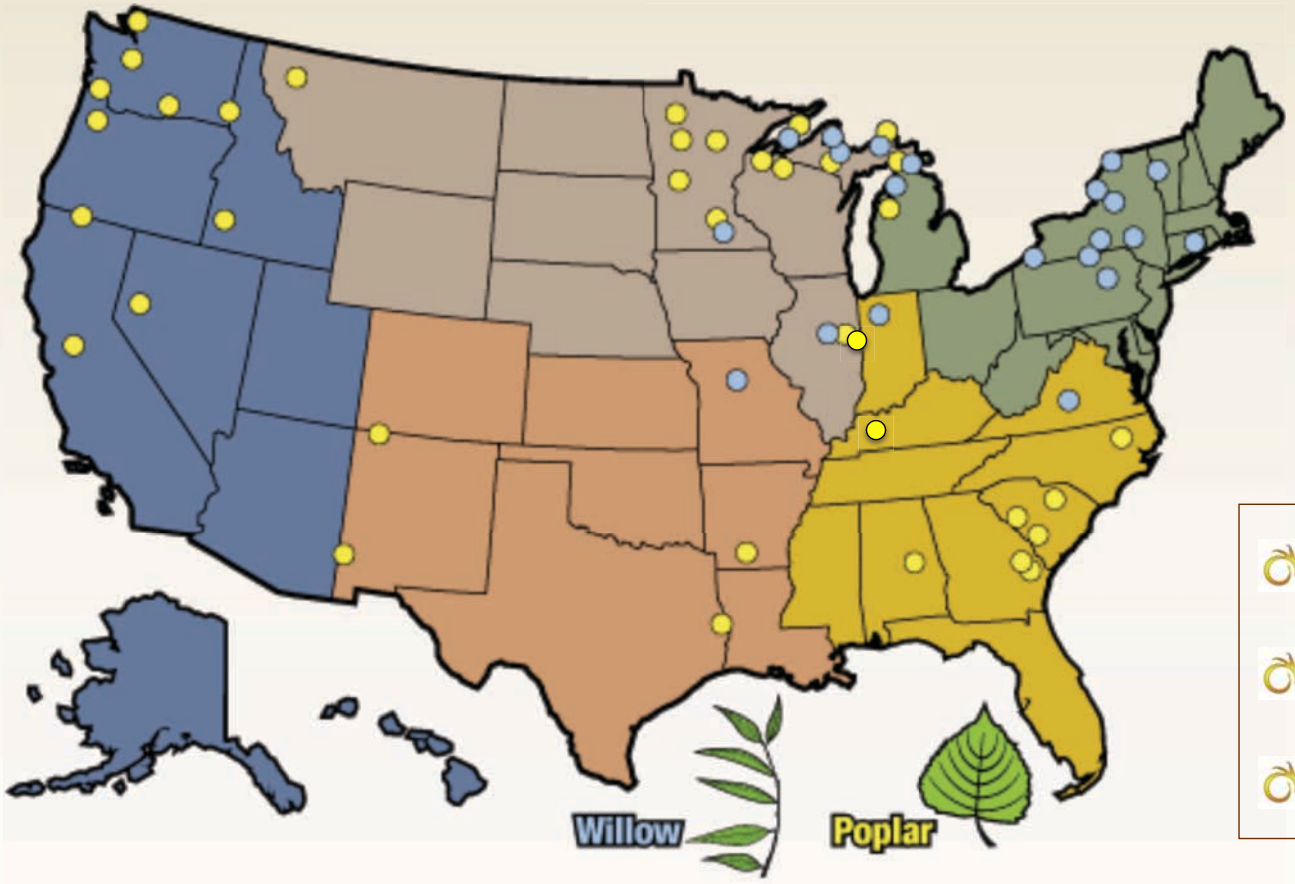
The Woody Crops Field Trial Network



68 Total Sites

- Genetics tests
- Yield trials
- Nurseries

AG Clone Test – Randolf, AL

Age 4 measurement summaries:

- Clone Test
  - ID: ArCW335
  - Mean height: 20.3 ft (range: 13-30 ft)
  - Mean DBH: 2.4 in (range: 1.4-3.6 in)
- Clone Screening Test
  - ID: ArCW568
  - Mean height: 21.5 (range: 13-32 ft)
  - Mean DBH: 2.1 in (range: 1-3.3 in)

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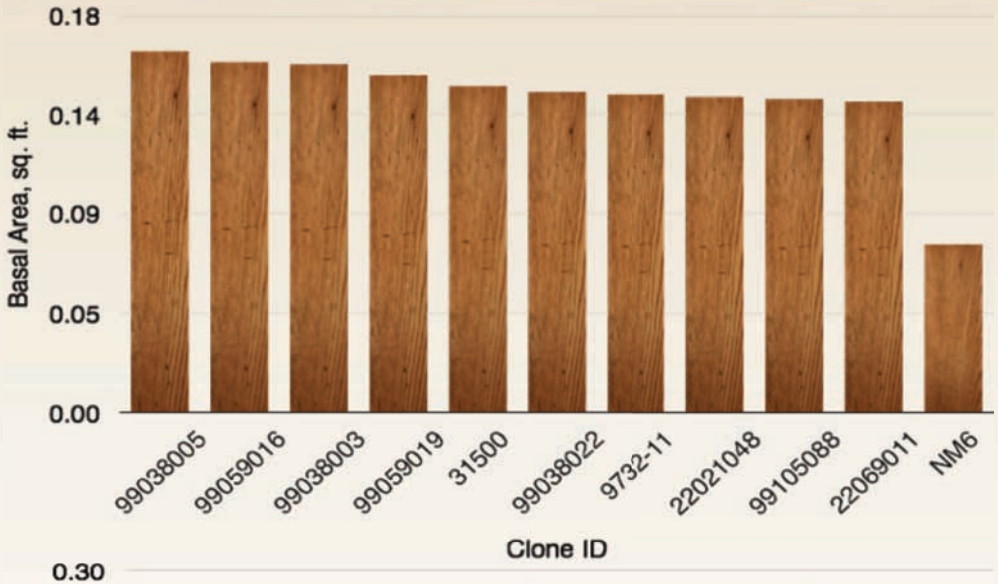
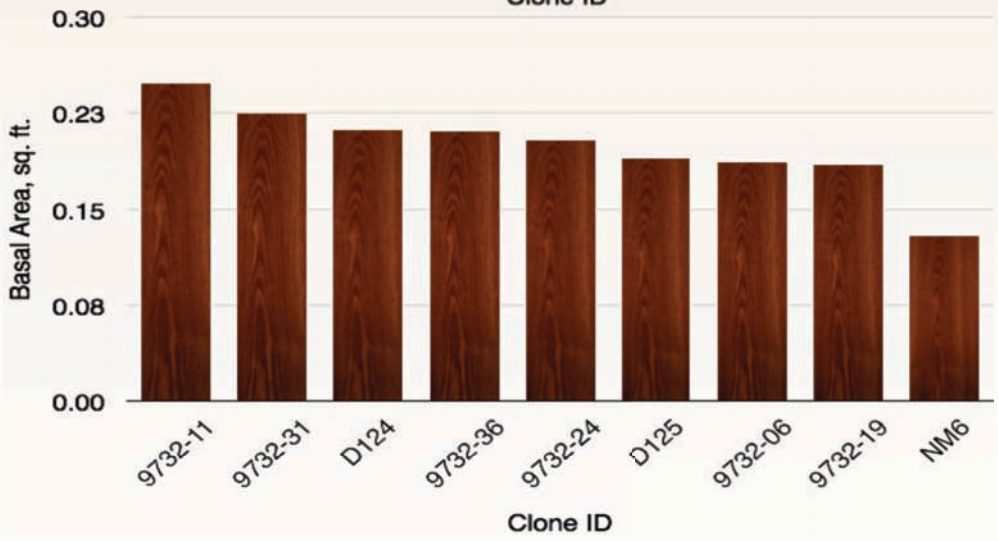
Advances In Biomass Yield



- Avg. for 5 clone trials, MN
- 71 clones/site planted, 2008
- Top 10 clones: NM6 = 1.98



- Large yield trials, MN
- Schultz site planted in 2007
- Top 8 clones: NM6 = 1.6

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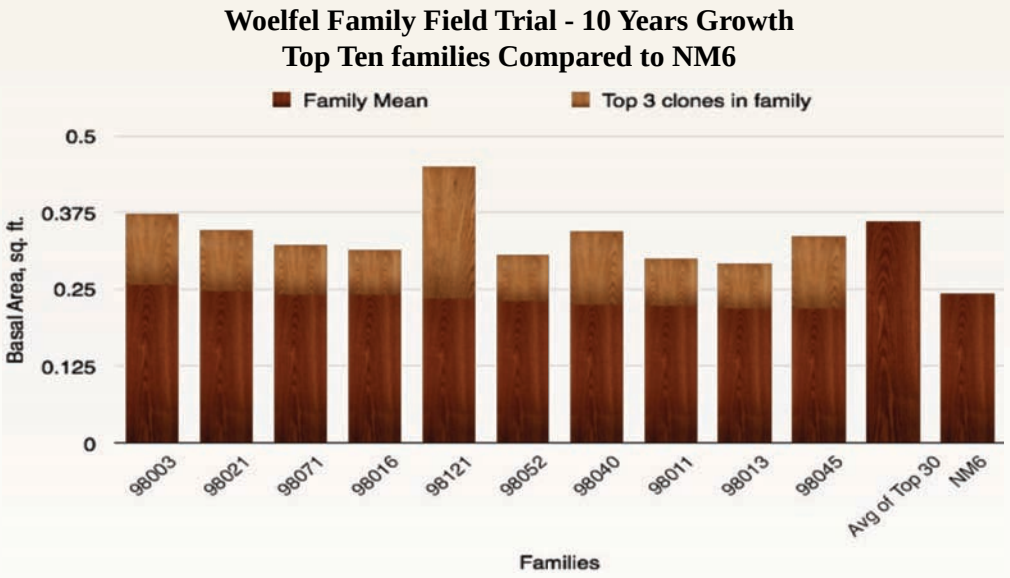
Breeding and Genetic Improvement

- Created one of the largest collections of new clonal material in the world adapted to northern climates
- Expanding breeding for southern regions using the best parents with proven performance in the South
- Large-scale "family field tests" in Minnesota have developed unique understanding of underlying genetic mechanisms in poplar
- Largest network of field tests including clone test and biomass yield studies in US
- Support of breeding has led to opportunities for distribution of new clones to support cooperative tests at locations in the US and strategic areas of Europe



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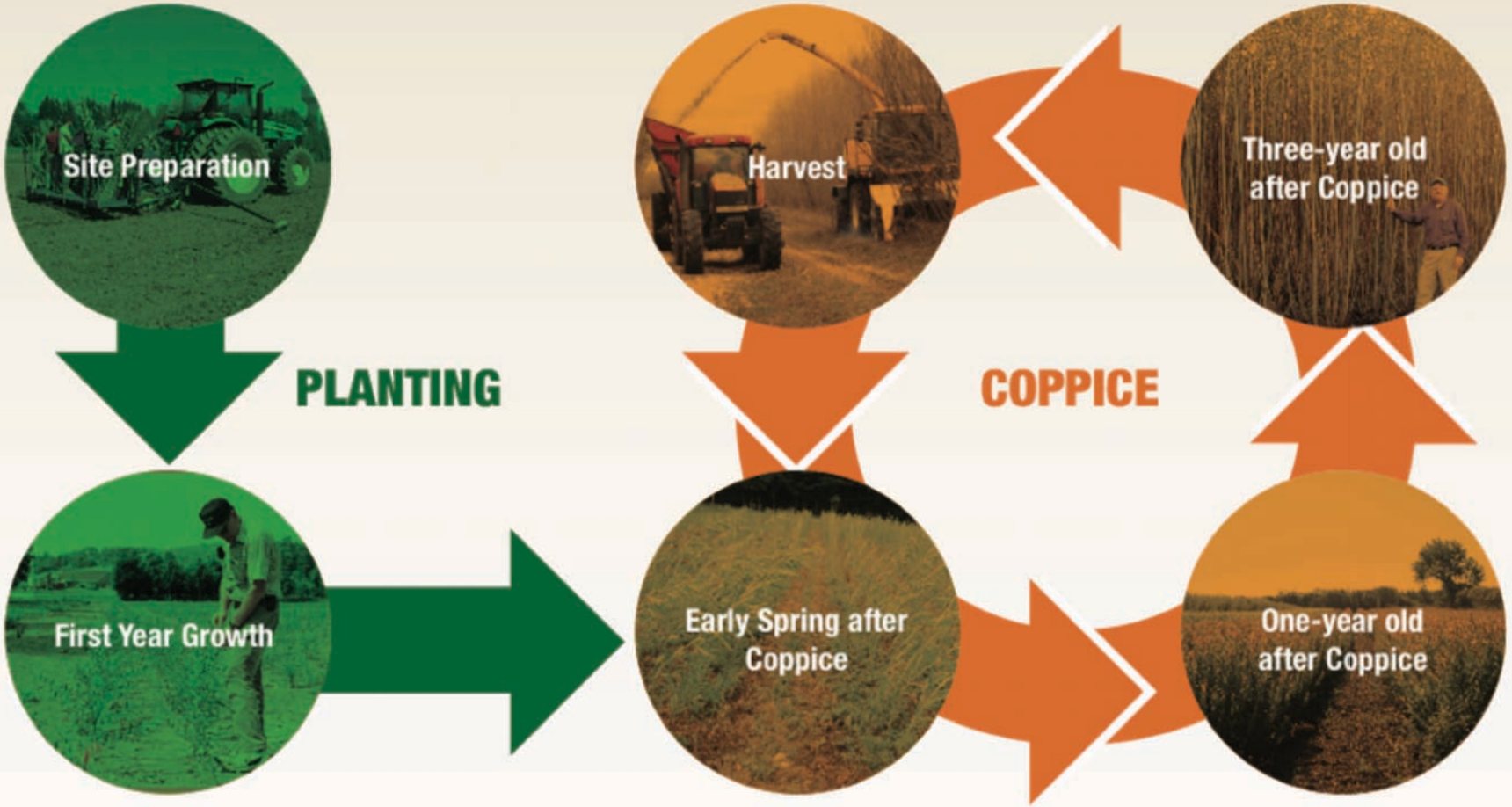
Willow Biomass Production Cycle



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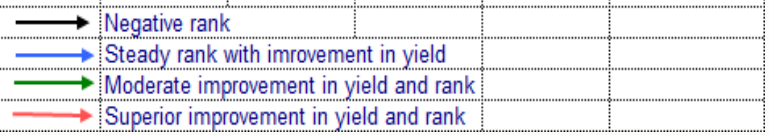
Long-Term Trials

Changes in ranking of cultivars over 5 harvests

- Essential to monitor trials over multiple rotations for a system that is designed to function for 20-25 years and include 5 to seven harvests
- Long-term yield data impacts economic analysis, environmental assessments, and selection of improved cultivars

Realtive yield performance of willow clones from first rotation to fifth rotation

Rank	Cultivar	Yield (Mg/ha-yr)	Rank	Cultivar	Yield (Mg/ha-yr)
1	SV1	8.93	1	SV1	14.52
2	S287	7.33	2	SP3	7.81
3	S365	6.87	3	S557	7.37
4	S301	6.12	4	S19	7.19
5	S34	5.77	5	S287	7.1
6	S25	5.63	6	S25	6.83
7	S652	5.3	7	S365	6.71
8	S625	5.26	8	SH3	6.61
9	S19	5.25	9	S599	6.47
10	S185	5.14	10	S185	6.18
11	S599	4.91	11	S652	5.81
12	SH3	4.9	12	S34	5.25
13	S546	4.73	13	S646	5.21
14	S646	4.39	14	S625	4.82
15	S566	4.2	15	S71	4.49
16	SP3	4.14	16	SA2	4.41
17	SA2	3.42	17	S546	4.12
18	S71	3.05	18	S566	3.33
19	S557	2.78	19	S301	1.05



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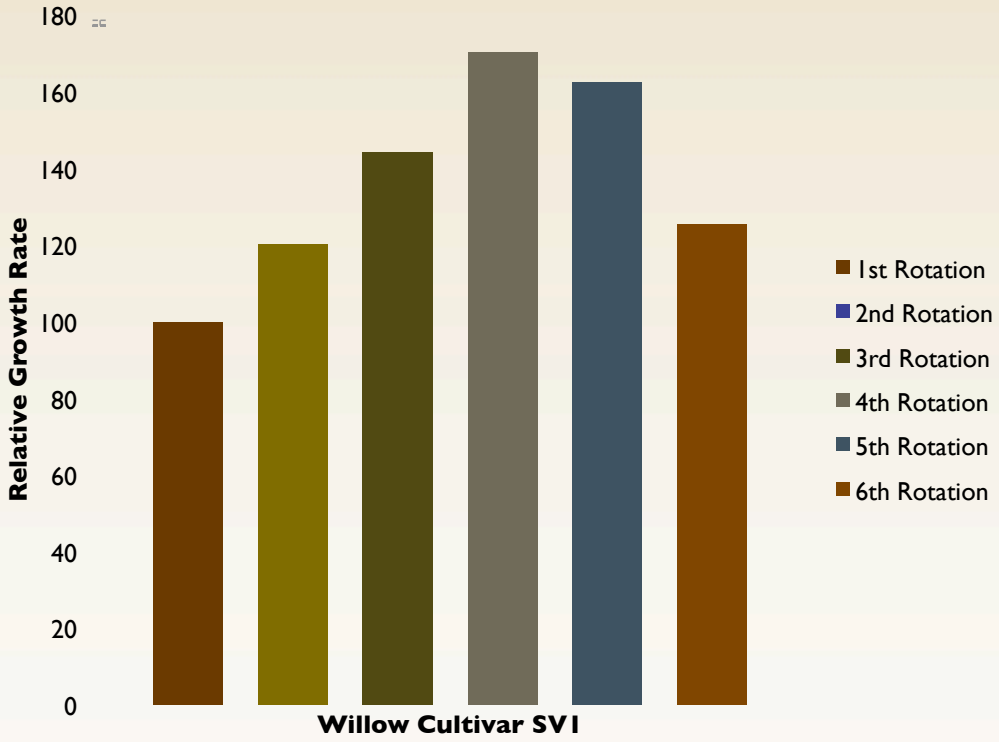
Longest Continuous Trial in U.S.



- Only one of 19 cultivars in this trial still being sold commercially for biomass production
- Over 6 rotations growth has consistently been greater than 1st rotation
- Supports assumption of long term productivity of systems

Relative growth rate of willow cultivar SV1 over 6 rotations. First rotation yield is baseline for relative growth calculations

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Improvements in Yield

- Yield increased by 13 – 35% for the top cultivars.
- Much smaller yield decrease in top five cultivars for post 2005 trials (6%) versus pre 2005 (21%).
- Survival for the best producing cultivars increased by 16%.

	Pre-2005 Yield Trials (n=11)	Post-2005 Yield Trials (n=5)	One-way ANOVA	
	Yield (dry Mg ha^{-1} yr^{-1})	Yield (dry Mg ha^{-1} yr^{-1})	Percent Change in Yield	p-value (yield)
Top cultivar	10.5 ± 0.7	11.9 ± 0.6	13.3%	0.1755
Top 3 cultivars	9.3 ± 0.4	11.5 ± 0.4	23.7%	0.0017
Top 5 cultivars	8.3 ± 0.3	11.2 ± 0.3	34.9%	<0.0001
All cultivars	5.6 ± 0.2	8.8 ± 0.1	57.1%	<0.0001

(Liu 2014)

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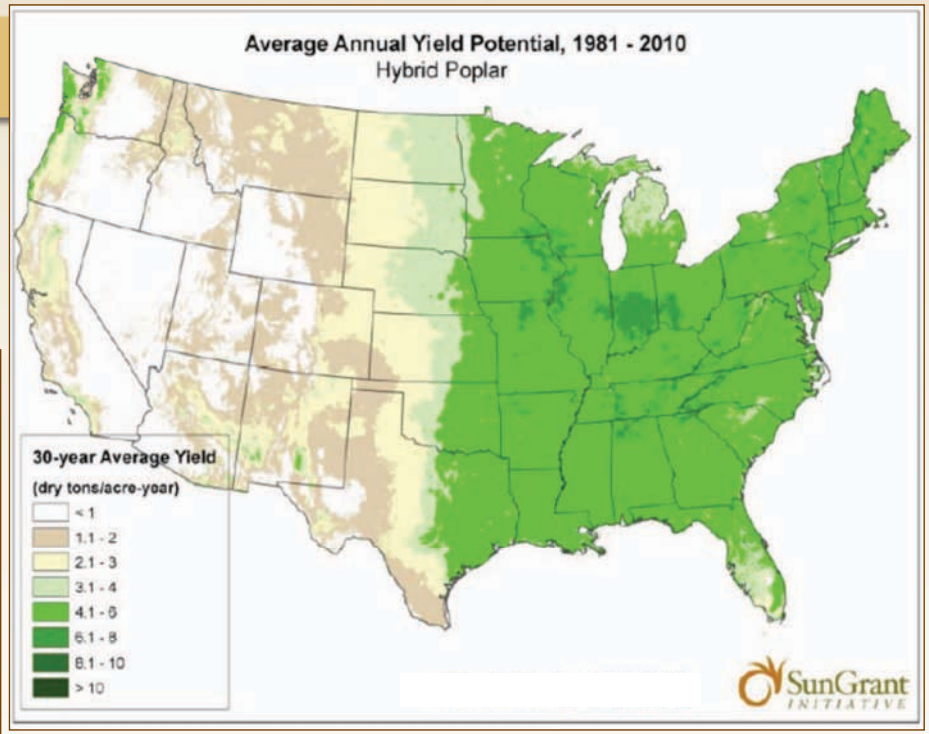
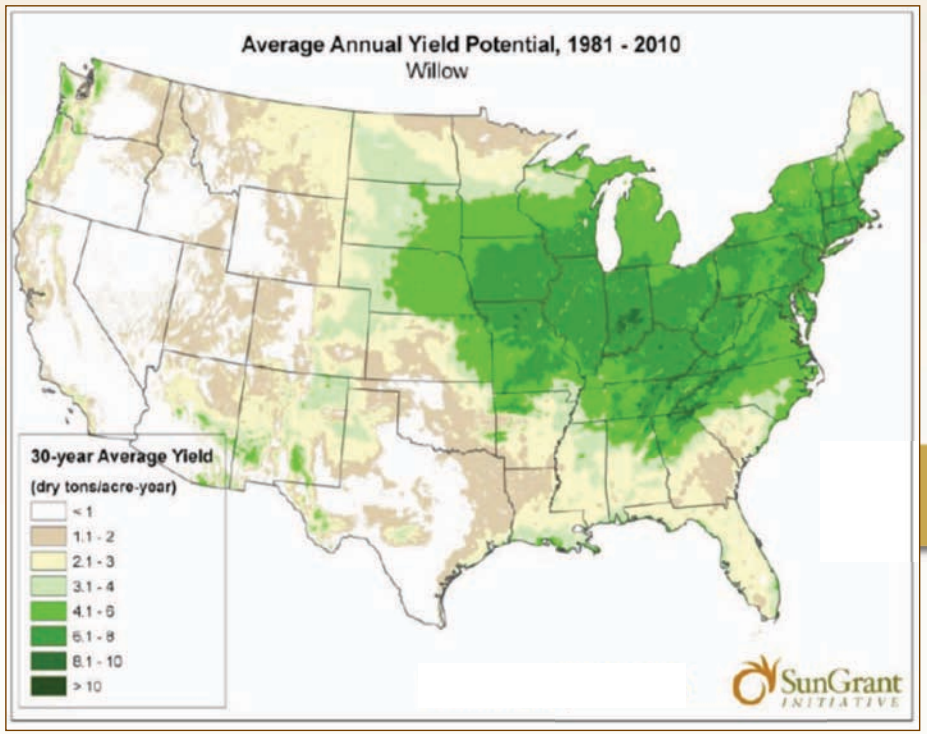
PRISM Mapping

Hybrid Poplar

Data from network of yield trials was the basis for regional yield modeling efforts





Willow

Draft manuscript in development

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Broader Impacts

- Woody crops team data and expertise supported PRISM modeling
- Material (willow and poplar) provided to INL Biomass Library
- Chemical composition data provided to INL database
- Continued populating KDF Data
- Trail data used for willow LCA (net energy balance and GHG emissions)
- EcoWillow model updated with RFP trial data
- Best cultivars from trials have been licensed to a commercial nursery in NY (Double A Willow) for large scale production and sale
- Data from yield trials was instrumental in USDA BCAP project approval and helping landowners make selections for expansion of willow biomass crops in northern NY
- Yield trials network used for related studies (pests and diseases, nutrient management and changes in soil characteristics)

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Woody Team – Future Work

- Measure and maintain existing trial network
- Collect and submit yield data to KDF
- Complete yield modeling (PRISM) manuscript and several others

Poplar Specific

- Distribute *P. nigra* parents Breed new *deltoides* clones and distribute for field testing
  - DxN to improve *P. deltoides* rooting

Willow Specific

- 1st rotation data from 14 RFP trials
- Compile data from related trials outside RFP
- Develop long-term productivity projections (old and new varieties).

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Summary Remarks

- The RFP's Woody Crops Team is defining today's state-of-the-art with an eye on tomorrow's targets.
- From the Billion Ton Report to BCAP and the KDF, the team is informing policy and science with data created through its innovative protocol.
- The coordinated national structure offers one-of-a-kind data, information, and knowledge on woody crop genetics.
- The RFP's Woody Crops Team continues to develop new germplasm for deployment while monitoring and maintaining existing trials.

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Questions

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- Berguson, Bill, Brian Stanton and Jake Eaton. 2010. Development of Hybrid Poplar for Commercial Production in the United States: The Pacific Northwest and Minnesota Experience. In: A Sustainable Alternative Fuel Feedstock Opportunities, Challenges and Roadmaps for Six U.S. Regions, Proceedings of the Sustainable Feedstocks for Advanced Biofuel Workshop, Ross Braun, Douglas L. Karlen, and Dewayne Johnson (editors), SWCS publisher. 24pp.
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- Herr, J. R., Kemanian, A., DiFazio, S., Volk, T., Jacobson, M., Miller, R., Smart, L. (2012). Studying the Effects on Woody Biomass Productivity of Genotype-by-Environment Interactions. Proceedings from Sun Grant National Conference: Science for Biomass Feedstock Production and Utilization, New Orleans, LA.
- Serapiglia, M.J., K. Cameron, A.J. Stipanovic, L.P. Abrahamson, T.A. Volk and L.B. Smart. 2012. Yield and Woody Biomass Traits of Novel Shrub Willow Hybrids at Two Contrasting Sites. Bioenergy Research DOI 10.1007/s12155-012-9272-5
- Volk, T A, L P Abrahamson, K D Cameron, P Castellano, T Corbin, E Fabio, G Johnson, Y Kuzovkina-Eischen, M Labrecque, R Miller, D Sidders, L B Smart, K Staver, G R Stanosz And K Van Rees. Yields of willow biomass crops across a range of sites in North America. Aspects of Applied Biology 112:67-74.
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- Zalesny , Jr., R.Z., M.W. Cunningham, R.B. Hall, J. Mirck, D.L. Rockwood5, J.A. Stanturf, T.A. Volk. 2011. Wood biomass from short rotation woody crops. *Sustainable Production of Fuels, Chemicals, and Fibers from Forest Biomass. ACS Symposium Series*, Vol. 1067*:27-63.*
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- Carlson, J.E., J.R. Herr, A. Kemanian, S. DiFazio, T. Volk, M. Jacobson, R.O. Miller, L. Smart. 2012. Studying the effects on woody biomass productivity of genotype by environment interactions. Sun Grant Initiative National Conference, New Orleans, October 2 – 5.
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- Pacaldo, R., T.A. Volk, R.D. Briggs, L.P. Abrahamson, E. Bevilacqua and E. Fabio. 2012. Soil CO2 effluxes in shrub willow biomass crops along a 21-year chronosequence as affected by continuous production and crop removal. Sun Grant Initiative National Conference, New Orleans, October 2 – 5.
- Smart, L.B., F.E. Gouker, M.J. Serapiglia, C.D. Town, H. Tang, E.S. Buckler, R.J. Elshire, S.E. Mitchell, S. Difazio, E. Rodgers-Melnick, G.A. Tuskan, J.E. Carlsong, R.O. Miller, T. A. Volk. 2012. Development of genomic resources and novel species hybrids for the genetic improvement of shrub willow feedstocks. Sun Grant Initiative National Conference, New Orleans, October 2 – 5.

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- Volk, T.A. 2009. Commercializing willow biomass crops for bioenergy, biofuels, and bioproducts in the northeast and Midwest U.S. Presentation to Mario Musolino, Executive Deputy Commissioner of Labor for NYS, SUNY-ESF, Syracuse, NY, September 18, 2009.
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- Volk, T.A. 2010. Commercializing Willow Biomass Crops for Bioenergy, Bioproducts, Phytoremediation and Agroforestry in the Northeastern and Midwestern United States. Entrepeneurship Class, SUNY ESF Syracuse, NY August 9, 2010.
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SunGrant INITIATIVE
Southeastern Regional Center

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