2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

Regional Feedstock Partnership: Woody Crops

May 21, 2013
Feedstock Supply & Logistics

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Univ. of Minnesota-NRRI

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Oak Ridge National Laboratory

Tim Rials, SGA Coordinator
The University of Tennessee

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

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Goal Statement

- Development of more accurate cost supply information and improved communication with partners in the feedstock supply chain
  - Replicated field trials across regions to determine the impact of residue removal on future grain yield.
  - Replicated field trials to develop energy crops within geographical regions.
  - Regional assessment of feedstock resources which can be used to determine supply curves.

The Woody Crop's Goal

•Address knowledge gaps limiting the deployment of woody resources as an economically viable feedstock for fuels and energy production

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Quad Chart Overview

Timeline

- Start date – 10/1/2007
- End date – 9/30/2013
- 90 percent complete

Barriers

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

Budget

- Funding for FY11: DOE- $928,596
  - Cost Share - $232,149
- Funding for FY12: $0
- Funding for FY13: ?
- Funded for 4 years at $631,579/yr

Partners

- Land-grant universities
- Tree genetics industries
- USDA-FS
- Oak Ridge National Lab
- SRWC-Operations Working Group

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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
- Data is fed into the KDF, which provides informed decisions for consumers, policy makers, and private industry

Wood Resources

Sun Grant Lead: The University of Tennessee

Agency Lead: Oak Ridge National Laboratory; Department of Agriculture

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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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Approach

Tim Rials, UT (SE Sun Grant Center)
Mark Downing, DOE (Oak Ridge National Lab)

Poplar Development Team

Bill Berguson, Lead
Univ. of Minnesota-NRRI

Mike Cunningham/Jeff Wright ArborGen, Summerville, SC

Randy Rousseau, Mississippi State University, Starkville, MS

Brian Stanton/Rich Shuren GreenWood Res., Portland, OR

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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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

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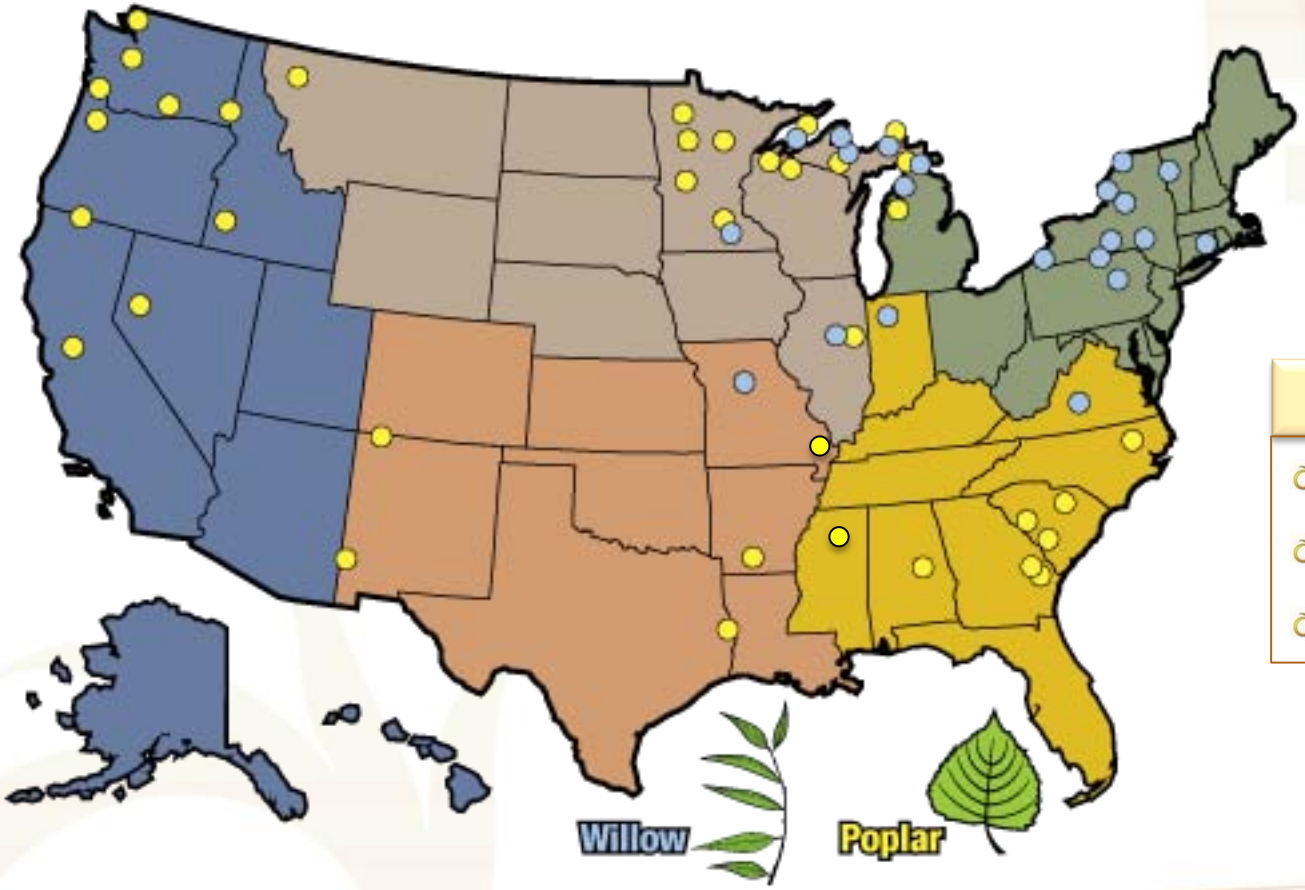
The Woody Crops Field Trial Network



68 Total Sites

- Genetics tests
- Yield trials
- Nurseries

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Evaluating New Genetic Material

Consolidated Clone Tests – assemble genetic material from cooperators programs to evaluate adaptability and productivity in various environments

- 80 clones per test, 20 from each of four groups, six reps/genotype
- Belle River, MN; New Madrid, MO; Pontotoc, MS; Bellville, GA; Westport, OR

Overall survival >80%

West Coast Tests:
propagation step due to Septoria concerns

All sites successfully established

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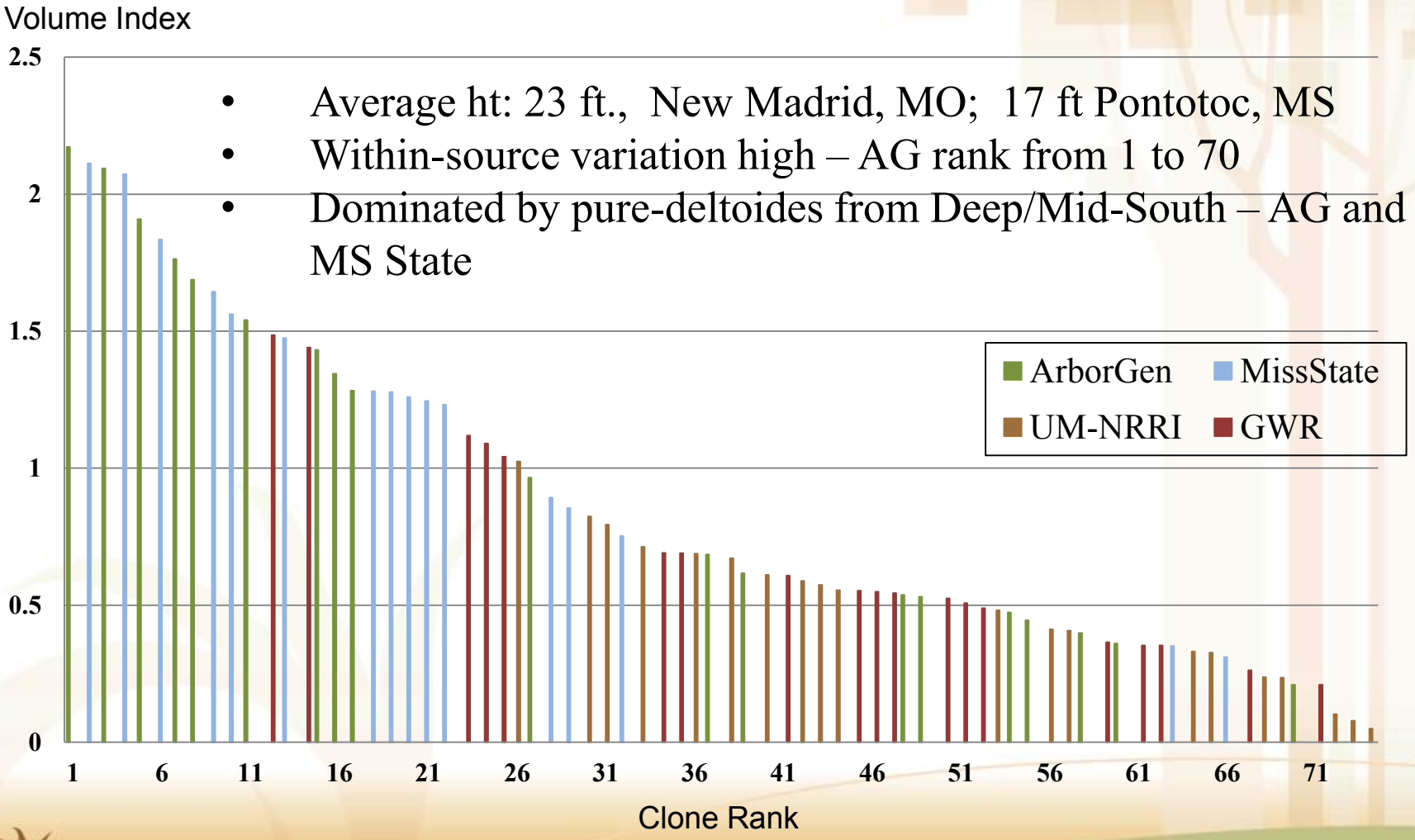
New Madrid Clone Test, 2010



- Average ht: 23 ft., New Madrid, MO; 17 ft Pontotoc, MS
- Within-source variation high – AG rank from 1 to 70
- Dominated by pure-deltoides from Deep/Mid-South – AG and MS State

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Two Year AG Clone Test – Randolf, AL

- 2-yr height up to 24 ft – best clone
- Question on effect of drought in 2012
- Year 3 measurements to be made in spring of 2013 but observation is that height growth recovered

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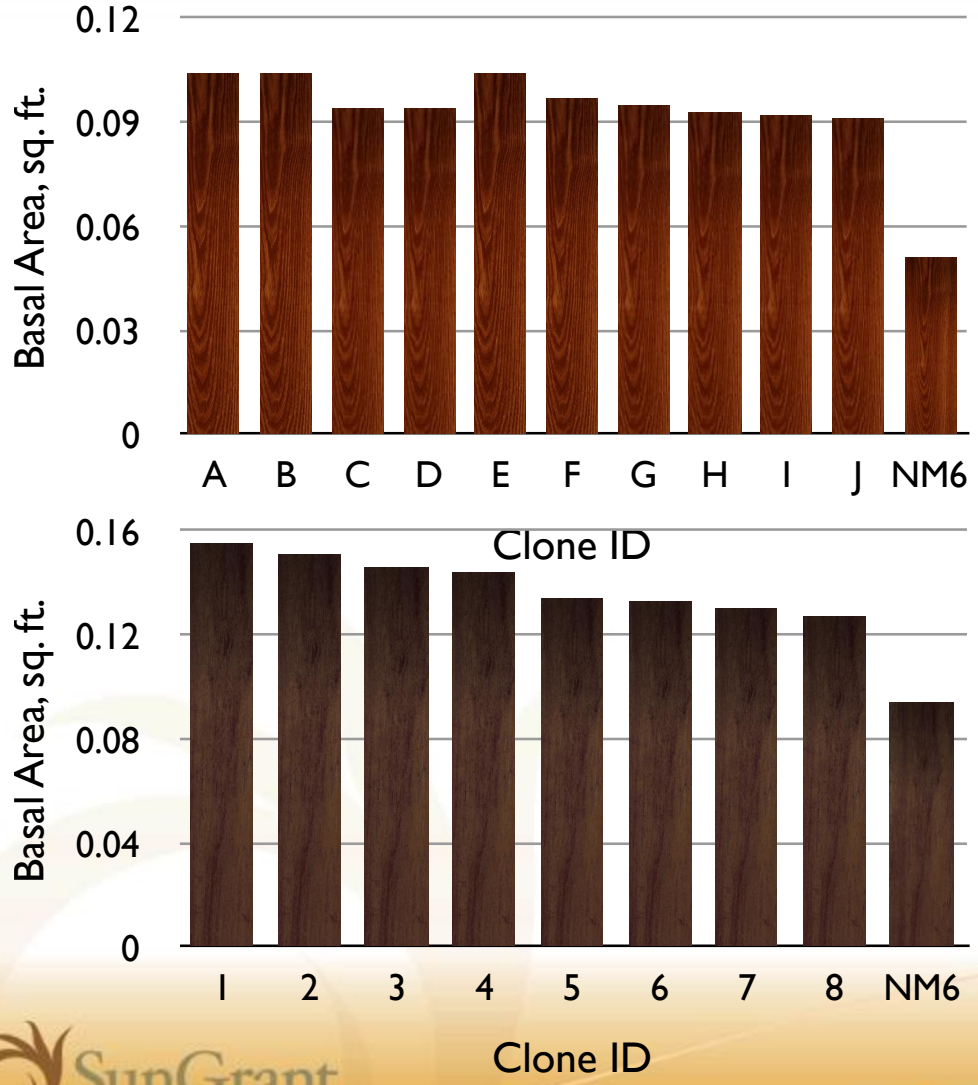
Advances In Biomass Yield



- Avg. for 6 clone trials, MN
- 71 clones/site planted, 2008
- Top 10 clones:NM6 = 1.8

- Large yield trials, MN
- Schultz site planted in 2007
- Top 8 clones:NM6 = 1.5

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P. Nigra Clone Testing

P. nigra an important species in breeding and yield improvement of poplar as an energy crop

Collections made in 2005 by University of Minnesota and GreenWood Resources

Cross with fast growing *P. deltoides* to increase rooting percentage leading to less expensive commercial plantings and potential for higher yield

P. nigra has been planted in archives and clone tests in:

- Minnesota – in long-term breeding archive and clone tests
- Oregon – long-term breeding archive
- New Clone Test at: VA Tech near Martinsville, VA, Clemson University near Florence SC, University of Tennessee near Knoxville TN

Seedlings for two trials of *P. nigra* to Mississippi State for planting on two sites in Mississippi

Established an excellent trial base of *P. nigra* in the SE US.

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Breeding and Genetic Improvement

- Capitalize on existing programs in MN, OR and the South to expand deployment of new clones to the entire U.S.
- 2012 Breeding – ca. 24,000 new genotypes produced to be planted in nurseries in 2013 in MN and OR
- 2013 Breeding – selected mid-South cottonwood and MN *P. nigra* (MS State and UM-NRRI)
- Breeding is underway in U MN lab (pollinations completed in April)

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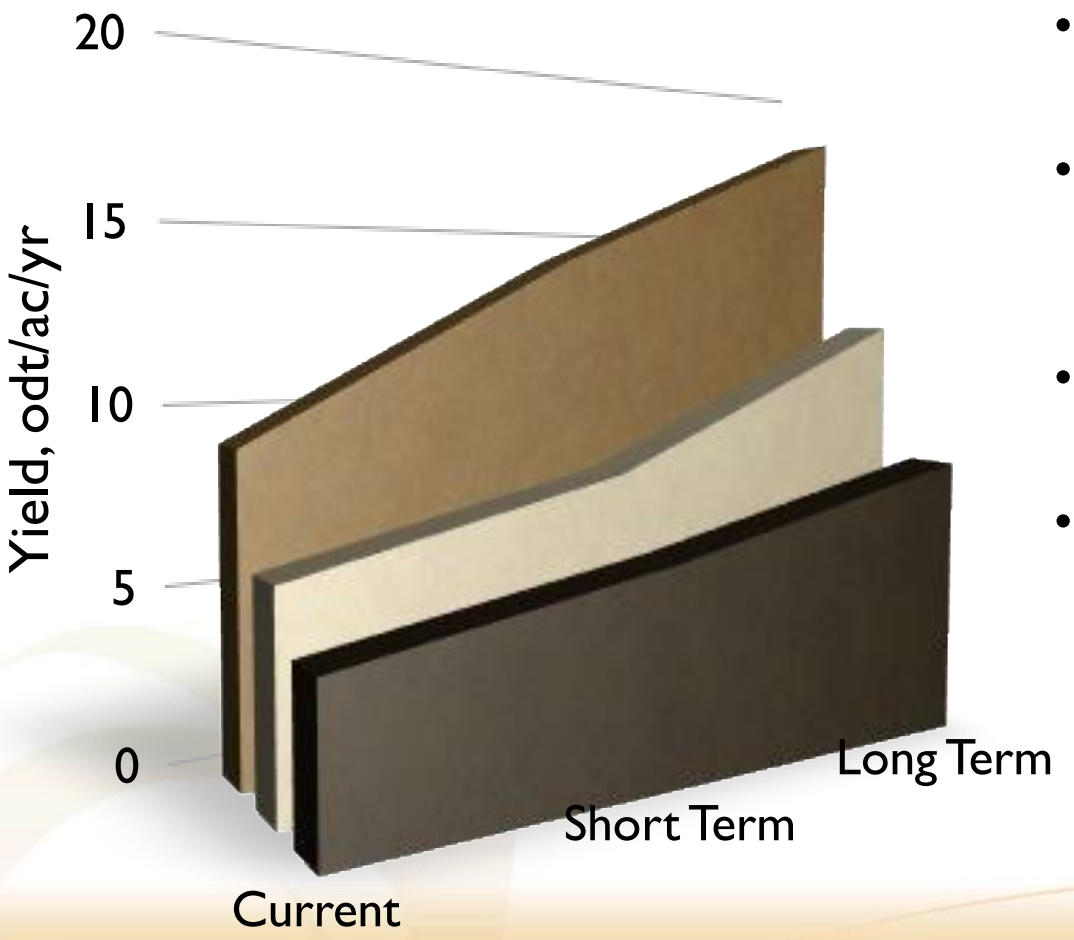
Poplar Yield Projections



- "Near-term" – next 10 years with genetic improvement
- "Future" – genetic improvement and application of genomics
- Midwest and Pacific Northwest – DT, DN, DM
- Deep/Mid-South – D, DN, *(likely hybrid aspens in the mix)*

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Critical Success Factors

- Overall – demonstration of a cost-effective, efficient liquid fuels conversion system using biomass (market pull)
- Genetic improvement of poplar leading to regionally-adapted pool of diverse set of high-yielding clonal material
- Nationalization of demonstrated success in the PNW and Midwest and continued yield improvement in all regions underway
- Demonstration of coppice production systems using improved clones selected from the program (yield potential)
- Yields of minimum of 5 to 7 tons in unirrigated Midwest to South and 8 to 10 tons under irrigation in the PNW

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Plans for Upcoming Year

- Distribute parent populations (*P. nigra*) to expand regional field test network
- Breed new clones and distribute for field testing
  - Broaden breeding using Southern, Mid, Northern *P. deltoides* as parents with University of Minnesota and GWR *P. nigra* collection
  - DXN focus to improve rooting of *P. deltoides* (cottonwood)
- Continued yield analysis in South and Mid-South
- Measurement of Trial Network (clone tests, large genetics tests, yield blocks)
- Continued submission of information to KDF

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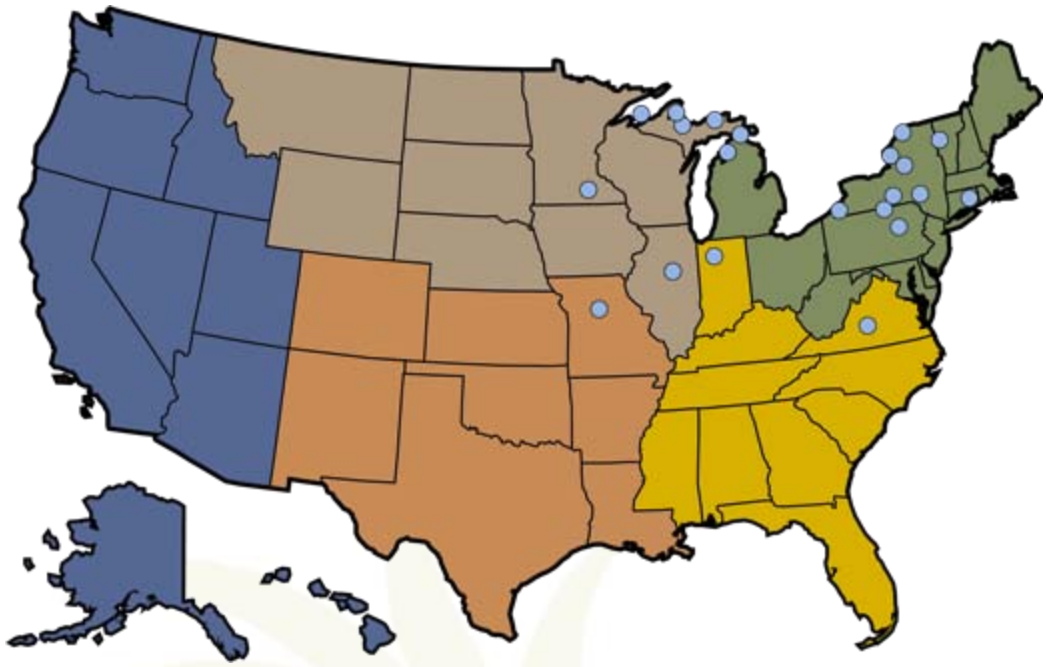
Willow Field Trial Network



Network of willow biomass trials across 10 states

- Network of 20 willow biomass crop yield trials
- 2 trials of older varieties to determine long term production
- 8 trials with new willow varieties planted before the start of project
- 10 new trials established with new willow varieties in this project

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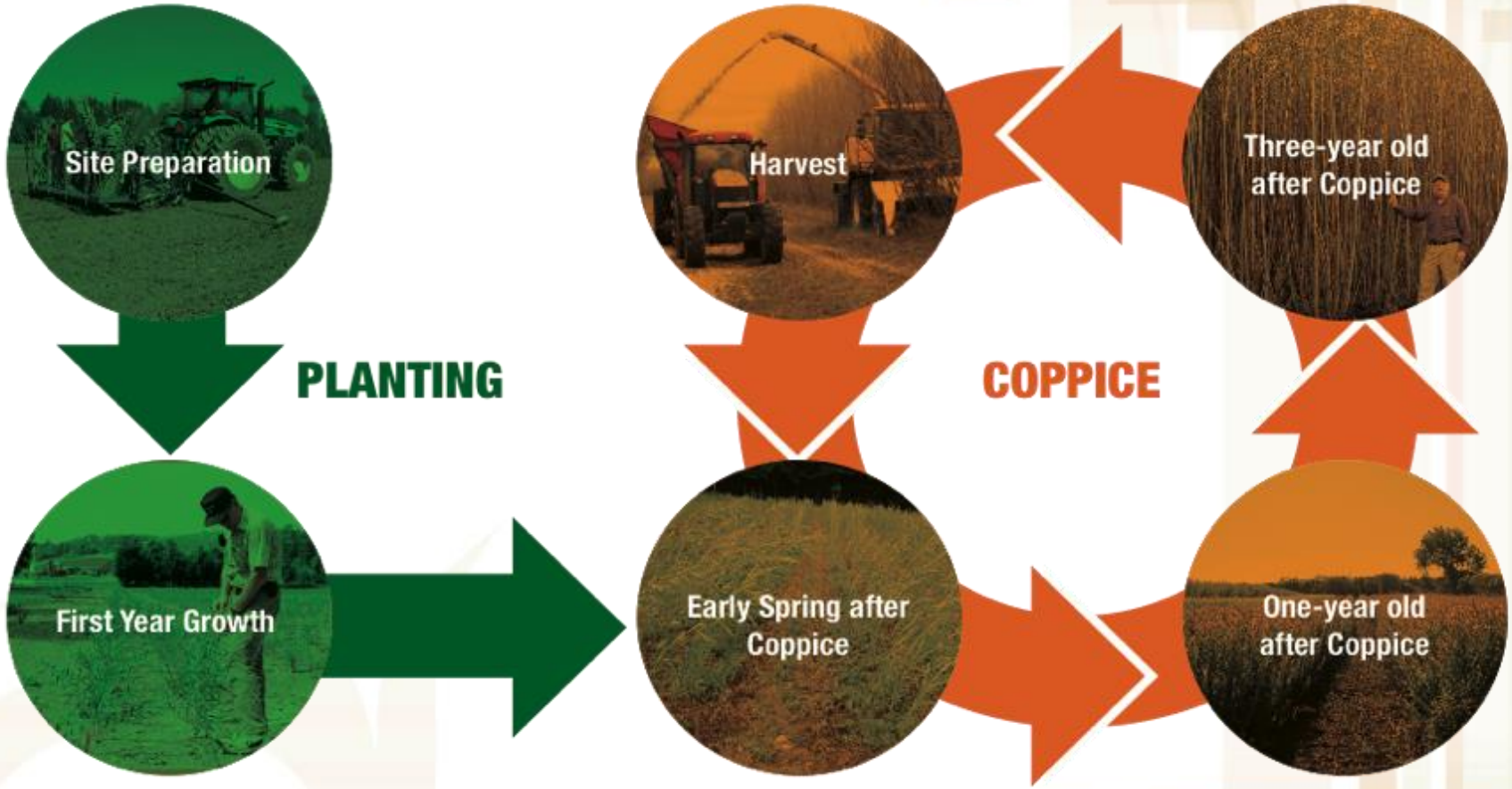
Willow Biomass Production Cycle



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Willow Yield Projections

- Two different factors needed to project willow biomass yields, both of which this project is providing from the network of trials:
  - Changes in production over multiple rotations from trials planted in 1990s
  - Improvements in production with new willow varieties across a range of sites
- Combine the two sets of data to project yield estimates for willow biomass crops

Three year old willow trial in Middlebury, VT prior to harvesting.

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Willow Yield Projections

- Changes over multiple rotations
  - Data of commercially available varieties across 5 rotations shows yield increases 21.6% from 1st to 2nd rotation and 30.8% from 1st to 4th rotation
- Improvements with new willow varieties
  - 13.9% for best three varieties compared to reference varieties
- Combine the two sets of data to project yield estimates for willow biomass crops

Harvesting willow from long term trial in Tully, NY

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Willow Yield Projections

Importance of Improved Varieties and Long Term Data

	Mean Yield from First Rotation in New Yield Trials	Mean Yield Over 7 Rotations Only Using Increase from 1st – 2nd Rotations	Mean Yield Over 7 Rotations with Increase from 1st – 2nd and 1st – 4th Rotations
		(odt ha^{-1} yr^{-1})	
Top variety	17.2	18.6	21.4
Top 3 varieties	11.8	14.1	14.7
Top 5 varieties	11.2	13.4	13.9
Top 3 New varieties	11.5	13.8	14.3

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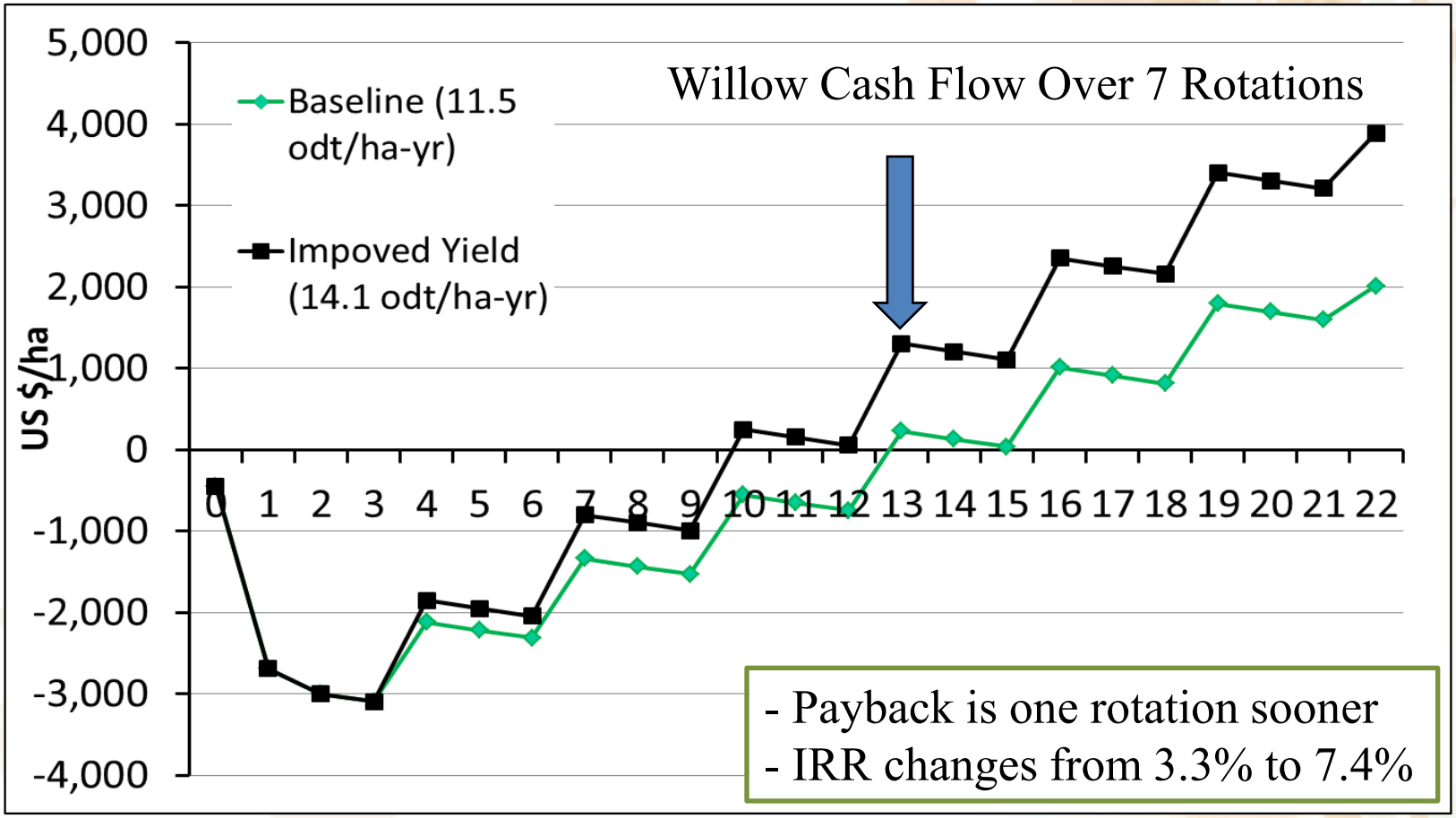
Willow Yield Impacts



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Willow Field Trial Network – Benchmark to BTR2

- Baseline yield is 11.5 odt ha^{-1} yr^{-1} (5.1 odt ac^{-1} yr^{-1})
  - Baseline yield (1% growth rate) in 2030 is 13.7 odt ha^{-1} yr^{-1} (6.1 odt ac^{-1} yr^{-1})
  - Current projections of 14.1 odt ha^{-1} yr^{-1} with new varieties has exceeded the base case 2030 projection
- High yield scenarios
  - Current yield estimates match 2022 projections for 2% growth and 2017 for 4% growth

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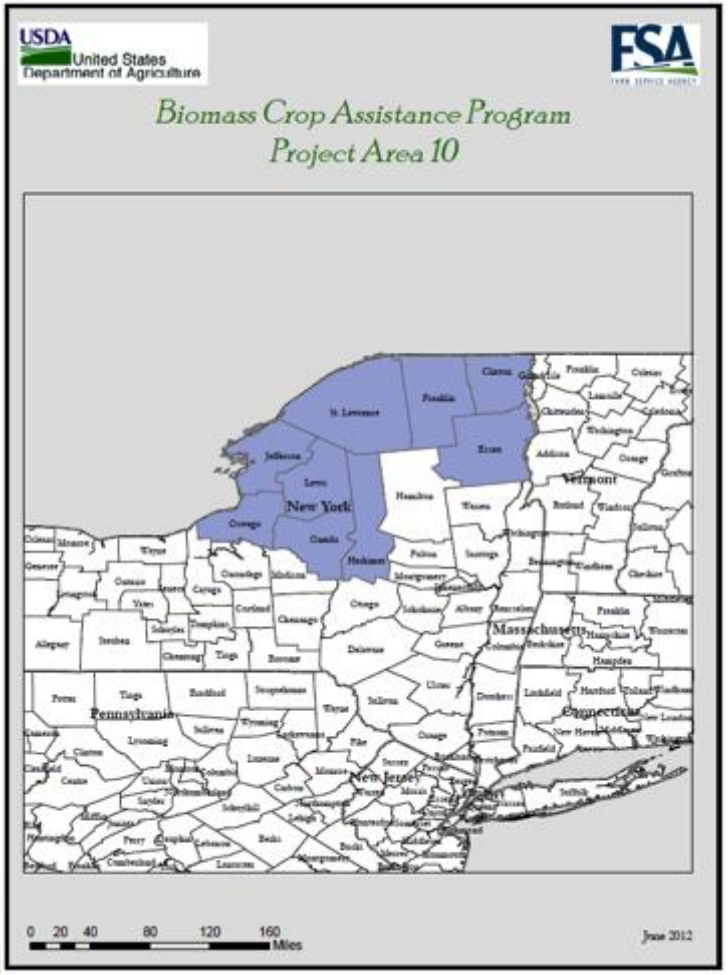
Willow Field Trial Network – USDA BCAP



- Data from Sun Grant trials provided essential information for landowners, investors and USDA
- Almost 1,200 acres enrolled with over $1.2 million allocated for landowners
- Yield trial data is the basis for variety recommendations for willow expansion
- 2 year outreach project supported by NYSERDA

FSA BIOMASS CROP ASSISTANCE PROGRAM

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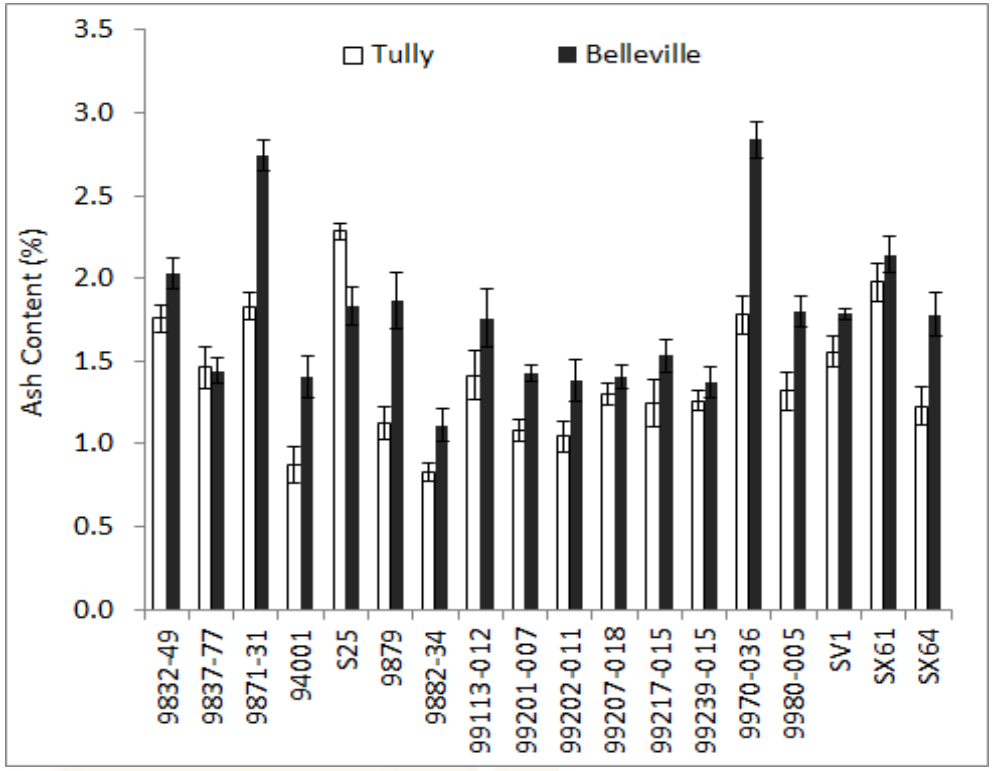
Willow – Chemical Analysis



- Stem nutrient analysis completed for a range of willow varieties in different trials
- Generally differences found among varieties and across sites
  - Ash: 0.9 – 2.8%, with most varieties <2%
  - N: 0.2 – 0.5%
  - P: 496 – 703 mg/kg

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Poplar – Chemical Analysis

% Chemical Composition of Hybrid Poplar

sample	Cellulose	Hemicellulose	Lignin	Ash	Extractives
1	42.53 (0.50)	18.17 (0.11)	27.79 (0.24)	1.06 (0.04)	6.22 (0.14)
2	43.41 (0.07)	16.86 (0.07)	28.12 (0.38)	1.15 (0.07)	5.31 (0.11)
3	44.45 (0.12)	17.31 (0.17)	27.95 (0.14)	0.78 (0.02)	5.25 (0.04)
4	44.44 (0.24)	17.71 (0.06)	28.25 (0.06)	0.84 (0.02)	5.15 (0.08)
5	44.27 (0.24)	20.19 (0.13)	25.76 (0.23)	1.11 (0.03)	3.92 (0.03)
6	42.45 (0.13)	17.70 (0.14)	28.86 (0.30)	0.81 (0.03)	4.43 (0.00)
7	42.58 (0.18)	18.47 (0.14)	28.49 (0.36)	1.12 (0.02)	4.22 (0.08)
8	44.60 (0.29)	17.88 (0.17)	29.40 (0.35)	1.24 (0.04)	4.44 (0.05)
9	46.04 (0.24)	18.12 (0.16)	27.43 (0.10)	0.90 (0.05)	4.82 (0.09)
10	47.17 (0.39)	17.65 (0.31)	27.51 (0.23)	0.82 (0.04)	4.03 (0.05)
11	44.14 (0.18)	17.68 (0.09)	28.65 (0.12)	1.03 (0.01)	4.42 (0.03)
12	44.76 (0.51)	18.37 (0.14)	29.25 (0.26)	1.45 (0.00)	4.19 (0.01)
13	43.39 (0.23)	17.32 (0.07)	27.32 (0.23)	0.87 (0.01)	6.18 (0.08)

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Poplar Py-GC/MS Analysis Data

Samples were pyrolyzed at 450°C for 12 seconds. Lignin content, %S, %G, %H and S/G ratio were calculated based on the Py-GC/MS data.

Sample	Py-GC/MS Analysis data					Lignin content by wet chemistry
	% Lignin	%S	%G	%H	S/G	
D109	25.8 (0.5)	19.1 (0.33)	4.7 (0.2)	1.97 (0.16)	4.03 (0.15)	25.76
D945	28.1 (0.8)	17.9 (1.3)	7.1 (1.2)	3.1 (0.3)	2.6 (0.6)	29.4
DN2	27.6 (0.7)	17.8 (0.4)	6.4 (0.4)	3.4 (0.2)	2.8 (0.1)	27.51

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Woody Crops Team – Next Steps

- Measure trial network and submit KDF uploads
- Develop regional production maps
- Determine chemical composition for INL database

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 enables 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.
- Chemical information is supplementing yield data to add more value and populate the INL database.

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Questions

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Response to Reviewers' Comments

Reviewer Comment: The short rotation woody crops, poplar and willow, are led by northern universities while the potential for wood crops is more in the SE. Why is this so?

Presenter Response: A diversity of feedstocks for all areas is in the best interest of the overall program due to significant differences in feedstock harvest timing, logistics and chemical characteristics. We have begun a more comprehensive breeding program using the considerable genetic resources of the collective Sun Grant poplar group to expand the range of climatic adaptability of poplar hybrids to a wider region with particular emphasis on creation of hybrids of southerly-derived cottonwood crossed with other species with the aim to create new hybrid clones adapted to more southerly regions. The large collections of cottonwood clones available at Stoneville, MS and in the Mid-South are being used as a base for these crosses. Crosses of southern P. deltoides X nigra are currently underway in our facilities in Minnesota. Seed arising from these crosses will be distributed to the southern partners (Mississippi State and ArborGen) for field testing. While the work is being coordinated in the north, strong partners across the country are contributing expertise targeted to their specific regional experience. In part, the leadership of the northern universities reflects the strong breeding programs and extensive history that they have in the genetics of poplar, and willow.

Response to Reviewers' Comments

Reviewer Comment: During Q&A the presenters commented that aspen, a species that is not included in their work, is likely to be better for use in Tennessee than the poplar or willow they chose to include. Presenters did not offer any suggestion that aspen would be added in response to industry siting of conversion facilities. This raises a question about how species are chosen by researchers with or without consideration of the siting of early biorefineries.

Presenter Response: Our consideration of aspen has been limited at this time because aspen must be propagated by root cuttings (clonal) or through seed (not clonal). This limits the ability for rapid yield improvement versus clonal propagation and increases establishment costs of aspen plant material. It is being evaluated at a site in east Tennessee through another program.

Response to Reviewers' Comments

Reviewer Comment: How many years to establish steady state yields? How will they make estimates on what these yields before the project ends?

Presenter Response: Through research done on closed-canopy plantations over the years, we have developed an understanding of yield curves and expected annual increments (in terms of stand basal area and biomass) through time. Once canopy closure occurs, annual increments are generally stable and can be used as an indicator of ultimate realized total yield. As a result, we are able to understand the significance of yield improvement using new clones by comparing the early-rotation growth patterns of new field tests to growth curves of long-term yield tests using currently available commercial hybrids. For example, stand basal area targets (a metric linearly related to aboveground biomass) are well established in the Midwest and Pacific Northwest. We can use these data to determine the relative gain in yield in new yield studies and estimate the likely yield and final harvest.

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Response to Reviewers' Comments

Reviewer Comment: No tech transfer mentioned. How will they transfer the results to producers or forest industry companies?

Presenter Response: The program, particularly the poplar team, has industrial practitioners (GreenWood Resources, Verso Paper, ArboGen) as project cooperators or actual team members (in the case of GWR in the Pacific Northwest and ArborGen). This provides a valuable direct link to practitioners through the network of forest products companies and energy concerns. Also, we have recently published a paper describing the commercial poplar programs in the U.S. and the research history associated with these programs as part of the national Soil and Water Conservation Society's meeting. This paper is entitled "Commercial Development of Poplar in the United States" describing the program history, biomass yields, economics and future research direction in the Pacific Northwest and Lakes States was written and will be published as part of the "Sustainable Feedstocks for Advanced Biofuels Workshop" proceedings recently held in Atlanta, GA. Tech transfer is occurring through participation at extension meetings in the South (Mississippi State) and field tours in the Midwest (Minnesota). An important technology transfer effort is through the SRWCOWG's conference, which was held at Knoxville in 2012. Also, as new data begins to flow from the RFP trials we will develop manuscripts for publication, as well.

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Publications

- Abrahamson, L.P., Castellano, P., Lewis, A., McArdle, M., Posselius, J., Shuren, R., Stanton, B., Summers, B., Volk, T.A. (2012). Development and Deployment of a Short Rotation Woody Crops Harvesting System Based on a New Holland Forage Harvester and SRC Woody Crop Header. Proceedings from Sun Grant National Conference: Science for Biomass Feedstock Production and Utilization, New Orleans, LA.
- 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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- Gouker, F. E., Serapiglia, M. J., Town, C. D., Tang, H., Buckler, E. S., Elshire, R. J., Mitchell, S. E., DiFazio, S., Rodgers-Melnick, E., Tuskan, G. A., Carlson, J.E., Miller, R. O., Volk, T. A., Fabio E. S. (2012). Development of Genomic Resources and Novel Species Hybrids for the Genetic Improvement of Shrub Willow Feedstock Crops. Proceedings from Sun Grant National Conference: Science for Biomass Feedstock Production and Utilization, New Orleans, LA.
- 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.
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Publications

- Volk, T.A., Briggs, R. D., Abrahamson, L. P., Fabio E. S. (2012). *Soil Respiration in Shrub Willow Biomass Crops Along a 21-Year Chronosequence as Affected by Continuous Production and Crop Removal (Tear-Out)*. Proceedings from Sun Grant National Conference: Science for Biomass Feedstock Production and Utilization, New Orleans, LA.
- Volk, T.A., M.A. Buford, B. Berguson, J.Caputo, J.Eaton, J.H. Perdue, T.G. Rials, D. Riemenschneider, B. Stanton, and J.A. Stanturf. 2011. Woody Feedstocks – Management and Regional Differences. In: Sustainable Alternative Feedstock Opportunities, Challenges and Roadmap for 6 U.S. Regions. Soil and Water Conservation Society, pp 210-141.
- 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.*
- Volk, T.A., *et. al.* 2011. Yields of willow biomass crops across a range of sites in North America. From the proceedings of Biomass and Energy Crops IV conference. IN: Aspects of Applied Biology 112:67-74.

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Presentations

- Volk, T.A. Willow biomass crops for bioproducts and bioenergy. TAPPI, Atlanta, GA March 14 – 16, 2011.
- Volk, T.A. and R. Miller. 2011. Willow biomass crop feedstock development. Sun Grant/DOE Regional Feedstock Partnership meeting, Knoxville, TN, Feb. 15 – 17. 2011
- Rials, T. and T. A. Volk. 2011. Sun Grant/DOE Feedstock Development Partnership – Woody Crops. DOE Feedstock Peer Review meeting, April 7-8, 2011, Annapolis, MD.
- Rials, T. and T. A. Volk. 2011. Sun Grant/DOE Feedstock Development Partnership – Woody Crops. DOE Feedstock Peer Review meeting, April 7-8, 2011, Annapolis, MD.
- Volk, T.A. 2011. Biomass Energy. Advanced Training Workshops in Alternative Energy. SUNY – ESF, August 16, 2011, Tully, NY .
- Volk, T.A. 2011. Short rotation woody crops for energy in the Northeast. Northeast Wood Energy Webinar Series, Pennsylvania State University, August 26, 2011.
- Volk, T.A, M. Buford, B. Berguson, J. Caputo, J. Eaton, J. Perdue, T. Rials, D. Riemenschneider, B. Stanton, J. Stanturf, B. Stokes. 2011. Sources of Woody Biomass. EPA Workshop on Biofuels and the Environment, November 29 – Dec. 1, 2011, Washington, DC. .
- Volk, T.A. 2011. Development of short rotation woody crops for the Northeast U.S. Binghamton University, November 28, 2011.
- Volk, T.A. 2012. The potential for woody biomass for biofuels, bioenergy and bioproducts. Biotechnology Symposium, Syracuse, NY, May 21-22, 2011.
- Volk, T.A. 2012. The current state of bioenergy. Bioenergy Opportunities in Upstate NY. Dryden, NY, April 27, 2012.
- Volk, T.A. 2012. Woody biomass as a source of renewable energy. Energy Innovation Day. SUNY Binghamton, Vestal, NY, April 17, 2011.
- Miller, R.O. 2011. Woody Biomass Production Systems for the Upper Great Lakes Region of the United States. AT: International Conference on Response of Forests and Adaptation Management to Climate Change. Yichun, Heilongjiang, China. August 9, 2011.

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Presentations

- Miller, R.O. and B.A. Bender. 2011. Spacing Effects on Stand Development and Tree Growth of Seven Hybrid Poplar Clones After Four Years in a Replicated Trial in Escanaba, Michigan. IN: Poplars & Willows on the Prairies, Joint Conference of the Poplar Council of Canada, the International Poplar Commission, and the Poplar Council of the United States. Edmonton, Alberta, Canada. September 18, 2011.
- Volk, T.A., L.P. Abrahamson and M. Kelleher. 2012. Developing willow biomass crops as a source of home grown energy. International District Energy Association Meeting, Chicago, NY, June 29 – July 2.
- Volk, T.A. 2012. Willow biomass crop production. Training for USDA FSA and NRCS staff for the Biomass Crop Assistance Program willow biomass project. Watertown, NY, July 9, 2012.
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- Carlson, J.E., J.R. Herr, A. Kemanian, S. DiFazio, T. Volk, M. Jacobson, R.O. Miller, L. Smart. Studying the effects on woody biomass productivity of genotype by environment interactions. 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. 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.
- Eisenbies, M.H., L.P. Abrahamson, P. Castellano, C. Foster, M. McArdle, J. Posselius, R. Shurn, B. Stanford, B. Summers, T.A. Volk, J. Zerpa. 2012. Development and deployment of a short-rotation woody crop harvesting system based on a New Holland forage harvester and SRC woody crop header. Sun Grant Initiative National Conference, New Orleans, October 2 – 5.
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- Keathley, D., R. Miller, and P. Bloese 2012. Initial willow biomass yield trial results for Michigan. IN PRESS. Presented at the Sun Grant Initiative 2012 National Conference, New Orleans, LA, October 2, 2012.
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