



# Regional Feedstock Partnership: Woody Crops

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Feedstock Supply and Logistics

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The University of Tennessee

- 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



## Woody Resources

*Sun Grant Lead:* The University of Tennessee

*Agency Lead:* ORNL;  
Department of Agriculture

# Management Approach

## Willow Development Team



**Tim Volk, Lead**  
**SUNY-ESF**

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

Collaborators: Belleville Henderson Central School, Celtic Energy Farms, Double A Willow, Middlebury College, SUNY Potsdam, University of Illinois, University of Minnesota SROC, USDA NRCS Big Flats

## Poplar Development Team



**Bill Berguson, Lead**  
**UMN, NRRI**

Mike Cunningham – ArborGen, Inc.  
Randy Rousseau – Miss. State University  
Brian Stanton/Rich Shuren – Greenwood Res.  
Bernard McMahon – UMN, NRRI

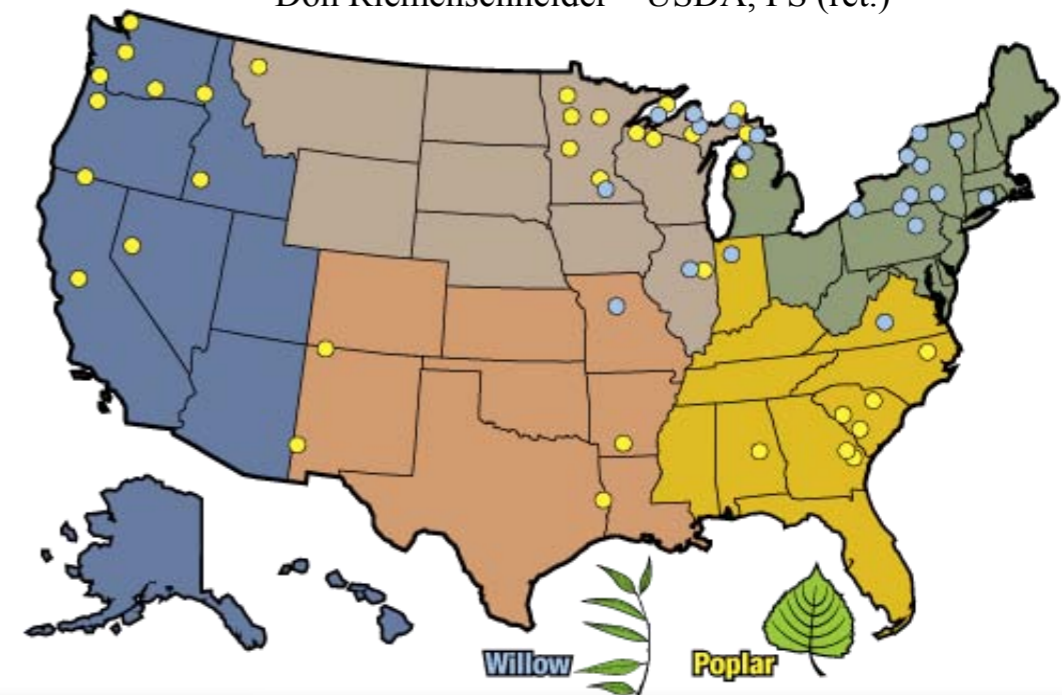
## Advisory Team



Bryce Stokes – CNJV, LLC  
Marilyn Buford – USDA, Forest Service  
Jim Perdue – USDA, FS – Southern Res. Station  
Don Riemenschneider – USDA, FS (ret.)

**68 Total Sites**

- 🌱 Genetics tests
- 🌱 Yield trials
- 🌱 Nurseries



# Technical 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

## Crop Development



- Woody crops (poplar & willow) offer significant genetic variation to draw on for advancement
- Presents the prospect of tailoring crops for optimal conversion

## Sustainable Production



- Woody crops fulfill the need for a portfolio of feedstock sources to:
- 1) Minimize supply chain disruptions
  - 2) Diversify the landscape, and
  - 3) Maximize ecological and environmental benefits

## Harvest Systems



- Woody crops provide material for diverse markets
- Flex management targets the range of landowner interests and objectives

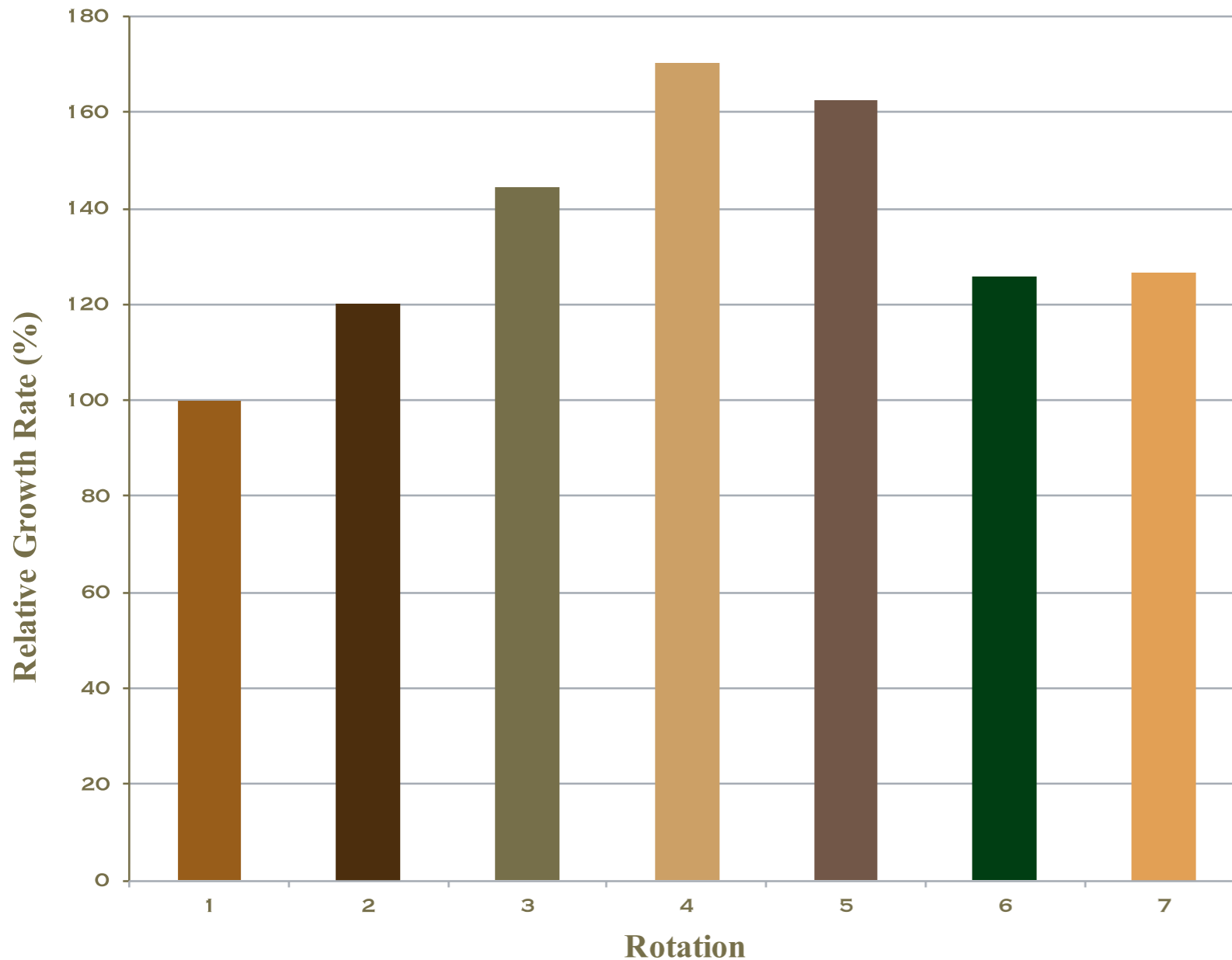
## Supply & Logistics



- Woody crops provide an important approach to address annual supply issues
- The supply chain infrastructure is in place due to FPI



# Longest Continuous Trial in U.S.



- First U.S. willow trial to be harvested over seven rotations
- Relative growth rate of top cultivars ranged from 120 – 170%
  - Across all cultivars it was 104% to 129%
- Provides data to support assumption of long term productivity of willow systems

*Relative growth rate of willow cultivar SV1 over 7 rotations. First rotation yield is baseline for relative growth calculations.*

## Willow Cultivars in Trials

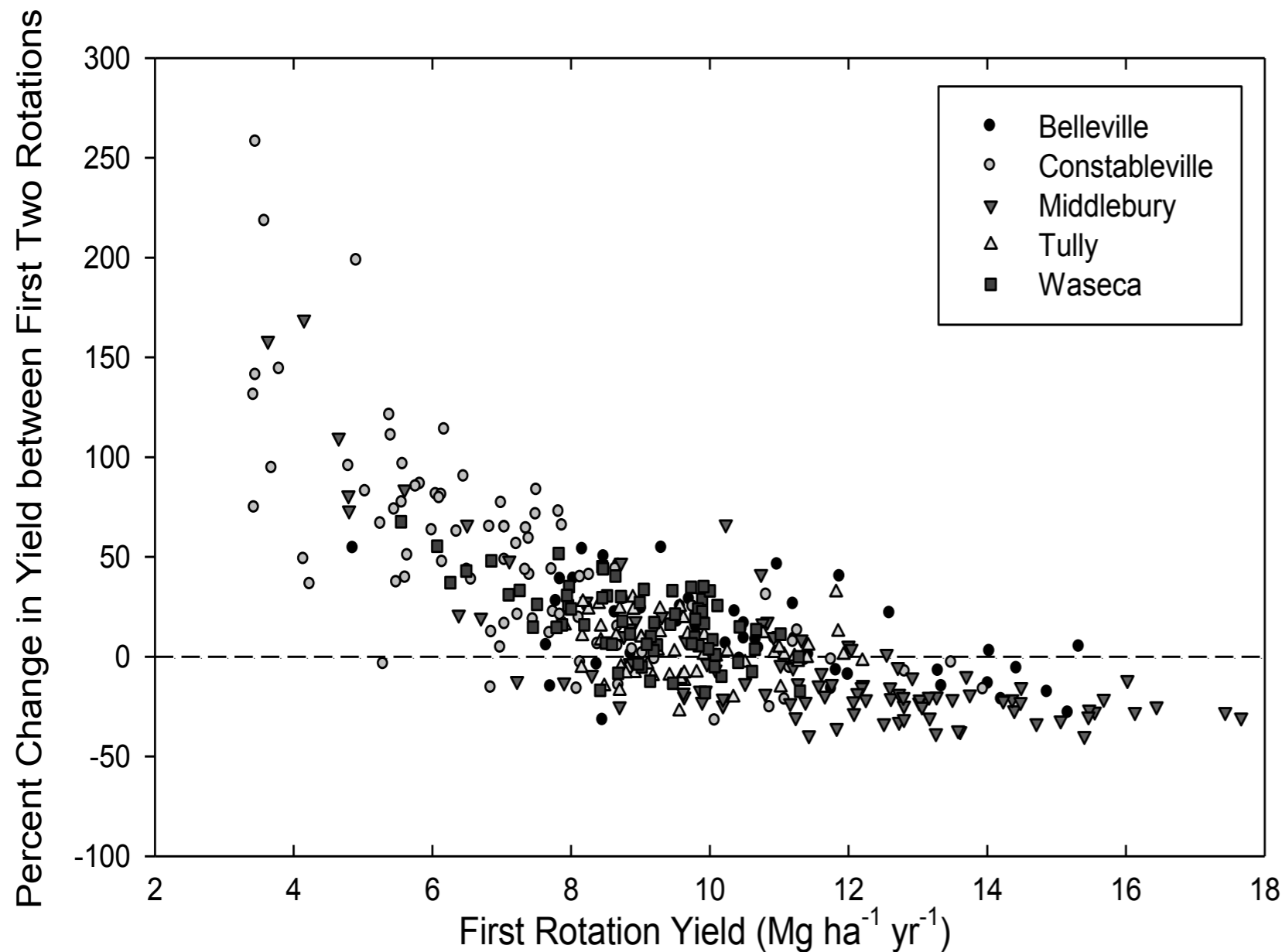
- Trials established in 2005 and beyond include cultivars developed in breeding programs in NY
- For top five cultivars survival of new material was 16.3% greater and yield was 34% higher
- Picture to right is 3-year old prior to harvesting



## Changes in Yield Over Time

- Continuous funding provided the first set of multiple rotation data for new cultivars
  - Across 5 sites for both two (Sleight et al. 2016) and three rotations (Sleight and Volk 2016)
- Revealed important patterns about long term yields
  - High yield cultivars have smaller increase from 1<sup>st</sup> to 2<sup>nd</sup> rotation
  - Yields of good cultivars are high and consistent over three rotations
- Changes in yield from 1<sup>st</sup> to 2<sup>nd</sup> and subsequent rotations are crucial to modelling yields, LCA, and economic projections

# Changes in Yield: 1<sup>st</sup> to 2<sup>nd</sup> Rotation



*Percent change in yield from first to second rotation based on first rotation yield across willow plots at five sites (Sleight et al. 2016)*

- Changes in yield are not consistent across the range first rotation yields but can be ~200% (Miller 2016)
- Models developed to predict 2<sup>nd</sup> rotation yield using 1<sup>st</sup> rotation yield and site factors has  $R^2=0.69$  (Sleight et al. 2016)
- Essential to understand for economic and environmental impact analysis



# Yield Over Three Rotations

**a**

Belleville				
Rank	Yield after 1 rotation		Yield after 3 rotations	
	Cultivar	Mg ha <sup>-1</sup> yr <sup>-1</sup>	Cultivar	Mg ha <sup>-1</sup> yr <sup>-1</sup>
1	Fish Creek	14.5	Fish Creek	13.1
2	SV1	13.6	SV1	12.6
3	Onondaga	13.2	Millbrook	12.6
4	94001	12.3	SX61	12.4
5	Millbrook	12.0	Oneida	11.9
6	Oneida	11.5	Onondaga	11.9
7	SX61	11.4	Canastota	11.6
8	Owasco	10.6	Oneonta	11.5
9	Canastota	10.6	94001	11.4
10	Allegany	10.3	Tully Champion	11.2
11	Tully Champion	10.1	Owasco	11.1
12	Oneonta	10.0	SX64	11.0
13	SX64	9.8	Allegany	10.4
14	Otisco	9.7	Otisco	9.4
15	Sherburne	9.1	Sherburne	9.3
16	9837-77	9.0	9837-77	7.9
17	S25	8.6	S25	7.4
18	9832-49	6.8	9832-49	5.0

Spearman rank correlation coefficient = 0.91

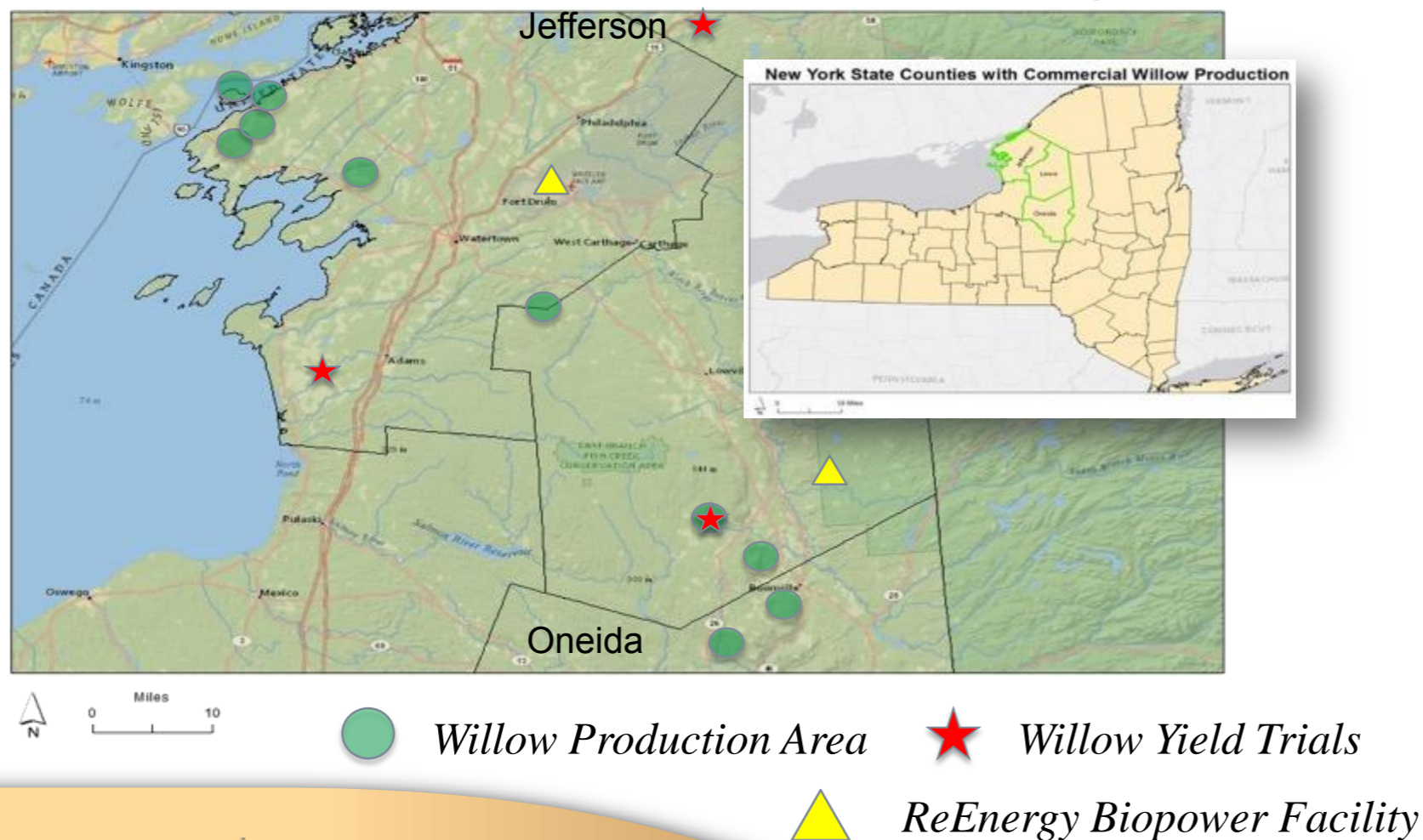
- Top five cultivars varied by site and from 1<sup>st</sup> to 3<sup>rd</sup> rotation
- Selections after 3<sup>rd</sup> rotation from the same site gave highest yields
- Picking cultivars from the 1<sup>st</sup> rotation from a different site reduced yield by 11 – 14% and NPV by 18 – 50% over 22 years
- In MI selecting site specific cultivars increased biomass by 2 – 13% and picking cultivars from a distant site reduced biomass by up to 27% (Miller 2016)

*Changes in ranking of 18 willow cultivars over two rotations in Belleville, NY (Sleight and Volk 2016)*

# Impact of Willow Yield Trials

- Best cultivars are licensed to commercial nursery in NY (Double A Willow) for large scale production
- Data used to patent one new willow variety in U.S. and plant breeders rights in Europe and Canada
- Trial data incorporated into national yield map and recently released version of EcoWillow model used for economic analysis

## Northern New York Willow Biomass Production and Biopower



Double  Willow

# Willow in Northern NY

- >7,200 tons of willow chips delivered
- Willow found to be suitable fuel in terms of moisture and ash content, now incorporated with other feedstocks
- Existing willow acreage will produce roughly 9,000 – 11,000 Mg<sub>wet</sub> of feedstock annually



- Yield trials have been used extensively for outreach and education events
  - Continue to be used as sites for these activities
- High school and college students have used sites for classes and experiments
- Series of fact sheets and research summaries have been created ([www.esf.edu/willow](http://www.esf.edu/willow))



# Poplar Field Trial Network

## **Clone Screening**

- Evaluation of existing clones from each region to determine variation in growth rate and disease resistance

## **Genetic Improvement/Breeding**

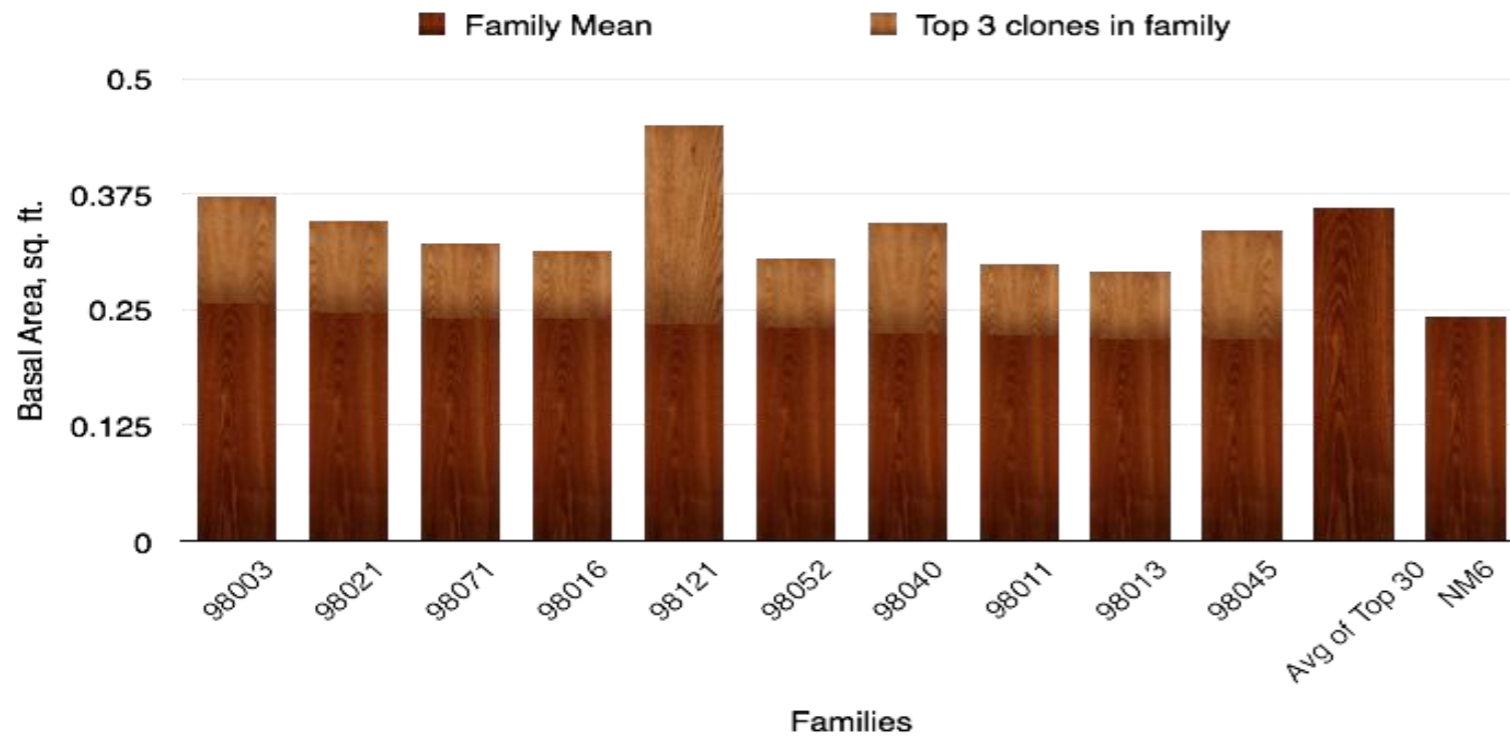
- Using unique resources of the Poplar Team, develop new hybrid and pure-species clones for future testing and commercial deployment

## **Yield Analysis**

- Under conditions resembling commercial plantations, evaluate long-term production of poplar using currently-available genetics

# Clone Test in Minnesota – Age 10

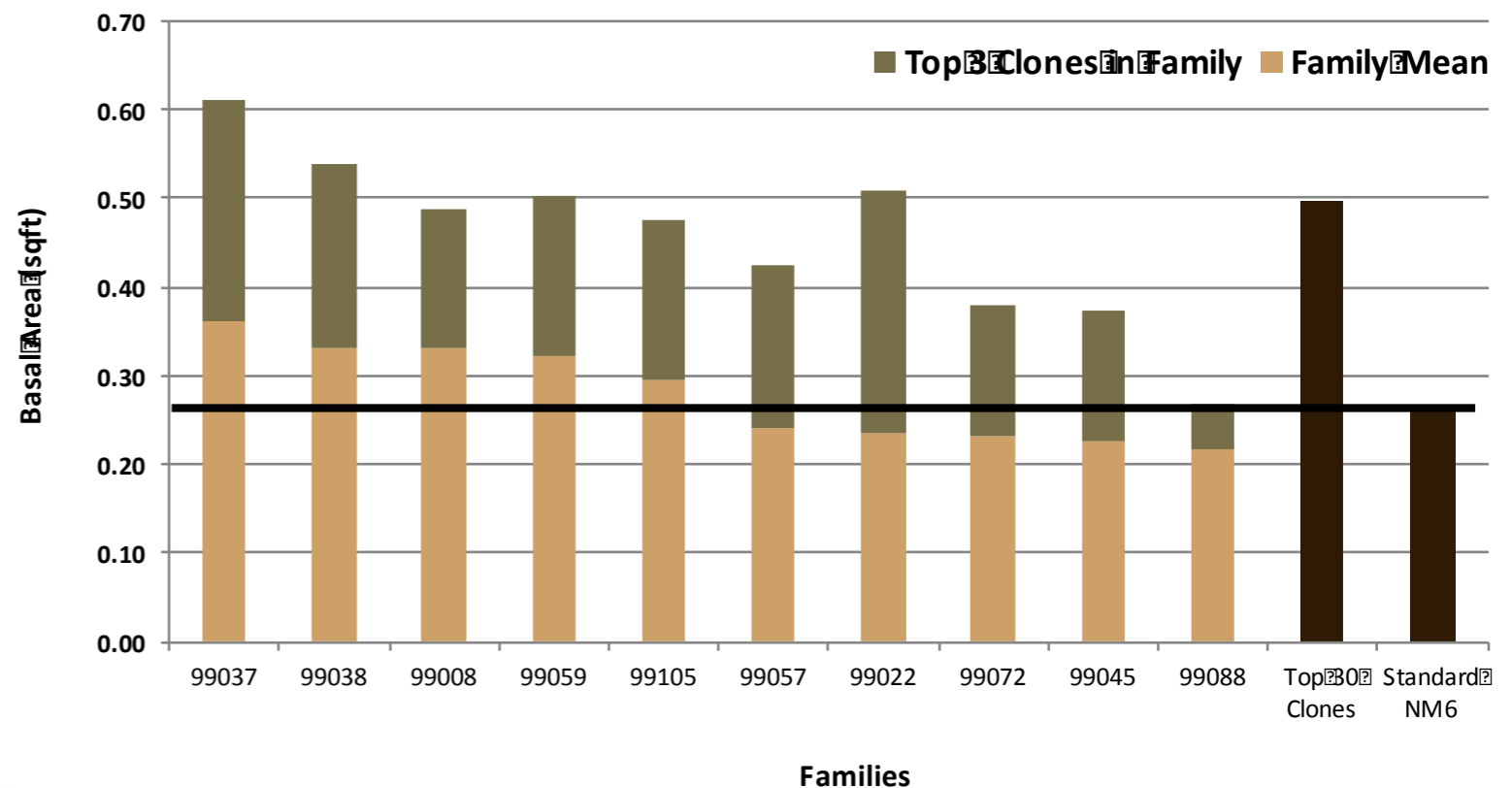
**Woelfel Family Field Trial - 10 Years Growth**  
**Top Ten families Compared to NM6**



- 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

- Largest network of field tests including clone test and biomass yield studies in US

**Sturgis Family Field Trial - 10 Years Growth**  
**Top Ten Families Compared to NM6**



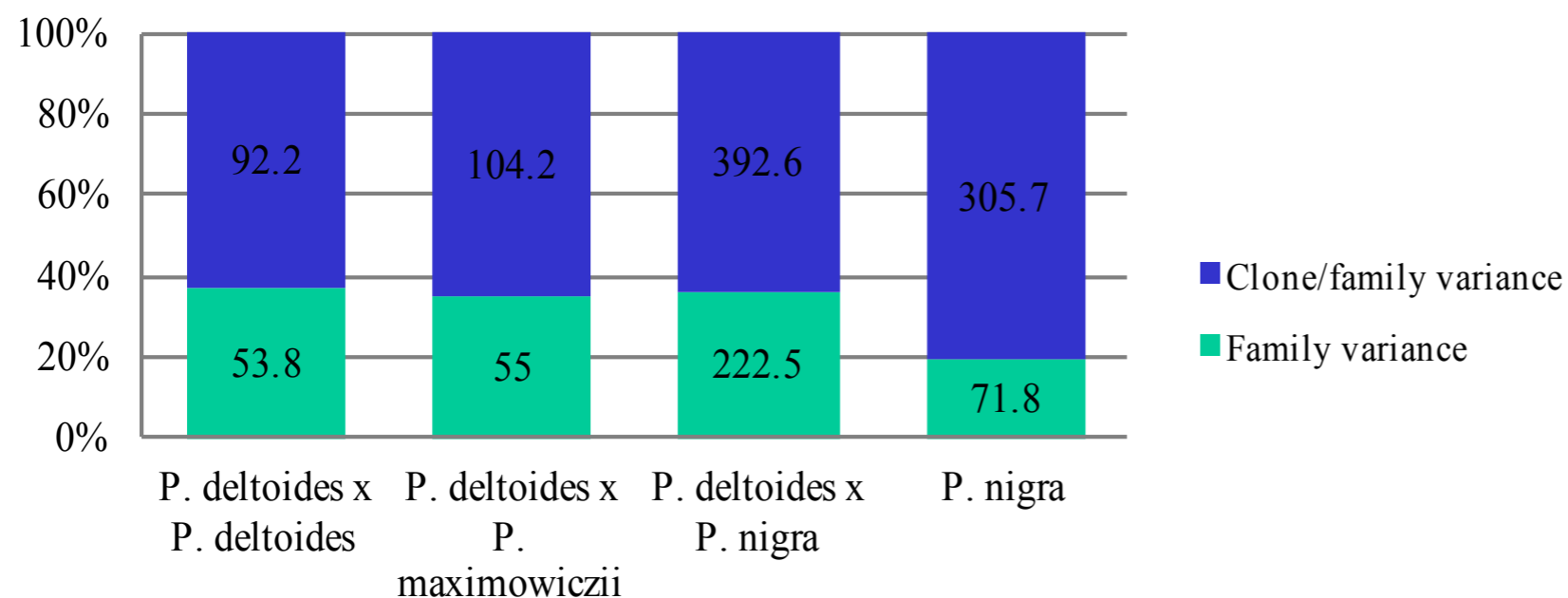
# Partnership Poplar Breeding

- Can we exceed the yield of commercial standards while maintaining disease resistance?
- Can we increase genetic diversity while maintaining growth rate?
- What is the long-term potential to increase volume growth with successive cycles?
- What is the most productive breeding design for long term success?
- Results:
  - Produced over 10,000 new genotypes as a source for future clone testing
  - Providing clones to cooperators



- Operation of our breeding program allowed heretofore impossible studies of inheritance and genetic effects in controlled-pollinated populations in “Family Field Tests”.
- Four sites, four taxa - *P. deltoides*, *P. deltoides* x *nigra*, *P. maximowiczii* and *P. nigra*.
- Typically 900 genotypes, 30 families with 30 clones within-family replicated three to five times per clone
- **Question: Why should anyone fund breeding? What is the expected gain and how do you get there?**

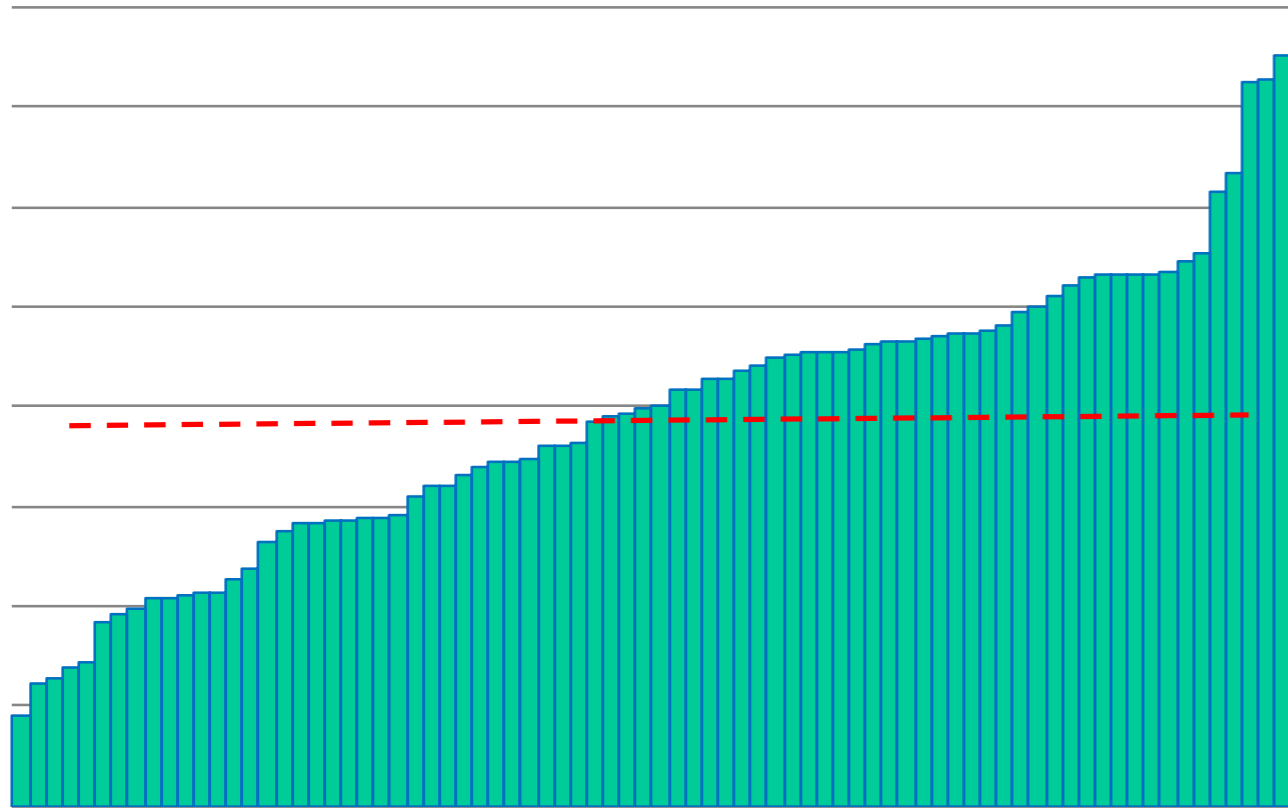
**Proportion of Total Genetic Variance by Component by Taxa**



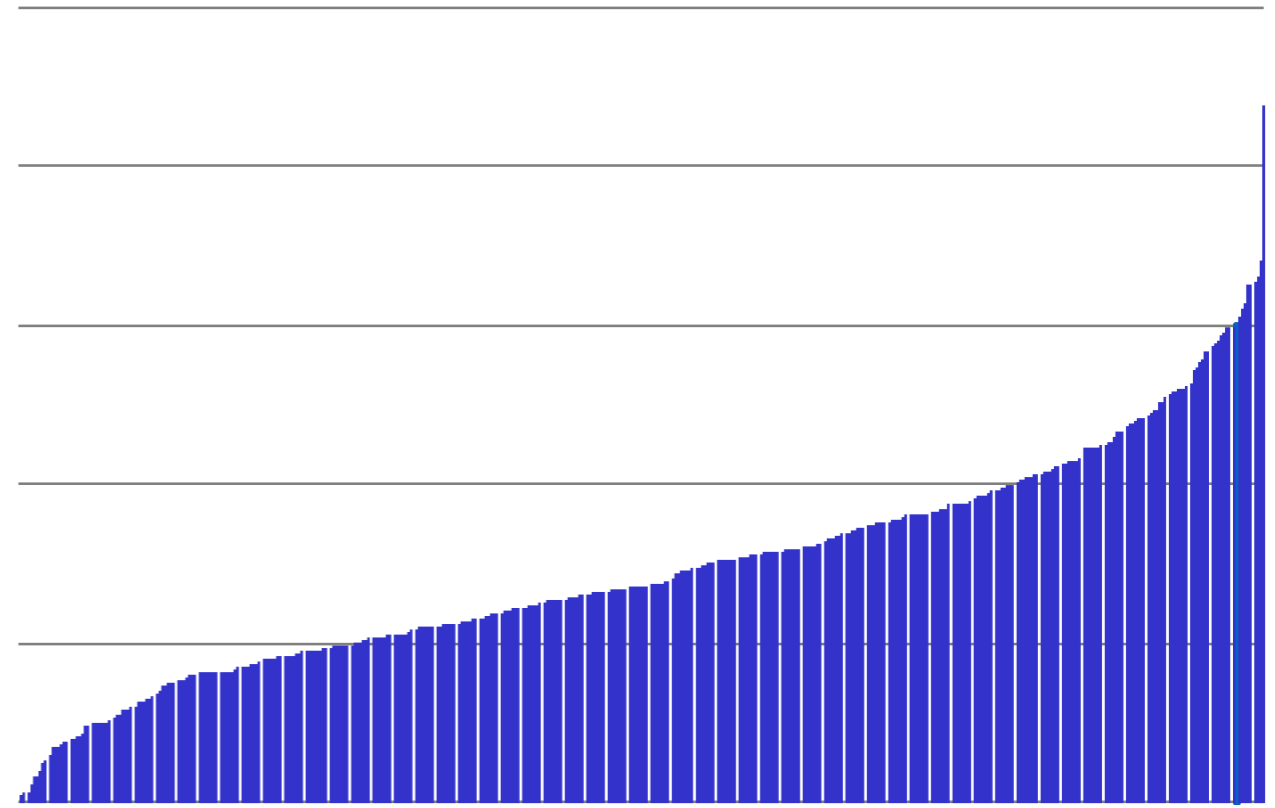
- Using a combination of genetic variance estimates, equations of genetic expectation and a realistic selection intensity:
- Long-term Yield Gain = 17.5 to 25.2% each generation by improvement of parents and crossing within improved parents



Volume distribution of *P. deltoides* collection at age five



Volume distribution of *P. nigra* collection at age five



- Given the high natural variation among native *P. deltoides* and *P. nigra* collections, selection of high-yielding parent will result in high differentiation and,
- Our new knowledge of additive genetic effects indicates that hybridization among elite genotypes will “carry over” thereby capturing yield gain with each generation



*Photo courtesy of Steve Thomas, DOE-BETO*

- New clones surpassing current commercial clone by a significant margin
- Yields in Midwest are is 3.5 to 5 tons acre<sup>-1</sup> yr<sup>-1</sup>
- Yield in Pacific Northwest, Mid-South and South – 4.5 to 6.5 tons acre<sup>-1</sup> yr<sup>-1</sup>
- Provided data to yield mapping effort

- Clone trials show that gains of 1.3 to 1.5 over current commercial hybrids possible
- Tests of *P. deltoides* and *P. nigra* clones in both Midwest and Mid-South show that DxN hybrids most likely the most productive and disease resistant
- *P. nigra* adaptability tests in Minnesota, Washington, Mississippi, South Carolina, Tennessee and Virginia
- No shortcuts in field testing – four years needed for initial selection plus additional monitoring in subsequent years
- Yields currently in the range of 3.5 to 7 tons acre<sup>-1</sup> yr<sup>-1</sup>
- Economics in the range of \$70 to \$90/dry ton delivered – within DOE target range
- Produced over 10,000 new genotypes as a source for future clone testing
- Developed a new understanding of genetic effects and most efficient design of future breeding programs