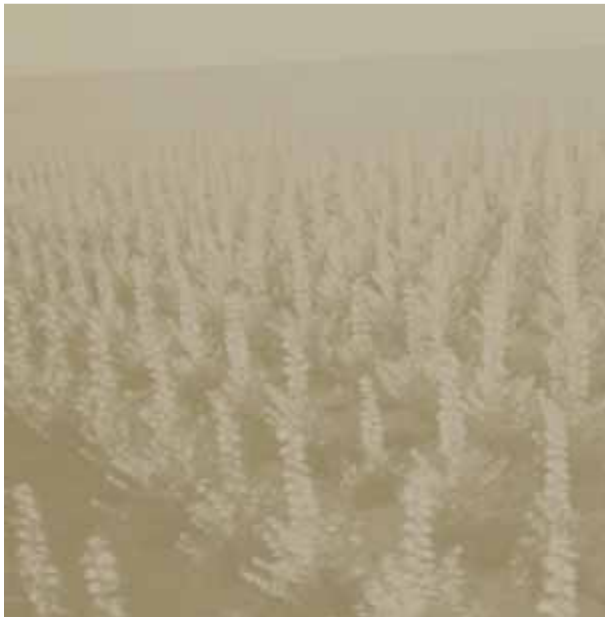


A Resource That Lasts Forever™



*Poplar Genetic Improvement:
Overview of Global Approaches and
Opportunities for Virginia*



**Brian J. Stanton
November 5, 2009**

Presentation Content



1. Domestication of the genus *Populus*
2. Scope of GreenWood tree improvement program
3. Global approaches to poplar improvement
4. GreenWood-VPI collaborative program
5. Conclusion and outlook



Populus Domestication



What is Hybrid Poplar ?



- **Genus *Populus***
 - 6 sections and 29 species from the northern hemisphere
 - Aspens, cottonwoods, poplars

- **Habitat**
 - Warm to cold temperate climates
 - Adapted to wetlands and uplands

- **Fastest growing tree in the temperate zone**
 - Acceleration phase of stand development can occur within three years of establishment
 - Mean annual increment of up to 40 cum/ha/yr

- **Unusual domestication strategy**
 - Bred as species hybrids
 - Managed as clonal varieties



Species Hybridization: Important species and taxa

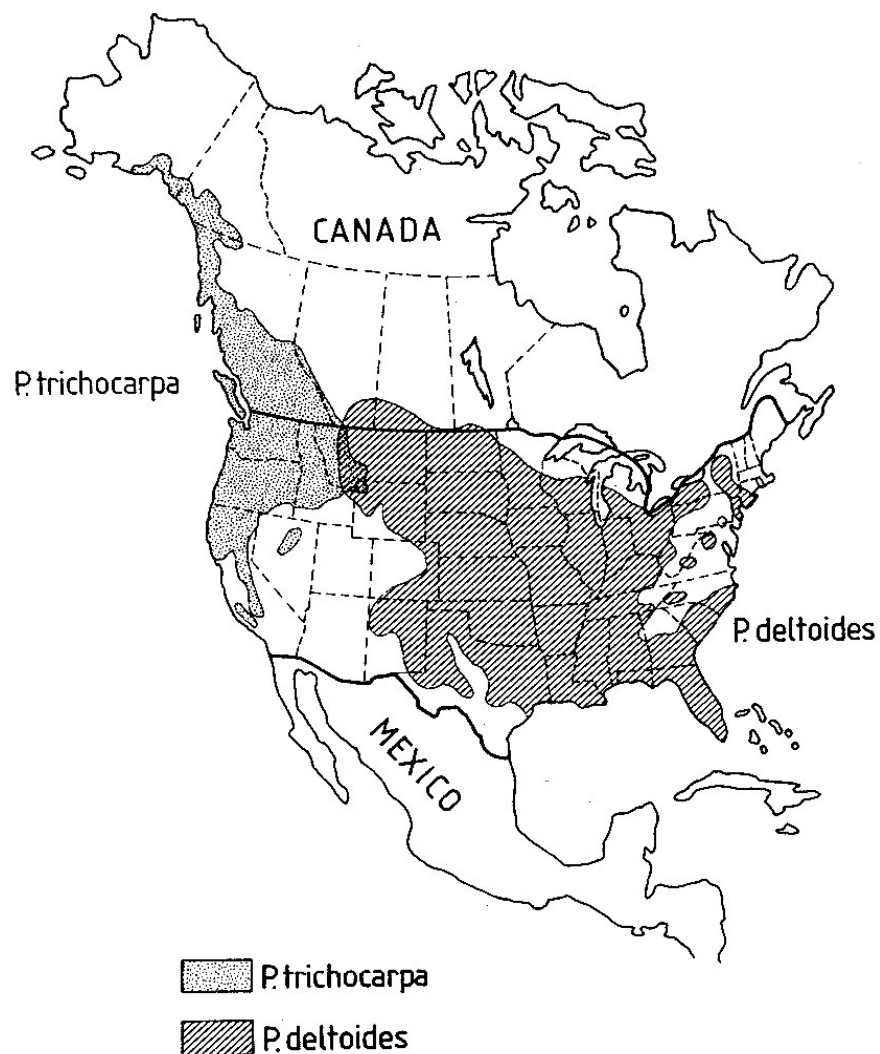


<i>Aigeiros</i> (cottonwoods)	<i>Tacamahaca</i> (balsam poplar)
<i>P. deltoides</i>	<i>P. maximowiczii</i>
<i>P. nigra</i>	<i>P. trichocarpa</i>

1. *P. ×canadensis*
2. *P. ×generosa*
3. *P. deltoides* × *P. maximowiczii*
4. *P. nigra* × *P. maximowiczii*
5. *P. deltoides* × *P. deltoides*



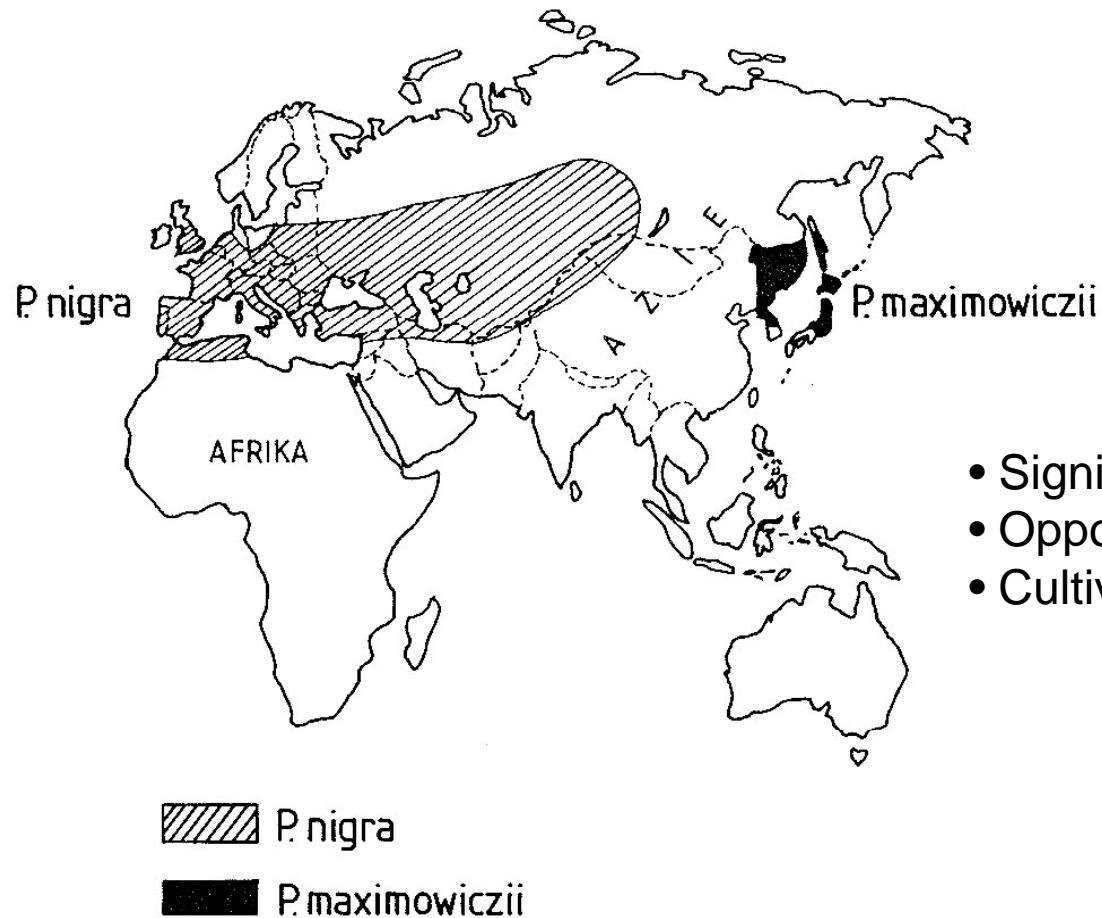
Key Species - Distribution



- Extensive geographic ranges
- Considerable genetic diversity
- High breeding potential



Key Species - Distribution



- Significant inter-species crossability
- Opportunity to combine desirable traits
- Cultivation of productive hybrid taxa

Regions and Hybrid Taxa



1. North Central:

- *P. ×canadensis*
- *P. deltoides* × *P. maximowiczii*
- *P. nigra* × *P. maximowiczii*

2. Pacific Northwest:

- *P. ×canadensis*
- *P. deltoides* × *P. maximowiczii*
- *P. ×generosa*

3. Southeast:

- *P. deltoides* × *P. deltoides*



North Central *P. nigra* × *P. maximowiczii* 'NM6'



Pacific Northwest *P. ×canadensis* 'OP-367'



Southeast

P. deltooides × *P. deltooides* 'WV-350'



Species Hybridization: Future Emphasis



<u><i>Tacamahaca</i></u> (balsam poplars)	<u><i>Populus</i></u> (aspens and white poplars)
<i>P. ciliata</i>	<i>P. alba</i>
<i>P. simonii</i>	<i>P. tremula</i>
<i>P. yunnanensis</i>	<i>P. tremuloides</i>

1. *P. deltoides* × *P. ciliata*
2. *P. deltoides* × *P. yunnanensis*
3. *P. deltoides* × *P. simonii*
4. *P.* × *canescens*
5. *P.* × *wettsteinii*



Poplar Hybridization Centers



1. GreenWood Resources

- *P. ×canadensis*, *P. ×generosa*, *P. deltoides* × *P. maximowiczii*
P. deltoides × *P. deltoides*

2. Natural Resource Research Institute

- *P. ×canadensis*, *P. nigra* × *P. maximowiczii*

3. Agriculture Canada

- *P. deltoides* × *P. simonii*, *P. ×petrowskyana*

4. Province of Quebec

- *P. ×jackii*, *P. maximowiczii* × *P. balsamifera*,

5. Western Boreal Aspen Cooperative

- *P. ×wettsteinii*



Geographic Scope of Tree Improvement Operations – Regional Taxa and Genetic Gains



Pacific Northwest: lower Columbia River Valley



- ***P. ×generosa***
- **2,500 hectares**
- **28-35 cu m
ha⁻¹ yr⁻¹**



Pacific Northwest: mid-Columbia River Basin



- *P. ×canadensis*
- 11,500 hectares
- 35-42 cu m
ha⁻¹ yr⁻¹



Southeast: lower Mississippi River Valley



- *P. deltoides* select varieties
- Nursery operations
- 21-28 cu m
ha⁻¹ yr⁻¹



Approaches to Poplar Improvement



Key Features in Poplar Improvement



I. F₁ Species Hybridization

- Main breeding approach worldwide above ~ 35 degrees of latitude.
- Combines the genomes of distinct species into a new hybrid variety.
- Hybrid vigor appears to be maximized in the F₁ generation.

II. Varietal Propagation

- Sole propagation method worldwide.
- Reproduction without sexual recombination.
- Faithful replication of genetic constitution within limits of environmental effects.



F₁ Species Hybridization – The Process



1st Stage - Parental Selection

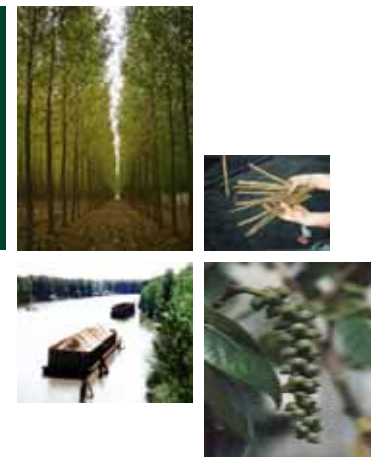


2nd Stage - Controlled Crossing



3rd Stage - Progeny Production

Prominence of F₁ hybridization: Hybrid Vigor



- *P. ×canadensis*:
 - increases of 75%¹ and 44%² in two-year-old stem volume.
- *P. ×generosa*:
 - increases of 50% in four-year-old stem volume³
- *P. ×wettsteinii*:
 - Increase of 90% in three-year-old stem volume⁴

[1] Dillen et al. 2009

[2] Marron and Ceulemans 2006

[3] Ceulemans et al. 1992

[4] Li et al. 1998

Components of an F₁ Hybridization Program



1. **Recurrent breeding** – Improvement of each parental species to increase the frequency of favorable alleles.
2. **Non-recurrent breeding** – Hybridization of the best parents designed to capture genetic gains achieved in recurrent breeding programs.



Varietal Propagation – The Process



**1st Stage -
Seedling Selection**



**2nd Stage -
Vegetative
Propagation**



**3rd Stage –
Varietal Testing**



Prominence of Varietal Deployment: Stand Uniformity in Tree Size



Taxon	Varietal Stands (Coefficient of Variation)	Full-Sib Stands (Coefficient of Variation)
<i>P. ×canadensis</i>	10	26
<i>P. ×generosa</i>	10	18



CONFIDENTIAL DISCUSSION THAT IS NOT TO BE DISTRIBUTED WITHOUT EXPRESS WRITTEN PERMISSION OF GREENWOOD RESOURCES

A Resource That Lasts Forever™

Evaluation Criteria - Adaptability



Growing Season Length



Winter Injury

Evaluation Criteria – Yield



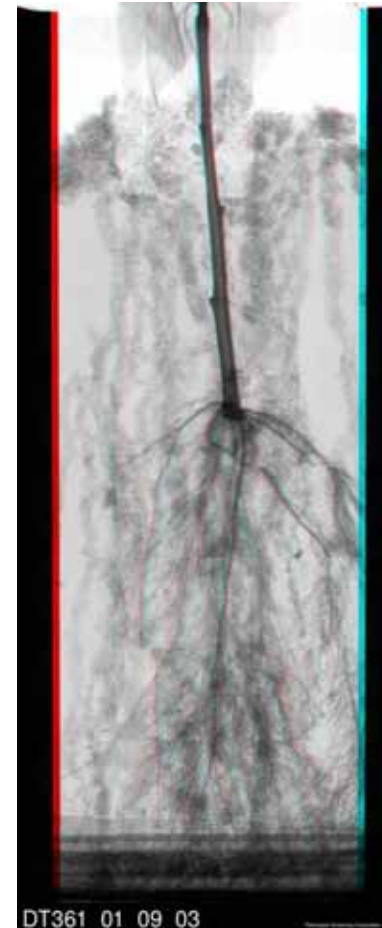
Growth Rate



Pest Resistance



Evaluation Criteria - Protection

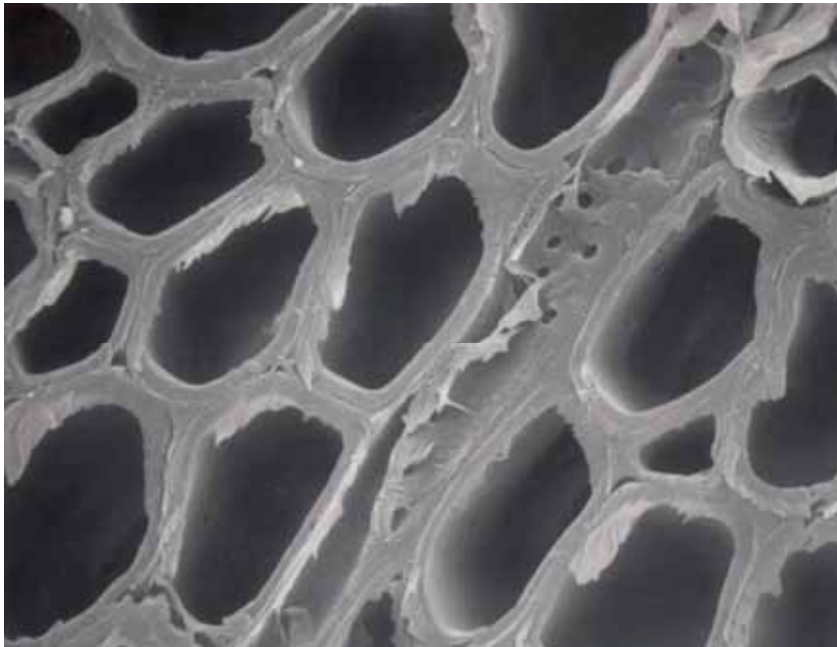


Field Selection for wind throw resistance

Indirect Selection using x-Ray Imaging at Phenotype Screening Corporation



Evaluation Criteria – Wood Quality



Specific gravity: .265 to .373

Microfibril angle: 9 to 21 degrees

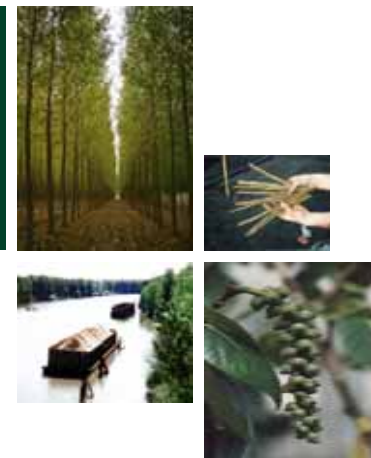
Lignin: 21.9 to 26.0 percent

Fiber wall thickness: 5.1 to 7.2 μm

Fiber length: 0.6 to 1.1 mm



Multiple Stage Field Testing



1. Poplar field testing usually involves multiple stages
2. Sequential truncation of test populations between stages
3. Evaluations conducted at 1/3 to 1/2 rotation length
4. Entire process can take 3 to 15 years dependent on:
 - ✓ end product/market
 - ✓ diversity of sites within plantation program
 - ✓ assumption of risk associated with early selections

Test Stage	Number of Test Varieties	Experimental Efficiency
1 st	Many ↓ Few	Low ↓ High
2 nd		
3 rd		
4 th		



Varietal Multiplication

39 months to deployment of newly selected clone



Clone introduced into laboratory *in vitro* culture

300,000 micro-cuttings delivered to greenhouse

280,000 stools established in propagation nursery

1,000,000 cuttings available for production plantations

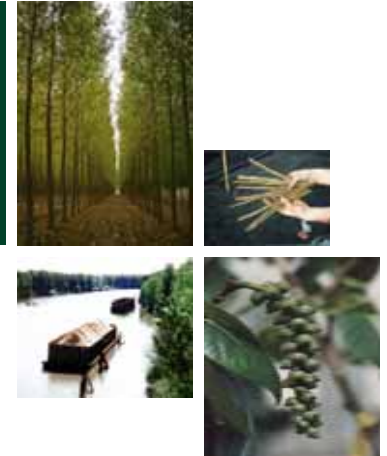
e



GreenWood Resources – Virginia Polytech Poplar Collaborative Program



Poplar Testing in Virginia



- Project initiated in 2008 to identify potential planting stock for biomass-for-energy plantations.
- Initial experimental focus primarily on taxonomic performance.
- Intent to move to adaptability and yield trials after initial confirmation of varietal selections.

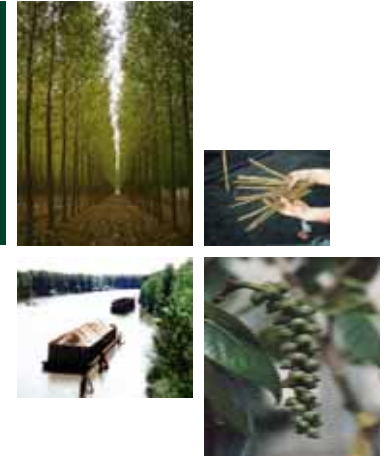


Poplar in the Region



P. ×generosa
stand near
Emporia,
Virginia

Experimental Design



- Gretna, Powell River, Petersburg
- Multiple varieties of each of three taxa
 - 35 *P. ×generosa*
 - 39 *P. × canadensis*
 - 46 *P. deltoides* × *P. maximowiczii*
- Stock propagated in Gretna greenhouse and nursery in 2008
- Field trials established in 2009
- Four replications of large-size taxonomic plots with single tree varietal plots
- Spacing of 10 feet × 2 feet

Plot Design



B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	
B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	
B	B	7188	6198	5117	B	B	B	B	10183	10232	10161	B	B	B	B	11800	11789	11779	B	B
B	B	5077	7161	7282	B	B	B	B	6329	10149	10230	B	B	B	B	11802	11893	11785	B	B
B	B	8360	4303	4739	B	B	B	B	10167	8002	10179	B	B	B	B	11783	11803	11773	B	B
B	B	5138	6588	4492	B	B	B	B	10143	10150	6320	B	B	B	B	11780	11857	11821	B	B
B	B	6600	1428	7849	B	B	B	B	10243	10202	10182	B	B	B	B	11776	11795	11824	B	B
B	B	7300	4400	5944	B	B	B	B	10244	10267	10178	B	B	B	B	11822	11798	11809	B	B
B	B	6612	6018	4962	B	B	B	B	10144	10184	10168	B	B	B	B	11836	11881	11794	B	B
B	B	7945	4987	4512	B	B	B	B	7476	10242	10209	B	B	B	B	11882	11796	11807	B	B
B	B	8199	6276	4491	B	B	B	B	10145	10164	7416	B	B	B	B	11799	11859	11786	B	B
B	B	5914	4206	6214	B	B	B	B	10185	10238	10207	B	B	B	B	11777	11855	11792	B	B
B	B	6616	4700	5903	B	B	B	B	7388	6318	10224	B	B	B	B	11775	11862	11845	B	B
B	B	5905	4284	F	B	B	B	B	10190	10205	10187	B	B	B	B	11778	11811	11825	B	B
B	B	F	F	F	B	B	B	B	10226	10175	10146	B	B	B	B	11866	11804	11858	B	B
B	B	F	F	F	B	B	B	B	F	F	F	B	B	B	B	11864	11827	11834	B	B
B	B	F	F	F	B	B	B	B	F	F	F	B	B	B	B	11772	11793	F	B	B
B	B	F	F	F	B	B	B	B	F	F	F	B	B	B	B	11797	11830	F	B	B
B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B

P. ×generosa

P. deltoides × *P. maximowiczii*

P. ×canadensis



Varietal Observations



1. No survival differences among taxa; *P. deltoides* from lower Mississippi Valley not cold hardy.
2. *P. deltoides* × *P. maximowiczii* > *P.* × *generosa* > *P.* × *canadensis* as regards height growth.
3. *P. deltoides* × *P. maximowiczii* showing extremely high levels of rust resistance.
4. Too early to say the extent to which winter injury will manifest itself among the taxa.
5. Within-taxon varietal variation appears sufficient for both height growth and rust resistance to support selections across all three taxa.

Closing

- 1. Historically, poplar varietal development has been indispensable in guaranteeing the success of plantation programs throughout Europe, Asia, and North and South America.**
- 2. Cultivation has heretofore relied mainly on four species. Good opportunities exist to exploit more of the genetic resources in the genus.**
- 3. F_1 hybridization has been the most popular approach in view of the frequency and intensity of hybrid vigor.**
- 4. Varietal selection and deployment of extremely productive genotypes will maximize genetic gains as well as the uniformity of wood properties.**



Closing



- 1. Good start to varietal testing in Virginia; preliminary screening trials should point to well-adapted taxa and initial selections.**
- 2. VPI effort should be viewed as a component of the DOE/DOT's national poplar biomass feedstock development effort.**
- 3. Effort will also benefit from the DOE BioEnergy Science Center's program to identify selectable markers associated with energy conversion traits so as to improve timeliness and precision of future varietal selections.**
- 4. GreenWood anticipates a continuation of varietal testing and initiation of a hybridization program specific for the northeastern and Mid-Atlantic regions of the U.S.**



Thank You!



Fifth International Poplar Symposium



- ***“Poplars and willows: from research models to multipurpose trees for a biobased society”***
- **Sponsored by IUFRO’s Poplar Genetics Working Group**



IPS-V, Orvieto, Italy



<http://www.sisef.it/IPS-V/>

Date: 20-25 September, 2010

Hosts:

**National Research Council - Institute of Forest &
Environmental Biology,
University of Tuscia,
The Agricultural Research Council.**

