Chestnut Breeding and Restoration: Elements of Success

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The Pennsylvania State University
Breeding Pest-Resistant Trees, Proc. of a NATO/NSF Advanced Study Institute, held in 1964

Henry Gerhold
Ernie Schreiner
Bob McDermott
Jack Winieski
1964 programs with no apparent impact on forests 48 years later:

- Resistance to *Fomes* root rot in slash pine
- . . . white pine weevil in eastern white pine
- . . . oak wilt in northern red oak and others
- . . . Dutch elm disease in American elm
- . . . bark beetles in several western & southern pines
- . . . pine reproduction weevil in Jeffry pine
- . . . pine tip moth in ponderosa pine
Resistance to brown spot in longleaf pine
... balsam woolly adelgid in several true firs
... littleleaf disease in shortleaf pine
... pine tip moth in loblolly and shortleaf pines
... eastern pine gall rust in jack pine
... European pine shoot moth in red pine
... spruce gall aphid in Norway spruce
... sweetfern blister rust in jack pine
... cedar-apple rust in eastern redcedar
... locust borer in black locust
1964 programs that have had an impact:

- Resistance to fusiform rust in loblolly pine
- Resistance to blister rust in western white pine
- Resistance to *Phytophthora lateralis* in Port-Orford-cedar
Jim Hanover: “In the long run, most diseases of [forest] trees will probably be best controlled by use of resistant varieties. But the “long run” may be a very long time.” (1964 NATO/NSF meeting)
Previous conferences:

- *Breeding Pest-Resistant Trees*, University Park, PA (Penn State) (1964)
- *Biology of Rust Resistance in Forest Trees*, Moscow, ID (Univ. of Idaho) (1969)
- *Fourth International Workshop on the Genetics of Host-Parasite Interactions in Forestry*, Eugene, OR (2011)
Fourth International Workshop on the Genetics of Host-Parasite Interactions in Forestry

News and Updates

We’ve added Photos!

Individual presentations can be viewed on the Agenda page

Field trip video - if you remember it, you weren’t really there

Press Release

WATCH THE WEBCAST

Final Conference Agenda

Course handout for statistics session

Check the Book of Abstracts for more information on all of the talks and posters

Additional oral presentation abstracts

Additional poster abstracts

Information on Proceedings

July 31 – August 5, 2011
Valley River Inn
Eugene, Oregon, USA

Native and non-native pathogens, insects and animals continue to negatively impact forest ecosystems and plantations worldwide. Climate change will alter host-damage agent relationships and may increase detrimental impacts from many biotic agents. Genetic resistance within tree species is a key element to maintaining forest health. Utilizing genetic resistance is one of the few management options available to combat the impacts of insects, animals and pathogens. Resistance programs, including resistance breeding, will be vital as they increase the efficiency in utilizing genetic variation to maintain or restore forest health when mortality becomes unacceptably high.
Selection and breeding for insect and disease resistance

Pest and disease resistance has been an essential part of crop breeding for many years, but has only had marginal impact in tree breeding to date. Crop varieties are domesticated and their continued cultivation depends on continuous breeding programmes for insect, disease and virus resistance, since large-scale monocultures are generally more susceptible to variable pathogens. Forest trees are mainly wild, undomesticated, outbred organisms and their natural populations retain a wide genetic diversity that helps them resist insect pests and pathogens. In addition, the genetic control of insect pest and disease resistance is sophisticated and probably more complex than for annual crops. Moreover, conventional tree selection and breeding for insect and disease resistance requires complex and lengthy laboratory and field tests, especially since resistance patterns may change from young to adult trees.

Over the past 20 years, tree breeding programmes have been reduced worldwide and now focus on a limited number of species and traits. However, since the risk of introducing new pests is likely to increase in the future, insect and disease resistant breeding programmes may be particularly important for several large-scale or valuable commercial plantations.

Pest resistance breeding may be a technical option in large-scale or valuable commercial plantations if there:

- are few silvicultural options to mitigate losses to insect pests and diseases;
- are no alternative species;
- is an increasing risk of introductions of exotic pests.

In order to determine the global status of research and applications regarding breeding for resistance in the forest sector, the FAO Forestry Department, in collaboration with Alvin Yanchuk of the Research Branch, British Columbia Ministry of Forests, Canada and Nicholas Wheeler of the Molecular Tree Breeding Services, US, conducted an informal yet comprehensive review of the topic. It is hoped that this review will give practitioners and reporting agencies a snapshot of the level of activity in pest resistant breeding around the world, and help to focus it where future efforts would be best applied.
Summary of insect and disease resistance programs, world-wide

- 260 resistance “research programs” identified
- 36 genera: *Pinus* > *Populus* > *Eucalyptus* > *Picea* > *Betula* > *Larix* > *Pseudotsuga* > *Castanea* (2%)
- 24 (9%) actual breeding programs with deployed material
- 4-5 (2%) of programs have documented “impacts” – all commercial
US programs with deployed resistance:

- *Pinus monticola* to white pine blister rust
- *Pinus albicaulis* to white pine blister rust
- *Pinus lambertiana* to white pine blister rust
- *Pinus contorta* to western gall rust
- *Pinus ponderosa* to western gall rust
- *Pinus elliottii* to fusiform rust
- *Pinus taeda* to fusiform rust
- *Chamaecyparis lawsoniana* to *Phytophthora lateralis*
- *Larix occidentalis* to needle cast and blight
- *Pseudotsuga menziesii* to Swiss needle cast
- *Populus* species to rust, leaf and shoot blight, insects
Biggest successes:

- Resistance to fusiform rust in loblolly pine (southeastern US) (825 million seedlings/yr)
- Resistance to needle blight in radiata pine (New Zealand) (150 million seedlings/yr)
- Resistance to white pine weevil in spruces in western Canada) (80 million seedlings/yr)
- Resistance to blister rust on western white pine (western US)
1960s & 1970s were the golden years for tree improvement:

- There was a forest geneticist or tree improvement specialist in every Forest Service experiment station,
- . . . in every National Forest Region,
- . . . in many individual national forests,
- . . . in many state forestry agencies,
- . . . on the staff of most large timber companies,
- . . . on the faculty of almost every forestry school.
Forest genetics and tree improvement

R&D in the Northeast, 1970s:

- US Forest Service, Durham, NH – Pete Garrett, Tim Demeritt, Ron Wilkinson
- US Forest Service, Burlington, VT – Bill Gabriel
- US Forest Service, NJ – Si Little
- US Forest Service, S&PF – Clyde Hunt
- US Forest Service, NF, Zone Geneticist – Don Dorn
- Georgia Pacific, Maine – Oscar Selin, Bill Sayward
- PA Dept. Forestry – Jack Winieski
Continued:

- Univ. of Maine – Dave Canavera, Kathy Carter
- Univ. of New Hampshire – Tom Adams, Bob Eckert
- Univ. of Vermont – Don DeHayes
- Yale University – Tom Ledig
- SUNY-ESF – Fred Valentine, Bob Westfall
- Rutgers – John Kuser
- Penn State – Henry Gerhold, Kim Steiner
- University of Maryland – John Genys
- CT Ag Exper Station – Dick Jaynes (+/-)
Forest genetics and tree improvement
R&D in the Northeast, 2012:

- US Forest Service, Durham, NH
- US Forest Service, Burlington, VT
- US Forest Service, NJ
- US Forest Service, S&PF
- US Forest Service, NF, Zone Geneticist
- Georgia Pacific, Maine
- PA Dept. Forestry
Continued:

- University of Maine
- University of New Hampshire – Bob Eckert
- University of Vermont
- Yale University
- SUNY-ESF – Bill Powell, Chuck Maynard
- Rutgers
- Penn State – Kim Steiner, John Carlson
- University of Maryland
- CT Ag Exper Station – Sandy Anagnostakis
Why ambitions have not been realized:

- Applied genetics research is divorced from an actual breeding program
- Breeding program is divorced from an actual planting program
- Improvement in resistance is not silviculturally or economically meaningful
- Institutional fatigue
Chestnut Breeding -- A Short History

- USDA program (Glen Dale, MD)
  - Russell Clapper (beginning 1925)
    - Intercrossing Asian x Asian and Asian x American, few F$_2$ s, some backcross hybridization
    - Goal: Superior blight resistance to replace American chestnut
    - Emphasis on superior individuals that would have to be propagated by grafting
  - Program was abandoned in 1960
Chestnut Breeding -- A Short History

- Brooklyn Botanic Garden >>> Connecticut Agric. Experiment Station Program
  - Arthur Graves (beginning 1930)
    - Hybridization of American with *C. mollissima* and *C. crenata*
    - Goal: Superior blight resistance to replace American chestnut
    - Emphasis on superior individuals that would have to be propagated by grafting
  - R. A. Jaynes (beginning 1963)
  - Sandra Anagnostakis (beginning in 1983)
The promise of the early programs

- They are bringing back the chestnut tree. *Readers’ Digest* 82(492): 129-132 (1963)
- Chestnut blight and resistant chestnuts. *USDA Farm Bulletin* 2068, 21 pp. (1959)
But . . . by 1970 almost no work was being done on the breeding or genetics of American chestnut.

Jonathan Wright (1970): It would be feasible to breed a blight-resistant, “American” chestnut, but it won’t happen.

- Would require too much money and too many decades.
- Industry is not interested enough to invest.
- State agencies are too small to do it.
- USDA failed for 60 years and will not try again.
TACF takes up the challenge

- TACF founded in 1983

- **Approach**
  - Breeding goal was a population of near-American chestnuts that would breed true for resistance
  - “Backcross” hybridization: 3 generations to recover American type while carrying along resistance genes from original cross with Asian chestnut
  - Intercross at end, among $B_3F_1$s, to recover homozygosity for resistance
  - Operations consolidated at Meadowview in 1989
Resistant does not mean disease-free

Resistant canker

Susceptible canker
### Screening of Progeny for Segregation in Blight Resistance, 1993 Test (Hebard 2006)

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Recovery of American chestnut characteristics through backcross breeding

TACF Progress toward Completion of the Burnham Plan

- National program (Meadowview) has mostly completed the $\text{B}_3\text{F}_2$ generation with “Clapper” and “Graves” sources of resistance.

- Other sources of resistance are in the pipeline.
Progress toward completion of Burnham Plan at Meadowview, Clapper source (Hebard, 2011 data)
Genetic superiority can only be proven with a \textbf{progeny test} – a replicated, statistically designed comparison of the offspring of different mother trees.
Mean canker length for representative families in Meadow progeny test, 2011 data

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Future of the BC breeding program

- Finish and thin orchards to best trees proven by tests
  Unproven good (♀) x Average (♂)
  → Proven good (♀) x Proven good (♂)

- Incorporate new sources of resistance to $B_3F_2$ and, if appropriate, through genetic engineering.

- Expedite with marker-assisted selection when available.
Future (continued)

- “Advance” 3rd backcross generations:
  - Select for *Phytophthora* resistance for Piedmont
  - Enhance “American” w/ backcrossing (e.g., to B₄F₂)
  - Consolidate resistance gains with intercrossing
    - Partial diallel within and between Graves and Clapper B₃F₂ trees
    - Replicate best parents in an isolated, grafted seed orchard
  - Delayed objectives: 1) improvement beyond 15/16 American and 2) maximum American diversity
Conclusions / Observations / Predictions

1) Optimistic forest tree improvement programs have come and (mostly) gone.

2) Successful programs require a realistic assessment of the strength of the motivation to plant (usually money) and they need to understand how their material will be deployed silviculturally.
Conclusions / Observations / Predictions

3) Restoration of American chestnut is an impractical idea.
   1) It is not easy to put chestnut trees into the forest, and there is no profit in it.
   2) Replacement was a bad idea.
   3) Restoration is a compelling idea.

4) The TACF program has reawakened interest in American chestnut and optimism for success.
Conclusions / Observations / Predictions

5) Partial success with the Burnham plan is confirmed, and there is more to come.
   1) But continued interest is not guaranteed,
   2) and rapid progress toward resistant American chestnut is essential.
Conclusions / Observations / Predictions

6) Completion of the Burnham plan has been the objective of TACF, but restoration is its mission.

7) Eventually, other programs and technologies will help TACF achieve its mission.

Breakthroughs in hypovirulence, genetic engineering, and perhaps other breeding programs.

8) But success will materially depend on the ability of TACF to sustain optimism that the mission is possible.