

Hazelnuts Resistant to Eastern Filbert Blight: Are We There Yet?

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Nut Tree Breeding at Rutgers

- Based on the tremendous genetic improvements demonstrated in several previously underutilized turf species, Dr. C. Reed Funk strongly believed similar work could be done with nut trees
- Title of project started in 1996: Underutilized Perennial Food Crops Genetic Improvement Program



Tom Molnar and Reed Funk
Adelphia Research Farm
August 2001

Nut Breeding at Rutgers

- Starting in 1996, species of interest included
 - black walnuts, Persian walnuts and heartnuts
 - pecans, hickories
 - chestnuts,
 - almonds,
 - hazelnuts
- We built a germplasm collection of over 25,000 trees planted across five Rutgers research farms
 - Cream Ridge Fruit Research Farm (Cream Ridge, NJ)
 - Adelfia Research Farm (Freehold, NJ)
 - HF1, HF2, HF3 (North Brunswick, NJ)



Nut Breeding at Rutgers



- Goals

- Identify species that show the greatest potential for New Jersey and Mid-Atlantic region
- Develop breeding program to create superior well-adapted cultivars that reliably produce high-quality, high-value crops
 - while requiring reduced inputs of pesticides, fungicides, management, etc.



Nut Breeding at Rutgers

- While most species showed great promise for substantial improvement, we had to narrow our focus to be most effective
- **Hazelnuts** stood out as the species where we could make significant contributions in a relatively short period of time
 - Major focus since 2000



Hazelnuts at Rutgers

- Why we chose to focus on hazelnuts:
 - success of initial plantings made in 1996/1997 with few pests and diseases
 - short generation time and small plant size (4 years from seed to seed)
 - wide genetic diversity and the ability to hybridize different species
 - ease of making controlled crosses
 - backlog of information and breeding advances
 - existing technologies and markets for nuts



Hazelnuts:
Corylus spp.





***Corylus* spp.**



World production is based on the European hazelnut, *Corylus avellana*

Several other species with smaller nuts are native to North America and China that are useful for breeding better adapted plants

Hazelnuts – some background

- Called hazelnut or filbert
- Hazelnuts are the 5th most important tree nut crop in the world (748,000 MT/yr) behind cashews, almonds, walnuts, and chestnuts
- Current commercial production centers are restricted to areas with climates moderated by large bodies of water
- The U.S. produces around 4% of the world crop, behind Turkey (70%) and Italy (18%)
- 99% of the U.S. hazelnut crop is grown in the Willamette Valley of Oregon



Current world production regions - *Corylus avellana*

Hazelnut Culture

- Hazelnuts naturally grow as a large bush, but are pruned to a single trunk in the U.S. to facilitate mechanical harvesting
- In Italy and Spain, trees are pruned to a single trunk or several stems and are mechanically harvested
- In Turkey, hazelnuts remain multi-stemmed, are planted in clumps, and are hand harvested



90% of the world crop is used as kernels in candy, baked-goods, and other products





8-year-old European plant
pruned to a single trunk

In Oregon, single trunk
trees are traditionally
spaced on 20' centers
(‘Barcelona’ x ‘Daviana’)

Some newer plantings
using smaller statured
cultivars are 20' between
row and 10' in rows

Layered or grafted trees
begin to bear nuts in 3-4
years, with significant
production by 7 or 8

- around 2400 pounds per
acre Oregon ave.



Nuts develop in a leafy husk of varying shape and size



They ripen from mid-August to late September and can fall from or be retained in the husk at maturity











Nuts typically fall to the ground in September

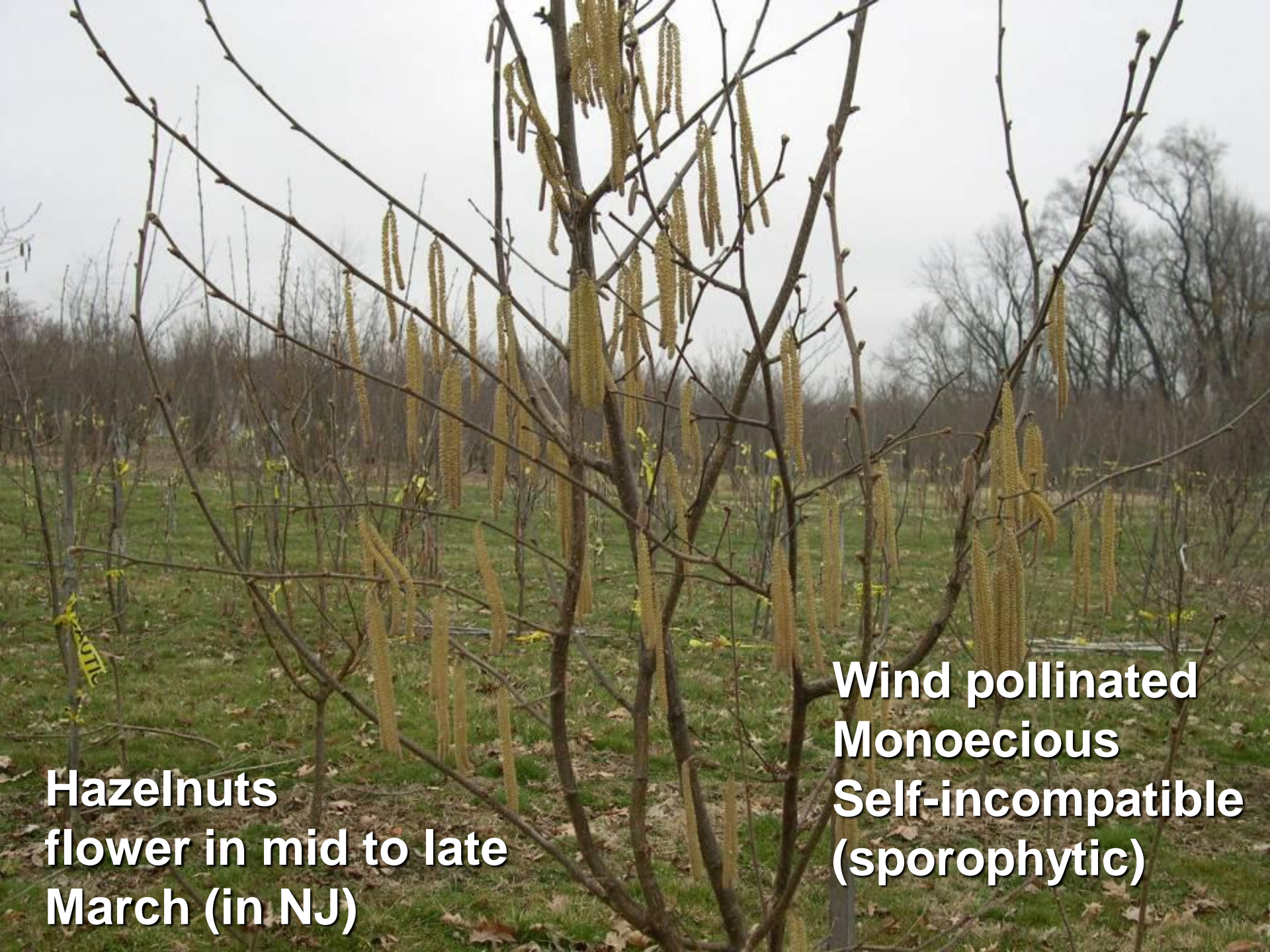
Commercial hazelnut orchard in Eugene, Oregon August 2011





Harvest in Italy





**Hazelnuts
flower in mid to late
March (in NJ)**

**Wind pollinated
Monoecious
Self-incompatible
(sporophytic)**



**Male (staminate) flowers
(catkins)**



**Female
(pistillate) flowers**



Hazelnuts in Eastern North America

- Early colonists brought hazelnuts from Europe – very few records, no production established
- The fungal disease **Eastern Filbert Blight** killed most European hazelnut trees
- Disease is naturally occurring on the wild American hazelnut, *Corylus americana*
- EFB is the **primary reason** no commercial hazelnuts are grown in the east



Native range of wild American hazelnut and associated pathogen *Anisogramma anomala* that causes Eastern filbert blight (EFB)

Wild *Corylus americana* in New Jersey



Corylus americana

- While the native hazelnut is cold hardy and tolerant to EFB, its nuts are tiny and thick shelled
- Nuts do not drop from husk and some remain attached to branches after maturity





Eastern Filbert Blight

Fungus - *Anisogramma anomala*



Stromata
(fruiting body)



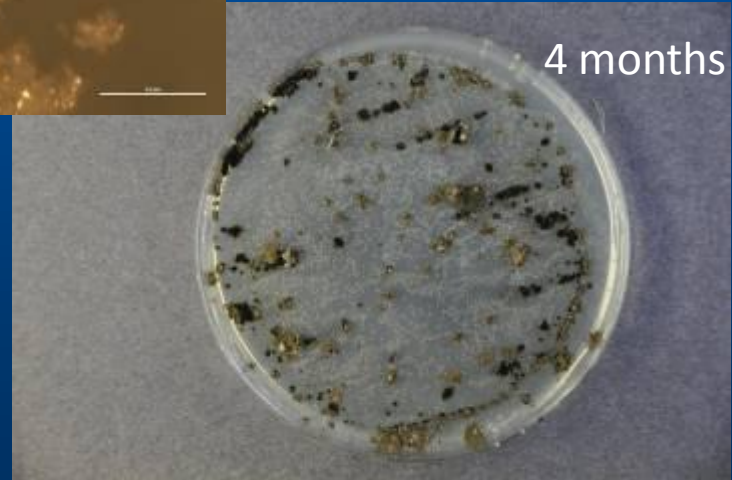
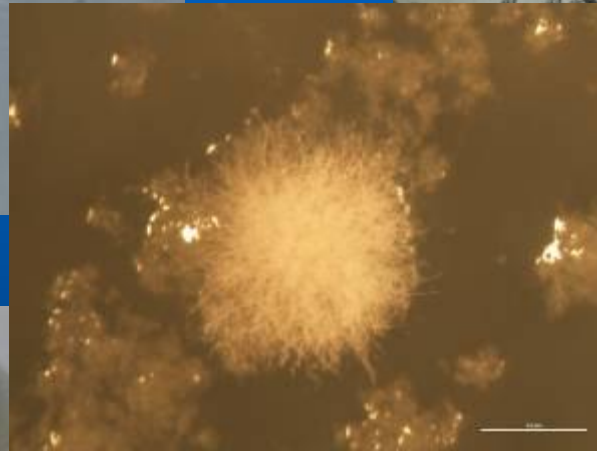
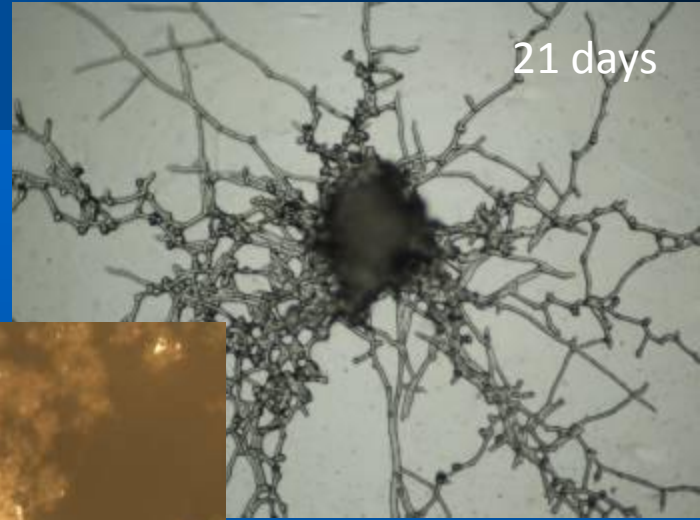
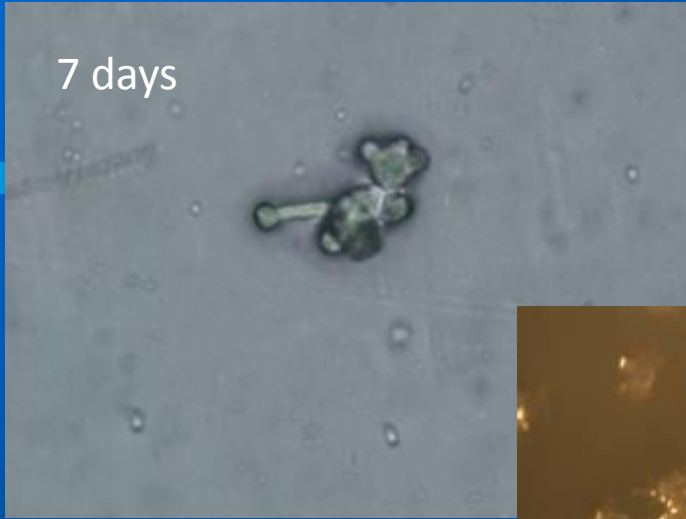
- Wild hazelnut harbors EFB across its range
- Most European hazelnuts are highly susceptible
- Fungus grows under bark
- When reproducing, it creates cankers that kill the trees

Anisogramma anomala

- Ascomycete in the order Diaporthales
 - same as chestnut blight and dogwood anthracnose pathogens
- Obligate biotroph of only *Corylus*
 - infects only living hazelnut tissue
- Found only in North America
 - Would be quite devastating in Europe where *C. avellana* is a common understory tree



A. anomala grows slowly on media; no subculture yet





**Ornamental Contorted hazelnut:
Very susceptible to ESB**

Hazelnuts in the Pacific Northwest – very successful, until...

- Hazelnuts first brought to the Pacific Northwest in the late 1800s by nurseryman Felix Gillet
- European cultivars were well adapted to the climate of the coastal valleys of Oregon and Washington and **no eastern filbert blight was found there**
- Hazelnut industry thrived for nearly 100 years, until-

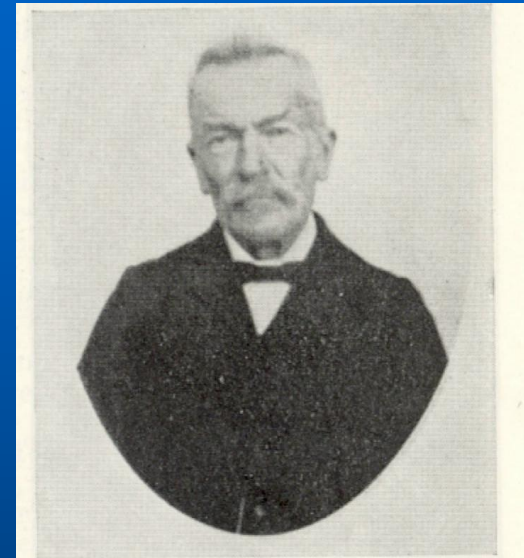


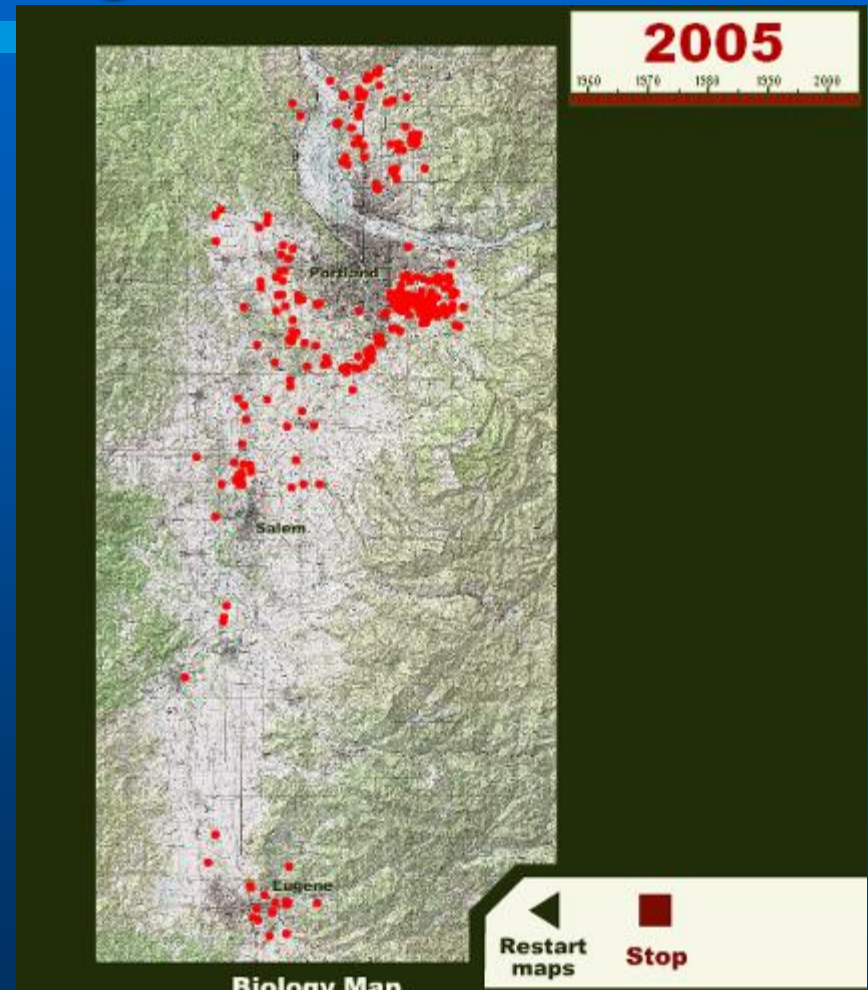
Figure 3.—Felix Gillet (1835–1908), proprietor of Barren Hill Nurseries, which he established at Nevada City, Calif., in 1871. He was one of the most outstanding figures of his time in introducing carefully selected varieties of filbert, Persian walnut, and chestnut from Europe.

Felix Gillet (1835-1908)

*Picture from 1937 USDA
Yearbook of Agriculture*

...Eastern Filbert Blight makes it out to Washington State

- Despite quarantine efforts, EFB was found in southwest Washington in the 1960s
- Orchards consisted of highly susceptible cultivars leading to major EFB epidemics and orchard destruction and loss in Washington and Oregon
- Fortunately, prevailing weather patterns slowed the spread southward; however, EFB can now be found throughout the entire Willamette Valley



<http://oregonstate.edu/dept/botany/epp/EFB/location/map1.htm>

Hazelnuts research at Rutgers is supported by breakthroughs in Oregon

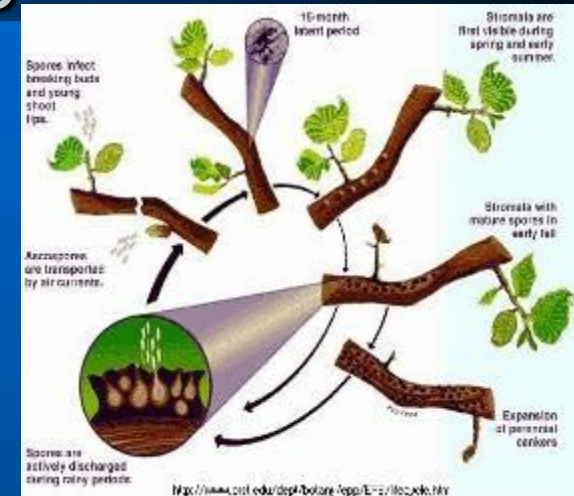
- Studying the fungus and searching for resistance began at Oregon State Univ. (OSU) in the 1970s, including methods to better identify resistant plants
- Success at OSU is clearly exemplified by the new EFB resistant cultivars released: 'Santiam', 'Yamhill', and 'Jefferson'
- At Rutgers we have been building on these advances for eastern North America



Greenhouse inoculations with *A. anomala* to identify resistant seedlings

EFB is a complicated disease: breeding for durable resistance is a challenge

- Long lifecycle (~24 months from spore to spore).
 - Cankers show 16 months after infection (needs a chilling treatment)
- Recent studies suggests pathogenic variation exists in *Anisogramma anomala*
 - In greenhouse studies at Rutgers, an isolate from Michigan was able to infect significantly more “Oregon resistant” plants than any of the others (also, it was the only isolate to infect: ‘Gasaway’, ‘Zimmerman’, OSU 408.040)
 - ‘Gasaway’ and many of its progeny now get EFB in field trials at Rutgers (to varying degrees)



Lifecycle of *Anisogramma anomala*

<http://oregonstate.edu/dep/botany/epp/EFB/>



Furthermore, much remains to be known about the fungus...



- Besides tedious greenhouse studies, there is no simple way to differentiate isolates or to study the genetic diversity and population structure of the fungus
- After a partial sequencing of its genome last winter (11x coverage), we have now identified many thousands of potential SSR regions, from which we can develop robust primers to fingerprint the isolates
- To date, we have 8 sets of potential SSR primers, with more on the way to assess our large collection of isolates
- Early evidence supports our hypothesis that *A. anomala* is homothallic and spores from one canker are quite uniform (not seeing heterozygosity like in diploid plants)

Rutgers *A. anomala* Isolates

City	State	<10 isolates	10-20 isolates	>20 isolates
Monmouth	IL	●		
Boston	MA			●
Boothbay	ME	●		
East Lansing	MI			●
Leslie	MI			●
Tustin	MI	●		
Canton	MN		●	
Montevideo	MN		●	
St. Paul	MN			●
Wycoff	MN		●	
Columbia	MO	●		
Adelphia	NJ		●	
Colts Neck	NJ	●		
Cream Ridge	NJ			●
Jackson	NJ		●	
Morristown	NJ	●		
New Brunswick	NJ			●
Amherst	NY		●	
Belmont	NY	●		
Bronx	NY	●		
Findley Lake	NY	●		
Columbus	OH			●
Kirtland	OH		●	
Corvallis	OR			●
Alburtis	PA	●		
Etters	PA	●		
Gettysburg	PA	●		
Harrisburg	PA	●		
Hop Bottom	PA	●		
Philadelphia	PA		●	
Wayne	PA	●		
Grantsburg	WI	●		
Moquah	WI		●	

One more challenge:

Cold hardiness of catkins also a limiting factor:



Cold hardiness of male flowers (catkins) is also an issue in the east and may be a major limiting factor to **consistent yields** in colder regions. Female flowers are very cold tolerant.



95% catkin death on OSU pollenizer C. avellana 'Delta' at Rutgers in 2011

Rutgers Breeding Program:

- Rutgers now has over 35,000 breeding progeny, foreign germplasm collections, and clonal accessions under evaluation in the field and greenhouse
- Working closely with Oregon State Univ., and on our own, we have about 15 distinct sources of EFB resistance that transmit a high level to progeny
 - *C. avellana*, *C. colurna*,
C. americana, *C. heterophylla*
- Now, it is a matter of combining excellent nut quality and cold hardy catkins with genes for EFB resistance
 - Easier said than done



Plants bagged for
controlled crosses



Extracting Pollen



Collect catkins from field once they begin to elongate – leave over night on white paper



Catkins shed pollen overnight – collect early next morning



Store pollen in freezer – viable for 1 year

Making Controlled Pollinations



Remove catkins (emasculate) with shears, tie-up branches prior to pollen shed
Open bag to make crosses only after pollen shed – stigmas stay receptive



Shake pollen onto fingertip



Carefully dab stigmas with pollen – when done, recover branch with pollen-proof bag



Pollinated stigmas turn black and shrivel in a few days



Entire trees can be covered for large numbers of hybrid seed

**Harvest nuts in August –
early Sept.**



**After 4-5 months moist-
chilling, germinate in
greenhouse**



**Transplant to 1-gallon pots,
continue growth in greenhouse**



**Acclimate under shade prior to field
planting in September**



**EFB →
inoculation**

Speed up the process

Artificial inoculations with EFB pathogen

- In the greenhouse we can test for disease resistance using spores from the EFB pathogen

- only highest levels of resistance can survive greenhouse inoculations
- We can identify resistant trees faster and more economically
- However, trees must be overwintered to express EFB next year



Germ tube



Germinating ascospores of *Anisogramma anomala*



Spraying spore solution

In the fall, transplant seedlings to field for next stage of evaluation



- In field, trees are not sprayed to control pests or diseases
- Inputs are limited to irrigation at planting and maybe year 2, yearly fertilizer and weed control

We are pushing to plant large populations of plants each year, from 5,000 to 10,000 seedlings





Field inoculations to keep disease pressure high

- Field EFB inoculations are made each spring to infect trees, reduce escapes, and greatly increase natural disease pressure
- After 5 years of continual exposure to EFB we are confident a tree has a high level of resistance
 - Nut evaluations begin



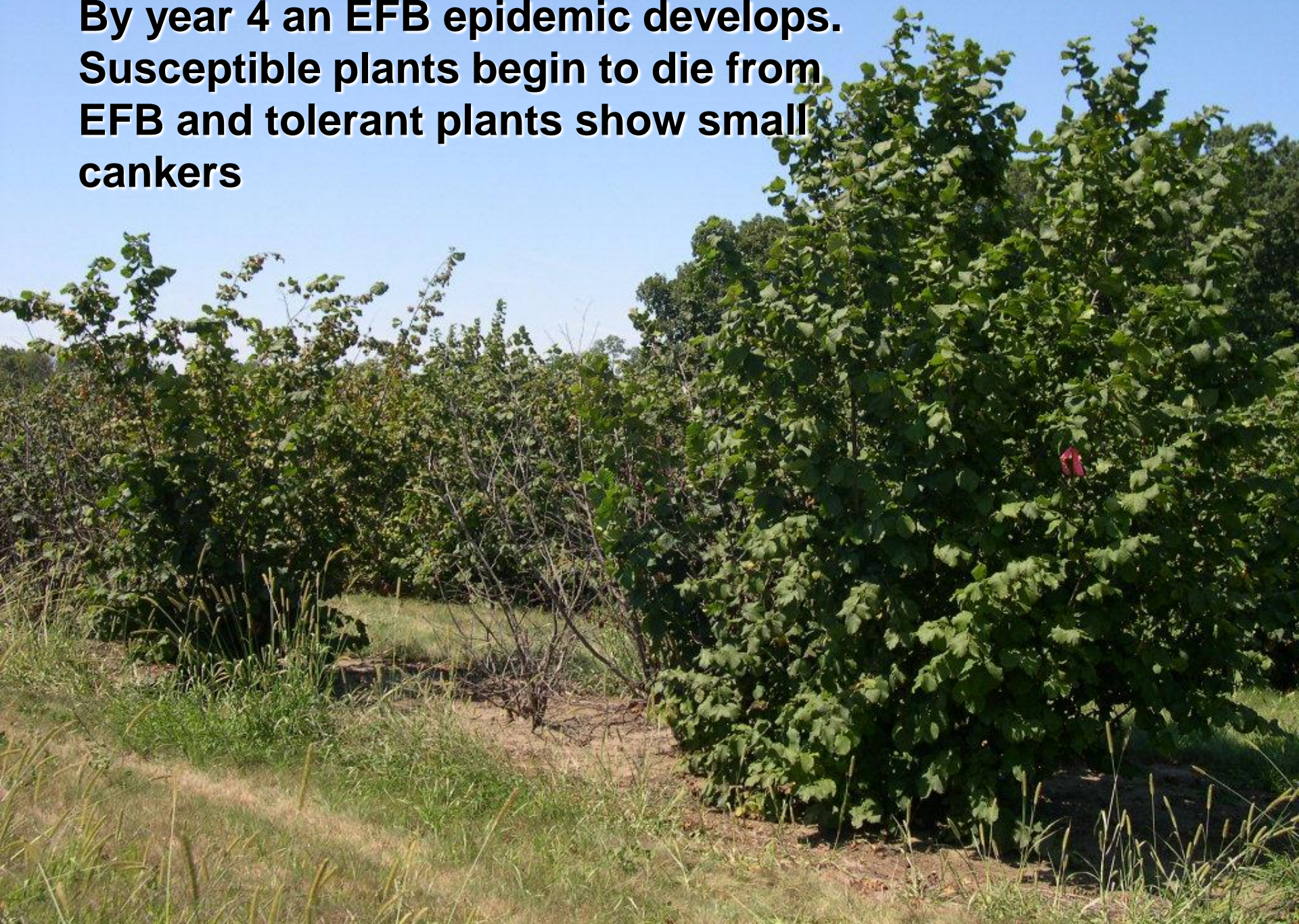
Trials at 3 years



EFB starts to be visible in year 3 on susceptible plants
Although they could be, no plants are removed to further
spread disease – Field inoculation also continues



**By year 4 an EFB epidemic develops.
Susceptible plants begin to die from
EFB and tolerant plants show small
cankers**





By year 5 susceptible trees are clearly evident or already dead

At this time nuts are being produced

Goal is to identify EFB-resistant, late-flowering, healthy, vigorous plants by year 5. The remaining plants are discarded (cut)







Samples of nuts are collected from every EFB resistant plant

Nut Evaluations start in 5th year

- We evaluate nut characteristics such as:
 - size, shape, kernel weight, percent kernel, kernel defects, etc.
- Those with poor quality nuts are discarded as soon as it is evident
 - Small, long nuts, kernel defects, etc.



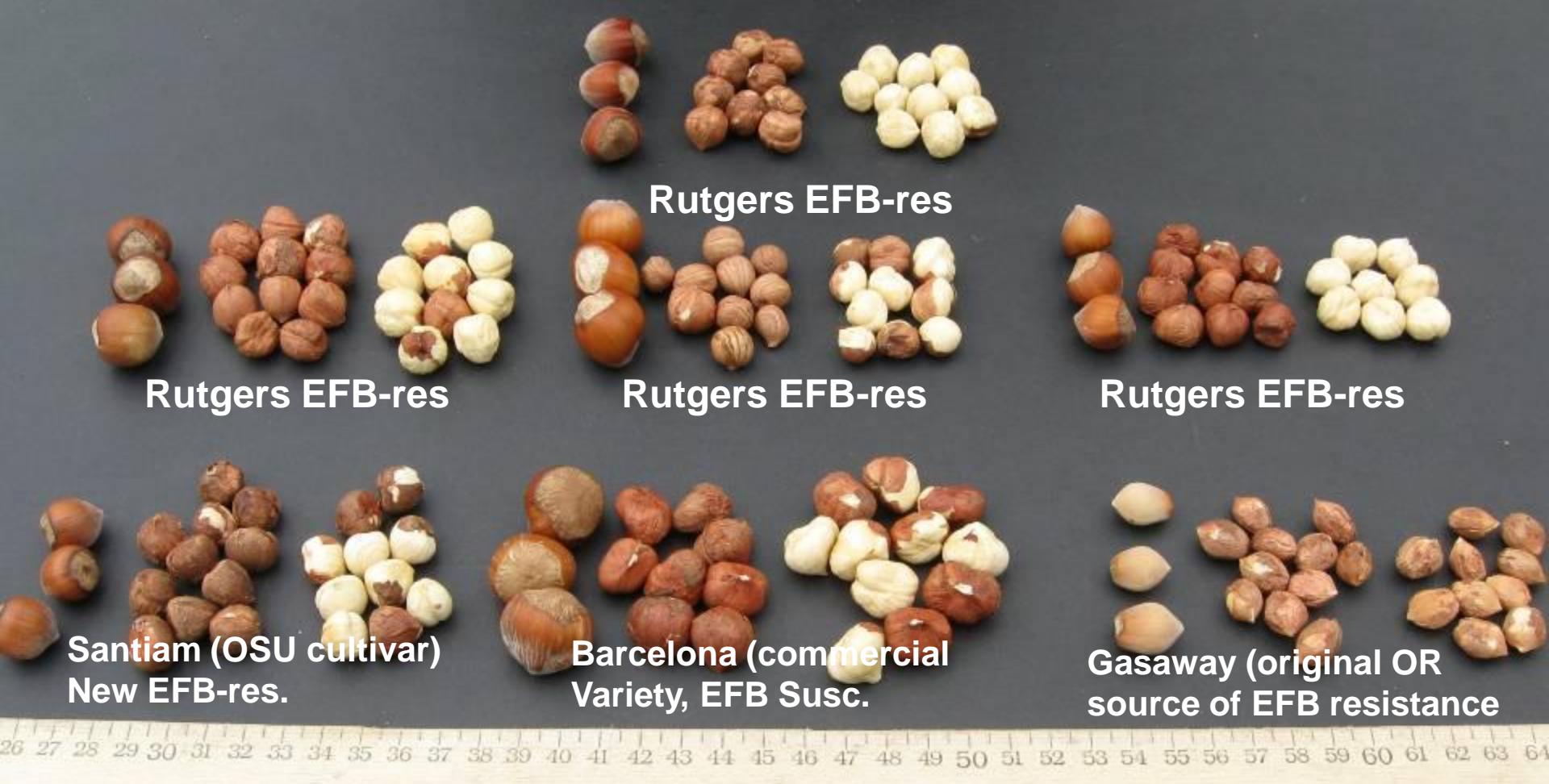
Promising EFB resistant Rutgers hybrid with large nuts



High quality kernels are desired by the world export market (only 10% is in-shell nuts)



Breeding goals now include developing plants with excellent kernels



Rutgers EFB-res

Rutgers EFB-res

Rutgers EFB-res

Rutgers EFB-res

Santiam (OSU cultivar)
New EFB-res.

Barcelona (commercial
Variety, EFB Susc.)

Gasaway (original OR
source of EFB resistance)



H3R13P40



H3R10P88

Wide germplasm collections yielded two excellent EFB-resistant clones
with near-commercial potential

- We evaluate nuts again in years 6, 7 and 8 if they meet size and quality standards and remain EFB resistant
- By year 7 only the best healthy trees with large, round nuts and high quality kernels remain



In year 8, from the thousands of trees, only a small percent of the best trees are propagated for replicated yield trials in multiple locations



Where are we today?

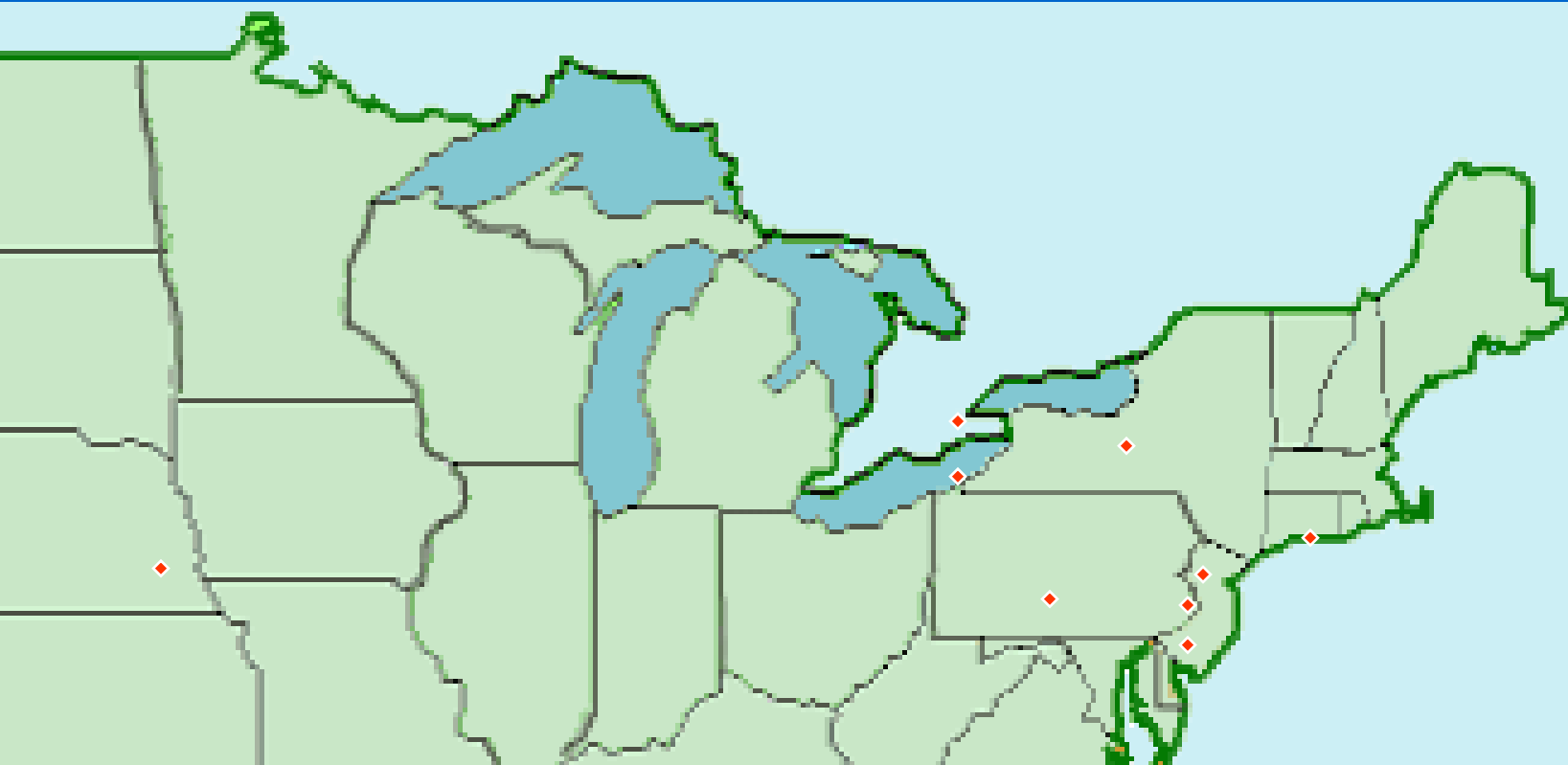
- While we have many thousands of seedlings in the field, so far those in the most advanced stage came from seedlings planted from OSU controlled crosses made in 2000
- From this group of 1,200 plants, about 50 remain today with 14 showing excellent qualities (based on original plant):
 - Highly EFB resistant; medium to large size nut, with over 50% kernel by weight; round kernels; high crop loads few kernel defects.
- The breeding programs continues--Ten years ago we had few EFB resistant selections with decent kernel quality
 - Today we have many hundred of seedlings that meet these criteria



Clonal Yield Trial at Rutgers July 2011 (established 2009)

- **Trials must be evaluated for 7 years or more**
- **Testing in multiple locations with different climates and soils will help us identify the best plants and to measure if any are suitable for release, and larger scale propagation and planting**





Trials located at:

Rutgers (2009 and 2010; New Brunswick, NJ)

University of Nebraska, Lincoln (2009)

University of Guelph, Ontario, Canada (2011)

Malcolm Olsen (2010; Findley Lake, NY—western NY)

Jeff Zarnowski (2010; Cortland, NY—central NY)

Peter Haarmann (2010; Aquebogue, NY—eastern Long Island)

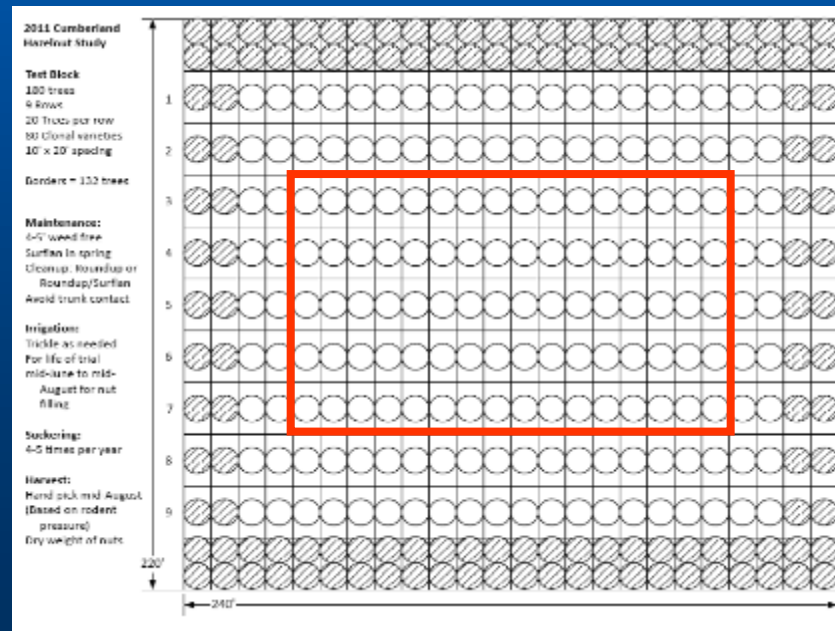
Tucker Hill (2009/2010; Etters, PA)

Shuster Farms (2011; Stockton, NJ—western NJ)

Ruscke Farms (2011; Millville, NJ—southern, NJ)

First Replicated Yield Trials in the Northeast

- Trials are established in a randomized complete block design and include Rutgers selections and several available in the trade ('Jefferson' and 'Theta' from OSU, 'Barcelona', and Tonda di Giffoni)
- Plants evaluated for nut yield, EFB presence, presence of other disease and insect pests, growth habit, vigor, etc.
- Long-term trials will allow us to make educated, data supported decisions on plants to move forward with (if any)



Identifying the best clones for release

Are our selections high enough yielding (consistently) and of high enough quality for commercial use?

Replicated yield trials take 7 years to complete – year to year variations in environment can be significant

Growing them in many locations will reduce the time required to fully evaluate them





Besides what cultivars to grow, many other questions need to be answered for production in the east --

- Timing of flowering a concern in areas with widely fluctuating winter and spring temperatures
 - A series of cultivars, including pollinizers, is likely needed with different flowering times
- What is the most appropriate plant architecture and orchard design?
 - Single-trunk trees or multi-stemmed shrubs
 - Spacing in field like Oregon (20' x 20')
 - Grow as high-density hedges?
- What is most appropriate harvesting method?
 - Sweep nuts from orchard floor
 - Develop picking machine that goes over top of bushes?

Acknowledgments and thanks!

RUTGERS

New Jersey Agricultural
Experiment Station

- New Jersey Agricultural Experiment Station
- Rutgers Center for Turfgrass Science
- Contributors:

Reed Funk

Brad Hillman

John Capik

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Adam Morgan

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David Zaurov

Clayton Leadbetter

Shawn Mehlenbacher

Scott Josiah

Troy Pabst



Hybrid Hazelnut

Consortium partners:

