Developing Hazelnuts (*Corylus* spp.) With Durable Resistance to Eastern Filbert Blight

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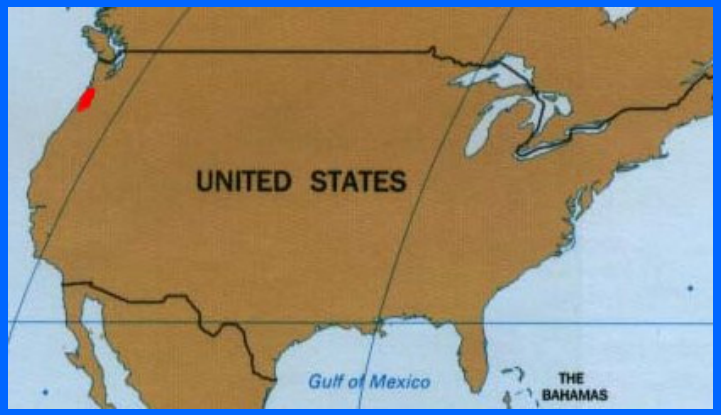
Hazelnuts (filberts) – some background

- **World production based on European hazelnut, *Corylus avellana***
- **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 regions with Mediterranean-like 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*

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

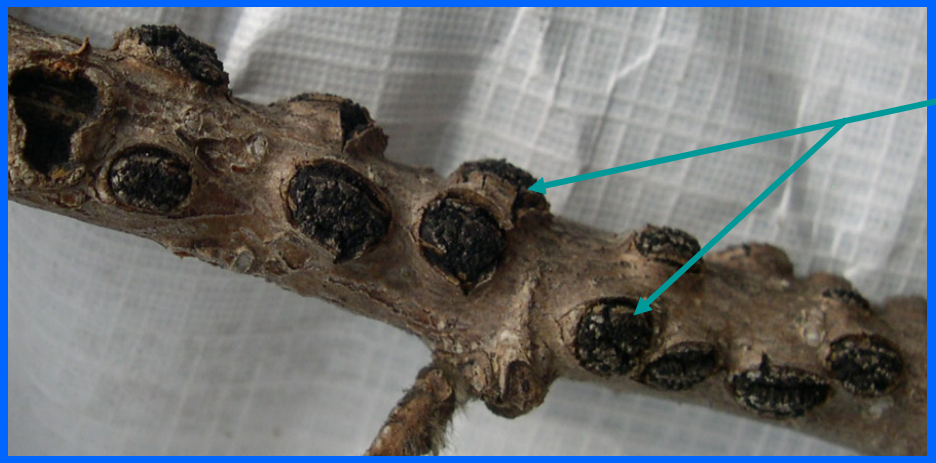
Hazelnuts in Eastern North America

- **Early colonists brought hazelnuts from Europe—very few records, no production established**
- **The fungal disease** Eastern Filbert Blight **(EFB) killed most, if not all, European hazelnut trees**
- **EFB is naturally occurring on the wild American hazelnut, *Corylus americana***
- EFB is the primary reason there are no commercial hazelnut plantings in the east

Native range of American hazelnut *Corylus americana* and associated pathogen *Anisogramma anomala*

EFB on Harry Lauder's Walking stick

Eastern Filbert Blight Fungus - *Anisogramma anomala*



Stromata
(fruiting body)

- Ascomycete in the order Diaporthales
- Obligate biotroph that infects only *Corylus spp.*
- Nearly all European hazelnuts are highly susceptible
- Fungus grows under bark and when reproducing creates cankers that kill the trees

Eastern Filbert Blight is only found in North America

5-year-old *C. avellana* seedlings in New Jersey

Hazelnuts research at Rutgers is built upon breakthroughs in Oregon

- **EFB was absent in Washington and Oregon until late 1960s**
  - **Prior to this time little was known about the disease**
- **Studying the fungus and searching for resistance began at Oregon State Univ. (OSU) in the 1970s, including methods to identify resistant plants and to use them in breeding ('Gasaway' and others)**
- **Breeding success at OSU is exemplified by the new EFB-resistant cultivars 'Yamhill' and 'Jefferson', now being widely planted in OR**
- **At Rutgers we have been building on these research and breeding advances to develop plants for the**

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

Still, very little is known about variation in the EFB pathogen

- Do sources of resistance to EFB from one location hold up in other locations?
- **Oregon provides a useful case study since all the EFB is believed to trace back to a single infection**
- **we tried to answer this question by collecting isolates from around the country and inoculating "resistant" plants in the greenhouse**

Cultivars/selections showing complete resistance to EFB in Oregon at time of trial

Corylus avellana

- **'Gasaway' (OR, USA)**
- **VR20-11 (OR, USA)**
- **'Zimmerman' (OR, USA)**
- **'Closca Molla' (Spain)**
- **'Ratoli' (Spain)**
- **OSU 408.040 Weschcke Seedling (WI, USA)**
- **OSU 495.072 (Russia)**
- **OSU 759.007 (Georgia)**

***Corylus* hybrids**

- **'Grand Traverse' (*C. colurna* hybrid - MI, USA)**
- **OSU 526.041 (*C. heterophyla* hybrid)**
- **OSU 541.147 (*C. americana* hybrid)**
- **OSU 587.044 (*C. cornuta* var. c*alifornica* hybrid)**

EFB isolate populations collected from:

- New Jersey - 2
- New York - 3
- Pennsylvania - 3
- Massachusetts - 1
- Minnesota - 2
- Michigan - 1
- Oregon - 1

Replicated greenhouse inoculations were conducted from 2003-2007

Final conclusion: 5 of 12 selections showed no signs or symptoms of EFB across all isolates all years

Corylus avellana

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These plants have also been exposed in field for 10 years with no signs or symptoms of EFB

We also learned pathogenic variation exists in *Anisogramma anomala*

One isolate from Michigan was able to infect significantly more "resistant" plants than any of the others:

Also, it was the only isolate to infect:

'Gasaway'*,

'Zimmerman'

OSU 408.040

*The 'Gasaway' source of resistance has been widely used in the Oregon State Univ. breeding program—all new orchards are planted to cultivars using this gene for protection. 'Gasaway' has been free of EFB in OR for over 30 years.

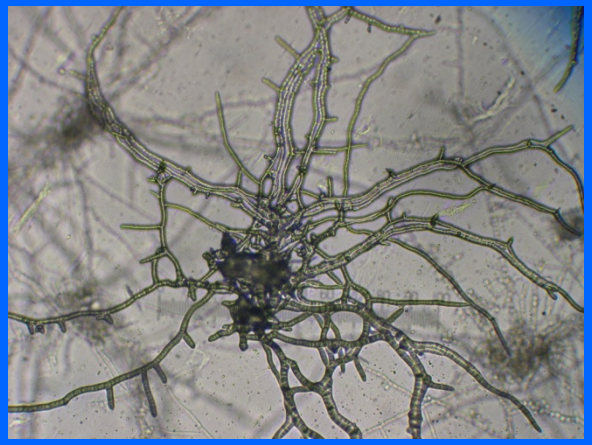
New turn of events at Rutgers

- **Previously, the only EFB cankers observed on 'Gasaway' were from greenhouse inoculated plants using the isolate from MI**
- **Now, field grown plants of 'Gasaway' naturally exposed to EFB are showing disease**
  - **Trees grew in infected nursery for 8 years with no EFB**
  - **In winter 2008, Over 25 trees of 'Gasaway' at Rutgers on two research farms all showing EFB (small cankers)**
  - **VR20-11, an offspring of 'Gasaway', also showing EFB (with larger cankers)**

Is EFB on 'Gasaway' due to a change in the NJ "strain", a new isolate introduction, or a specific climatic event?

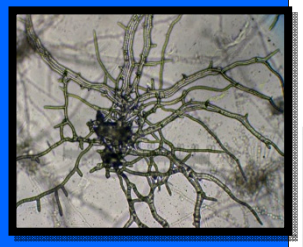
- **Previously, there was no clear way to differentiate isolates or study the genetic diversity and population structure of the fungus.**
  - ***A. anomala* grows poorly in culture**
  - **gene regions ITS, EF-1alpha, beta tubulin 2, and calmodulin showed little variability**
- **After a partial sequencing of its genome last winter, we have identified many thousands of potential SSR loci, from which we are developing primers to fingerprint and study the isolates**
  - **To date, we have developed 8 very promising SSR primer pairs, with more on the way**

Germinating spores of *A. anomala*



A. anomala culture at 8 weeks

Genetic diversity study now underway



- **Isolates collected from over 30 locations, with multiple cankers from each location**
  - **Collections from Wisconsin represent cankers found on wild hazelnuts in forest setting**
- **Early results supports our hypothesis that *A. anomala* is homothallic and sexual spores from one contiguous canker are**

Rutgers *A. anomala* Isolates

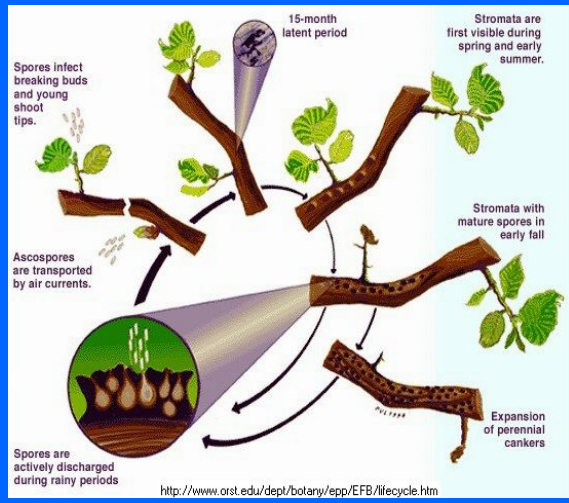
City	State	<10 isolates	10-20 isolates	>20 isolates
Monmouth	IL	●		
Boston	MA			●
Boothbay	ME	●		
East Lansing	MI			●
Leslie	MI			●
Tustin	MI	●		
Canton	MN		●	
Montevideo	MN		●	
St. Paul	MN			●
Wycoff	MN		●	
Columbia	MO	●		
Adelphia	NJ		●	
Colts Neck	NJ	●		
Cream Ridge	NJ			●
Jackson	NJ		●	
Morristown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

Rutgers Breeding Program:

- Started in 1996, we now have 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 obtained about 15 (likely distinct) sources of EFB resistance that transmit to their progeny
  - *C. avellana, C. colurna, C. americana, C. heterophylla*
- We are studying inheritance of EFB resistance while working to combine resistance with excellent nut quality and cold hardy catkins

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

- **Long lifecycle (~24 months from spore to spore). Inoculations = 16 months for cankers**
- **We developed a method to induce cankers after 9 months, but is labor intensive**
- **OSU developed rapid (6 month) ELIZA assay, but requires supply of antibody**
- **Currently are developing a realtime PCR assay for much earlier detection (2-3 months from infection)**
- **OSU developing and using MAS in breeding**
  - **Takes time/resources to characterize populations and to develop markers, but very effective/efficient once developed**



Lifecycle of *Anisogramma anomala* http://oregonstate.edu/dept/botany/epp/EFB/