Late Blight situation in the USA

Bill Fry
Cornell University, Ithaca NY, USA

- Clonal populations
- Near “real-time reporting” → USAblight
- Sexual reproduction
Phytophthora infestans 1997-2015

- Rare and diverse genotypes
- US-24
- US-23
- US-22
- US-21
- US-20
- US-19
- US-18
- US-17
- US-16
- US-15
- US-14
- US-13
- US-12
- US-11
- US-10
- US-9
- US-8
- US-7
- US-6
- US-5
- US-4
- US-3
- US-2
- US-1

Year

Slide: Giovanna Danies
US-8 clonal lineage

1992/1993
US-8 clonal lineage
US8 – more aggressive
US8 requires more fungicide
Pasco et al (2015). "And the nasty ones lose in the end: foliar pathogenicity trades off with asexual transmission in the Irish famine pathogen Phytophthora infestans." New Phytologist:

(not in the USA).

--- The nasty ones win in the end.
Phytophthora infestans 1997-2015

Rare and diverse genotypes
US-24
US-23
US-22
US-21
US-20
US-19
US-18
US-17
US-16
US-15
US-14
US-13
US-12
US-11
US-8
US-7
US-6

Slide: Giovanna Danies
Phytophthora infestans 1997-2015

2015: 158 samples (52 from NY, US23 except research plots)

US23: 101
(FL, WI, NY, NJ, MD, NC, PA, CT, ID, ME, CA, NM, WA, MT, OR, MN)

US11: 5 (OR, CA)

US8: 6 (CA, CO, WA, NE)

2 new strains (TX)
Host preference

Host

- Potato
- Tomato

Sporulation (sporangia per ml)

Clonal lineage

- US-8
- US-22
- US-23
- US-24

(Daines, 2013. Plant Disease)
Phenotypes of common lineages

Sensitivity to mefenoxam
<table>
<thead>
<tr>
<th>Lineage</th>
<th>mating type</th>
<th>Rid R/S?</th>
<th>host</th>
</tr>
</thead>
<tbody>
<tr>
<td>US8</td>
<td>A2</td>
<td>R</td>
<td>P(t)</td>
</tr>
<tr>
<td>US11</td>
<td>A1</td>
<td>R</td>
<td>P/T</td>
</tr>
<tr>
<td>US22</td>
<td>A2</td>
<td>S</td>
<td>P/T</td>
</tr>
<tr>
<td>US23</td>
<td>A1</td>
<td>S</td>
<td>P/T</td>
</tr>
<tr>
<td>US24</td>
<td>A1</td>
<td>S</td>
<td>P(t)</td>
</tr>
</tbody>
</table>
Late Blight situation in the USA

Bill Fry
Cornell University, Ithaca NY, USA

• Clonal populations
• Near “real-time reporting” → USAblight
• Sexual reproduction
From: USABlight.org [mailto:notify@usablight.org]
Sent: Thursday, August 01, 2013 9:16 AM
To: William Earl Fry
Subject: Late Blight found nearby

Location: Wayne County, OH
Host: Tomato
Distance is within 200-500 miles of NC State - Raleigh

Do not reply to this e-mail; it was automatically generated based on your indicated preferences.

Change your alert criteria: http://usablight.org

Genotype Identification:
• Samples (overnight) → Fry Lab
• SSR analysis
• report to sender (24-48 hr)
Timeline of *P. infestans* samples 2013

- US7 - 2 (FL)
- US8 - 2 (PA, MA)
- US11 - 3 (OR, CA)
- US23 - 4 (3 OR, 1 ME)
- US23 175
- Other: 11

~195 samples (Oct)
Click on a county below for more report information.

- Boone County, AR
- Clark County, AR
- Conway County, AR
- Dallas County, AR
- Garland County, AR
- Grant County, AR
- Hot Spring County, AR
- Independence County, AR
- Lee County, AR
- Lonoke County, AR
- Poinset County, AR
- Pulaski County, AR
- Washington County, AR
- Kern County, CA
- Collier County, FL
- Hillsborough County, FL
- Manatee County, FL
Click on a county below for more report information.
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1. Boone County, AR
2. Clark County, AR
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5. Garland County, AR
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11. Poinsett County, AR
12. Pulaski County, AR
13. Washington County, AR
14. Kern County, CA
15. Collier County, FL
16. Hillsborough County, FL
17. Manatee County, FL
DSS: BlightPro

Input

Cultivar: Yukon Gold
Resistance: susceptible

Emergence date: 05/15/2013
First potato foliage (culls, volunteers, current crop) or first tomato foliage (e.g., transplants) in the region - approx. 30 mile radius

Pathogen Lineage: US-24

Potato: susceptible
Tomato: not susceptible
Mefenoxam: generally effective (only moderately effective in some cases)

Please fill in the requested information and then click on the 'Submit Fungicide' button.

Date
Select Hour
Select Fungicide Ingredient

Submit Fungicide  Cancel Fungicide

Get Reports
## Pathogen lineage information

<table>
<thead>
<tr>
<th>Pathogen lineage</th>
<th>Susceptible crop</th>
<th>Sensitivity to mefenoxam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown (default)</td>
<td>Potato Tomato</td>
<td>?</td>
</tr>
<tr>
<td>US-1</td>
<td>Potato Tomato</td>
<td>Sensitive</td>
</tr>
<tr>
<td>US-2</td>
<td>Potato Tomato</td>
<td>?</td>
</tr>
<tr>
<td>US-3</td>
<td>Potato Tomato</td>
<td>?</td>
</tr>
<tr>
<td>US-4</td>
<td>Potato Tomato</td>
<td>?</td>
</tr>
<tr>
<td>US-5</td>
<td>Potato Tomato</td>
<td>Sensitive</td>
</tr>
<tr>
<td>US-6</td>
<td>Potato Tomato</td>
<td>Resistant</td>
</tr>
<tr>
<td>US-7</td>
<td>Potato Tomato</td>
<td>Resistant</td>
</tr>
<tr>
<td>US-8</td>
<td>Potato</td>
<td>Intermediate/Resistant</td>
</tr>
<tr>
<td>US-9</td>
<td>Potato Tomato</td>
<td>Resistant</td>
</tr>
<tr>
<td>US-10</td>
<td>Potato Tomato</td>
<td>Sensitive</td>
</tr>
<tr>
<td>US-11</td>
<td>Potato Tomato</td>
<td>Resistant</td>
</tr>
<tr>
<td>US-12</td>
<td>Potato Tomato</td>
<td>Resistant</td>
</tr>
<tr>
<td>US-13</td>
<td>Potato Tomato</td>
<td>Resistant</td>
</tr>
<tr>
<td>US-14</td>
<td>Potato Tomato</td>
<td>Resistant</td>
</tr>
<tr>
<td>US-15</td>
<td>Potato Tomato</td>
<td>Resistant</td>
</tr>
<tr>
<td>US-16</td>
<td>Potato Tomato</td>
<td>Resistant</td>
</tr>
<tr>
<td>US-17</td>
<td>Tomato</td>
<td>Resistant</td>
</tr>
<tr>
<td>US-18</td>
<td>Potato Tomato</td>
<td>Sensitive (Intermediate)</td>
</tr>
<tr>
<td>US-19</td>
<td>Potato Tomato</td>
<td>Sensitive (Intermediate)</td>
</tr>
<tr>
<td>US-20</td>
<td>Potato Tomato</td>
<td>Intermediate/Resistant</td>
</tr>
<tr>
<td>US-21</td>
<td>Potato Tomato</td>
<td>Sensitive/Intermediate/Resistant</td>
</tr>
<tr>
<td>US-22</td>
<td>Potato Tomato</td>
<td>Sensitive (Intermediate)</td>
</tr>
<tr>
<td>US-23</td>
<td>Potato Tomato</td>
<td>Sensitive (Intermediate)</td>
</tr>
<tr>
<td>US-24</td>
<td>Potato</td>
<td>Sensitive (Intermediate)</td>
</tr>
</tbody>
</table>

Photos courtesy G. Danies
Screenshot: Input page for disease forecasters

- Cultivar: Yukon Gold
- Resistance: susceptible

Emergence date: 05/15/2013
First potato foliage (culls, volunteers, current crop) or first tomato foliage (e.g. transplants) in the region - approx. 30 mile radius

Pathogen Lineage: US-24

Potato: susceptible  Tomato: not susceptible  Mefenoxam: generally effective (only moderately effective in some cases)

Please fill in the requested information and then click on the 'Submit Fungicide' button.

Submit Fungicide  Cancel Fungicide

Get Reports
# Potato cultivar resistance database

<table>
<thead>
<tr>
<th>Cultivar Name</th>
<th>Susceptibility</th>
<th>Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adirondack Red</td>
<td>susceptible</td>
<td>early</td>
</tr>
<tr>
<td>All Blue</td>
<td>susceptible</td>
<td>late</td>
</tr>
<tr>
<td>All Red</td>
<td>susceptible</td>
<td>late</td>
</tr>
<tr>
<td>Allegany</td>
<td>moderately susceptible</td>
<td>late</td>
</tr>
<tr>
<td>Ambra</td>
<td>(susceptible)</td>
<td>early</td>
</tr>
<tr>
<td>Amey</td>
<td>susceptible</td>
<td>late</td>
</tr>
<tr>
<td>Andover</td>
<td>susceptible</td>
<td>early</td>
</tr>
<tr>
<td>Atlantic</td>
<td>susceptible</td>
<td>mid season</td>
</tr>
<tr>
<td>Austrian Crescent</td>
<td>(susceptible)</td>
<td>late</td>
</tr>
<tr>
<td>Bake King</td>
<td>susceptible</td>
<td>mid season</td>
</tr>
<tr>
<td>Banana</td>
<td>susceptible</td>
<td>late</td>
</tr>
<tr>
<td>Butte</td>
<td>(susceptible)</td>
<td>mid season</td>
</tr>
<tr>
<td>Carbe</td>
<td>(susceptible)</td>
<td>early</td>
</tr>
<tr>
<td>Carola</td>
<td>(susceptible)</td>
<td>mid season</td>
</tr>
<tr>
<td>Carrera</td>
<td>(susceptible)</td>
<td>early</td>
</tr>
<tr>
<td>Castile</td>
<td>moderately susceptible</td>
<td>mid season</td>
</tr>
<tr>
<td>Cherry Red</td>
<td>susceptible</td>
<td>(mid season)</td>
</tr>
<tr>
<td>Chieftain</td>
<td>susceptible</td>
<td>mid season</td>
</tr>
<tr>
<td>Chippewa</td>
<td>susceptible</td>
<td>early</td>
</tr>
<tr>
<td>Donia</td>
<td>moderately susceptible</td>
<td>(mid season)</td>
</tr>
<tr>
<td>Elba</td>
<td>moderately resistant</td>
<td>late</td>
</tr>
<tr>
<td>Eramosa</td>
<td>susceptible</td>
<td>early</td>
</tr>
<tr>
<td>Eva</td>
<td>susceptible</td>
<td>mid season</td>
</tr>
<tr>
<td>Fabula</td>
<td>(susceptible)</td>
<td>early</td>
</tr>
<tr>
<td>French Fingerling</td>
<td>(susceptible)</td>
<td>mid season</td>
</tr>
<tr>
<td>Genesee</td>
<td>susceptible</td>
<td>late</td>
</tr>
<tr>
<td>Carmen Butterfly</td>
<td>(susceptible)</td>
<td>late</td>
</tr>
</tbody>
</table>
# Tomato cultivar resistance database

<table>
<thead>
<tr>
<th>Variety</th>
<th>Susceptibility to LB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defiant PHR F1</td>
<td>Resistant (Ph2 &amp; Ph3)</td>
</tr>
<tr>
<td>Matt’s Wild Cherry</td>
<td>Resistant</td>
</tr>
<tr>
<td>Mountain magic F1</td>
<td>Resistant (Ph2 &amp; Ph3)</td>
</tr>
<tr>
<td>Plum regal F1</td>
<td>Resistant (Ph3)</td>
</tr>
<tr>
<td>Aunt Ginny’s Purple</td>
<td>Moderately resistant</td>
</tr>
<tr>
<td>Aunt Ruby’s German Green</td>
<td>Moderately resistant</td>
</tr>
<tr>
<td>Black Krim</td>
<td>Moderately resistant</td>
</tr>
<tr>
<td>Black Plum</td>
<td>Moderately resistant</td>
</tr>
<tr>
<td>Brandywine</td>
<td>Moderately resistant</td>
</tr>
<tr>
<td>Prudens Purple</td>
<td>Moderately resistant</td>
</tr>
<tr>
<td>Red Currant</td>
<td>Moderately resistant</td>
</tr>
<tr>
<td>Yellow Currant</td>
<td>Moderately resistant</td>
</tr>
<tr>
<td>Yellow Pear</td>
<td>Moderately resistant</td>
</tr>
<tr>
<td>BHN 589</td>
<td>Moderately susceptible</td>
</tr>
<tr>
<td>BHN 961</td>
<td>Moderately susceptible</td>
</tr>
<tr>
<td>Big Beef</td>
<td>Moderately susceptible</td>
</tr>
<tr>
<td>Celebrity</td>
<td>Moderately susceptible</td>
</tr>
<tr>
<td>Mountain Fresh Plus F1</td>
<td>Moderately susceptible</td>
</tr>
<tr>
<td>Mountain Supreme</td>
<td>Moderately susceptible</td>
</tr>
<tr>
<td>West VA 63</td>
<td>Moderately susceptible</td>
</tr>
<tr>
<td>Glamour</td>
<td>Susceptible</td>
</tr>
<tr>
<td>Gold Nugget</td>
<td>Susceptible</td>
</tr>
<tr>
<td>Jetstar F1</td>
<td>Susceptible</td>
</tr>
<tr>
<td>Market Pride</td>
<td>Susceptible</td>
</tr>
<tr>
<td>New girl F1</td>
<td>Susceptible</td>
</tr>
<tr>
<td>New Yorker</td>
<td>Susceptible</td>
</tr>
<tr>
<td>Pik Rite</td>
<td>Susceptible</td>
</tr>
<tr>
<td>Pilgrim</td>
<td>Susceptible</td>
</tr>
<tr>
<td>Primo red F1</td>
<td>Susceptible</td>
</tr>
<tr>
<td>Scarlet red</td>
<td>Susceptible</td>
</tr>
<tr>
<td>Sunbrite VFF</td>
<td>Susceptible</td>
</tr>
<tr>
<td>Sunrise</td>
<td>Susceptible</td>
</tr>
<tr>
<td>Supersonic F1</td>
<td>Susceptible</td>
</tr>
<tr>
<td>Ultra Sweet</td>
<td>Susceptible</td>
</tr>
</tbody>
</table>
Late Blight situation in the USA

Bill Fry
Cornell University, Ithaca NY, USA

- Clonal populations
- Near “real-time reporting → USAblight
- Sexual reproduction?
Phytophthora infestans 2009-2015

- Rare and diverse genotypes
- US-24
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- US-12
- US-11
- US-10
- US-9
- US-8
- US-7
- US-6
- US-5
- US-4
- US-3
- US-2
- US-1

Year

(371)  (89)  (68)  (198)  (284)  (174)  (160)  (114)

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%


Slide: Giovanna Danies
New York State
2010 and 2011

Mating types
- A1
- A2
- A1 and A2
*Phytophthora infestans* genotypes from central NYS in 2011 and 2012

- Diverse genotypes for:
  - Allozyme *Glucose-6-phosphate isomerase*
  - Microsatellite
  - RFLP probe RG57
  - Nuclear genes
  - Mefenoxam sensitivity

- Monomorphic for mitochondrial haplotype
1. Lineages that have not been prevalent in the United States for the past 10 years

2. Lineages that have been dominant in the past five years or that have been first described during the past five years in the United States

3. NYS-2010/11 *P. infestans* isolates that are the focus of this study

Slide: Giovanna Danies
STRUCTURE analysis of 12 microsatellite loci

Recombinants?

probably 
Parents?

US8?
US11?
US21?
US22?

Slide: Giovanna Danies
New York State 2010 and 2011

An ephemeral recombinant population
US22 as one of at least three parents?

The Second report of a recombinant sexual pop’n in the USA
(First report: Pacific NW; → US11)

Map showing mating types:
- A1
- A2
- A1 and A2

Slide: Giovanna Danies
Late Blight situation in the USA

Bill Fry
Cornell University, Ithaca NY, USA

- Clonal populations
- Near “real-time reporting” → USAblight
- Sexual reproduction
Thanks for listening

.... and thanks to:

Giovanna Danies         Kevin Myers

Ian Small

USDA NIFA program on global food security
SSR analysis of potential Parents?

US8?
US11?
US21?
US22?

<table>
<thead>
<tr>
<th>PITG_11126</th>
<th>Microsatellite loci</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>D13</td>
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<tr>
<td>US-8</td>
<td>108</td>
</tr>
<tr>
<td></td>
<td>112</td>
</tr>
</tbody>
</table>

All new genotypes

<table>
<thead>
<tr>
<th></th>
<th>110</th>
<th>134</th>
<th>166</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-</td>
<td>156</td>
<td>170</td>
</tr>
</tbody>
</table>

US-22

GDT-1
GDT-2
GDT-3
GDT-4
GDT-5
GDT-6
GDT-7
GDT-8
GDT-9
GDT-10
GDT-11

US-22

G          T          G
Recent developments concerning the population biology and control strategies of *Phytophthora infestans* in the USA.

Bill Fry
Cornell University, Ithaca NY, USA

- 2009 epidemic
- USAblight

- Enhanced interest
- Rapid diagnostics
  → informed management
Glucose-6-phosphate isomerase (Gpi)

RFLP probe RG57

Markers

Microsatellite markers

Mitochondrial haplotyping

Nuclear genes

Slide: G. Danies
US-8 vs US-24 on potato

- US-8 (default)
- US-24 Spor. Rate (0.31)
Lineage ID (Genotypic analysis):

Day 1:
• Sample collection
• overnight transit:

Day 2:
• Receipt in lab
• DNA extraction
• PCR
  → Sequencing (overnight)

Day 3:
• Result from sequencing
• Communication to sender
Timeline of *P. infestans* samples 2013

- August 2013
  - US7 - 2 (FL)
  - US8 – 2 (PA, MA)
- Sept-Oct 2013
  - US11 – 3 (OR, CA)
  - US24- 4 (3 OR, 1 ME)
- Other: 11

~195 samples (Oct)
Genotypes of *P. infestans* in USA from 1997 to 2014 (potato and tomato)

- Rare and diverse genotypes
- US-24
- US-23
- US-22
- US-21
- US-20
- US-19
- US-18
- US-17
- US-11
- US-8
- US-7
- US-6
- US-1

*Fry lab; Hu et al., 2012 Plant Disease; and Wangsomboondee et al., 2002 Ecology and Population Biology

Slide: G. Danies
**Phytophthora infestans 2009-2015**

**2015**: 158 samples

US23: 101
(FL, WI, NY, NJ, MD, NC, PA, CT, ID, ME, CA, NM, WA, MT, OR, MN)

US11: 5 (OR, CA)

US8: 6 (CA, CO, WA, NE)

2 new strains (TX)
Lineage ID (Genotypic analysis):

Day 1:
- Sample collection
- overnight transit:

Day 2:
- Receipt in lab
- DNA extraction
- PCR
  ➔ Sequencing (overnight)

Day 3:
- Result from sequencing
- Communication to sender

Phenotypic Analysis

Isolate ➔ pure culture (3-10 weeks)

Then:
- Mating type (>2 weeks)
- Host preference (>4 weeks)
- Mefenoxam sensitivity (2 weeks)
- Aggressiveness (>6 weeks)
- Other tests (2-6-? weeks)
<table>
<thead>
<tr>
<th>Lineage</th>
<th>mating type</th>
<th>Rid</th>
<th>host</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>US8</td>
<td>A2</td>
<td>R</td>
<td>P(t)</td>
<td>USA</td>
</tr>
<tr>
<td>US11</td>
<td>A1</td>
<td>R</td>
<td>P/T</td>
<td>USA</td>
</tr>
<tr>
<td>US22</td>
<td>A2</td>
<td>S</td>
<td>P/T</td>
<td>USA</td>
</tr>
<tr>
<td>US23</td>
<td>A1</td>
<td>S</td>
<td>P/T</td>
<td>USA</td>
</tr>
<tr>
<td>US24</td>
<td>A1</td>
<td>S</td>
<td>P(t)</td>
<td>USA</td>
</tr>
<tr>
<td>2014 “A”</td>
<td>A1*</td>
<td>R*</td>
<td>--</td>
<td>NY Su</td>
</tr>
<tr>
<td>2014 “B”</td>
<td>A2*</td>
<td>S/I*</td>
<td>P/T*</td>
<td>NY Al, St</td>
</tr>
<tr>
<td>2015 “A”</td>
<td>--</td>
<td>S*</td>
<td>--</td>
<td>TX</td>
</tr>
<tr>
<td>2015 “B”</td>
<td>A2*</td>
<td>S*</td>
<td>--</td>
<td>TX</td>
</tr>
</tbody>
</table>

* Funding from ESPG

**Why care?**
we don’t ship plants, transplants are produced locally we ship plugs
we don’t ship plants, transplants are produced locally we ship plugs
Phytophthora infestans 1997-2015

2015: 158 samples (52 from NY, US23 except research plots)

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(FL, WI, NY, NJ, MD, NC, PA, CT, ID, ME, CA, NM, WA, MT, OR, MN)

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US8: 6 (CA, CO, WA, NE)

2 new strains (TX)
Epidemics – almost exclusively clonal – only one genotype