Fusarium yellows on celery

Lynn Epstein
Department of Plant Pathology, UCD
lepstein@ucdavis.edu, 530-754-7916

SRA’s: Sukhwinder Kaur & Vince D’Antonio
Undergraduate: Selene Bello

Cooperator: Richard Hurstak, Crop Science Services
History of fusarium yellows on celery in California

1906 - 1978
Fusarium yellows is apparently caused by *Fusarium oxysporum* f. sp. *apii* “race 1”

“Race 1” is virulent on self blanching (yellow) celery

Late 1950’s: Tall Utah 52-70 is introduced

1978 – 2013
Fusarium yellows is apparently caused by *Fusarium oxysporum* f. sp. *apii* “race 2”

Race 2 is highly virulent on Tall Utah, and to a lesser extent on Sonora & Conquistador

“Resistance” (or really tolerance) is primarily due to a single dominant gene from celeriac (PI 169001) (Orton et al. 1984).

The gene(s) is in Challenger, Stix, Sabroso, Green Bay, & Picador
Tolerant plants are actually infected but are asymptomatic

We used DNA sequencing to ID “race 2,” (we call it “clade 3”), which is a single strain

Race 2/clade 3 causes the classic vascular discoloration

Two of the *Fusarium*-tolerant varieties in development by the UC Davis Breeding Program: UC390S-2 & UC12A45

A commercial, *Fusarium*-tolerant variety developed using material from the UC Davis Breeding Program

*Fusarium*-susceptible

Tall Utah 52-70 Improved

Some cultivars from the CCRAB trial in Oxnard, CA in November 2013 in *Fusarium*-infested soil
Fusarium yellows
Symptomatic plants are yellowed & stunted
The xylem has an orange-brown discoloration
## Fusarium ratings in the CCRAB Field trials from 2003 to 2012

**Data from Richard Hurstak from the CCRAB trials**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tall Utah</td>
<td>1.7 a</td>
<td>0.6 a</td>
<td>2.8 a</td>
<td>1.9 a</td>
<td>4.5 a</td>
<td>4.6 a</td>
<td>4.2 a</td>
<td>4.6 a</td>
<td>4.2 a</td>
</tr>
<tr>
<td>Tall Utah'</td>
<td>1.7 a</td>
<td>0.5 a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| (Sonora)   | 1.4 ab|      |      |      |      |      |      | 2.8 b|      |
| Conquistador| 1.2 ab| 0.4 a| 1.2 b| 0.5 b| 2.6 b| 3.2 b| 2.0 b| 3.2 b| 2.3 b |
| Command'    | 0.7 ab| 0.3 a|      |      | 2.4 bc| 2.8 b| 2.8 b| 2.0 bc|      |
| Sonora      | 0.2 a | 0.7 b| 0.4 b|      | 2.5 bc| 1.8 bc| 2.5 bc| 2.0 bc|      |
| Stix'       | 0.7 b | 0.3 b| 1.6 cd|      |      |      |      |      | 1.4 bc|
| (Command')  | 0.6 b | 0.3 b|      |      |      |      |      | 1.8 bc|      |
| (Stix')     |      |      |      |      |      |      |      | 1.0 bc|      |
| Promise'    | 0.4 b |      |      |      |      |      | 1.1 d|      | 1.0 de|
| Green Bay   | 0.4 b |      |      |      |      |      |      |      |      |
| Challenger  | 0.3 b | 0.1 a| 0.4 b| 0.2 b| 0.9 d| 1.3 cd| 0.5 c| 1.3 cd| 0.5 e |
| (Stix')     |      | 0.1 a| 0.3 b|      |      |      |      |      |      |
| (Green Bay')|      |      |      |      |      |      |      | 1.1 d | 1.1 d |
| (Promise')  |      | 0.1 a|      |      |      |      |      |      |      |
| UC040A      |      |      |      |      |      |      |      | 1.0 d | 1.0 d |

**Fusarium rating:** 0, no discoloration; 5, nearly dead

Data from Richard Hurstak from the CCRAB trials
Results from the CCRAB field trials 2003 – 2013: the more Fusarium-sensitive varieties have a significant negative correlation between yield and the Fusarium rating system.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Fusarium-sensitivity</th>
<th>Celery weight &amp; Fusarium rating</th>
<th>Celery height &amp; Fusarium rating</th>
<th>Celery weight &amp; height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tall Utah</td>
<td>Highly susceptible</td>
<td>-0.86</td>
<td>-0.72</td>
<td>0.83</td>
</tr>
<tr>
<td>Sonora</td>
<td>Susceptible</td>
<td>-0.66</td>
<td>-0.48</td>
<td>0.74</td>
</tr>
<tr>
<td>Conquistador</td>
<td>Susceptible</td>
<td>-0.59</td>
<td>-0.55</td>
<td>0.82</td>
</tr>
<tr>
<td>Green Bay</td>
<td>Somewhat tolerant?</td>
<td>-0.59</td>
<td>-0.69</td>
<td>0.58</td>
</tr>
<tr>
<td>Command</td>
<td>Somewhat tolerant?</td>
<td>-0.29</td>
<td>NS</td>
<td>0.52</td>
</tr>
<tr>
<td>Stix</td>
<td>Tolerant?</td>
<td>NS</td>
<td>NS</td>
<td>0.47</td>
</tr>
<tr>
<td>Promise</td>
<td>Tolerant</td>
<td>NS</td>
<td>NS</td>
<td>0.67</td>
</tr>
<tr>
<td>Challenger</td>
<td>Tolerant</td>
<td>NS</td>
<td>NS</td>
<td>0.63</td>
</tr>
</tbody>
</table>
Greenhouse assay of the *Fusarium*-susceptible *Tall Utah*
Greenhouse assay of the *Fusarium*-tolerant Challenger

**Clade 3**  
Mock-inoculated
The story becomes more complicated

We (and previously Krishna Subbarao) consistently isolate both “race 2” (which we call “clade 3”) and a set of related but diverse *Fusarium oxysporum* isolates (which we call “clade 2”) from symptomatic tissue.

These “clade 2” isolates do not cause discoloration but they have a range of virulence in a new seedling assay, from causing no disease to highly virulent...
Oxnard, Celery Research Advisory Board trial, 28 May 2013: total loss

We identify a different strain(s) of *Fusarium oxysporum* f. sp. *apii* that is highly virulent & causes vascular discoloration. It is unrelated to race 2/our “clade 3;” we call it “clade 1.”
IGS polymorphisms in Clade 1 and Clade 3

Clade 1
GATGTGTCGTCTCGGACGGGCCGG
100 110 120

Clade 3
GATGTGTCGTCTCTGGACGGGCCGG
100 110 120

Clade 1
GGACATGGTCGGCTCAGGCTCGA
220 230 240

Clade 3
GGACATGGTCGGCTCAGGATCGA
220 230 240

Clade 1
GGCGCGGCTCTGTGAGTGATGTCT
250 260 270

Clade 3
GGCGCGGCTCTGTGAGTGATGTGN
250 260 270

Clade 1
TCTTGGTCAAATTTGATGTCCGG
300 310 320

Clade 3
TCTTGGTCAAATTTGATGTCCGG
310 320

Tall Utah planted in soil apparently only with clade 1 and clade 2 isolates

etc.
Phylogenetic tree of the ef1 DNA sequence of 209 *Fusarium oxysporum* isolates from symptomatic celery

Clade 1 is a group of highly divergent international isolates. We have recently isolated a highly virulent clade 1 in 3 fields in the Oxnard area. There is some variability in clade 1 sequence.

Clade 2 is a group of isolates with variable but related sequences. None of the currently tested isolates cause discoloration, but they are frequently isolated from infected celery roots, and some of them cause stunting in a lab seedling assay.

Clade 3 is a group of isolates with identical sequence. We believe this is the classic “race 2” that has been in California since at least the late 1970’s.

Many *Fusarium oxysporum* isolates in soil are either non-pathogenic (presumably mostly saprophytic) or pathogenic on other crops, and are not in any of the clades shown above.
What are we doing now?

- We’re screening the entire UC Davis celery germplasm (including related wild species) for tolerance/resistance to both clade 1 and for additional genes for tolerance/resistance to “race 2”

- We’re collecting sufficient DNA sequence of the different strains so that we can determine for growers the pre-plant inoculum concentration of the different strains in soil

- We’re determining the role of the “clade 2” isolates in fusarium yellows
What should you do?

• Keep records of fusarium yellows incidence in particular fields
• Avoid moving soil from infested to presumably clean fields
• Maintain a rotation out of celery
• Control chewing insects and reduce plant water stress
• Plant Fusarium-tolerant varieties (for “race 2”):
  – Challenger or Mission are fusarium-tolerant
  – Sabroso (a traditionally a juicing variety), Samba, Green Bay, Stix, & Picador are also fusarium-tolerant (but I don’t know how well they produce in Oxnard)
    • Command seems less tolerant of fusarium than Challenger
    • Sonata & Conquistator are even less tolerant of fusarium than Command
• Contact us if you think you might have “clade 1”-infected plants
  – “Clade 1” appears to be virulent on formerly Fusarium-tolerant cultivars
  – So far, we have only isolated “clade 1” in some fields in Oxnard
Questions on Fusarium yellows on celery?

E-mail or call:

Lynn Epstein
Department of Plant Pathology, UCD
lepstein@ucdavis.edu
530-754-7916

Sukhwinder Kaur 530-754-7919