Fusarium wilt of strawberry

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Steve Koike
Steve Knapp
Glenn Cole
Fusarium wilt
Verticillium wilt
Macrophomina crown rot
Fusarium wilt

Caused by *Fusarium oxysporum* which survives in soil

Infects plant roots

Damage results when the fungus enters the core of the root
Within the root core the fungus invades xylem vessels, which transport water to the crown and leaves.

Microconidia carried upward in xylem vessels.

Section of crown from infected plant showing fungal growth from colonized vascular tissue.
Reduced flow of water from roots results in collapse of the plant.

Fusarium also rots the crown, producing symptoms similar to those caused by Macrophomina.
Management

Avoid introduction

Pathogen can be moved with soil on equipment

Infected transplants
Transmission of *Fusarium* to daughter plants?
Experiments were conducted to test for transmission of *Fusarium* from infected mothers to daughter plants.

**Inoculation**

Plants were infected.

But vigorous enough to produce runners and daughter plans.
Transmission of *Fusarium* to daughter plants

Tag stolons and daughter plants
Transmission of *Fusarium* to daughter plants

Test for infection by the pathogen
Albion

Symptomless
No transmission in resistant cultivars

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Crown</th>
<th>Petiole</th>
<th>Runner</th>
<th>Daughter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albion</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>San Andreas</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fronteras</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Petaluma</td>
<td>+</td>
<td>+</td>
<td>+</td>
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</tr>
</tbody>
</table>
Transmission of *Verticillium dahliae* through stolons
Verticillium wilt in high elevation nurseries

Mother plants may show symptoms only late in the season

Overgrown by daughter plants
Plants infected by *Verticillium dahliae* may not be detectable by visual inspection.
Infected daughter plants

Show no symptoms

Disease may develop in fruit production field
Management

Avoid introduction

→ Reduce inoculum levels in soil

Pre-plant fumigation

Flat fumigation to treat the entire field
Mortality is not evenly distributed across beds

Incomplete treatment
Fumigation is fully effective only directly under drip tapes.

Beds fumigated with Pic-60

Spores per gram of soil

Location in bed

- Center
- Shoulder
- Under tape

6” depth
12” depth
Anaerobic soil disinfestation

Effect on survival of *Fusarium oxysporum*

Rice hulls at 9 tons per acre

- **Cool conditions**
  - Day/night = 77/64°F
  - Increase in pathogen population: +310%

- **Warm conditions**
  - Day/night = 82/68°F
  - No change: +0.01%
Anaerobic soil disinfestation

Effect on survival of *Fusarium oxysporum*

Rice hulls at 9 tons per acre

Cool conditions
Day/night = 77/64°F

Mustard seed meal

<table>
<thead>
<tr>
<th>None</th>
<th>3 tons/acre</th>
</tr>
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<tr>
<td>+ 310%</td>
<td>- 74%</td>
</tr>
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</table>
Duration of anaerobic conditions

Average % change in pathogen population vs. Average total reduced mV hours

-100 0 20000 40000 60000 80000 100000 120000 140000 160000
Crop rotation

Inoculum levels decline when other crops are grown

Rotation crops do not support pathogen development
Colonization of rotation crops
Colonization of rotation crops

Broccoli
Lettuce
Spinach
Cilantro
Wheat
Raspberry
Root tip

Percentage of root tips infected
Percentage of root tips infected

Colonization of root tips (%)

Extent of colonization?
Pathogen biomass in root cortex

Limited growth

Colony forming units per gram

Cilantro  Lettuce  Broccoli  Wheat  Spinach  Raspberry
Fusarium wilt

*Fusarium oxysporum*

Effect of blackberry pathogen on strawberry

Albion
Monterey
San Andreas
Portola
Petaluma

Blackberry
Susceptibility of strawberry to blackberry pathogen

Inoculated plants were rated on a 1 – 5 scale
Susceptibility of strawberry to blackberry pathogen

Plants were rated on a 1 – 5 scale

Healthy plant = 1  Dead plant = 5
Stunting and yellowing of leaves = 3
Susceptibility of strawberry to blackberry pathogen

1 – 5 scale

<table>
<thead>
<tr>
<th>Cultivar</th>
<th><em>F. o. mori</em></th>
<th><em>F. o. fragariae</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Albion</td>
<td>3.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Monterey</td>
<td>2.1</td>
<td>5.0</td>
</tr>
</tbody>
</table>

*F. o. mori* = blackberry pathogen
Some plants were killed by the blackberry pathogen.
## Susceptibility of strawberry to blackberry pathogen

1 – 5 scale

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<td>5.0</td>
</tr>
<tr>
<td>Monterey</td>
<td>2.1</td>
<td>5.0</td>
</tr>
<tr>
<td>San Andreas</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Portola</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Petaluma</td>
<td>1.0</td>
<td>5.0</td>
</tr>
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</table>
Management

Disease resistance
The Population of *Fusarium oxysporum* f. sp. *fragariae*, Cause of Fusarium Wilt of Strawberry, in California

P. M. Henry, S. C. Kirkpatrick, C. M. Islas, A. M. Pastrana, and J. A. Yoshisato, Department of Plant Pathology, University of California, Davis 95616; S. T. Koike, University of California Cooperative Extension, Salinas 93901; O. Daugovish, University of California Cooperative Extension, Ventura 93003; and T. R. Gordon, Department of Plant Pathology, University of California, Davis

Abstract

The objectives of this study were to investigate the structure of the population of *Fusarium oxysporum* f. sp. *fragariae* in California and to evaluate methods for its detection. Fifty-nine isolates of *F. oxysporum* f. sp. *fragariae* were obtained from diseased strawberry plants and their identity was confirmed by pathogenicity testing. The full nuclear ribosomal intergenic spacer (IGS) and elongation factor 1-α gene (EF-1α) were amplified by polymerase chain reaction (PCR) and sequenced to elucidate phylogenetic relationships among isolates. IGS and EF-1α sequences revealed three main lineages, which corresponded to three somatic compatibility groups. Primers designed to detect *F. oxysporum* f. sp. *fragariae* in Japan amplified a 239-bp product from 55 of 59 California isolates of *F. oxysporum* f. sp. *fragariae* and from no nonpathogenic isolates of *F. oxysporum*. The sequence of this PCR product was identical to the sequence obtained from *F. oxysporum* f. sp. *fragariae* isolates in Japan. Intensive sampling at two locations in California showed results of tests based on PCR and somatic compatibility to be in agreement for 97% (257 of 264) of isolates tested. Our findings revealed considerable diversity in the California population of *F. oxysporum* f. sp. *fragariae*, and indications that horizontal gene transfer may have occurred.
Genome sequenced
Likely there have been multiple introductions of the strawberry Fusarium to California.

Most likely on infected plants.
Source of introduction to California?

Australia  ?  Japan

Discovered in California in 2008
Do *F. o. fragariae* strains differ in virulence?

<table>
<thead>
<tr>
<th>Genotype * strain test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albion</td>
</tr>
<tr>
<td>Benicia</td>
</tr>
<tr>
<td>Fronteras</td>
</tr>
<tr>
<td>San Andreas</td>
</tr>
<tr>
<td>5.165</td>
</tr>
</tbody>
</table>
Strains differ in virulence
Virulence averaged across all susceptible cultivars

Disease severity

GL1381 | GL1315 | AMP132

- GL1381
- GL1315
- AMP132
Resistance is effective against all strains

Disease severity

Resistant to all strains

Fronteras  San Andreas  Albion  Benicia  5.165

1315  1381  AMP132
Tests conducted in naturally infested field
Susceptibility to Fusarium wilt

Disease severity

- 2015
- 2016

San Andreas  Fronteras  Festival  Ventana  Portola  Petaluma  Radiance  Grenada  Albion  Monterey  Sweet Ann
Susceptibility to Fusarium wilt

- San Andreas
- Portola
- Fronteras
  - Highly resistant

- Ventana
  - Resistant

- Monterey
- Albion
  - Susceptible
Pathogen can colonize resistant crops

May allow inoculum build-up in soil
Colonization of roots

Cultivar

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Colony forming units per gram</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Andreas</td>
<td>Very low</td>
</tr>
<tr>
<td>Ventana</td>
<td>Very low</td>
</tr>
<tr>
<td>Portola</td>
<td>Very low</td>
</tr>
<tr>
<td>Fronteras</td>
<td>Very low</td>
</tr>
<tr>
<td>Albion</td>
<td>Low</td>
</tr>
<tr>
<td>Monterey</td>
<td>High</td>
</tr>
</tbody>
</table>
Colonization of roots

San Andreas Ventana Portola Fronteras

Cultivar

Colony forming units per gram
Colonization of crowns

Colony forming units per gram

Cultivar

San Andreas  Ventana  Portola  Fronteras  Albion  Monterey
Colonization of crowns

Cultivar

Colony forming units per gram
Resistance may be overcome

Risk is proportional to pathogen growth and reproduction

Every cell is a reproductive unit

Suppression of pathogen populations still important
Management of soilborne pathogens

Reduce inoculum levels

Avoid introductions

Disease resistance
Planting buffer zones will increase pathogen inoculum levels
Thanks