

California Pest Rating Proposal for *Fusarium oxysporum* f. sp. *fragariae* Winks & Williams

Fusarium wilt of strawberry

Current Pest Rating: none

Proposed Pest Rating: C

Domain: Eukaryota, Kingdom: Fungi,
Phylum: Ascomycota, Subphylum: Pezizomycotina,
Class: Sordariomycetes, Subclass: Hypocreomycetidae,
Order: Hypocreales, Family: Nectriaceae

Comment Period: 01/04/2024 through 02/18/2024

Initiating Event:

This pathogen has not been through the pest rating process. The risk to California from *Fusarium oxysporum* f. sp. *fragariae* is described herein and a permanent rating is proposed.

History & Status:

Background:

California is the largest producer of strawberries in the United States with close to a 90% market share. They are grown on 39,000 acres and fruit production had a total value in 2021 of over \$3B (CDFA Agricultural Statistics, 2021-2022). Strawberry fruit is grown mainly along the coast, from Monterey to Orange counties, with additional production in the San Joaquin Valley. California is also the nation's top producer of strawberry transplants, produced at high-elevation nurseries in northern California and valued at approximately \$1B. Nursery stock is shipped internationally throughout the Americas and Europe.

Fusarium oxysporum is a soil-borne, highly variable fungal species that contains many saprophytic and pathogenic forms that are morphologically identical. It predominantly uses asexual reproduction. *Fusarium oxysporum* is generally regarded as a 'species complex'—a collection of clonal lines that differ in their host range and aggressiveness. The various forms cannot be distinguished without the use of molecular tools and/or pathogenicity tests. *Fusarium oxysporum* is best known as a vascular wilt

pathogen, colonizing the xylem of its hosts, turning vascular tissue brown, causing progressive yellowing as it grows internally up into the plant, eventually causing collapse and death. Some strains cause crown rot, root rot, or bulb rot instead of vascular wilts (Olivain and Alabouvette, 1999). The plant pathogenic parasitic strains of *F. oxysporum* were grouped into formae speciales (f. sp.) by Snyder and Hansen (1940) based on their selective pathogenicity to a narrow range of plants, often a single species. The concept of formae speciales continues to evolve, especially with improvements in molecular approaches to characterize isolates (Edel-Hermann and Lecomte, 2019). More than 120 different formae speciales have been identified based on specificity to host species across a wide range of plant families. *Fusarium oxysporum* Schltd.: Fr. f. sp. *fragariae*, Winks & Williams (Fof) is the cause of Fusarium wilt of strawberry (*Fragaria x ananassa*). It is an anamorphic fungus with no known teleomorph. It produces micro- and macroconidia plus chlamydospores.

Fusarium wilt of strawberries was first described in 1962 in Queensland, Australia (Winks and Williams, 1965). It was first found in California in Ventura and Santa Barbara counties in 2006 and subsequently has become established in every major strawberry production area of the state (Koike et al., 2009). Field tests have shown that popular strawberry cultivars such as Fronteras, Portola, and San Andreas are resistant to Fusarium wilt, whereas Albion and Monterey are susceptible. Additional research is being conducted to develop new resistant cultivars (Koike et al., 2017).

In 2023, Dilla-Ermita et al. published the first report of Fof race 2 in California. It was detected in the fall of 2022 in Oxnard, Ventura County. Symptoms were similar to race 1, but race 2 can infect Portola, a variety that carries the *FW1* gene and is resistant to race 1. In inoculation studies, another *FW1* cultivar, San Andreas, was also susceptible. The authors caution that losses to Fof are likely to increase until genetic resistance to race 2 is deployed in commercially viable cultivars.

Hosts: Fragaria x ananassa (strawberry).

Symptoms: Fof infects through the strawberry's roots and grows into the xylem, causing a systemic infection. Pathogen growth in the xylem, and the plant's response to the infection, impede the movement of water to the leaves. In fields with no or inadequate pre-plant fumigation, strawberries can show initial symptoms of decline as early as 30 days after transplanting. These plants will stop growing and be stunted when compared to healthy plants.

Often the initial symptoms of Fof in strawberry occur after the plants are well established and begin to flower or produce fruit. At this time, the older leaves wilt, turn gray-green, and begin to dry up. Symptoms resemble those of water stress, including stunting, wilting, and dieback. The youngest leaves in the center of the plant often remain green and alive with older leaves brown and desiccated. Plants bearing heavy fruit loads or subjected to other stresses often show the most severe symptoms; they can collapse and die. The internal tissues of plant crowns, including the vascular and cortical tissues, turn dark brown to orange-brown. Internal tissues of the main roots are not typically discolored (Koike et al., 2017).

Transmission: Long-distance movement of the pathogen would most likely occur through the transport of infected plants. Strawberry nurseries typically use pre-plant fumigation to suppress soilborne

pathogens, and vigorous crowns that appear to be healthy are shipped to fruit producers. Various factors may allow nursery plants to become infected, and where infections with systemic pathogens remain cryptic, the nursery plants can introduce pathogens to fruit production fields.

Strawberry plants can be infected with Fof without showing symptoms. Fof can move through stolons of infected mother plants and colonize first-generation daughter plants. The pathogen can also move through stolons from first to second-generation daughter plants (Pastrana et al., 2019). Fof produces chlamydospores, which are long-lasting in soils. Any practices that move soil, including disking and irrigation, can spread the chlamydospores.

Damage Potential: Since 2006, Fusarium wilt of strawberry has increased in incidence and severity in California. In some fields, the disease affects large sections that run the length of the field. Fof poses a serious threat to commercial strawberry production worldwide and can cause severe economic losses to susceptible varieties (Fang et al., 2012; Koike and Gordon, 2015). The disease is of significant economic importance because infected plants can collapse and die. In heavily infested fields, plants may be severely stunted and fail to produce any fruit (Koike and Gordon 2015).

Worldwide Distribution: Australia, Italy, Japan, Jordan, South Korea, Spain, Turkey, United States (California, Florida) (CABI, 2023; Tahat et al., 2023).

Official Control: Fof is on the EPPO's A1 list for Argentina, the quarantine pest list for China, and is a regulated non-quarantine pest in Egypt (EPPO, 2023). It is on the USDA PCIT's harmful organism list for China, Ecuador, and Peru (USDA PCIT, 2023).

California Distribution: Statewide in all strawberry production areas (Henry et al., 2017).

California Interceptions: none

The risk that *Fusarium oxysporum* f. sp. *fragariae* would pose to California is evaluated below.

Consequences of Introduction:

- 1) Climate/Host Interaction:** Fof has been found in a range of soils and climates and produces long-lasting chlamydospores to survive drought and long fallow periods. It's likely to survive anywhere its hosts can grow.

Evaluate if the pest would have suitable hosts and climate to establish in California.

Score: 3

- Low (1) Not likely to establish in California; or likely to establish in very limited areas.
- Medium (2) may be able to be established in a larger but limited part of California.
- **High (3) likely to establish a widespread distribution in California.**

- 2) Known Pest Host Range:** The host range is limited to strawberries.
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Evaluate the host range of the pest.

Score: 1

- **Low (1) has a very limited host range.**
- Medium (2) has a moderate host range.
- High (3) has a wide host range.

- 3) Pest Reproductive Potential:** This pathogen is a soil-borne fungus that lives within the soil and its hosts. It does not have an aerial spore stage. It reproduces with chlamydo spores that can move with soil, irrigation water, flooding, and machinery.

Evaluate the natural and artificial dispersal potential of the pest.

Score: 2

- Low (1) does not have high reproductive or dispersal potential.
- **Medium (2) has either high reproductive or dispersal potential.**
- High (3) has both high reproduction and dispersal potential.

- 4) Economic Impact:** Since 2006, Fusarium wilt of strawberries has increased in incidence and severity in California. In some fields, the disease affects large sections that run the length of the field.

Evaluate the economic impact of the pest on California using the criteria below.

Economic Impact: A, C, G

- A. The pest could lower crop yield.**
- B. The pest could lower crop value (including increasing crop production costs).
- C. The pest could trigger the loss of markets (including quarantines).**
- D. The pest could negatively change normal cultural practices.
- E. The pest can vector, or is vectored, by another pestiferous organism.
- F. The organism is injurious or poisonous to agriculturally important animals.
- G. The organism can interfere with the delivery or supply of water for agricultural uses.**

Economic Impact Score: 3

- Low (1) causes 0 or 1 of these impacts.
- Medium (2) causes 2 of these impacts.
- **High (3) causes 3 or more of these impacts.**

- 5) Environmental Impact:** Fof impacts cultural practices and can be a problem in home/urban gardens.

Evaluate the environmental impact of the pest on California using the criteria below.

Environmental Impact: E

- A. The pest could have a significant environmental impact such as lowering biodiversity, disrupting natural communities, or changing ecosystem processes.
 - B. The pest could directly affect threatened or endangered species.
 - C. The pest could impact threatened or endangered species by disrupting critical habitats.
 - D. The pest could trigger additional official or private treatment programs.
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- E. The pest significantly impacts cultural practices, home/urban gardening, or ornamental plantings.**

Environmental Impact Score: 2

- Low (1) causes none of the above to occur.
- **Medium (2) causes one of the above to occur.**
- High (3) causes two or more of the above to occur.

Consequences of Introduction to California for *Fusarium oxysporum* f. sp. *fragariae*: Medium

Add up the total score and include it here. **11**

- Low = 5-8 points
- Medium = 9-12 points
- High = 13-15 points

- 6) Post-Entry Distribution and Survey Information:** Evaluate the known distribution in California. Only official records identified by a taxonomic expert and supported by voucher specimens deposited in natural history collections should be considered. Pest incursions that have been eradicated, are under eradication or have been delimited with no further detections should not be included.

Evaluation is 'high'.

Score: -3

- Not established (0) Pest never detected in California or known only from incursions.
- Low (-1) Pest has a localized distribution in California or is established in one suitable climate/host area (region).
- Medium (-2) Pest is widespread in California but not fully established in the endangered area, or pest established in two contiguous suitable climate/host areas.
- High (-3) Pest has fully established in the endangered area, or pest is reported in more than two contiguous or non-contiguous suitable climate/host areas.**

- 7) The final score is the consequences of the introduction score minus the post-entry distribution and survey information score: (Score)**

Final Score: Score of Consequences of Introduction – Score of Post Entry Distribution and Survey Information = 8

Uncertainty:

Foliar dieback and internal crown discoloration symptoms from *Fusarium* wilt are identical to those caused by *Macrophomina* crown rot. Plant collapse symptoms resembled *Verticillium* wilt. Therefore, confirmation of *Fof* requires diagnostic procedures in a pathology lab.

Conclusion and Rating Justification:

Based on the evidence provided above the proposed rating for *Fusarium oxysporum* f. sp. *fragariae* is
C.

References:

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Responsible Party:

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***Comment Period: 01/04/2024 through 02/18/2024**

***NOTE:**

You must be registered and logged in to post a comment. If you have registered and have not received the registration confirmation, please contact us at [permits\[@\]cdfa.ca.gov](mailto:permits[@]cdfa.ca.gov).

Comment Format:

- ❖ Comments should refer to the appropriate California Pest Rating Proposal Form subsection(s) being commented on, as shown below.

Example Comment:

Consequences of Introduction: 1. Climate/Host Interaction: [Your comment that relates to “Climate/Host Interaction” here.]

- ❖ Posted comments will not be able to be viewed immediately.
- ❖ Comments may not be posted if they:

Contain inappropriate language which is not germane to the pest rating proposal;

Contains defamatory, false, inaccurate, abusive, obscene, pornographic, sexually oriented, threatening, racially offensive, discriminatory or illegal material;

Violates agency regulations prohibiting sexual harassment or other forms of discrimination;

Violates agency regulations prohibiting workplace violence, including threats.

- ❖ Comments may be edited prior to posting to ensure they are entirely germane.
 - ❖ Posted comments shall be those which have been approved in content and posted to the website to be viewed, not just submitted.
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Proposed Pest Rating: C
