CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

California Pest Rating Proposal for

Fusarium oxysporum f. sp. *vasinfectum* (G.F. Atk.) W.C. Snyder & H.N. Hansen 1940

Fusarium wilt of cotton

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: 02/21/2023 through 04/07/2023

Initiating Event:

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

History & Status:

Background:

Cotton is grown primarily in the San Joaquin Valley, in Fresno, Kern, Kings, Merced and Tulare counties on approximately 115,000 acres (CDFA Ag Statistics, 2021). There is also production in the Palos Verde and Sacramento valleys. Two types or species of cotton are grown; Upland or Acala types (*Gossypium hirsutum*) make up 25% of production in California while the extra-long staple or Pima type (*G. barbadense*) make up 75% (2022 USDA NASS). There are two main products produced from cotton plants, fiber and seed. Fiber is used for fabrics and textiles. Cottonseed yields hulls that are used for animal feed, and oil, that is used for cooking and salad dressing, cosmetics, soap, and as a carrier for agricultural sprays. After oil extraction, there remains cottonseed meal or cake that is used for fertilizers and as feed for cattle, sheep, horses, pigs, fish, and shrimp.

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. *vasinfectum* (Atk.) W.C. Snyd. & H. N. Hans., (Fov) the cause of Fusarium wilt of cotton (*Gossypium* spp.), occurs in most major cotton production regions of the world. It is an anamorphic fungus with no known teleomorph.

Fusarium wilt of cotton, caused by Fov, was first described in California in 1960 by Garber and Paxman (1963). For many decades it caused mild symptoms on Upland cotton cultivars except when plants were in fields also infested with *Meloidogyne incognita*, the southern root-knot nematode. *Meloidogyne incognita* is widespread in California (Chitambar et al., 2018). Plants that were parasitized by both *M. incognita* and Fov were stunted and suffered greater yield losses. Management was based on growing root-knot nematode tolerant cultivars, crop rotation, and fumigation for nematode control (Kim et al., 2005).

Within Fov, multiple races of the pathogen are recognized based on their selective pathogenicity to a range of differential hosts (Edel-Hermann and Lecomte, 2019); these races are known by their numbers, 1, 2, 3, 4, 6 and 8. Previously described races 5 and 7 were determined to be identical to races 3 and 4, respectively (Cianchetta and Davis, 2015). Also, there are distinct biotypes of Fov which are grouped differently from the described races The vascular-colonizing or 'vascular-competent' pathotypes include races 1, 2, 6 and 8, while the root-rotting pathotypes include races 3 and 4. (Kim et al., 2005).

In the mid-1990s, reports were published about extremely virulent strains of Fov in Australia causing extensive damage to cotton without root-knot nematodes (Davis et al., 1996). This prompted a survey of California where at the time, only race 1 and 2 were known to occur. Work by Kim et al. (2005) showed California isolates represented four lineages. Lineage I contained race 3, lineage II contained races 1, 2, and 6, lineage III contained race 8, and lineage IV contained race 4. The Australian isolates that they compared to California isolates formed a strongly supported, independent, and separate clade. In greenhouse pathogenicity tests with California isolates, those from the race 4 lineage were highly aggressive on certain Pima cotton cultivars and less aggressive on Upland cotton cultivars. All isolates belonging to the other lineages caused relatively mild symptoms. The discovery of FOV race 4 in the San Joaquin Valley renewed interest in the possibility that infected seed could potentially spread

this race to noninfested areas. Fov race 4 has become the race of greatest concern to California and export markets for California cottonseed.

Hosts: Abelmoschus esculentus (okra), *A. manihot* (sunset muskmallow), *Arachis hypogaea* (peanut), *Cajanus cajan* (pigeon-pea), *Capsicum annuum* (sweet pepper), *Capsicum* sp. (pepper), *Carica papaya* (papaya), *Carthamus tinctorius* (safflower), *Cicer arietinum* (chickpea), *Citrullus vulgaris*, *Citrus* sp. (citrus), *Crotalaria juncea* (sunn-hemp), *C. spectabilis* (showy rattlebox), *Cucumis melo* (melon), *Datura stramonium* (jimsonweed), *Dolichos lablab* (hyacinth bean), *Elaeis guineensis* (oil palm), *Gladiolus hybrida* (sword lily), *Gossypium arboretum* (tree cotton), *G. barbadense* (upland cotton), *G. herbaceum* (levant cotton), *G. hirsutum* (upland cotton), *G. indicum*, *G. nanking*, *G. neglectum* (tree cotton), *Gossypium* sp. (cotton), *Hibiscus cannabinus* (Deccan hemp), *H. esculentus* (okra), *H. rosa-sinensis* (Chinese hibiscus), *Lathyrus odoratus* (sweet-pea), *Lupinus angustifolius* (blue lupine), *L. luteus* (yellow lupine), *Musa* sp. (banana), *Musa ×paradisiaca* (plantain), *Nicotiana tabacum* (tobacco), *Panicum virgatum* (switch grass), *Phaseolus angularis* (adzuki bean), *P. vulgaris* (bean), *Pinus* sp. (pine), *Prunus avium* (sweet cherry), *Sesamum indicum* (sesame), *S. orientale* (sesame), *Solanum esculentum* (garden tomato), *S. melongena* (eggplant), *S. tuberosum* (potato), *Vicia* sp. (vetch), *V. faba* (bell-bean), *Vigna radiata* (celera-bean), *Zea mays* (maize) (CABI, 2022).

Symptoms: Symptoms of FOV can appear at any stage of crop development. When soil inoculum is high or when infection begins from infested seeds, plants may be killed by damping off at the seedling stage. For older plants, symptoms are seen first on the lower leaves as a leaf chlorosis beginning at the margin and spreading between the main veins. As the disease spreads upwards in the plant, more leaves become chlorotic and flaccid, giving the plant a wilted appearance during the middle of the day. Chlorotic leaves may drop from the plant and the infected plants grow slowly, appearing to be stunted. As the disease develops, all the leaves are affected, and chlorotic areas turn necrotic, the wilt becomes permanent, and the plant dies from moisture deficit.

With FOV races that colonize the vascular systems, plants will have the foliar or wilting symptoms and brown to black discoloration of the xylem. Roots will not be affected. With root-rotting FOV races, plants with foliar or wilting symptoms will have very limited vascular discoloration in the stems, only in the lower stem and only seen when there is also substantial root rot. Root rot can be seen as early as the one to true leaf growth stage and range from brown to black streaks in the center of the root. In some susceptible varieties, internal root rot may be present when there is no visible foliar or external root symptoms (CABI, 2023).

Transmission: Fov produces thick walled chlamydospores which are spread locally by moving soil with machinery or containers, with irrigation or flood water movement, and with crop residues including gin trash (Davis, 2013). The chlamydospores will germinate in the soil, producing mycelium that penetrates the roots, most efficiently through wounds caused by root-knot nematodes. In the absence of a cotton crop, chlamydospores can persist for years. Fov can also survive as a saprophyte on the organic matter in the soil and can colonize roots of weeds and other plant species (Hu and Nelson, 2020). Long-distance spread can occur when infected seed is used for planting. Seeds can be infested at a low

incidence and can result in infected seedlings. Infection of seed with Fov4, at less than 0.1% incidence in seed, was confirmed in some California fields (Bennett et al., 2008).

Damage Potential: Disease incidence and yield losses can be highly variable from region to region depending on susceptibility of cotton cultivars, aggressiveness or virulence of fungal strains or races, pathogen inoculum levels that can build-up in the soil, soil type and pH, and nematode populations (Hu and Norton, 2020). Some Fov races such as race 1, 3 and 8 are mildly virulent and cause few, if any, symptoms. Only with an interaction with the southern root-knot nematode do they cause significant damage to cotton. Fov4 does not require that interaction and consequently, losses to disease are not restricted to the sandy soils favorable for survival of *M*. *incognita* (Kim et al., 2005). "Blank" areas of infested fields that are either devoid of plants or contain dying plants will be evident. The size of affected areas will depend on how long the inoculum has been accumulating and the susceptibility of the current variety and previously planted varieties. First-year infestations typically result in a few affected plants over a few feet of row. Second- and third-year infestations will leave expanded blank areas in adjacent rows and down the field as inoculum spreads (Huntmacher, 2017).

Worldwide Distribution: Africa: *Congo, Egypt, Ethiopia, South Africa, Sudan, Tanzania, Zimbabwe*. Americas: *Argentina, Brazil, Chile, El Salvador, Mexico, Nicaragua, Puerto Rico, Trinidad and Tobago, United States* (Alabama, Arizona, Arkansas, California, Florida, Georgia, Hawaii, Louisiana, Mississippi, Missouri, New Mexico, New York, North Carolina, South Carolina, Oklahoma, Tennessee, Texas, Virginia), *Venezuela, Virgin Islands*. Asia: *China, India, Iran, Korea, Myanmar, Pakistan, Taiwan, Thailand, Uzbekistan.* Europe: *Greece, Netherlands, Poland, Romania.* Oceania: *Australia, Fiji.* (CABI, 2023).

Official Control: Fov is on the EPPO's quarantine pest list for Israel and Mexico, and a regulated non-quarantine pest in Egypt. It is on the USDA PCIT's harmful organism list for Cambodia, Ecuador, Israel, Madagascar, and Panama

California Distribution: Race 1 is widely distributed in the San Joaquin Valley; races 3 and 8 are found in a limited number of fields in Tulare and Fresno counties. The distribution of race 4 is not fully known, but it is becoming more common in Fresno, Merced, Tulare, Kings, and Kern counties (Davis, 2013).

California Interceptions: None

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

Consequences of Introduction:

1) **Climate/Host Interaction:** Fov is adapted to a range of soils and climates, and with long lasting chlamydospores to survived drought and long fallow periods, its likely to survived 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 establish 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 moderate including many agricultural crops and weeds

Evaluate the host range of the pest.

Score: 2
- 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 within its hosts. It does not have an aerial spore stage. It reproduces with chlamydospores that can move with soil, irrigation water, flooding, machinery and with seed.

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:** Most races only cause only mild yield losses except in fields co-infected with *M. incognita*. Race 4 is the exception and fields known to have this pathogen should not be used for seed production. It is a quarantine pest in several places, and a non-regulated pest of concern for other states.

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

Economic Impact: 3
A. The pest could lower crop yield.
B. The pest could lower crop value (includes increasing crop production costs).
C. The pest could trigger the loss of markets (includes 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:** None have been reported. The main host, cotton, is not grown in urban or home gardens.

Evaluate the environmental impact of the pest to California using the criteria below

Environmental Impact: 1

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.
E. The pest significantly impacts cultural practices, home/urban gardening, or ornamental plantings.

Environmental Impact Score:
- 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. *vasinfectum:* 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 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:

none

Conclusion and Rating Justification:

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

References:

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Snyder, W.C. and Hansen, H.N., 1940. The species concept in Fusarium. American Journal of Botany, pp.64-67.

USDA NASS 2022. California Cotton County Estimates. https://www.nass.usda.gov/Statistics_by_State/California/Publications/County_Estimates/2022/202205COTCNTYE.pdf)

Responsible Party:

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*Comment Period: 02/21/2023 through 04/07/2023

*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.

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.

Proposed Pest Rating: C