California Pest Rating Proposal for

Xanthomonas citri ssp. *citri* (Hasse, 1915) Constantin, Cleenwerck, Maes, Baeyen, Van Malderghem, De Vos, Cottyn 2016

Asiatic citrus canker

Current Pest Rating: A

Proposed Pest Rating: A

Kingdom: Bacteria, Phylum: Proteobacteria,
Class: Gammaproteobacteria, Order: Lysobacterales,
Family: Lysobacteraceae

Comment Period: 05/19/2021 through 07/03/2021

Initiating Event:

This pathogen has not been through the pest rating process. The risk to California from *Xanthomonas citri* ssp. *citri* (Xcc) is described herein and a permanent pest rating is proposed.

History & Status:

Background: Xcc is a bacterial pathogen and the cause of Asiatic citrus canker. This disease can result in heavy economic losses because of direct damage to trees (particularly reduced fruit production), costs of prevention and control, and reduced access to export markets due to quarantines. Lesions will develop on leaves, twigs, and fruit, resulting in defoliation, premature fruit abscission and blemished fruit, and even death of trees.

Endemic to southeast Asia, Xcc is introduced to new areas through the movement of infected citrus fruits and seedlings, and all possible carriers are subject to strict quarantine restrictions. Once introduced, it can be rapidly disseminated by rainwater running over the surfaces of lesions and splashing onto uninfected shoots. The most severe epidemics occurring under conditions of high temperature, heavy rainfall, and strong winds (Gottwald et al., 1997).

Citrus canker was first identified in the United States near the Florida-Georgia border in 1910 on imported seedlings from Japan. Through destruction of infected trees, it was considered eradicated by 1933. Citrus canker was re-discovered in Manatee County, Florida, near Tampa Bay in 1986 and was again declared eradicated in 1994. However, in 1995, canker was found to be widespread across Miami-Dade County (Gottwald et al., 1997).

The severity of canker in Florida was increased by the presence of the Asian citrus leaf miner, *Phyllocnistis citrella*. This insect's feeding activities create wounds that expose leaf mesophyll tissues, thus increasing the probability of infection by Xcc (Gottwald et al., 1997). This leaf miner was introduced to California in 2000 from Mexico, and it is now widespread (Grafton-Cardwell et al., 2017).

Pathologists hoped that citrus canker could be eradicated from Florida in the early 2000's because the pathogen is unable to survive outside of the host for extended periods, it lacks an efficient vector, the raised lesions are easily identifiable, the host range is restricted to citrus, and many commercial varieties are moderately to highly susceptible, so disease control was a very high priority. Monumental efforts were made, which included the destruction of millions of commercial and residential trees (Graham et al., 2004). A combination of programmatic challenges and unprecedented storms in 2004 and 2005 spread the pathogen to the point where the USDA deemed that eradication was no longer possible. Efforts have shifted to containment and establishing protocols for the safe movement of fruit and nursery stock. Citrus canker was found in limited areas of Louisiana and Texas in 2014 and 2016, respectively. The USDA maintains a Federal domestic quarantine with restrictions on shipping fruit or plants out of the quarantined areas (http://www.aphis.usda.gov/plant-health/citrus-canker).

The citrus canker bacterium has gone through several taxonomic revisions and is separated into named strains. In 1915, Hass named the bacterium *Pseudomonas citri* and it has at times since been placed in various genera, including *Bacterium, Phytomonas* and, finally, *Xanthomonas* in 1939. It has been in the Xanthomonad species *campestris*, *axonopodis, fuscans,* and *citri*.

The Asiatic type of canker (Canker A) is the most widespread and severe form, caused by *X. citri* ssp. *citri* (syn. *X. citri*, *X. campestris pv. citri*, and *X. axonopodis pv. citri*). Cancrosis B, caused by the B strain, *X. citri* ssp. aurantifolii, is a minor canker disease of diminishing importance on lemons in Argentina, Paraguay and Uruguay; Mexican lime, sour orange and pummelo are also susceptible. Cancrosis C, also *X. citri* ssp. *aurantifolii*, was isolated in the 1970s from Mexican lime in Sao Paulo State, Brazil, but has rarely been encountered since then, and sour orange is also a host. Group D (citrus bacteriosis) was reported on Mexican lime in Mexico in 1981.

Additional isolates causing Asiatic citrus canker have been reported from Oman, Saudi Arabia, Iran, and India. Antibiotic-resistant strains produce canker A-like lesions (termed A* strains), but only on Mexican lime, and an atypical form of canker A have been described from Reunion and surrounding islands in the Indian Ocean. A variant of canker A, known as canker A^w exists on the south east coastal areas of Florida, and has a host range restricted to Mexican lime and Alemow (*Citrus macrophylla*). Although cultures of all the groups of strains exist in collections, the diseases caused by the group C and D are no longer found in the environment. Group B may also no longer exist because of the pathogen's non-competitiveness with the group A strains which were introduced into the areas previously colonized by the group B strains.

The A strains were transferred to back *X. campestris pv. citri* in 1989 when the B and C strains were placed in *X. campestris* pv. *aurantifolii*. In 1995, using DNA–DNA hybridization, A strains were then moved again to *X. axonopodis pv. citri* and the B and C strains to *X. axonopodis pv. aurantifolii*. Using the S1 nuclease technique for DNA–DNA relatedness, *X. axonopodis* pv. *aurantifolii* strains were re-classified as *X. fuscans* ssp. *aurantifolii* in 2005 (CABI-CPC, 2021).

Constantin et al. (2016) proposed changes to xanthomonad taxonomy, including within *X. citri*. Using a polyphasic approach which included multiple genetic and phenotypic analyses. They recommended placement of some citrus-infecting members of *X. fuscans* into *X. citri*, including *X. fuscans* ssp. *aurantifolii*. For now, *X. citri* ssp. *citri* (Xcc) and *X. citri* ssp. *aurantifolii* (Xca) are the most recent names with standing. However, many of the older names are still in use and in regulation.

Hosts: Atalantia buxifolia (Chinese box orange), *Citroncirus* sp., *x Citrofortunella macrocarpa* (calamondin), *Citrus aurantiifolia* (lime), *Citrus aurantium* (sour orange), *Citrus depressa* (shekwasha), *Citrus junos* (yuzu), *Citrus latifolia* (Tahiti lime), *Citrus limon* (lemon), *Citrus macrophylla* (alemow), *Citrus maxima* (pummelo), *Citrus medica* (cintron), *Citrus paradisi* (grapefruit), *Citrus reticulata* (tangerine), *Citrus sinensis* (orange), *Citrus* sp., *Citrus unshiu* (satsuma), *Fortunella japonica* (kumquat), *Fortunella margarita* (oval kumquat), *Fortunella* sp., *Poncirus trifoliata* (trifoliate orange) and *Swinglea glutinosa* (tabog).

Symptoms: Citrus canker causes necrotic lesions on leaves, stems, and fruit of susceptible hosts. Severe disease can cause defoliation, premature fruit drop, twig dieback, general tree decline, and significant blemishes on fruit. Trees infected with canker become weak and unproductive. Symptoms may differ between citrus varieties (Gottwald and Graham, 2000).

Leaf lesions appear within 5-7 days of infection under optimal conditions. The lesions are at first slightly raised, tiny, and blister-like. As the lesions age, they become tan to brown, and a water-soaked margin appears surrounded by a yellow ring or halo. The center becomes raised and corky. The lesions are visible on both sides of the leaf. Symptoms on stems, twigs, and fruit are similar and consist of dark brown or black raised corky lesions surrounded by an oily or water-soaked margin. As the lesions mature, they appear scabby or corky. Fruit lesions are dark brown to black and raised, often surrounded by yellow halos (Zekri et al., 2005).

Transmission: Citrus canker is highly contagious and can be spread rapidly by wind-driven rain and storm events such as tornadoes, hurricanes, and tropical storms. Movement of infected or exposed trees, seedlings, propagative material, and fruit is the primary means of spreading the canker pathogen over long distances.

The pathogen reproduces in lesions in leaves, stems, and fruit. With free moisture on the lesions, bacteria ooze out and can be dispersed to new growth and other parts of a plant or other plants. Wind-driven rain is the main natural dispersal agent, and higher wind speeds aid in the penetration of bacteria through the stomatal pores or wounds (Graham et al., 1992).

Contaminated clothing, tools, lawnmowers and other landscaping equipment, ladders, containers, and other items associated with harvesting and postharvest handling of fruit are all implicated as sources of infection and should be decontaminated with an approved chemical such as quaternary ammonium. Stem lesions on infected trees are an important reservoir for persistent inoculum. Eradication programs require trees to be cut and burned (Zekri et al., 2005; Gottwald et al., 2002).

The citrus leafminer (*Phyllocnistis citrella*) increases the susceptibility of citrus trees to canker. Leaves and stems damaged by the citrus leafminer are more likely to be infected because the wounds caused by leafminer tunneling allow the bacterium to easily penetrate the tissue. When leaf miner feeding galleries become contaminated with canker, the number of lesions and the area infected greatly expand and result in enormous inoculum production. The leaf lesions sometimes fall out, leaving holes (Hall et al., 2010).

Damage Potential: Lesions cause blemishes and early fruit drop, thereby reducing fruit yield. Among citrus cultivars and rootstocks, citrus canker is most severe on grapefruit, some sweet oranges such as Hamlin, Pineapple, and Navel; plus, Mexican (Key) lime, lemon, and trifoliate orange and their hybrids that are grown for rootstocks. These cultivars are very challenging or impossible to grow profitably in the presence of citrus canker in moist subtropical and tropical climates because in addition to the debilitation of the trees, the market standards for fresh fruit are so high that any level of lesions renders them unmarketable and subject to quarantine (Gottwald et al., 2001; Gottwald et al., 2002).

Worldwide Distribution: Africa: *Burkina Faso, Comoros, Democratic Republic of the Congo, Cote d'Ivoire, Ethiopia, Gabon, Madagascar, Mali, Mauritius, Mayotte, Reunion, Senegal, Seychelles, Somalia, Sudan, Tanzania*. Americas: *Argentina, Bolivia, Brazil, Paraguay, United States of America* (Florida, Louisiana, Texas), *Uruguay, Virgin Islands (British)*. Asia: *Afghanistan, Bangladesh, Cambodia, China, Christmas Island, Cocos Islands, East Timor, India, Indonesia, Iran, Iraq, Japan, Korea Democratic People's Republic, Laos, Malaysia, Maldives, Myanmar, Nepal, Oman, Pakistan, Philippines, Saudi Arabia, Singapore, Sri Lanka, Taiwan, Thailand, United Arab Emirates, Vietnam, Yemen*. Oceania: *Australia, Fiji, Guam, Marshall Islands, Micronesia, Northern Mariana Islands, Palau, Papua New Guinea, Solomon Islands* (EPPO, 2021).

Official Control: *Xanthomonas citri* is on USDA PCIT's harmful organism list for Angola, Benin, Botswana, Brazil, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Democratic Republic of the Congo, Costa Rica, Cote d'Ivoire, Ecuador, Egypt, El Salvador, Equatorial Guinea, Kingdom of Eswatini, European Union, Gabon ,Gambia, Ghana, Guinea, Guinea-Bissau, Lesotho, Liberia, Mali, Mauritania, Mexico, Mozambique, Nicaragua, Niger, Nigeria, Peru, Rwanda, Senegal, Sierra Leone, Somalia, United Republic of Tanzania, Togo, United Kingdom, Uruguay, Uganda, and Zimbabwe. It is on the EPPO's A1 list for Azerbaijan, Chile, Egypt, European Union, Georgia, Jordan, Turkey, and Uzbekistan; A2 list for Argentina, Bahrain, East Africa, and Uruguay, and on the quarantine pest list for Belarus, Israel, Mexico, Morocco, New Zealand, Tunisia, and the United States (USDA PCIT, 2021; EPPO, 2021).

There is a Federal Domestic quarantine for citrus canker for the entire state of Florida, and parts of Texas and Louisiana (https://www.aphis.usda.gov/plant_health/plant_pest_info/citrus/citrus-downloads/spro/DA-2020-13.pdf) . Citrus canker is a state quarantine pest in Alabama, Florida, Louisiana, Mississippi, and Puerto Rico (https://nationalplantboard.org/laws-and-regulations/). California maintains a state exterior quarantine against citrus pests that includes citrus canker (http://pi.cdfa.ca.gov/pqm/manual/pdf/301.pdf). The California Department of Food and Agriculture has an annual citrus commodity survey. Twenty percent of all commercial citrus is surveyed for pests of quarantine significance. Citrus nurseries are surveyed annually.

California Distribution: None

California Interceptions: Occasional detections are made from non-commercial/back yard fruit that are intercepted at border stations, or at carriers attempting to ship in error or smuggle fruit to California residents. In 2004, US customs officials intercepted three shipments with 450 citrus cuttings with canker smuggled from Japan, at a Daly City mail center serving San Francisco International Airport. The packages were labeled "candy and chocolates" or "books and chocolates" and were destined for Ventura County. USDA-Smuggling Interdiction and Trade Compliance (SITC), CDFA and Ventura County joint agency inspections of the destination address found over 3,600 grafts that were previously brought in illegally from Japan. SITC Officers issued Emergency Action Notifications for the destruction by incineration of plants from the address and two additional private properties, working for several days to oversee the removal and burning of quarantined citrus trees.

The risk *Xanthomonas citri* ssp. *citri* would pose to California is evaluated below.

Consequences of Introduction:

1) **Climate/Host Interaction:** The maximum and optimum temperature ranges for growth of Xcc are 39°C (95 to 102°F) and 28 to 30°C (82 to 86°F), respectively. There must be free moisture on the lesions for the bacteria to ooze out and be dispersed to infect new growth. (Gottwald et al., 2000). Although California citrus growing areas have the appropriate temperatures, generally low relative humidity and free water should be limiting factors in disease establishment and spread. Citrus canker is not known from the Mediterranean region, an area that has a more similar climate to California than does Florida.

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

   Score: **2**

   - 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 limited to citrus. Grapefruit, Mexican limes, and trifoliate orange are highly susceptible; sour orange, lemon and sweet orange are moderately susceptible; and mandarins are moderately resistant. When plant mesophyll tissues are disrupted by wounds or by the

feeding galleries of the citrus leafminer, most citrus that express some level of field resistance can become infected (Gottwald and Graham, 2000).

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:** Under ideal climatic conditions, citrus canker reproduces exponentially and spreads rapidly. The presence of citrus leaf miner increases disease incidence and severity. The pathogen can spread easily with nursery stock, backyard fruit, equipment, and people.

Evaluate the natural and artificial dispersal potential of the pest.

Score: 3

- 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:** The economic impact to any area that produces table fruit is severe as there is low to zero tolerance for the damage to the fruit caused by citrus canker. The disease also impacts the productivity of trees, and it is a quarantine pest in many US states and other countries. The cost of containment or eradication is very high.

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

Economic Impact: A, B, C, D

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:** There are no native hosts in California, but citrus canker has been nearly impossible to control in residential areas in Florida, even with quarantine and tree removal.

Establishment of citrus canker would likely trigger USDA to require commercial fruit inspection, washing, and waxing protocols as are employed by Florida, prior to export.

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

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

Environmental Impact Score: 3

- 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 *Xanthomonas citri* ssp. *citri:* High

Add up the total score and include it here. **13**
-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 'not established'.

Score: -0

-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 =* ***13***

Uncertainty:

Changes in taxonomy and nomenclature seem inevitable with this pathogen. New strain designations are also possible.

Conclusion and Rating Justification:

Based on the evidence provided above the proposed rating for *Xanthomonas citri* ssp. *citri* is A.

References:

Constantin, E.C., Cleenwerck, I., Maes, M., Baeyen, S., Van Malderghem, C., De Vos, P. and Cottyn, B., 2016. Genetic characterization of strains named as *Xanthomonas axonopodis* pv. *dieffenbachiae* leads to a taxonomic revision of the *X. axonopodis* species complex. Plant Pathology, 65(5), pp.792-806.

EPPO Global Database. 2021. https://gd.eppo.int/taxon/ XANTCI. Accessed 4/21/2021

Ference, C.M., Gochez, A.M., Behlau, F., Wang, N., Graham, J.H. and Jones, J.B., 2018. Recent advances in the understanding *of Xanthomonas citri* ssp. *citri* pathogenesis and citrus canker disease management. Molecular plant pathology, 19(6), pp.1302-1318.

Gottwald, T.R., and Graham, J.H. 2000. Citrus canker. The Plant Health Instructor. DOI: 10.1094/PHI-I-2000-1002-01. Updated 2005.

Gottwald, T.R., Graham, J.H. and Schubert, T.S., 2002. Citrus canker: the pathogen and its impact. Plant Health Progress, 3(1), p.15.

Gottwald, T.R., Graham, J.H. and Schubert, T.S., 1997. An epidemiological analysis of the spread of citrus canker in urban Miami, Florida, and synergistic interaction with the Asian citrus leafminer. Fruits, 6(52), pp.383-390.

Grafton-Cardwell, E.E., Morse, J.G. Haviland, D.R., and Faber B.A. 2017. Citrus Leafminer. *Phyllocnistis citrella*. UC IPM Pest Management Guidelines: Citrus. UC ANR Publication 3441

Graham, J. H., Gottwald, T. R., Riley, T. D., and Achor, D. 1992. Penetration through leaf stomata and strains of Xanthomonas campestris in citrus cultivars varying in susceptibility to bacterial diseases. Phytopathology 82:1319-1325.

Graham, J.H., Gottwald, T.R., Cubero, J. and Achor, D.S., 2004. Xanthomonas axonopodis pv. citri: factors affecting successful eradication of citrus canker. Molecular plant pathology, 5(1), pp.1-15.

Hall, D.G., Gottwald, T.R. and Bock, C.H., 2010. Exacerbation of citrus canker by citrus leafminer *Phyllocnistis citrella* in Florida. Florida Entomologist, 93(4), pp.558-566.
USDA Phytosanitary Certificate Issuance and Tracking System, Phytosanitary Export Database (PExD) Harmful Organisms Database Report. Xanthomonas citri ssp. citri. Accessed 2/26/2021

Zekri, M., Chamberlain, H., Timmer, P., Roberts, P. and Muchovej, R., 2005. Field identification of citrus canker symptoms and decontamination procedures. EDIS, 2005(13).

Responsible Party:

Heather J. Scheck, Primary Plant Pathologist/Nematologist, CDFA/PHPPS ECOPERS, 2800 Gateway Oaks Suite 200, Sacramento, CA 95833 Phone: (916) 654-1017, permits[@]cdfa.ca.gov.

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*Comment Period: 05/19/2021 through 07/03/2021

*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: A