CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

California Pest Rating Proposal for

Pseudomonas syringae pv. *actinidiae*
Takikawa, Serizawa, Ichikawa, Tsuyumu and Goto 1989

Bacterial canker of kiwifruit

Current Pest Rating: none

Proposed Pest Rating: A

Domain: Bacteria, Phylum: Proteobacteria,
Class: Gammaproteobacteria, Order: Pseudomonadales,
Family: Pseudomonadaceae

Comment Period: 10/27/2021 through 12/11/2021

Initiating Event:

This pathogen has not been through the pest rating process. The risk to California from *Pseudomonas syringae* pv. *actinidiae* (Psa) is described herein and a permanent pest rating is proposed.

History & Status:

Background: Kiwifruit (*Actinidia deliciosa* and *A. chinensis*) are perennial, deciduous, woody vines native to south China. Commercial production of kiwifruit began in California in the late 1960s, and today nearly all the commercial acreage in the United States is here. California is also the nation's sole exporter of kiwifruit. In 2019/20, kiwifruit was reported in commercial production on 4400 acres, yielding 51,500 tons of fruit valued at $86M. Production increased 36% in 2019/2020 (CDFA, 2020).

California mostly grows *A. deliciosa* and the dominant cultivar is the green-fleshed cv. Hayward. Production is mainly in the northern Sacramento Valley in Butte, Sutter, and Yuba counties, with additional production in the southern San Joaquin Valley in Fresno, Kern, Kings, Madera, and Tulare counties. Kiwifruit is dioecious with separate female and male plants. Plants require winter chill, adequate summer irrigation, and protection from wind.

Pseudomonas syringae is one of the most-studied bacterial plant pathogens and is used as a model for understanding host–pathogen interactions and bacterial virulence mechanisms, microbial evolution,

ecology, and epidemiology. *Pseudomonas syringae* is commonly found on the phyllosphere of its hosts, where it can live as an epiphyte. Pathovar *syringae* was originally isolated from lilac but is pathogenic on many dicotyledonous and monocotyledonous hosts (Hirano and Upper, 2000).

The *P. syringae* species complex forms a monophyletic group in the Pseudomonas fluorescens-like division of Pseudomonas. *Pseudomonas syringae* strains are split into 13 phylogroups. Strains of *P. syringae* have been subdivided into more than 60 pathovars based on host of original isolation, host range, and biochemical properties. *Pseudomonas syringae* pathogenicity is strongly influenced by external environmental conditions, such as humidity and temperature and the other microbiota that live on plants (Young, 1991). It can attack leaves, stems, trunks, bark, limbs, branches, twigs, buds, flowers, and fruit. It survives on crop and non-crop species, which can serve as sources of primary inoculum for infection of susceptible hosts (Agrios, 2005).

Bacterial canker caused by *P. syringae* pv. *actinidiae* has a devastating impact on kiwifruit production worldwide, causing tremendous economic losses by destroying a vine or vineyard in one or a few seasons (Scortichini et al., 2012). Kiwifruit canker was first described in 1983 on the cultivar Hayward in Japan and in Korea in 1988 (Serizawa et al., 1989; Koh et al., 1994). By 1994, it had been found in Italy (Scortichini et al., 1994), and by 2010 was seen to be causing massive disease outbreaks on yellow-fleshed golden kiwifruit (*A. chinensis*) in major kiwifruit-growing countries (CABI-ISC, 2021). Psa is not known to be in California or anywhere in the United States, and it is a regulated plant pathogen (APHIS-USDA).

Psa populations are mainly divided into three biovars based on genetic diversity and toxin production (Chapman et al., 2012). Psa1 and Psa2 produce phaseolotoxin and coronatine, two well studied toxins used by *P. syringae* to overcome plant immune responses. In Japan and Korea, canker disease in cv. Hayward was caused by Psa1 and Psa2 in 1980s (Koh et al., 1994; Serizawa et al., 1989; Takikawa et al., 1989). Strains belonging to Psa3 produce neither phaseolotoxin nor coronatine but are primarily responsible for the global outbreaks of bacterial canker in recent years (Scortichini et al., 2012). Psa3 causes lethal damage to the cultivars of yellow- and red-kiwifruit varieties of *A. chinensis*.

The disease has become pandemic in major producing countries of kiwifruit, such as Italy, France, New Zealand, and Chile, resulting in serious damage to the kiwifruit industries in those counties (Balestra et al., 2009; Scortichini et al., 2012). Analysis of the genome of Psa3 strains that are causing pandemics on *A. chinensis* revealed that all the Psa3 strains belong to the same lineage originating from China (Butler et al., 2013; McCann et al., 2013). There was a fourth described biotype of Psa, but in 2014, Cunty et al. reclassified isolates of Psa4 from France as a new and distinct pathovar, naming it *Pseudomonas syringae* pv. *actinidifoliorum* (Psaf). Psaf is non-systemic and is associated with leaf spot symptoms only; it shows low aggressiveness on kiwifruit (Butler et al., 2013, Chapman et al., 2012; Vanneste et al., 2013; Cunty et al., 2014), and does not cause the more serious canker symptoms. Psaf is present in California and holds a C- rating (Scheck, 2020).

In 2010, the USDA issued a Federal Order for *P. syringae* pv. *actinidiae* to state and territory agricultural regulatory officials. This Federal Order was issued to prevent the introduction and dissemination of a bacterial canker of kiwifruit into the United States. APHIS began to prohibit

importations of *Actinidia* spp. plants for planting (including pollen but excluding fruit and seed) hosts of Psa from all other countries. https://www.aphis.usda.gov/import_export/plants/plant_imports/federal_order/downloads/2010/DA-2010-11.pdf.

In 2012, USDA APHIS issued a quarantine pest evaluation datasheet for Psa describing the scientific evidence that it is a quarantine pest for the United States and describing the damage potential of this pathogen as follows: Psa is present in infected plant material and is thought to be introduced into new regions in nursery material. The pathogen can be dispersed in aerosols and can be carried between trees and adjacent vineyards in wind-driven rain. As a wound-infecting pathogen, it can also be transmitted on vineyard equipment such as pruning tools. This confirmed in regulation the status of *Actinidia* spp. plants for planting as "Not Authorized Pending Pest Risk Analysis" from all countries. https://downloads.regulations.gov/APHIS-2011-0072-0044/content.pdf

Hosts: Actinidia sp., *A. arguta* (tara vine), *A. chinensis* (Chinese gooseberry), *A. chinensis* var *chinensis*, *A. deliciosa* (kiwifruit), *A. eriantha, A. hemsleyana, A. kolomikta, A. rufa, Alternanthera philoxeroides* (alligator weed), *Broussonetia papyrifera, Paulownia tomentosa* (paulownia), *Prunus mume* (Japanese apricot tree), *P. persica* (peach), *Sertaria viridis* (green foxtail) (CABI-ISC, 2021: EPPO, 2021).

Symptoms: In spring, canes can become water-soaked and exude a pale, translucent to dark reddish colored ooze from lenticels of apparently healthy tissue. This ooze contains infectious Psa. Small (1-3 mm) cracks form above olive-colored, water-soaked lesions and exude gums. Lesions can elongate and whole canes can become necrotized and die back. Leaves develop small, water-soaked spots as they expand in spring. These become brown and angular with bright, chlorotic halos. On lower leaf surfaces, translucent gum may exude from stomata. Infected floral buds become brown and wither without opening and they may exude translucent gums. Heavily infected flower buds may drop.

On trunks and leaders, symptoms of canker are seen in mid-winter when small droplets of ooze are produced. In late winter oozing increases and becomes reddish brown. When vines break dormancy, canker symptoms with bark that is dark and necrotic, appear with gum exuding from natural openings, from cracks in the bark, and from pruning cuts. Tissues below the cankers are necrotic, trunks and leaders may be girdled. Prolific suckering can occur below girdling cankers (Serizawa et al., 1989; Balestra et al., 2009). Psa can overwinter in leaf litter and pruning debris (Tyson et al., 2012).

Transmission: Natural spread occurs within and between vineyards with passive transmission. Bacterial exudates from kiwifruit cankers can be disseminated by rain-splash and wind driven rain (Serizawa et al., 1989; Scortichini et al., 2012). Psa can infect the plant through stomata, flowers, leaf, and fruit abscission scars, broken trichomes and natural wounds. Contaminated pruning tools can contribute to spread within and between vineyards. Psa has been moved short and long distances with infected nursery stock, and this is considered the primary means for long-distance spread of the pathogen.

Psa can be transmitted via infected pollen. Bacteria have been reisolated from within plants artificially pollinated with Psa-contaminated pollen and from plants artificially pollinated with naturally Psa-contaminated pollen. The disease can become systemic from pollen-infection and viable Psa was

recovered two years after pollination (Spinelli et al., 2015; Tontou et al., 2014). Insects, especially pollinating insects, have been shown to vector viable Psa and other *P. syringae* pathovars. However, this role in the transmission of disease caused by Psa has not been established (Balestra et al., 2017).

Damage Potential: Serious losses were reported from Psa in Japan and Korea in the 1990s. The pathogen was accidentally introduced into Northern Italy in 1994, where it was seen sporadically until 2007/8 when it became a serious epidemic. Before 2008, Psa in all cases, was isolated from *Actinidia deliciosa* cv. *Hayward*. Since 2008, it has become a major problem for both yellow and green fleshed kiwifruit production (*A. chinensis* and *A. deliciosa*), with separate outbreaks reported in Italy, France, Portugal, Spain, New Zealand, and Chile (CABI-ISC, 2021). The disease was found in New Zealand in 2010 and has severely damaged their Kiwifruit industry which is based on only two cultivars. Only four years after the first detection New Zealand in 2010, it was estimated that 81% of kiwifruit hectares had been confirmed as infected and this disease was projected to cause economic losses in the hundreds of millions of NZ dollars (Donati et al., 2014). Most of the severe disease has been credited to Psa Biovar 3. However, Psa is clonal and there is evidence that it has evolved rapidly by exchanging mobile genetic elements, including integrative conjugative elements (ICEs), which, in some cases, has led to copper resistance (Vanneste, 2017).

Worldwide Distribution: Asia: *China, Japan, North Korea, South Korea, Turkey*. Europe: *France, Greece, Italy, North Macedonia, Portugal, Slovenia, Spain, Switzerland*. Oceania: *Australia*, *New Zealand*. South America: *Argentina, Chile*.

Official Control: Psa is on the EPPO's A1 list for Argentina, Egypt, Georgia, Turkey; on the A2 list for Chile, El Comité de Sanidad Vegetal (COSAVE), and European plant protection organization (EPPO); and a quarantine pest for Morocco (EPPO, 2021). Psa is on the USDA's Harmful organisms list for Australia, Chile, Colombia, Egypt, French Polynesia, Georgia, Republic of Korea, Peru, and the United Kingdom (USDA PCIT 2021). Psa is a regulated plant pest for the United States (APHIS-USDA, 2021).

California Distribution: None

California Interceptions: None

The risk *Pseudomonas syringae* pv. *actinidiae* would pose to California is evaluated below.

Consequences of Introduction:

1) **Climate/Host Interaction:** The microclimate in the vineyard is critical in determining the local severity of disease. Rainy and humid weather conditions and mild temperature favor the bacterial infection. Thus, the highest risk of bacterial canker is in areas and seasons in which the combination of such conditions is more frequent. The disease is likely to be found wherever kiwifruit grow in California, although places with higher relative humidity and rain will have reduced latent period between infection and symptom development (Donati et al., 2014).

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:** In the environment, the host range is limited to kiwifruit (*Actinidia* spp.) A few additional experimental hosts have been identified.

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:** PSA seems to spread very easily within and between vineyards. Bacterial exudates, which ooze from the cankers during the end of autumn–winter and early spring and are dispersed by the wind, are very effective sources of inoculum (Serizawa et al., 1989).

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:** Economic losses, sometimes severe, have occurred worldwide, directly from loss of vines, and indirectly from quarantine regulations. To manage epidemics, vineyards use bactericides and modify pruning and sanitation.

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:** This pathogen has a limited host range. There are no native *Actinidia* sp. in California. All producers and home gardeners with kiwifruit would be significantly impacted by a detection of Psa on their property, likely to receive and emergency action notice from USDA-APHIS requiring eradication.

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 *Pseudomonas syringae* pv. *actinidiae:* 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:

There are several strains of Psa found worldwide, with some causing moderate damage (biovars 1,2) and others causing important damage (biovar 3) (McCann et al. 2013). New biovars could still be evolving and spreading. Other risk factors can increase the amount of disease that develops and the spread of disease, including other environmental factors (e.g. temperature), host factors (e.g. cultivar) and management factors (e.g. pruning practices), and not all of these have been delimited (Froud et al., 2015).

Conclusion and Rating Justification:

Based on the evidence provided above the proposed rating for *Pseudomonas syringae* pv. *actinidiae* is A.

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Responsible Party:

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***Comment Period: 10/27/2021 through 12/11/2021**

***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
