California Pest Rating Proposal for

Clavibacter michiganensis corrig. (Smith 1910) Davis et al. 1984

emend. Nouioui et al. 2018

Bacterial canker of tomato

Current Pest Rating: B

Proposed Pest Rating: B

Kingdom - Bacteria; Class - Actinobacteria

Order- Actinomycetales; Family- Microbacteriaceae

Comment Period: 8/18/2020 through 10/2/2020

Initiating Event:

On August 9, 2019, USDA-APHIS published a list of "Native and Naturalized Plant Pests Permitted by Regulation". Interstate movement of these plant pests is no longer federally regulated within the 48 contiguous United States. There are 49 plant pathogens (bacteria, fungi, viruses, and nematodes) on this list. California may choose to continue to regulate movement of some or all these pathogens into and within the state. In order to assess the needs and potential requirements to issue a state permit, a formal risk analysis for *Clavibacter michiganensis* is given herein and a permanent pest rating is proposed.

History & Status:

Background:

Bacterial canker is a seed-borne pathogen and one of the most damaging diseases of tomato worldwide. It was first reported in Michigan by E.F. Smith in 1919 and it remains an important quarantine pest in the European Union. It was first placed in the genus *Corynebacterium*, which was originally intended to accommodate all phytopathogenic coryneform (gram-positive, catalase-positive, non-spore-forming, non-motile, rod-shaped) bacteria with peptidoglycan containing B2γ diaminobutyrate. Subsequently all but one species of *Corynebacterium* was reclassified into other genera, leaving only *C. michiganensis*. The genus name was changed to *Clavibacter* by Davis et al. in 1984 *and C. michiganensis* was further divided into nine subspecies, all of which were highly host specific. For example, those causing wilts on alfalfa were placed in subspecies *insidiosus,* and ring rot of potato in subspecies *sepedonicus*. The pathogen of tomato was called *C. michiganensis* subsp.

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michiganensis. Whole genome analysis, DNA–DNA hybridization, and multi-locus sequence analysis by Li et al. (2018) supported raising each of the subspecies to species status. *Clavibacter michiganensis* has a nearly worldwide distribution on tomatoes as the result of movement of contaminated seed.

Hosts: Tomato (*Solanum lycopersicon*) is the most important host but the pathogen has also been reported on perennial nightshade *(Solanum douglasii)*, black nightshade *(S. nigrum)*, cutleaf nightshade (*S. triflorum*), pepper (*Capsicum annuum*), and eggplant (*Solanum melongena*) (CABI-CPC, 2020).

Symptoms: Disease symptoms can involve all aboveground parts of the plants and include spots on leaves and fruits, small cankers on the stems and leaf veins, and wilting of the leaves and shoots. The first symptom in field-grown hosts is desiccation of the edges of leaflets, mainly on lower leaves. The lower leaves can have white, blister-like spots in the margins that become brown with age and may coalesce. Leaves wilt and curl upward and inward, and later turn brown and wither, but do not drop off the plants. The wilt may develop gradually, beginning on one side of the leaflet. The plants slowly desiccate with or without wilting and the whole plant can collapse. Infected young seedlings become stunted and wither rapidly with small whitish pustules developing on leaf veins, petioles, and peduncles. Infected greenhouse tomato transplants may not show visible symptoms when young; symptoms will appear when plants are near maturity.

On stems, shoots, and leaf stalks, light-colored streaks appear, usually at the joints of petioles and stems. Later, cracks develop in the streaks and develop into cankers. During advanced stages of disease, brown streaks appear on the stems and petioles. A white, yellow, or reddish-brown discoloration of vascular tissue develops along with cavities within pith. This is mostly seen at the junction of stems, petioles, and peduncles. Sometimes, a very light pink discoloration of the vascular tissue is observed which may confuse the diagnosis of bacterial canker with *Verticillium* or *Fusarium* wilt. In humid or wet weather, slimy masses of bacteria ooze through the cracks to the surface of the stems. This ooze can spread the bacteria to leaves and fruits, where they can cause secondary infections. If secondary infections happen later in the growing season, it mainly results in marginal leaf necrosis.

Fruits develop small, shallow, water-soaked white spots, the centers of which later become slightly raised, tan colored, and rough. This bird's-eye-like appearance of the spots, which have brownish centers and white halos around them, is characteristic of the disease on tomatoes. Discoloration of the vascular tissues extends all the way to the fruits, both outward toward the surface and inward toward the seeds, and small dark cavities may develop in the centers of the fruits. Fruits may remain small and fall prematurely or ripen unevenly. They frequently show external marbling and internal bleaching of vascular and surrounding tissue.

There are usually no canker type symptoms on seedlings; however, young plants can show poor growth and temporary wilting of branches. Lower leaves can prematurely yellow and shrivel, but symptoms may not manifest until flowering. On mature plants there are two types of symptoms. One is from systemic infections when the bacteria enter the vascular system and invade much of the plant causing wilts, and the other is from secondary infections when bacteria cause local infections of leaves, stems, and fruits.

Modes of Transmission: T

The disease arrives in new areas on contaminated tomato seeds (internally or externally) without visible symptoms (de Leon et al., 2011). The bacteria move through the xylem and invade the phloem, pith, and cortex of the developing seedling. In a highly conducive environment like a greenhouse, bacteria on the surface of infected plants can be splashed to surrounding plants with irrigation. Infected seed can be directly planted into open fields or seeds can be germinated in a nursery and latently infected but asymptomatic seedlings can be

transplanted out. Transplants may also be infected during planting after an infected plant is handled, especially if the plants are wet and suffer any wounding, even if very minor such as broken trichomes.

Most primary infections not from diseased seed result from bacteria that has overwintered in infected debris and enters through wounds on roots, stems, leaves, and fruits during transplanting, from windblown rain, and from cultural practices such as tying and suckering of tomatoes. Also, the bacterial ooze can survive on stakes or trellises for long enough to establish on newly planted tomato seedlings in the following season. Once inside the plant, bacteria move and multiply primarily in the xylem vessels, and move out of them into the phloem, pith, and cortex, where they form the large cavities that result in the cankers.

Secondary spread from plant to plant occurs with splashing water, on contaminated equipment, during clipping, cultivation, vine-training operations, and other cultural activities. In the field, such spread usually results in localized hot spots of infections (i.e., leaf, stem, and fruit spots). In greenhouses where conditions are highly favorable and plants are long lived, grafting, trimming, packaging and transportation of transplants, pruning and tying of trellis and staking tomato plants, or suckering operations can lead to an epidemic level of secondary disease and large losses even if the primary seed infection rate was very low (Gitaitis et al., 1991). Canker bacteria can also survive on volunteer tomato seedlings and alternative hosts, which can serve as sources of inoculum to crops (Strider, 1969).

Damage Potential:

Losses from bacterial canker in tomato remains a serious problem worldwide. New outbreaks and first reports are still periodically described in new regions of the globe. Current losses are variable among years but may be very high at the global level, both from infected seed and from the ability of the pathogen to survive in the field. In California, detectable disease in direct-seeded tomato fields is uncommon. *Clavibacter michiganensis* may occur at a low incidence in direct-seeded fields but almost always goes unnoticed as epidemics do not develop under normally dry summer conditions. (Davis et al., 2013). Seed contamination with only a few bacterial cells, apparently below the level of detection, can cause serious problems in a greenhouse because conditions are more conducive to epidemics with high potential for secondary spread. With unusually wet weather, secondary spread occurs with vine-training, harvesting, or other operations that cause wounding and can lead to extensive leaf loss and fruit spotting (Davis et al., 2013).

In the 21st century there have been multiple outbreaks causing significant disease losses in field grown tomatoes in countries such as Chile, Cyprus, and Italy. Mexico has reports of large losses in field and greenhouse production (Holguín-Peña et al., 2006). There were also outbreaks in the Netherlands associated with transplant propagators and in greenhouse tomato production in Japan. New occurrences in Korea, the Canary Islands, and Syria were all attributed to the importation of contaminated seed (de Leon et al., 2011).

Seed testing is an essential tool for the control of *C. michiganensis* and is important for phytosanitary certification and quarantine programs in the domestic and international seed trade (CABI-CPC, 2020).

Worldwide Distribution: Africa: *Egypt, Kenya, Madagascar, Morocco, South Africa, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe*. America: *Argentina, Belize, Brazil, Canada, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, Grenada, Guadeloupe, Mexico, Panama, Peru, United States of America, Uruguay*. Asia: *China, India, Indonesia, Iran, Israel, Japan, Korea, Lebanon, Syria.* Europe: *Armenia, Azerbaijan, Belarus, Bulgaria, Cyprus, Czech Republic, France, Germany, Greece, Hungary, Italy, Latvia, Poland, Portugal, Romania, Russia, Serbia, Spain, Switzerland, Turkey, Ukraine*. Oceania: *Australia, Fiji, Guam, New Caledonia, New Zealand, Tonga* (EPPO, 2020)

Official Control: *Clavibacter michiganensis* is a B rated pathogen in California and it is on the USDA's harmful organism list for Albania, Algeria Argentina, China, Costa Rica, Egypt, European Union, Guatemala, Holy See (Vatican City State), Honduras, Iceland, Israel, Jordan, Madagascar, Mexico, Monaco, Moldova, Morocco, New Caledonia, Nicaragua, Norway, Paraguay, Peru, San Marino, Serbia, South Africa Taiwan, Thailand, Timor-Leste, Tunisia, Turkey, and Yemen (USDA APHIS PCIT, 2020). It is on the A1 list in Georgia and Jordan and on the A2 list in Bahrain, East Africa, Egypt, European Union, and Turkey, and a quarantine pest in Israel, Morocco, Norway, and Tunisia (EPPO, 2020). In the CDFA Phytosanitary Field Inspection manual, it is listed as a pest of concern of export seeds of tomato and tomatillos.

California Distribution: Detections of *C. michiganensis* were made on tomato seed grown in Yolo County in 2011 and again in 2013. In 2014, detections were reported in tomato research plots located in Santa Clara County. In 2016, detections were reported in tomato seed fields in Colusa County. *Clavibacter michiganensis* was identified by culture, biochemical assays, immunoassay, and in some cases, by DNA sequence analysis and pathogenicity tests on tomatoes.

California Interceptions:

The risk *Clavibacter michiganensis* would pose to California is evaluated below:

Consequences of Introduction:

1) **Climate/Host Interaction:** In general, California's Mediterranean-like climates with hot dry summers is not favorable to foliar bacterial pathogens that require water to spread and infect like *Clavibacter michiganensis,* but greenhouse production is more vulnerable.

   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 main host is tomato plus other plants in the genus *Solanum* and *Capsicum*.

   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 Dispersal Potential:** *Clavibacter michiganensis* spreads with infected seed, irrigation water, asymptomatic seedlings, infected plant debris, and contaminated tools, tomato stakes, and trellises.

   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:** *Clavibacter michiganensis* is rare in field grown tomatoes under California conditions (Davis et al., 2013). Greenhouse outbreaks can be more damaging, but the use of pathogen-free seed is key. Severe disease has not been reported in CA cropping systems. This is an important pathogen for export seed, especially to the EU. California endeavors to remain disease free to protect growers and trading partners.

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

Economic Impact: A

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: **2**

- 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:** *Clavibacter michiganensis* can infect a few other Solanum species but these are weedy rather than desirable native plants. Establishment in the environment poses a risk to clean tomato seed production.

Environmental Impact: D

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: 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 *Clavibacter michiganensis*: Medium (10)

Add up the total score and include it here.
-Low = 5-8 points

-Medium = 9-12 points
-High = 13-15 points

6) **Post Entry Distribution and Survey Information**: *Clavibacter michiganensis* has been found on tomato seed in Yolo, Colusa, and Santa Clara counties.

Score: -1

-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:

Final Score: *Score of Consequences of Introduction – Score of Post Entry Distribution and Survey Information* ***= 9***

Uncertainty: none

Conclusion and Rating Justification:

Based on the evidence provided above the proposed rating for *Clavibacter michiganensis* is B.

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***Comment Period: 8/18/2020 through 10/2/2020**

***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: B