CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

California Pest Rating Proposal for

Pepper mild mottle virus

Current Pest Rating: C

Proposed Pest Rating: B

Kingdom: Viruses and viroids, Category: Riboviria,
Category: Orthornavirae, Phylum: Kitrinoviricota,
Class: Alsuviricetes, Order: Martellivirales,
Family: Virgaviridae, Genus: *Tobamovirus*

Comment Period: 08/26/2022 through 10/10/2022

Initiating Event:

Pepper mild mottle virus has previously been assigned an unofficial C-rating by the California Department of Food and Agriculture (CDFA), Plant Health and Pest Prevention Services, but has not undergone the current pest risk assessment process. The risk to California from Pepper mild mottle virus (PMMoV) is described herein and a permanent pest rating is proposed.

History & Status:

Background:

California is the number one producer of peppers in the United States. In 2021, it produced 341,000 tonnes on 165,000 acres with an estimated value of $200M (CDFA Crop Statistics, https://www.cdfa.ca.gov/Statistics/PDFs/2021_Ag_Stats_Review.pdf). There are four main pepper production areas in California: the southern desert valleys, the southern coast, the central coast, and the central valley. Pepper mild mottle virus (PMMoV) occurs worldwide in field-grown bell, hot, and ornamental peppers, but there is only one report from California, from the Imperial Valley. Epidemics reported in other countries are severe in greenhouses where production practices are ideal for rapid spread of the disease. The properties and genetics of the virus place it in the Tobamovirus genus, which also contains other economically important pathogens that infect members of the family Solanaceae.

PMMoV was first recognized as a distinct virus in Europe by Wetter et al. (1984), but it had been described previously in the United States as the latent strain of Tobacco mosaic virus (McKinney, 1952; Greenleaf et al., 1964). Isolates of PMMoV with the ability to overcome resistance genes in several

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Capsicum species have been designated as pathotypes (Garcia-Luque et al., 1990). PMMoV is serologically closely related to Bell pepper mottle, Odontoglossum ringspot, and Tobacco mild green mosaic, more distantly to Tobacco mosaic and Tomato mosaic, and only remotely to Cucumber green mottle mosaic and Sunn-hemp mosaic viruses (Brunt et al., 1996).

PMMoV has rod-shaped virus particles (virions). A single virion is composed of a coat protein that envelopes one positive single-stranded RNA. This single-stranded RNA encodes four genes: two replicase-associated proteins that are directly translated from the PMMoV RNA, and the movement protein and a coat protein that are translated from subgenomic RNAs.

Tobamoviruses are easily transmitted by mechanical inoculation and by handling during plant cultivation. They are transmitted at a high rate through contaminated seeds. No biological vectors are known. Losses can be considerable for pepper crops, particularly in greenhouses and in plastic tunnels. Tobamoviruses are exceptionally stable and are known to survive for years in plant debris in the soil and for weeks or months on greenhouse structures, pots, and horticultural tools. They persist on clothing and, most importantly, on workers hands.

PMMoV is used as an effective tool for microbial water quality monitoring and assessing waste-water treatment technologies. It is the most abundant RNA virus found in the feces of healthy people, who ingest it through the consumption of infected peppers, which are frequently used in processed pepper products (e.g., hot sauces, curry sauces, dry spices). Because PMMoV is consistently found at high concentrations in domestic wastewater, it can be used as a marker to trace untreated or treated wastewater in the environment. Acting as a surrogate, PMMoV can be used for estimating the presence and persistence of human enteric viruses, serving as a tool for monitoring microbial water quality, wastewater treatment efficiency, and food safety (Symonds et al., 2019).

Hosts: Capsicum spp. (peppers) are the only major natural hosts of the virus. Many other species in the genus *Solanum* are susceptible, but not tomato or tobacco. PMMoV is transmissible experimentally to at least 24 species in six genera of the Solanaceae and to five species in four genera in four other families, Chenopodiaceae, Cucurbitaceae, Labiatae, and Plantaginace (Brunt et al., 1996).

Symptoms: Because foliar symptoms can be mild, infected plants may not be noticed until the fruit symptoms are evident, resulting in accidental spread to neighboring plants and higher yield losses. Mild leaf chlorosis and growth reduction occur in naturally infected commercial pepper cultivars. Infected leaves are frequently puckered and mottled yellow or light green. Leaf symptoms are more evident on younger leaves (Lamb et al., 2001).

Fruits are small, malformed, mottled, and sometimes develop necrotic depressed areas. Stunting is very severe in peppers infected at early stages of growth. It was able to infect all commercial pepper cultivars tested by Alonso et al. (1989) in Spain, including those resistant to other tobamoviruses such as Tobacco mosaic virus.

Transmission: There are no reports of transmission by vectors. There can be a high rate of seed contamination with PMMoV. There are reports of 22% of *C. frutescens* seeds and 29% of *C. annuum*

seeds in given lots with the virus present on the outer seed coat, although it is rarely in the endosperm (Tosic et al., 1980). Seedlings may be heavily infected during transplanting, reportedly up to 41% (Brunt et al., 1996). Because PMMoV is seedborne in *Capsicum* species, it has probably been inadvertently distributed internationally; it is thus possibly more widespread than reported and may even occur worldwide. There is a great risk that it could be further disseminated to new areas with contaminated seed.

Diseased plant material will remain infectious until completely broken down. Tillage, increased irrigation, and high temperatures encourage the breakdown of plant material in the soil. Any infected plant material in the soil can serve as a source of inoculum for subsequent crops so crop rotation should be practiced, if possible. Volunteer peppers and weeds, particularly those in the Solanaceae family (such as nightshades), should be removed to reduce possible sources of infections (Lamb et al., 2001).

Damage Potential: Because foliar symptoms can be mild, infected plants may not be noticed until the fruit symptoms are evident, resulting in spread to neighboring plants and higher yield losses. In field crops, infection may reach 100% and the yield of marketable fruits is drastically reduced (Wetter et al., 1983). Yield losses (ca 20-30%) in field-grown and protected infected pepper crops as well as a significant loss of quality of fruits have been reported in by multiple locations (Conti and Marte, 1983; Marte and Wetter, 1986; Alonso et al., 1989). In addition, rogueing of infected and adjacent plants to minimize secondary spread in protected crops results in greatly reduced potential yields. Even the mild strain used for cross protection in Italy has some debilitating effect on protected plants (Cartia et al., 1985). None of several attenuated strains of PMMoV failed to confer significant levels of cross-protection in Japan (Tsuda et al., 2007).

Worldwide Distribution: Africa: *Egypt, Ethiopia, Senegal, South Africa, Tunisia, Zambia. Asia: China, Israel, Japan, Pakistan, South Korea, Taiwan, Turkey*. Europe: *Belgium, Bulgaria, Czechia, Denmark, France, Germany, Greece, Hungary, Iceland, Italy, Netherlands, Poland, Spain, United Kingdom*. North America: *Antigua and Barbuda, Barbados, Canada, Haiti, Jamaica, Mexico, Montserrat, Panama, Saint Lucia, Trinidad and Tobago, United States* (California, Colorado, Florida, Georgia, Louisiana, Oklahoma, Oregon, South Carolina, Texas). Oceania: *Australia, New Zealand*. South America: *Argentina, Brazil, Suriname, Venezuela* (CABI-CPC, 2022).

Official Control: Pepper mild mottle virus is on the USDA PCIT's harmful organism list for Colombia, Costa Rica, Ecuador, Georgia, Guatemala, Honduras, India, Japan, Mexico, Nicaragua, Panama, Paraguay, and the Syrian Arab Republic (USDA PCIT, 2022).

California Distribution: None

California Interceptions: There is one record of PMMoV, from trade seed sample submitted by Imperial County in 2004 (CDFA PDR database, 2022). The origin of the seed is not known.

The risk Pepper mild mottle virus would pose to California is evaluated below.

Consequences of Introduction:

1) **Climate/Host Interaction:** PMMoV is likely to occur in any climate where its hosts can grow. Peppers are a warm season crop, sensitive to freezing temperatures at any growth stage.

   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 natural host range is limited to *Capsicum* spp. and others in the family Solanum.

   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 virus does not have any insect vectors. It reproduces only within the cells of its hosts. It is dispersed easily with infected sap and with contaminated seeds and is highly dependent on agricultural practices such as international shipping of seed and extensive handling of plants in greenhouses to cause epidemics.

   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:** In addition to stunting plants, PMMoV reduces yield dramatically by causing unacceptable symptoms on pepper fruit. It is easily spread by normal cultural practices, requiring significant phytosanitary modifications to prevent epidemics in greenhouses. It is a pest of concern for several countries.

   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 directly impacts cultural practices. Seeds should be tested prior to import or planting, contaminated or exposed seed should be treated, and strict phytosanitary systems need to be used to prevent plant-to-plant spread.

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 Pepper mild mosaic virus*:* Medium

Add up the total score and include it here. **12**
-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* ***= 12***

Uncertainty:

At least five other tobamoviruses, Tobacco mosaic, Tobacco mild green mosaic, Tomato mosaic, Paprika mild mottle, and Bell pepper mild mottle, are very similar to PMMoV and occur naturally in *Capsicum* species. These can be distinguished by their serological and molecular properties but cannot be separated in the field by symptoms (CABI-CPC, 2022).

Conclusion and Rating Justification:

Based on the evidence provided above the proposed rating for Pepper mild mottle virus is B.

References:

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Responsible Party:

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***Comment Period: 08/26/2022 through 10/10/2022**

***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
