

EPPO Datasheet: *Clavibacter michiganensis*

Last updated: 2022-01-27

IDENTITY

Preferred name: *Clavibacter michiganensis*

Authority: (Smith) Davis et al.

Taxonomic position: Bacteria: Actinobacteria: Micrococcales:
Microbacteriaceae

Other scientific names: *Bacterium michiganense* Smith,
Clavibacter michiganensis subsp. *michiganensis* (Smith) Davis et al.,
Corynebacterium michiganense pv. *michiganense* (Smith) Dye &
Kemp, *Corynebacterium michiganense* pv. *michiganense* (Smith)
Jensen, *Corynebacterium michiganense* subsp. *michiganense* (Smith)
Jensen, *Corynebacterium michiganense* (Smith) Jensen

Common names: bacterial canker of tomato, bird's eye of tomato
fruits, vascular wilt of tomato

[view more common names online...](#)

EPPO Categorization: A2 list

[view more categorizations online...](#)

EU Categorization: RNQP (Annex IV)

EPPO Code: CORBMI



[more photos...](#)

Notes on taxonomy and nomenclature

For many years, the pathogen causing bacterial canker of tomato has been called *Clavibacter michiganensis* subsp. *michiganensis*. In the 2010s, the division of *Clavibacter michiganensis* into subspecies started to be reviewed, and subspecies were progressively moved to the species level, such as *C. sepedonicus*, *C. capsici* and *C. nebraskensis* (Li et al., 2018; Nouioui et al., 2018). More recently, based on genomic and phylogenetic analysis, *C. michiganensis* subsp. *phaseoli*, *C. michiganensis* subsp. *californiensis*, and *C. michiganensis* subsp. *chilensis* were also elevated to species rank, leaving only one subspecies, *C. michiganensis* subsp. *michiganensis* (Arizala et al., 2022; Osdaghi et al., 2020). As a consequence, this remaining subspecies should now be called *C. michiganensis*.

HOSTS

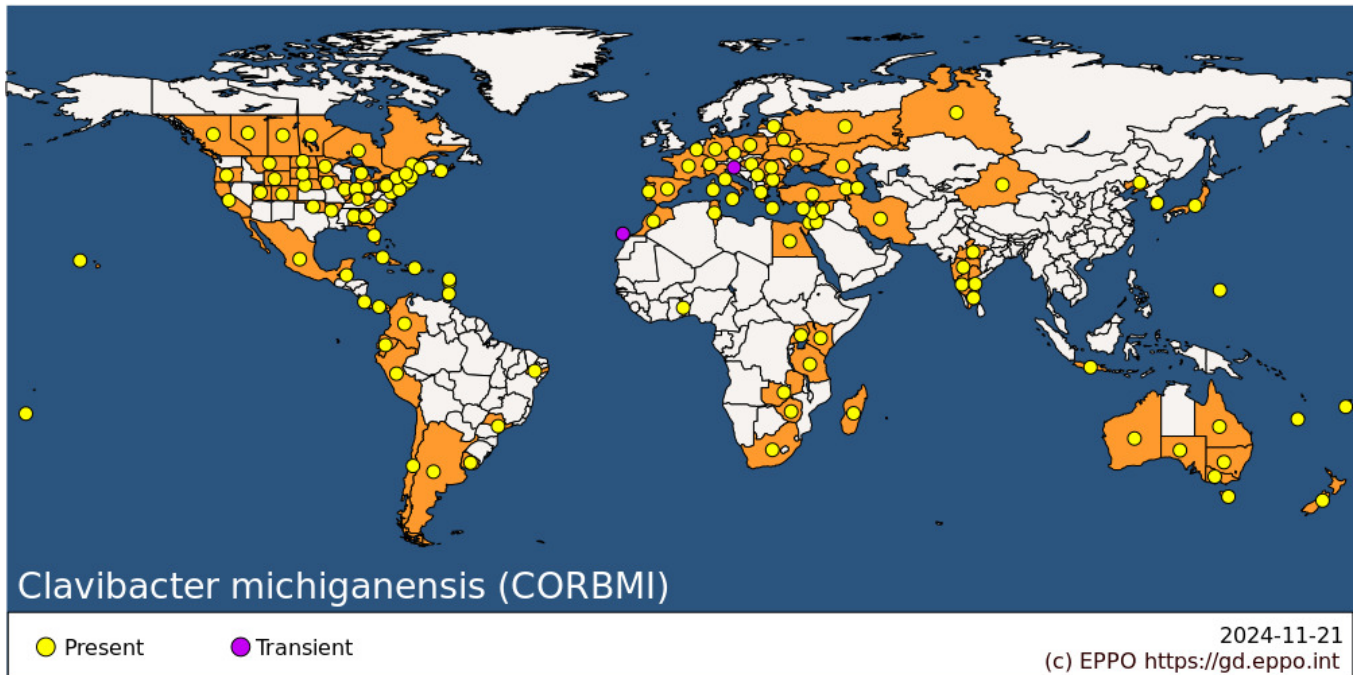
The only major host of economic importance is tomato (*Solanum lycopersicum*). Several strains which had been isolated from *Capsicum annuum* and *Capsicum frutescens* have been reclassified as *Clavibacter capsici* (Oh et al., 2016). Additionally, several weeds from the *Solanaceae* family have been shown to be susceptible to *C. michiganensis* under natural or experimental conditions (e.g. *Solanum douglasii*, *Solanum nigrum* and *Solanum triflorum*; Laj, 1976; Latin et al., 1995; Lewis Ivey & Miller, 2000; Nandi et al., 2018; Yim et al., 2012), and could be potential reservoirs of the pathogen. A number of solanaceous plants are susceptible after artificial inoculation (for details see Thyr et al., 1975; Yim et al., 2012), as well as other plant species including cucumber (*Cucumis sativus*), sunflower (*Helianthus* spp.) and watermelon (*Citrullus lanatus*). Additional monocotyledonous host plants reported susceptible after artificial inoculation, e.g. barley (*Hordeum vulgare*), maize (*Zea mays*), oat (*Avena sativa*) and wheat (*Triticum* spp.; Stamova & Sotirova, 1987) are considered doubtful pending confirmation.

Host list: *Solanum douglasii*, *Solanum lycopersicum*, *Solanum nigrum*, *Solanum pectinatum*, *Solanum quitoense*, *Solanum triflorum*, *Solanum tuberosum*

GEOGRAPHICAL DISTRIBUTION

The bacterial canker of tomato was first identified in tomato greenhouses in Michigan (USA) in 1909, and is now widespread in Africa, Asia, Europe, North America, Oceania and South America. Since the mid-twentieth century,

the intensification of the international tomato seed trade has caused *C. michiganensis* to spread within and between continents. It has also become widespread within a number of tomato producing countries of the EPPO region, but also in tomato producing countries outside the EPPO region.



EPPO Region: Armenia, Azerbaijan, Belarus, Belgium, Bulgaria, Cyprus, Czech Republic, France (mainland), Germany, Greece (mainland, Kriti), Hungary, Israel, Italy (mainland, Sardegna, Sicilia), Jordan, Latvia, Morocco, Poland, Portugal (mainland), Romania, Russia (Central Russia, Southern Russia, Western Siberia), Serbia, Slovenia, Spain (mainland, Islas Canarias), Switzerland, Tunisia, Türkiye, Ukraine

Africa: Egypt, Kenya, Madagascar, Morocco, South Africa, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe

Asia: China (Liaoning, Xinjiang), India (Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu), Indonesia (Java), Iran, Israel, Japan (Honshu), Jordan, Korea, Republic, Lebanon, Syria

North America: Canada (Alberta, British Columbia, Manitoba, Nova Scotia, Ontario, Québec, Saskatchewan), Mexico, United States of America (Alabama, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Hawaii, Illinois, Indiana, Iowa, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Montana, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Dakota, Utah, Vermont, Wyoming)

Central America and Caribbean: Belize, Costa Rica, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Panama

South America: Argentina, Brazil (Pernambuco, Sao Paulo), Chile, Colombia, Ecuador, Peru, Uruguay

Oceania: Australia (New South Wales, Queensland, South Australia, Tasmania, Victoria, Western Australia), Fiji, Guam, New Caledonia, New Zealand, Tonga

BIOLOGY

Contaminated/infected tomato seeds and plants for planting are the primary source for *C. michiganensis* outbreaks. Contamination/infection levels as low as 1 in 10000 seeds can be enough to cause an epidemic. Plant debris containing the pathogen and alternative hosts can also play a role in disease outbreaks but are considered less important (De León *et al.*, 2011; EPPO, 2016a; Fatmi *et al.*, 1991; Moffett & Wood, 1984; Nandi *et al.*, 2018).

From the primary source the bacterium spreads locally mainly by water (rain splash, irrigation) and/or during cultural practices (e.g. trimming, chemical sprays). The bacterium can enter the plant tissue through hydathodes as well as different types of wounds on shoots and roots (Carlton *et al.*, 1998; Huang & Tu, 2001). Young plants have been shown to be more susceptible to *C. michiganensis* (Van Vaerenbergh & Chauveau, 1985). However, under natural conditions, tomato plants are susceptible throughout their life (Nandi *et al.*, 2018). After infection, there is a latent period which can range from 7 days up to almost 3 months (EFSA, 2014; Gleason *et al.*, 1993). *C. michiganensis*

can cause systemic infections, generally when the infection occurs at an early stage of plant development, or only a local infection, when the plant is infected later during its development (Sharabani *et al.*, 2013).

The bacterium colonizes and multiplies in the xylem vessels which allows it to spread rapidly through the plant. Inside the xylem *C. michiganensis* expresses a large set of virulence factors and enzymes leading, for example, to the degradation of the vascular tissue. Heavily infected vessels contain viscous granular deposits, tyloses and bacterial masses that block water transport which causes wilting of the plant. From the xylem, *C. michiganensis* can also enter the seed coat and endosperm leading to (new) seed infections (Nandi *et al.*, 2018). During later stages of infection, the stem can crack, leading to the exudation of droplets containing *C. michiganensis*, and allowing further spreading.

The optimum temperature for growth of *C. michiganensis* populations is 24-28°C. The bacterium is highly tolerant to desiccation and can survive on seeds and dried plant material for years. In dried soil, the survival time is shorter, but can last up to 7 or 8 months (EFSA, 2014).

DETECTION AND IDENTIFICATION

Symptoms

The EPPO Diagnostic Standard PM 7/42 for *C. michiganensis* gives a detailed description of the disease symptoms (EPPO, 2016a). Symptoms can be divided in those that are triggered during a systemic infection and those that can appear during a local infection.

In systemic infections early symptoms include the appearance of dull green, oily areas that desiccate and later turn brown. With temperatures of 25-30°C and strong evapotranspiration a reversible wilting of leaves occurs which, within a few days, will become irreversible. Entire leaves, and eventually the whole plant, will wilt and desiccate. Contaminated/infected seeds usually give rise to apparently healthy seedlings, symptoms only appearing as plants approach maturity. Fruits may fail to develop and fall, or ripen unevenly. They also often show external marbling and internal bleaching of vascular and surrounding tissue. Less frequently, fruits may show characteristic 'bird's eye' spots. Initially slightly raised and white, these spots develop light-brown roughened centres surrounded by a flat whitish halo. On cutting stems, petioles and peduncles, particularly at their junctions, a creamy-white, yellow or reddish-brown discoloration of vascular tissue and pith and cavities within the pith will be evident. These discolorations are only visible at advanced stages of the disease (EPPO, 2016a).

Local infections can cause a granular appearance of leaves, stems and calyces which is caused by the presence of raised or sunken white to pale orange blisters. Infections through hydathodes commonly lead to dark brown spots that are surrounded by a yellow to orange area at the edge of the leaf. At later stages the edges of these leaves can curl and wilt. Local infections can sometimes cause yellow streaks along the stem that might split open and form cankers (EPPO, 2016a).

Morphology

C. michiganensis is an aerobic, non-motile, Gram-positive and non-spore forming bacteria, with a curved rod shape (for details see Bradbury, 1986).

Isolation of the causal organism can be performed on e.g. yeast peptone glucose agar. On this medium the bacterium develops flat and semi-fluidal, round or irregular, yellow colonies in 3 to 4 days (EPPO, 2016a). White, pink, red and orange mutants may also occur (Hayward & Waterston, 1964).

Detection and inspection methods

Visual inspection will generally allow detection of symptoms during the growing season. However, plantlets are usually symptomless when they are traded, and symptoms are not visible on seeds. Plants for planting should be inspected according to EPPO Standard PM 3/77 *Vegetable plants for planting under protected conditions – inspection of places of production* (EPPO, 2016b), whereas sampling of seeds for testing should follow EPPO PM 3/80 *Consignment inspection of seed of Solanum lycopersicum* (EPPO, 2021).

The EPPO Diagnostic Standard PM 7/42 for *C. michiganensis* provides thorough instructions on sampling, extracting, plating and diagnosing both symptomatic and symptomless plants. These include plating on both semi-selective and non-selective media and detection by immunofluorescence (IF) as well as PCR. Additionally, two procedures for detection of *C. michiganensis* in seeds are provided. The first procedure is based on plating seed extracts on different semi-selective media while the second procedure provides details on IF, PCR and selective enrichment protocols (EPPO, 2016a).

In addition, in recent years, a number of often TaqMan based qPCR protocols and a loop-mediated isothermal amplification assay were developed that can be used to confirm the identity of isolated bacteria suspected of being *C. michiganensis* and/or to specifically detect the bacterium in infected seeds and plant material (Dobhal *et al.*, 2019; Han *et al.*, 2018; Larrea-Sarmiento *et al.*, 2019; Ramachandran *et al.*, 2021; Thapa *et al.*, 2020).

PATHWAYS FOR MOVEMENT

Seed is the main long-distance pathway for movement of the pathogen. Cultivation measures contribute to local dispersion of the disease. Overhead irrigation, chemical sprays, handling during transport and wound inflicting actions such as clipping and pruning all favour the spread of *C. michiganensis*. The use of rotary mowers for clipping tomato plants has especially favoured disease dissemination (Carlton *et al.*, 1998; Huang & Tu, 2001; Sharabani *et al.*, 2013). Additionally, remaining contaminated crop debris can allow re-infection of the seedlings in the following season (EFSA, 2014).

PEST SIGNIFICANCE

Economic impact

Tomato is the world's most important vegetable crop with an annual production of over 180 million tonnes, representing a value of 93 billion USD (Food and agricultural organization, 2020). Since the first report of the disease in the USA in 1910, *C. michiganensis* has spread throughout the world and causes serious losses to both glasshouse and field tomato crops, either by killing the young plants or disfiguring the fruits making them unmarketable as fresh produce. Disease incidence in affected fields can be as high as 100% leading to severe yield losses. However, a high reduction in crop damage has been observed following the considerable efforts into preventing the introduction and dissemination of the pathogen, which involves the integral testing of seeds and plantlets (see Control). Compared to the damage in tomato, economic losses in pepper are limited (Baysal *et al.*, 2011; EFSA, 2014; Lamichhane *et al.*, 2011; Nandi *et al.*, 2018).

Control

Use of healthy seeds is the first and most important condition for controlling the disease. Seed lots should be laboratory tested for the presence of *C. michiganensis* and tomato seeds are often acid extracted to disinfect the seed surface (EPPO, 2021). A substantial reduction of infection can be achieved by chemical treatment of the seed (Dhanvantari, 1989). Once the disease has appeared in a crop, strict hygiene measures such as eradication of infected plants and isolation of infected rows can minimize yield loss. Prophylactic measures (destruction of crop residues, disinfection of structures and equipment) are essential to prevent infection in protected crops. At the moment there are no commercial tomato varieties which are fully resistant to *C. michiganensis* (Nandi *et al.*, 2018).

To prevent tomato seed and plant lots from being infected by *C. michiganensis* the 'Good Seed and Plant Practices' (GSPP) system was developed about a decade ago. GSPP provides standards for (hygiene) practices and participating companies are audited to ensure proper implementation (<https://www.gspp.eu/>).

Phytosanitary risk

Tomato is widely grown in glasshouses in the EPPO region, and the bacterium causes one of the most serious bacterial diseases of glasshouse tomatoes. For tomato field crops, the climatic conditions in southern Europe are favourable for disease development (EFSA, 2014). Disease outbreaks caused by *C. michiganensis* are sporadic but

the impact of these outbreaks can be high. Since the pathogen is seed borne and contaminated/infected seed usually gives rise to apparently healthy seedlings, this facilitates introduction, establishment and spread. This combined with the fact that there are no curative treatments and no fully resistant commercial varieties available, make *C. michiganensis* a major threat for tomato cultivation (EFSA, 2014).

PHYTOSANITARY MEASURES

Since seeds are the main pathway for entry, appropriate measures could consist of treating the seeds (i.e. by means of an appropriate acid extraction method or an equivalent method) and testing seed lots according to EPPO Standards PM 7/42 (EPPO, 2021; EPPO, 2016a). Alternatively, seeds could be produced in a pest free area or in a pest free production site.

When not regulated as a quarantine pest, the EU Quality pest project recommended *C. michiganensis* for regulation as a RNQP, for propagation material (including seeds) of tomato (Picard *et al.*, 2018). An alternative measure was recommended, involving the absence of symptoms of disease caused by *C. michiganensis* observed in inspections, at appropriate times, during the complete cycle of vegetation of the plants at the site of production.

Additionally, good hygiene practices are important to prevent large disease outbreaks. The guidelines provided by GSPP describe measures that will help to limit the risks for *C. michiganensis* infections. These guidelines focus on managing risk factors, continuous monitoring and seed testing (<https://www.gspp.eu/>; EFSA, 2014).

REFERENCES

Arizala D, Dobhal S, Alvarez AM & Arif M (2022) Elevation of *Clavibacter michiganensis* subsp. *californiensis* to species level as *Clavibacter californiensis* sp. nov., merging and re-classification of *Clavibacter michiganensis* subsp. *chilensis* and *Clavibacter michiganensis* subsp. *phaseoli* as *Clavibacter phaseoli* sp. nov. based on complete genome in silico analyses. *International Journal of Systematic and Evolutionary Microbiology* **72**(9).
<https://doi.org/10.1099/ijsem.0.005427>

Baysal Ö, Mercati F, ?kten H, Y?id?z RÇ, Carimi F, Aysan Y & Teixeira Da Silva JA (2011) *Clavibacter michiganensis* subsp. *michiganensis*: Tracking strains using their genetic differentiations by ISSR markers in Southern Turkey. *Physiological and Molecular Plant Pathology* **75**, 113-119.

Bradbury JF (1986) Guide to plant pathogenic bacteria. CAB International, Wallingford (GB).

Carlton WM, Braun EJ & Gleason ML (1998) Ingress of *Clavibacter michiganensis* subsp. *michiganensis* into tomato leaves through hydathodes. *Phytopathology* **88**, 525-529.

De León L, Siverio F, López MM & Rodríguez A (2011) *Clavibacter michiganensis* subsp. *michiganensis*, a seedborne tomato pathogen: healthy seeds are still the goal. *Plant Disease* **95**, 1328-1338.

Dhanvantari BN (1989) Effect of seed extraction methods and seed treatments on control of tomato bacterial canker. *Canadian Journal of Plant Pathology* **11**, 400-408.

Dobhal S, Larrea?Sarmiento A, Alvarez AM & Arif M (2019) Development of a loop-mediated isothermal amplification assay for specific detection of all known subspecies of *Clavibacter michiganensis*. *Journal of Applied Microbiology* **126**, 388-401.

EFSA (2014) Scientific Opinion on the pest categorisation of *Clavibacter michiganensis* subsp. *michiganensis* (Smith) Davis *et al.* *EFSA Journal* **12**, 3721.

EPPO (2016a) EPPO Standards PM 7/42 (3) *Clavibacter michiganensis* subsp. *michiganensis*. *EPPO Bulletin* **46**, 202-225.

EPPO (2016b) Phytosanitary procedures. EPPO Standard PM 3/77 Vegetable plants for planting under protected conditions – inspection of places of production. *EPPO Bulletin* **46**, 40-48.

- EPPO (2021) EPPO standards PM 3/80 (2) Consignment inspection of seed of *Solanum lycopersicum* and its hybrids. *EPPO Bulletin* **46**, 68-72.
- Fatmi M, Schaad NW & Bolkan HA (1991) Seed treatments for eradicating *Clavibacter michiganensis* subsp. *michiganensis* from naturally infected tomato seeds. *Plant Disease* **75**, 383-385.
- Gleason ML, Gitaitis RD & Ricker MD (1993) Recent progress in understanding and controlling bacterial canker of tomato in eastern North America. *Plant Disease* **77**, 1069-1076.
- Han S, Jiang N, Lv Q, Kan Y, Hao J, Li J & Luo L (2018) Detection of *Clavibacter michiganensis* subsp. *michiganensis* in viable but nonculturable state from tomato seed using improved qPCR. *Plos One* **13**, e0196525.
- Hayward AC & Waterston JM (1964) *Corynebacterium michiganense*. IMI Descriptions of Fungi and Bacteria. **2**, 19, CAB International, Wallingford (UK).
- Huang R & Tu JC (2001) Effects of nutrient solution pH on the survival and transmission of *Clavibacter michiganensis* ssp. *michiganensis* in hydroponically grown tomatoes. *Plant Pathology* **50**, 503-508.
- Laj M (1976) Bacterial canker of bell pepper caused by *Corynebacterium michiganense*. *Plant Disease Reporter* **60**, 339-342.
- Lamichhane JR, Balestra GM & Varvaro L (2011) Severe outbreak of bacterial canker caused by *Clavibacter michiganensis* subsp. *michiganensis* on tomato in central Italy. *Plant Disease* **95**, 221-221.
- Larrea-Sarmiento A, Alvarez AM, Stack JP & Arif M (2019) Synergetic effect of non-complementary 5' AT-rich sequences on the development of a multiplex TaqMan real-time PCR for specific and robust detection of *Clavibacter michiganensis* and *C. michiganensis* subsp. *nebraskensis*. *Plos One* **14**, e0218530.
- Latin R, Tikhonova I & Rane K (1995) First report of bacterial canker of pepper in Indiana. *Plant Disease* **79**, 860.
- Lewis Ivey ML & Miller SA (2000) First report of bacterial canker of pepper in Ohio. *Plant Disease* **84**, 810-810.
- Li X, Tambong J, Yuan K, Chen W, Xu H, Lévesque CA & De Boer SH (2018) Re-classification of *Clavibacter michiganensis* subspecies on the basis of whole-genome and multi-locus sequence analyses. *International Journal of Systematic and Evolutionary Microbiology* **68**, 234-240.
- Moffett ML & Wood BA (1984) Survival of *Corynebacterium michiganense* subsp. *michiganense* within host debris in soil. *Australasian Plant Pathology* **13**, 1-3.
- Nandi M, Macdonald J, Liu P, Weselowski B & Yuan Z-C (2018) *Clavibacter michiganensis* ssp. *michiganensis*: bacterial canker of tomato, molecular interactions and disease management. *Molecular Plant Pathology* **19**, 2036-2050.
- Nouioui I, Carro L, García-López M, Meier-Kolthoff JP, Woyke T, Kyrpides NC, Pukall R, Klenk H-P, Goodfellow M & Göker M (2018) Genome-based taxonomic classification of the phylum Actinobacteria. *Frontiers in Microbiology* **9**, 1-119.
- Oh EJ, Bae C, Lee HB, Hwang IS, Lee HI, Yea MC, Yim KO, Lee S, Heu S, Cha JS, Oh CS (2016) *Clavibacter michiganensis* subsp. *capsici* subsp. nov., causing bacterial canker disease in pepper. *International Journal of Systematic and Evolutionary Microbiology* **66**(10), 4065-4070.
- Osdaghi E, Rahimi T, Taghavi SM, Ansari M, Zarei S, Portier P, Briand M & Jacques MA (2020) Comparative genomics and phylogenetic analyses suggest several novel species within the genus *Clavibacter*, including nonpathogenic tomato-associated strains. *Applied and Environmental Microbiology* **86**, e02873-19.
- Ramachandran S, Dobhal S, Alvarez AM & Arif M (2021) Improved multiplex TaqMan qPCR assay with universal internal control offers reliable and accurate detection of *Clavibacter michiganensis*. *Journal of Applied Microbiology* **131**

, 1405-1416.

Sharabani G, Shtienberg D, Borenstein M, Shulhani R, Lofthouse M, Sofer M, Chalupowicz L, Barel V & Manulis-Sasson S (2013) Effects of plant age on disease development and virulence of *Clavibacter michiganensis* subsp. *michiganensis* on tomato. *Plant Pathology* **62**, 1114-1122.

Stamova L & Sotirova V (1987) Reaction of different crops to artificial inoculation with *Corynebacterium michiganense* (E.F. Sm.) H.L. Jensen. *Archiv fur Phytopathologie und Pflanzenschutz* **23**, 211-216.

Thapa SP, O'Leary M, Jacques M-A, Gilbertson RL & Coaker G (2020) Comparative genomics to develop a specific multiplex PCR assay for detection of *Clavibacter michiganensis*. *Phytopathology* **110**, 556-566.

Thyr BD, Samuel MJ & Brown PG (1975) New solanaceous host records for *Corynebacterium michiganensis*. *Plant Disease Reporter* **59**, 595-598.

Van Vaerenbergh J & Chauveau JF (1985) Host plant inoculations for the detection of (latent) *Corynebacterium michiganense* (E. F. Smith) Jensen. *Mededelingen van de faculteit landbouwwetenschappen Rijksuniversiteit Gent* **50**, 973-995.

Yim K-O, Lee H-I, Kim J-H, Lee S-D, Cho J-H & Cha J-S (2012) Characterization of phenotypic variants of *Clavibacter michiganensis* subsp. *michiganensis* isolated from *Capsicum annuum*. *European Journal of Plant Pathology* **133**, 559-575.

ACKNOWLEDGEMENTS

This datasheet was extensively revised in 2022 by Michiel J.C. Pel and Maria Bergsma-Vlami (NVWA, Netherlands Food and Consumer Product Safety Authority). Their valuable contribution is gratefully acknowledged.

How to cite this datasheet?

EPPO (2024) *Clavibacter michiganensis*. EPPO datasheets on pests recommended for regulation. Available online. <https://gd.eppo.int>

Datasheet history

This datasheet was first published in the EPPO Bulletin in 1982 and revised in the two editions of 'Quarantine Pests for Europe' in 1992 and 1997, as well as in 2022. It is now maintained in an electronic format in the EPPO Global Database. The sections on 'Identity', 'Hosts', and 'Geographical distribution' are automatically updated from the database. For other sections, the date of last revision is indicated on the right.

CABI/EPPO (1992/1997) *Quarantine Pests for Europe (1st and 2nd edition)*. CABI, Wallingford (GB).

EPPO (1982) Data sheets on quarantine organisms, *Corynebacterium michiganense*. *EPPO Bulletin* **12**(1), 13-18. <https://doi.org/10.1111/j.1365-2338.1982.tb01950.x>



Co-funded by the
European Union