

EPPO Datasheet: *Xanthomonas hortorum* pv. *gardneri*

Last updated: 2024-05-15

This datasheet covers the four bacterial species and pathovars that are associated with the bacterial spot of tomato and pepper: *Xanthomonas euvesicatoria* pv. *euvesicatoria*, *Xanthomonas euvesicatoria* pv. *perforans*, *Xanthomonas hortorum* pv. *gardneri*, *Xanthomonas vesicatoria*.

IDENTITY

Preferred name: *Xanthomonas hortorum* pv. *gardneri*

Authority: (Jones et al.) Morinière et al.

Taxonomic position: Bacteria: Proteobacteria:

Gammaproteobacteria: Lysobacterales: Lysobacteraceae

Other scientific names: *Xanthomonas cynarae* pv. *gardneri* (Timilsina et al.), *Xanthomonas gardneri* (ex ?uti?) Jones et al.

Common names: bacterial leaf spot of pepper, bacterial leaf spot of tomato, bacterial spot of pepper, bacterial spot of tomato, leaf spot of tomato, stem canker of tomato

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

EPPO Categorization: A2 list

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

EU Categorization: RNQP (Annex IV)

EPPO Code: XANTGA



[more photos...](#)

Notes on taxonomy and nomenclature

Bacterial spot of tomato and pepper was first reported in the early 1920s and, since then, the taxonomy of bacterial spot pathogens has been extensively revised. The causal agent was initially named *Bacterium vesicatorium* (Doidge, 1920, 1921; Gardner & Kendrick, 1921, 1923), which later changed to *Xanthomonas vesicatoria* and subsequently *Xanthomonas campestris* pv. *vesicatoria* (Dowson, 1939; Young *et al.*, 1978). Decades later, three phenotypically and phylogenetically distinct bacterial populations were established (Stall *et al.*, 1994; Jones *et al.*, 1995), which were associated with *Xanthomonas axonopodis* pv. *vesicatoria* (strains from groups designated A and C) and *Xanthomonas vesicatoria* (strains from group B) (Vauterin *et al.*, 1995). Independently in 1957 a bacterial pathogen was isolated from tomato in the former Yugoslavia and named as *Pseudomonas gardneri* (Šutic, 1957). The pathogen was later proposed to be reclassified as *Xanthomonas gardneri* and considered to be group D of the bacterial spot pathogens (Jones *et al.*, 2000). In 2004, DNA:DNA hybridization analysis led to a new taxonomic revision considering four distinct species: *Xanthomonas euvesicatoria* (group A), *Xanthomonas vesicatoria* (group B), *Xanthomonas perforans* (group C) and *Xanthomonas gardneri* (group D) (Jones *et al.*, 2004a). Later, new molecular analysis showed that *X. euvesicatoria* and *X. perforans* were not clearly differentiated as stand-alone species and were hence reclassified as pathovars of the same species, *X. euvesicatoria* pv. *euvesicatoria* and *X. euvesicatoria* pv. *perforans*, respectively (Constantin *et al.*, 2016). Finally, Morinière *et al.* (2020) reclassified *X. gardneri* as *X. hortorum* pv. *gardneri*. Currently, the bacterial spot *Xanthomonas* falls into four lineages within three validly described species: *X. euvesicatoria* pv. *euvesicatoria*, *X. euvesicatoria* pv. *perforans*, *X. hortorum* pv. *gardneri* and *X. vesicatoria*.

HOSTS

The main hosts of bacterial spot xanthomonads are tomato (*Solanum lycopersicum*) and pepper (*Capsicum* spp.). *X. euvesicatoria* pv. *euvesicatoria* and *X. hortorum* pv. *gardneri* are reported as pathogens for both tomato and pepper. Meanwhile, *X. vesicatoria* primarily infects tomato and, until recently, *X. euvesicatoria* pv. *perforans* strains had only been isolated from tomato (Timilsina *et al.*, 2015). However, over in recent years *X. euvesicatoria* pv. *perforans* has been isolated from pepper fields in Florida and Alabama (USA) (Potnis *et al.*, 2015; Newberry *et al.*, 2019).

Three pathotypes of strains have been distinguished among the bacterial spot causative agents: those exclusively infecting tomato (T races), those exclusively affecting pepper (P races), and those infecting both tomato and pepper. Several races have been identified based on the hypersensitive reaction (HR) triggered by effector proteins in *Xanthomonas* strains delivered via the type III secretion system into host cells and recognition by specific resistance proteins in tomato or pepper (Stall *et al.*, 2009). Currently 11 pepper races and five tomato races have been documented (Bouzar *et al.*, 1994; Stall *et al.*, 2009; Adhikari *et al.*, 2020; Jibrin *et al.*, 2022). Pathogenic races are determined by the presence or absence of HR in the susceptible *C. annuum* cultivar Early Calwonder (ECW), its near-isogenic lines and *Capsicum pubescens* PI235047, or in different *S. lycopersicum* genetic lines. Nevertheless, future studies may reveal unknown races and potential novel dynamics in pathogen-host interaction.

A range of solanaceous and non-solanaceous plants, mainly weeds, have also been recorded as incidental hosts (Osdaghi *et al.*, 2021).

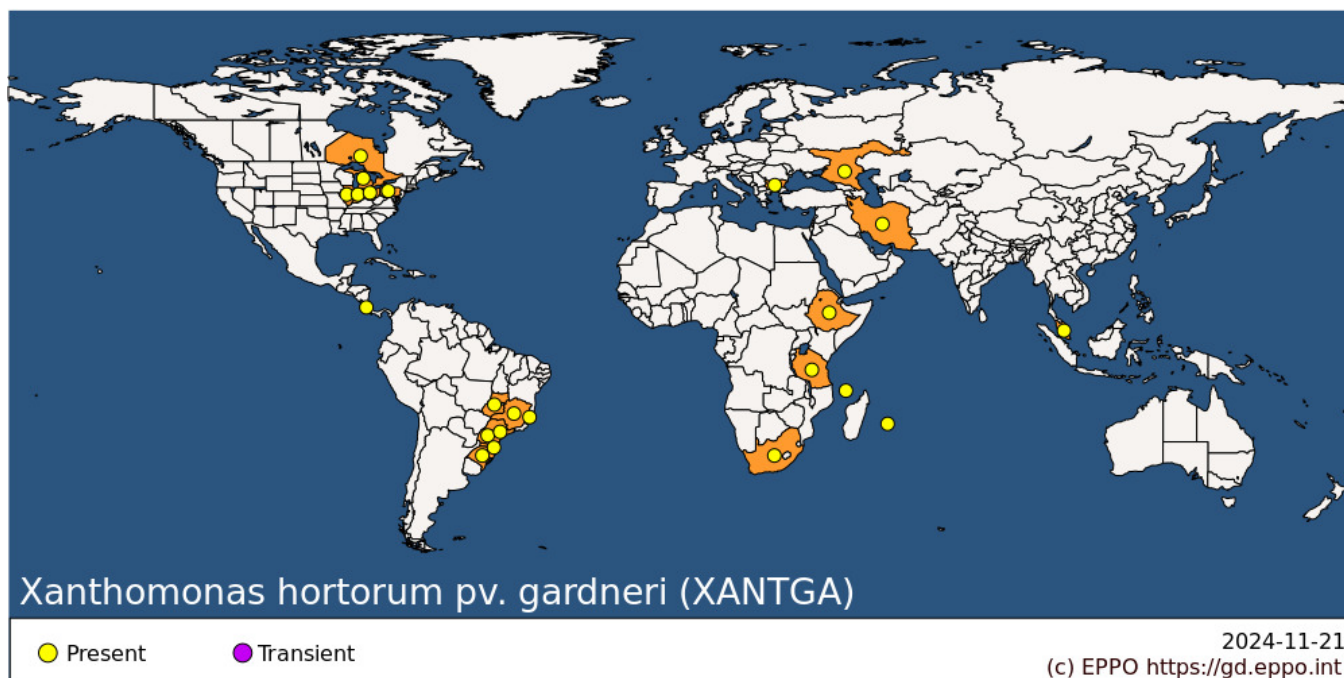
Host list: *Arctium lappa*, *Capsicum annuum*, *Capsicum baccatum*, *Capsicum chinense*, *Capsicum pubescens*, *Euphorbia heterophylla*, *Solanum lycopersicum*, *Tubocapsicum anomalum*

GEOGRAPHICAL DISTRIBUTION

Bacterial spot causative agents occur widely in tomato and pepper-growing areas, especially in tropical and subtropical regions with moderate or higher rainfall. The disease has primarily been observed in field crops but can also occur in greenhouses. The environmental conditions in Southern Europe are particularly favorable for disease expression in the field, given that the optimal growth temperature for xanthomonads is between 25 and 30°C (Holt, 1994).

The classification of the four lineages of bacterial spot xanthomonads has experienced several revisions due to the intricate taxonomic relationships within this group (see Notes on taxonomy and nomenclature). This has led to uncertainties regarding the specific species present in various geographical areas. As reported by Timilsina *et al.* (2015), shifts in the species composition of bacterial spot pathogens populations have occurred due to the global spread of dominant genotypes, and recombination between species has generated genetic diversity in these populations. Therefore, the global distribution and genetic diversity of bacterial spot xanthomonads are poorly understood. Strains belonging to *X. euvesicatoria* pv. *euvesicatoria* and *X. vesicatoria* were historically considered the dominant bacterial lineages with a worldwide distribution (Jones *et al.*, 2004b). However, more recently, *X. euvesicatoria* pv. *perforans* and *X. hortorum* pv. *gardneri* were increasingly isolated in North and South America, the Middle East, East Africa, and regions bordering the Indian Ocean (Vancheva *et al.*, 2021). Dramatic changes in the dominant lineages and population structure of bacterial spot in different local areas have been documented over the past few decades. For example, prior to 1991, *X. euvesicatoria* pv. *euvesicatoria* was the only species isolated from tomato in Florida (USA), while this taxon has been entirely replaced by *X. euvesicatoria* pv. *perforans* on this host since then (Klein-Gordon *et al.*, 2021). Similar changes are also reported in Taiwan (Burlakoti *et al.*, 2018).

The map includes only records where the *Xanthomonas* species has been identified. Articles mentioning ' *Xanthomonas* spp.' or 'bacterial spot of tomato' without mentioning the species are not included in the database. A map showing the records of *Xanthomonas axonopodis* pv. *vesicatoria* is available as an archive in [EPPO Global Database](#).



EPPO Region: Bulgaria, Russia (Southern Russia)

Africa: Comoros, Ethiopia, Reunion, South Africa, Tanzania

Asia: Iran, Malaysia (West)

North America: Canada (Ontario), United States of America (Illinois, Indiana, Michigan, Ohio, Pennsylvania)

Central America and Caribbean: Costa Rica

South America: Brazil (Espírito Santo, Goiás, Minas Gerais, Paraná, Rio Grande do Sul, Santa Catarina, São Paulo)

BIOLOGY

The primary source of inoculum for bacterial spot xanthomonads are infected seeds and planting material (Potnis *et al.*, 2015). Bacteria can survive from one season to another, mainly on tomato and pepper seeds, for at least 10 years (Bashan *et al.*, 1982b). A positive correlation was observed between the inoculum concentration of the bacterium on pepper blossoms and the percentage of infested seeds (Dutta *et al.*, 2013). These pathogens can also survive in infected debris and the soil to some extent, possibly in the rhizosphere of non-host plants (Bashan *et al.*, 1982a). Diverse solanaceous and non-solanaceous weeds may be alternative hosts (Osdaghi *et al.*, 2021).

Once introduced in an area, the spread of bacteria is primarily by rain-splash or overhead irrigation, with the handling of young plants also playing an important role (Goode & Sasser, 1980). Viable bacteria have been detected in aerosols over commercial fields, indicating a putative aerial dispersal (McInnes *et al.*, 1988; Bernal & Berger, 1996). Leaves are infected through stomata, while fruits are infected through small wounds, such as abrasions, and insect punctures. Young leaves and fruits are more sensitive to infection and the bacteria can multiply epiphytically on young plants in the absence of symptoms. Thinning of directly seeded tomato seedlings (practice of selectively removing weaker seedlings to improve the health and productivity of the plants) is reported to promote spread of the disease, and it is recommended to thin in the afternoon, when plants are dry, and to use prophylactic hand washes (Pohronezny *et al.*, 1990). The disease is favored by heavy rainfall, high humidity (Diab *et al.*, 1982) and temperatures between 25°C and 30°C (EFSA, 2014).

DETECTION AND IDENTIFICATION

Symptoms

All bacterial spot xanthomonads can induce a wide variety of symptoms on their host plants, including angular lesions that later become brown and necrotic on the leaves, fruits, petioles and stems. Some symptoms may be mistaken for those caused by other organisms (see below). Pathogen aggressiveness and the development of

symptoms often depend on the host-pathogen combination, with *X. euvesicatoria* pv. *euvesicatoria* appearing to be significantly more aggressive on bell pepper than on tomato (Ignjatov *et al.*, 2010).

Fruits of tomato show superficial corky spots or scabs, with water-soaked margins, oval or irregular in shape and with a diameter of around 2-10 mm. The 'flecks' caused by *Pseudomonas syringae* pv. *tomato* are distinctly smaller (diameter <1 mm), black, circular and elevated. Differences are also observed with symptoms of *Clavibacter michiganensis* on fruits, consisting of brown spots, slightly raised, and surrounded by a white halo (a distinctive 'bird's eye' appearance). Scabbing of fruit (but without water-soaking) may also be a symptom of the phytotoxicity of plant protection products. Bacterial spot xanthomonads fruit lesions in pepper are scab-like, raised and rapidly necrotising. Lesions on tomato or pepper leaves appear as irregular water-soaked areas, initially green and later becoming brown and necrotic. Speck lesions caused by *P. syringae* pv. *tomato* look similar in a first stage, but are surrounded by a more distinct yellow halo; lesions are often in streaks and the yellow haloes run together to give large chlorotic areas (Goode & Sasser, 1980). Severe infections in pepper cause defoliation, favoring sunscald of the fruits on hot and sunny days.

Bacterial spot xanthomonads can cause canker-like splits in stems, but their presence alone is not diagnostic as similar symptoms may also be caused by *P. syringae* pv. *tomato*, *C. michiganensis* and *Alternaria solani*. Pith necrosis has been associated with the presence of *X. euvesicatoria* pv. *perforans*, but this symptom could be confused with those of *Pseudomonas mediterranea* and *Pseudomonas corrugata* (Aiello *et al.*, 2013).

Morphology

Xanthomonads causing bacterial spot of tomato and pepper are aerobic, mobile, Gram-negative rods, occurring singly or in pairs, 0.6 x 1.0-1.5 µm, with a single polar flagellum. Like other species of the genus, they produce characteristic yellow pigments (xanthomonadins). On general media, such as yeast-glucose-calcium carbonate agar (YGCA) or yeast peptone glucose agar (YPGA), colonies are mucoid-fluidal, convex, and yellow with entire edges. Unlike *P. syringae* pv. *tomato*, bacterial spot xanthomonads are non-fluorescent on King's B medium.

Detection and inspection methods

Symptoms of bacterial spot xanthomonads can be confused with those caused by other pathogens. Confirmation through diagnostic analysis is necessary when the presence of spot-causing bacteria is suspected. The EPPO Diagnostic protocol Standard PM 7/110 (2) (EPPO, 2023) offers comprehensive guidelines for the preliminary screening of plant material or seeds. The Standard includes isolation and molecular tests and, if required, confirmatory pathogenicity tests in susceptible cultivars of tomato and pepper plants. The EPPO Standard recommends multiplex real-time PCR (Strayer *et al.*, 2016) and real-time PCR tests for specific identification of *Xanthomonas* species causing bacterial spot disease (Baldwin *et al.*, 2023). Serological methods are not recommended in the Standard; few antibodies are commercially available for immunofluorescence and ELISA, and no validation data could be retrieved.

The International Seed Health Initiative (ISHI) advises using a minimum of 10 000 tomato or pepper seeds for seed detection purposes to ensure effective screening (ISF, 2017). This approach, with subsamples capped at 10 000 seeds, aims to identify contamination levels as low as 0.03% with a 95% confidence interval. In instances where there is a high likelihood of saprophytic bacteria overshadowing the presence of *Xanthomonas* spp., opting for smaller subsample sizes, such as five sets of 2 000 seeds each, is recommended.

A procedure by which consignments of tomato seeds should be subjected to phytosanitary import inspection, including sampling and identification, is provided in EPPO Standard PM 3/80 (2) (EPPO, 2021).

PATHWAYS FOR MOVEMENT

Trade of infected seeds and plants for planting (transplants) are associated with long-distance dissemination of *Xanthomonas* spp. which are responsible of causing bacterial spot. Bacteria may escape from infected plants as exudates, and short-distance dispersal is then facilitated by splashing water, such as irrigation or rain. This becomes particularly concerning during transplant in greenhouse production when several thousands of transplants are growing closely together, as well as in the field, especially in the case of sprinkler irrigation. Short-distance-spread

of bacteria is also possible through contaminated tools (EFSA, 2014).

PEST SIGNIFICANCE

Economic impact

Bacterial spot xanthomonads are widespread and are considered significant pathogens of tomato and pepper in field-grown crops in warm-temperate and tropical countries, especially under overhead irrigation. They can also occur in greenhouses. Fruit yield losses are most substantial when infection occurs early, as observed in tomato in USA, and pepper in Israel (Dougherty, 1978; Bashan *et al.*, 1985). Damage to the leaves tends to expose fruits to the sun, increasing the risk of sunscald. Although fruit lesions are often only superficial, they result in loss of marketability.

Bacterial spot has been recognized as a severe disease accompanied by significant damages in production in countries of the EPPO region, such as Serbia (Ignjatov *et al.*, 2010; Vlajić *et al.*, 2017), Bulgaria and the Republic of North Macedonia (Kizheva *et al.*, 2011), or Türkiye (Aysan & Sahin, 2003). Although no recent data are available on economic losses caused by these pathogens in the European Union (EU), infections resulting in up to 30 % losses have been reported (EFSA, 2014). Yield losses of up to 66% have been reported in the USA (Pohronezny & Volin, 1983). Tomato yield loss estimated to be 7 413 USD per ha have been reported in Florida (USA) (Vallad *et al.*, 2013). Furthermore, outbreaks in 2009-2010 in 2000 ha of processing tomatoes in Northwest Ohio and Southeast Michigan resulted in total losses of up to 7.8 USD million (Ma *et al.*, 2011).

Control

Due to the seedborne nature of bacterial spot xanthomonads, management of the disease has been a major challenge since its original description. As no effective methods or chemical control agents are available for infected crops, disease control requires the adoption of integrated management measures, primarily focused on prevention and exclusion. Pathogen-free seeds and transplants are crucial to avoid the introduction and spread of bacteria. Tomato seed extraction from fruits using appropriate fermentative or acid treatments to reduce xanthomonads population is required in the EU (Anonymous, 2019). For both tomato and pepper seeds, hot water soak, dry heat therapy or selected chemicals have been recommended (EFSA, 2014).

Once infection occurs, control of disease in the field is particularly difficult. Cultural practices, such as four-year crop rotations, are recommended. Avoiding the handling of wet plant material and minimizing free moisture on foliage helps prevent disease development and spread. The application of protective chemicals or biological treatments is advised to reduce the severity and spread during transplant production.

The most common approach for managing bacterial spot pathogens is the preventive application of copper-based bactericides, but their success is limited as bacterial resistance to such chemicals has appeared worldwide (Lamichhane *et al.*, 2018). Additionally, in the EU a new legislation limits the use of copper compounds (Anonymous, 2018). Several biological control approaches have been studied, including bacteriophages (Jones *et al.*, 2012; Balogh *et al.*, 2018; Gašić *et al.*, 2018; Ríos-Sandoval *et al.*, 2020), plant growth-promoting rhizobacterium (Naue *et al.*, 2014; Liu *et al.*, 2018) and antagonistic bacteria. Integration of biological control agents, such as tailocins (phage-tail-like bacteriocins produced by *Pseudomonas fluorescens* SF4c (Príncipe *et al.*, 2018) and *Bacillus velezensis* GF267 (de Paula Kuyat Mates *et al.*, 2019), and SARS inducers (harpin and acibenzolar-S-methyl) enhances the effectiveness of bacterial spot management (Obradovic *et al.*, 2005; Abo-Elyours & El-Hendawy, 2008). The application of bacteriophages alone or in combination with biocontrol agents or copper hydroxide reduces disease incidence.

Efforts have been made to develop tomato and pepper lines with resistance to bacterial spot xanthomonads, and sources of resistance have been identified and incorporated into breeding programs and varieties (Stall *et al.*, 2009). However, the persistence of resistance can change rapidly due to the evolving geographical distribution of the pathogen and the rapid emergence of new pathogenic variants (Potnis *et al.*, 2015).

Phytosanitary risk

Xanthomonas spp. are important bacterial pathogens that affect tomato and pepper production. Environmental conditions in Southern Europe are particularly favorable for bacterial spot expression in the field, as the optimal growth temperature for xanthomonads is between 25°C and 30°C, but the disease also occurs in greenhouses (EFSA, 2014).

Long-distance spread of *Xanthomonas* spp. causing bacterial spot of tomato and pepper, is commonly related to the movement of infected seeds and planting material (transplants). Once introduced into a production area, such as a cultivation plot or a greenhouse, the pathogens disperse easily, and short-distance dispersal is facilitated by splashing water (from irrigation and rain) or contaminated tools (EFSA, 2014).

PHYTOSANITARY MEASURES

As the main means of spread of bacterial spot xanthomonads are with seeds and plants for planting, the use of healthy seed and plantlets are a key phytosanitary measure (Picard *et al.*, 2018).

Currently *Xanthomonas euvesicatoria* pv. *euvesicatoria*, *Xanthomonas euvesicatoria* pv. *perforans*, *Xanthomonas hortorum* pv. *gardneri* and *Xanthomonas vesicatoria* are classified as regulated non-quarantine pests (RNQP) in many EPPO countries, including those within the EU (Anonymous, 2019), and measures to prevent their presence on seeds and planting material are mandatory. The EU measures are as follows: the presence of these bacteria is not allowed in propagating material of ornamental plants or other plants for planting intended for ornamental purposes, vegetable seeds, and vegetable propagating and planting material other than seeds (threshold level 0%) (Anonymous, 2019 Annex IV, Parts D, F, and I). For tomato seeds, an appropriate extraction method for bacterial elimination is required (there is no indication whether or not pepper seeds should be treated). Tomato and pepper seeds should originate in areas known to be free from these pathogens where no symptoms of bacterial spot have been observed during the complete cycle of vegetation of the plants at site of production. Alternatively, seeds should have been subjected to official testing on a representative sample using appropriate methods and have been found free of the pathogens (Anonymous, 2019 Annex V, Parts C, E, and H).

REFERENCES

Abo-Elyousr KA & El-Hendawy HH (2008) Integration of *Pseudomonas fluorescens* and acibenzolar-S-methyl to control bacterial spot disease of tomato. *Crop Protection* **27**(7), 1118-1124.

<https://doi.org/10.1016/j.cropro.2008.01.011>

Adhikari P, Adhikari TB, Louws FJ & Panthee DR (2020) Advances and challenges in bacterial spot resistance breeding in tomato (*Solanum lycopersicum* L.). *International Journal of Molecular Sciences* **21**(5), 1734.

<https://doi.org/10.3390/ijms21051734>

Aiello D, Scuderi G, Vitale A, Firrao G, Polizzi G & Cirvilleri G (2013) A pith necrosis caused by *Xanthomonas perforans* on tomato plants. *European Journal of Plant Pathology* **137**(1), 29-41.

<https://link.springer.com/article/10.1007/s10658-013-0214-7>

Anonymous (2018) Commission Implementing Regulation (EU) 2018/1981 of 13 December 2018 renewing the approval of the active substances copper compounds, as candidates for substitution, in accordance with Regulation (EC) No 1107/2009 of the European Parliament and of the Council concerning the placing of plant protection products on the market, and amending the Annex to Commission Implementing Regulation (EU) No 540/2011. *Official Journal of the European Union*, L 317, 16-20. http://data.europa.eu/eli/reg_impl/2018/1981/oj

Anonymous (2019) Commission Implementing Regulation (EU) 2019/2072, of 28 November 2019, establishing uniform conditions for the implementation of Regulation (EU) 2016/2031 of the European Parliament and the Council, as regards protective measures against pests of plants, and repealing Commission Regulation (EC) No 690/2008 and amending Commission Implementing Regulation (EU) 2018/2019. *Official Journal of the European Union*, L 319, 1-279. http://data.europa.eu/eli/reg_impl/2019/2072/oj

Aysan Y & Sahin F (2003) Occurrence of bacterial spot disease, caused by *Xanthomonas axonopodis* pv. *vesicatoria*

, on pepper in the Eastern Mediterranean region of Turkey. *Plant Pathology* **52**(6), 781.
<https://doi.org/10.1111/j.1365-3059.2003.00890.x>

Baldwin TK, Woudt B, Lastdrager J, Berendsen S & Koenraadt H (2023) Development and validation of real-time PCR tests for specific identification of *Xanthomonas* species causing bacterial spot disease on tomato (*Solanum lycopersicum*) and pepper (*Capsicum annuum*). *EPPO Bulletin* **53**(2), 416-424. <https://doi.org/10.1111/epp.12939>

Balogh B, Nga NTT & Jones JB (2018) Relative level of bacteriophage multiplication *in vitro* or in phyllosphere may not predict *in planta* efficacy for controlling bacterial leaf spot on tomato caused by *Xanthomonas perforans*. *Frontiers in Microbiology* **9**, 2176. <https://doi.org/10.3389/fmicb.2018.02176> (Corrigendum: relative level of bacteriophage multiplication *in vitro* or in phyllosphere may not predict *in planta* efficacy for controlling bacterial leaf spot on tomato caused by *Xanthomonas perforans*. *Frontiers in Microbiology*, **9**, 2647.
<https://doi.org/10.3389/fmicb.2018.02647>

Bashan Y, Azaizeh M, Diab S, Yunis H & Okon Y (1985) Crop loss of pepper plants artificially infected with *Xanthomonas campestris* pv. *vesicatoria* in relation to symptom expression. *Crop Protection* **4**(1), 77-84.
[https://doi.org/10.1016/0261-2194\(85\)90007-9](https://doi.org/10.1016/0261-2194(85)90007-9)

Bashan Y, Diab S & Okon Y (1982a) Survival of *Xanthomonas campestris* pv. *vesicatoria* in pepper seeds and roots, in symptomless and dry leaves in non-host plants and in the soil. *Plant and Soil* **68**(2), 161-170.
<https://doi.org/10.1007/BF02373702>

Bashan Y, Okon Y & Henis Y (1982b) Long-term survival of *Pseudomonas syringae* pv. *tomato* and *Xanthomonas campestris* pv. *vesicatoria* in tomato and pepper seeds. *Phytopathology* **72**(9), 1143-1144.

Bernal RF & Berger RD (1996) The spread of epiphytic populations of *Xanthomonas campestris* pv. *vesicatoria* on pepper in the field. *Journal of Phytopathology* **144**(9-10), 479-484. <https://doi.org/10.1111/j.1439-0434.1996.tb00328.x>

Bouzar H, Jones JB, Stall RE, Hodge NC, Minsavage GV, Benedict AA & Alvarez AM (1994) Physiological, chemical, serological, and pathogenic analyses of a worldwide collection of *Xanthomonas campestris* pv. *vesicatoria* strains. *Phytopathology* **84**(7), 663-671. <https://doi.org/10.1094/phyto-84-663>

Burlakoti RR, Hsu CF, Chen J, & Wang J (2018) Population dynamics of xanthomonads associated with bacterial spot of tomato and pepper during 27 years across Taiwan. *Plant Disease* **102**(7), 1348-1356.
<https://doi.org/10.1094/PDIS-04-17-0465-RE>

Constantin EC, Cleenwerck I, Maes M, Baeyen S, Van Malderghem C, De Vos P & 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), 792-806. <https://doi.org/10.1111/ppa.12461>

Diab S, Bashan Y, Okon Y & Henis Y (1982) Effects of relative humidity on bacterial scab caused by *Xanthomonas campestris* pv. *vesicatoria* on pepper. *Phytopathology* **72**(9), 1257-1260.

Doidge EM (1920) A tomato canker. *Journal of the Department of Agriculture, Union of South Africa* **1**, 718-721.

Doidge EM (1921) A tomato canker. *Annals of Applied Biology* **7**(4), 407-430. <https://doi.org/10.1111/j.1744-7348.1921.tb05528.x>

Dougherty DE (1978) Yield reduction in tomato caused by bacterial spot and disease control with copper sprays. *Proceedings of the Florida State Horticultural Society* **91**, 291-293.

Dowson WJ (1939) On the systematic position and generic names of the Gram negative bacterial plant pathogens. *Zentralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten* **100**, 177-193.

Dutta B, Gitaitis R, Sanders RH, Booth C, Smith S & Langston DB, Jr (2013) Role of blossom colonization in pepper seed infestation by *Xanthomonas euvesicatoria*. *Phytopathology* **104**(3), 232-239.
<https://doi.org/10.1094/PHYTO-05-13-0138-R>

EFSA (2014) EFSA PLH Panel (EFSA Panel on Plant Health) (2014) Scientific Opinion on the pest categorisation of *Xanthomonas campestris* pv. *vesicatoria* (Doidge) Dye. *EFSA Journal* **12**(6), 3720, 26 pp.

<https://doi.org/10.2903/j.efsa.2014.3720>

EPPO (2021) EPPO Standards Phytosanitary procedures PM 3/80 (2). Consignment inspection of seed of *Solanum lycopersicum* and its hybrids. *EPPO Bulletin* **51**, 397-403. <https://doi.org/10.1111/epp.12773>

EPPO (2023) EPPO Standard Diagnostics PM 7/110 (2) *Xanthomonas* spp. (*Xanthomonas euvesicatoria* pv. *euvesicatoria*, *Xanthomonas hortorum* pv. *gardneri*, *Xanthomonas euvesicatoria* pv. *perforans*, *Xanthomonas vesicatoria*) causing bacterial spot of tomato and sweet pepper. *EPPO Bulletin* **53**, 558-579.

<https://doi.org/10.1111/epp.12960>

Gardner MW & Kendrick JB (1921) Bacterial spot of tomato. *Journal of Agricultural Research* **21**, 123-156.

Gardner MW & Kendrick JB (1923) Bacterial spot of tomato and pepper. *Phytopathology* **13**, 307-315.

Gašić K, Kuzmanović N, Ivanović M, Prokić A, Šević M & Obradović A (2018) Complete genome of the *Xanthomonas euvesicatoria* specific bacteriophage K?1, its survival and potential in control of pepper bacterial spot. *Frontiers in Microbiology* **9**, 2021. <https://doi.org/10.3389/fmicb.2018.02021>

Goode MJ & Sasser M (1980) Prevention - the key to controlling bacterial speck and bacterial speck of tomato. *Plant Disease* **64**, 831-834.

Holt JG (1994) Bergey's manual of determinative bacteriology. 9th Edition, Lippincott Williams and Wilkins, Baltimore. Philadelphia, Pennsylvania, 787 pp.

Ignjatović M, Gašić K, Ivanović M, Šević M, Obradović A & Milošević M (2010) Characterisation of *Xanthomonas euvesicatoria* strains pathogens of pepper in Serbia. *Pesticidi i Fitomedicina* **25**, 139-149. English summary (In Serbian).

ISF (2017) Method for the Detection of *Xanthomonas* spp. in Tomato seed (available online).

<https://worldseed.org/our-work/seed-health/ishi-methods/>

Jibrin MO, Timilsina S, Minsavage GV, Vallad GE, Roberts PD, Goss EM & Jones JB (2022) Bacterial spot of tomato and chili pepper in Africa: diversity, emergence of T5 race, and management. *Frontiers in Microbiology* **13**, 835647. <https://doi.org/10.3389/fmicb.2022.835647>

Jones JB, Bouzar H, Stall RE, Almira EC, Roberts P, Bowen BW, Jones JB, Bouzar H, Stall RE, Almira EC, Roberts PD, Bowen BW, Sudberry J, Strickler PM & Chun J (2000) Systematic analysis of xanthomonads (*Xanthomonas* spp.) associated with pepper and tomato lesions. *International Journal of Systematic Bacteriology* **50**(3), 1211-1219. <https://doi.org/10.1099/00207713-50-3-1211>

Jones JB, Lacy GH, Bouzar H, Stall RE & Schaad NW (2004a) Reclassification of the xanthomonads associated with bacterial spot disease of tomato and pepper. *Systematic and Applied Microbiology* **27**(6), 755-762. <https://doi.org/10.1078/0723202042369884>

Jones JB, Lacy GH, Bouzar H, Minsavage GV, Stall R & Schaad N (2004b) Bacterial spot—worldwide distribution, importance and review. *1st International Symposium on Tomato Diseases. Acta Horticulturae* **695**, 27-33. <https://doi.org/10.17660/ActaHortic.2005.695.1>

Jones J, Stall R, Scott J, Somodi G, Bouzar H & Hodge N (1995) A third tomato race of *Xanthomonas campestris* pv. *vesicatoria*. *Plant Disease* **79**, 395-398.

Jones JB, Vallad GE, Iriarte FB, Obradović A, Wernsing MH, Jackson LE, Balogh B., Hong JC & Momol T (2012) Considerations for using bacteriophages for plant disease control. *Bacteriophage* **2**(4), 208-214. <https://doi.org/10.4161/bact.23857>

- Kizheva Y, Vancheva T, Hristova P, Stoyanova M, Bogatzevska N & Moncheva P (2011) Diversity of *Xanthomonas* spp. causal agents of bacterial spot on pepper and tomato plants in Bulgaria. *Biotechnology & Biotechnological Equipment* **25**(4), (Suppl. 4), 98-104. <https://doi.org/10.5504/BBEQ.2011.0126>
- Klein-Gordon JM, Xing Y, Garrett KA, Abrahamian P, Paret ML, Minsavage GV, Strayer-Scherer AL, Fulton JC, Timilsina S, Jones JB, Goss EM & Vallad GE (2021) Assessing changes and associations in the *Xanthomonas perforans* population across Florida commercial tomato fields via a statewide survey. *Phytopathology* **111**(6), 1029-1041. <https://doi.org/10.1094/PHYTO-09-20-0402-R>
- Lamichhane JR, Osdaghi E, Behlau F, Köhl J, Jones JB, & Aubertot JN (2018) Thirteen decades of anti-microbial copper compounds applied in agriculture. A review. *Agronomy for Sustainable Development* **38**, 28. <https://doi.org/10.1007/s13593-018-0503-9>
- Ma X, Ivey MLL, & Miller SA (2011) First report of *Xanthomonas gardneri* causing bacterial spot of tomato in Ohio and Michigan. *Plant Disease* **95**(12), 1584. <https://doi.org/10.1094/PDIS-05-11-0448>
- Liu K, McInroy JA, Hu CH & Kloepper JW (2018) Mixtures of plant-growth-promoting rhizobacteria enhance biological control of multiple plant diseases and plant-growth promotion in the presence of pathogens. *Plant Disease* **102**(1), 67-72. <https://doi.org/10.1094/PDIS-04-17-0478-RE>
- McInnes TB, Gitaitis RD, McCarter SM, Jaworski CA & Phatak SC (1988) Airborne dispersal of bacteria in tomato and pepper transplant fields. *Plant Disease* **72**, 575-579.
- Morinière L, Bulet A, Rosenthal ER, Nesme X, Portier P, Bull CT, Lavire C, Fischer-Le Saux M & Bertolla F (2020) Clarifying the taxonomy of the causal agent of bacterial leaf spot of lettuce through a polyphasic approach reveals that *Xanthomonas cynarae* Trébaol *et al.* 2000 emend. Timilsina *et al.* 2019 is a later heterotypic synonym of *Xanthomonas hortorum* Vauterin *et al.* 1995. *Systematic and Applied Microbiology* **43**(4), 126087. <https://doi.org/10.1016/j.syapm.2020.126087>
- Naue CR, Rocha DJA & Moura AB (2014) Biological control of tomato bacterial spot by seed microbiolization. *Tropical Plant Pathology* **39**(5), 413–416. <https://doi.org/10.1590/S1982-56762014000500009>
- Newberry EA, Bhandari R, Minsavage GV, Timilsina S, Jibrin MO, Kemble J, Sikora EJ, Jones JB, Potnis N (2019) Independent evolution with the gene flux originating from multiple *Xanthomonas* species explains genomic heterogeneity in *Xanthomonas perforans*. *Applied and Environmental Microbiology* **85**(20), e00885-19. <https://doi.org/10.1128/AEM.00885-19>
- Obradovic A, Jones JB, Momol MT, Olson SM, Jackson LE, Balogh B, Guven K & Iriarte FB (2005) Integration of biological control agents and systemic acquired resistance inducers against bacterial spot on tomato. *Plant Disease* **89** (7), 712-716. <https://doi.org/10.1094/PD-89-0712>
- Osdaghi E, Jones JB, Sharma A, Goss EM, Abrahamian P, Newberry EA, Potnis N, Carvalho R, Choudhary M, Paret ML, Timilsina S & Vallad GE (2021) A centenary for bacterial spot of tomato and pepper. *Molecular Plant Pathology* **22**(12), 1500-1519. <https://doi.org/10.1111/mpp.13125>
- de Paula Kuyat Mates A, de Carvalho Pontes N & de Almeida Halfeld-Vieira B (2019) *Bacillus velezensis* GF267 as a multi-site antagonist for the control of tomato bacterial spot. *Biological Control* **137**, 104013. <https://doi.org/10.1016/j.biocontrol.2019.104013>
- Picard C, Afonso T, Benko?Beloglavec A, Karadjova O, Matthews?Berry S, Paunovic SA, Pietsch M, Reed P, Van Der Gaag DJ, Ward M (2018) Recommended regulated non-quarantine pests (RNQPs), associated thresholds and risk management measures in the European and Mediterranean region. *EPPO Bulletin* **48**(3), 552-568. <https://doi.org/10.1111/epp.12500>
- Pohronezny K, Moss MA, Dankers W & Schenk J (1990) Dispersal and management of *Xanthomonas campestris* pv. *vesicatoria* during thinning of direct-seeded tomato. *Plant Disease* **74**, 800-805.

- Pohronezny K & Volin RB (1983) The effect of bacterial spot on yield and quality of fresh market tomatoes. *HortScience* **18**(1), 69-70. <https://doi.org/10.21273/HORTSCI.18.1.69>
- Potnis N, Timilsina S, Strayer A, Shantharaj D, Barak JD, Paret ML, Vallad GE & Jones JB (2015) Bacterial spot of tomato and pepper: Diverse *Xanthomonas* species with a wide variety of virulence factors posing a worldwide challenge. *Molecular Plant Pathology* **16**(9), 907-920. <https://doi.org/10.1111/mpp.12244>
- Príncipe A, Fernandez M, Torasso M, Godino A & Fischer S (2018) Effectiveness of tailocins produced by *Pseudomonas fluorescens* SF4c in controlling the bacterial-spot disease in tomatoes caused by *Xanthomonas vesicatoria*. *Microbiological Research* **212–213**, 94–102. <https://doi.org/10.1016/j.micres.2018.05.010>
- Ríos-Sandoval M, Quiñones-Aguilar EE, Solís-Sánchez GA, Enríquez-Vara JN & Rincón-Enríquez G (2020) Complete genome sequence of *Xanthomonas vesicatoria* bacteriophage ?XaF18, a contribution to the biocontrol of bacterial spot of pepper in Mexico. *Microbiology Resource Announcements* **9**(16), e00213-20. <https://doi.org/10.1128/mra.00213-20>
- Stall RE, Beaulieu C, Egel D, Hodge NC, Leite RP, Minsavage GV, Bouzar H, Jones JB, Alvarez AM & Benedict AA (1994) Two genetically diverse groups of strains are included in *Xanthomonas campestris* pv. *vesicatoria*. *International Journal of Systematic Bacteriology* **44**(1), 47-53. <https://doi.org/10.1099/00207713-44-1-47>
- Stall RE, Jones JB & Minsavage GV (2009) Durability of resistance in tomato and pepper to xanthomonads causing bacterial spot. *Annual Review of Phytopathology* **47**, 265-284. <https://doi.org/10.1146/annurev-phyto-080508-081752>
- Strayer AL, Jeyaprakash A, Minsavage GV, Timilsina S, Vallad GE, Jones JB & Paret ML (2016) A multiplex real-time PCR assay differentiates four *Xanthomonas* species associated with bacterial spot of tomato. *Plant Disease* **100**(8), 1660-1668. <https://doi.org/10.1094/PDIS-09-15-1085-RE>
- Šutić D (1957) Bakterioze crvenog patlidzana (Tomato bacteriosis). *Posebna Izd. Inst. Zasht. Bilja Beograd (Spec. Edit. Inst. Plant Prot. Beograd)* **6**, 1-65. English summary: *Review of Applied Mycology* **36**, 734-735.
- Timilsina S, Jibrin MO, Potnis N, Minsavage GV, Kebede M, Schwartz A, Bart R, Staskawicz B, Boyer C, Vallad GE, Pruvost O, Jones JB & Goss EM (2015) Multilocus sequence analysis of xanthomonads causing bacterial spot of tomato and pepper plants reveals strains generated by recombination among species and recent global spread of *Xanthomonas gardneri*. *Applied and Environmental Microbiology* **81**(4), 1520-1529. <https://doi.org/10.1128/AEM.03000-14>
- Vallad GE, Timilsina S, Adkison H, Potnis N, Minsavage G, Jones J, & Goss EA (2013) A recent survey of Xanthomonads causing bacterial spot of tomato in Florida provides insights into management strategies. *Proceedings of the 2013 Florida Tomato Institute* (eds Ozores-Hampton M & Snodgrass C), pp. 25-27. University of Florida, Naples, FL (USA).
- Vancheva T, Bogatzevska N, Moncheva P, Mitrev S, Vernière C & Koebnik R (2021) Molecular epidemiology of *Xanthomonas euvesicatoria* strains from the Balkan Peninsula revealed by a new multiple-locus variable-number tandem-repeat analysis scheme. *Microorganisms* **9**(3), 536. <https://doi.org/10.3390/microorganisms9030536>
- Vauterin L, Hoste B, Kersters K & Swings J (1995) Reclassification of *Xanthomonas*. *International Journal of Systematic Bacteriology* **45**(3), 472-489. <https://doi.org/10.1099/00207713-45-3-472>
- Vlajić S, Ilić R, Maširević S, Feldeždi M, & Jošić D (2017) Appearance of *Xanthomonas euvesicatoria* on pepper in Vojvodina during 2016. *Proceedings of 69th International Symposium on Crop Protection*, p. 159. University of Ghent, Faculty of Bioscience Engineering. Ghent, Belgium.
- Young JM, Dye DW, Bradbury JF, Panagopoulos CG & Robbs CF (1978) A proposed nomenclature and classification for plant pathogenic bacteria. *New Zealand Journal of Agricultural Research* **21**(1), 153-177. <https://doi.org/10.1080/00288233.1978.10427397>

ACKNOWLEDGEMENTS

This datasheet was extensively revised in 2024 by Ana Palacio-Bielsa (CITA, Centro de Investigación y Tecnología Agroalimentaria de Aragón, Spain / Instituto Agroalimentario de Aragón - IA2 (CITA-Universidad de Zaragoza, Spain), Jaime Cubero (INIA/CSIC, Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria/Consejo Superior De Investigaciones Científicas, Spain) and Jerson Garita-Cambronero (ANOVE, Asociación Nacional de Obtentores Vegetales, Spain / ITACyL, Instituto Tecnológico Agrario de Castilla y León, Spain). Their valuable contribution is gratefully acknowledged.

How to cite this datasheet?

EPPO (2024) *Xanthomonas hortorum* pv. *gardneri*. 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 1988 and revised in the two editions of 'Quarantine Pests for Europe' in 1992 and 1997, as well as in 2024. 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* (2nd edition). CABI, Wallingford (GB).

EPPO (1988) Data sheets on quarantine organisms No. 157, *Xanthomonas campestris* pv. *vesicatoria*. *EPPO Bulletin* **18**, 521-526. <https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1365-2338.1988.tb00409.x>



Co-funded by the
European Union