CAPS Datasheets provide pest-specific information to support planning and completing early detection surveys.

Ralstonia solanacearum Race 3 Biovar 2

Scientific Name

Ralstonia solanacearum (Smith, 1896) Yabuuchi et al. (1995), phylotype IIB, sequevars 1 and 2 (known historically and for regulatory purposes as race 3 biovar 2)

Synonyms:

Burkholderia solanacearum (Smith,1896) Yabuuchi et al.,1993
Pseudomonas solanacearum (Smith,1896) Smith,1914

Common Names

Brown rot of potato, Southern wilt of geranium, bacterial wilt of tomato

Type of Pest

Bacterium

Taxonomic Position

Class: Betaproteobacteria, **Order:** Burkholderiales, **Family:** Burkholderiaceae

Notes on taxonomy and nomenclature:

Four phylotypes, corresponding to geographic origin and three species have been identified in the *R. solanacearum* species complex based on sequence analyses. *Ralstonia solanacearum* (phylotype II) originated in the Americas, *R. pseudosolanacearum* (phylotype I and III) originated in Asia and Africa, respectively, and *R. syzygii* (phylotype IV) originated in the Indonesian Archipelago (Prior et al., 2016; Safni et al., 2014). Strains in phylotype IIB sequevar 1-2 (abbreviated IIB-1 and IIB-2) are known for regulatory purposes as race 3 biovar 2 (EPPO, 2022b; USDA-APHIS-PPQ, 2022).

Pest Recognition

This section describes characteristics of the organism and symptoms that will help surveyors recognize possible infestations/infections in the field, select survey sites, and collect symptomatic material. For morphological descriptions, see the Identification/Diagnostic resources on the AMPS pest page on the CAPS Resource and Collaboration website.

Pest Description

This datasheet presents information for *Ralstonia solanacearum* Race 3 Biovar 2 (herein abbreviated R3 Bvr2), also known as phylotype IIB, sequevars 1 and 2. It is a quarantine pathogen in Europe and United States (EPPO, 2022b; Ozakman and Schaad, 2003).

Symptoms

Primary symptoms of bacterial wilt induced by R3 Bvr2 include leaf wilting (often as upward-rolling margins appearing unilaterally, leaf chlorosis (yellowing), necrosis (browning) of vascular tissue, stunting, vascular rings, and rotting of tubers (Champoiseau et al., 2009; Swanson et al., 2007; Swanson et al., 2005). Wilted leaves are usually the first symptom, followed by chlorosis and plant death. In the early stages of the disease, infected plants may appear to recover at night (Champoiseau et al., 2009). The stem may collapse, and gray-white bacterial ooze may be present, especially when the stem is cut or broken. Stems may also blacken (Janse, 2004). A common diagnostic sign of bacterial wilt is bacterial streaming (Fig. 1), which occurs when freshly cut stems from infected plants are placed in water. Fine, milky white strands of a viscous white slime containing bacteria often run from the cut end of the stem within 15 minutes (Dickstein et al., 2017).

Figure 1: Shows positive results for bacterial streaming. Photo Courtesy of David B. Langston, University of Georgia, www.bugwood.org.

On potatoes and other solanaceous hosts: The first visible symptom of *R. solanacearum* R3 Bvr2 on solanaceous hosts is wilting of the youngest leaves during the hottest part of the day, often on just one side of a leaflet or on a single branch (Fig. 2a). Another common field symptom associated with bacterial wilt is plant stunting. The entire plant may rapidly wilt under favorable conditions, starting with wilting and yellowing of foliage, and eventually leading to plant death. In infected potato tubers, the vascular ring turns a grey-brown color, which can spread into the pith or cortex as the infection advances. When these infected potatoes are sliced open, they release a milky-white sticky exudate. Threads may become apparent from the ooze when the two sides of a cut potato are pressed together and then separated. Additionally, ooze may emerge from the tuber eyes, causing dirt to stick on tuber surface (Champoiseau et al., 2009) (Fig. 2b). In tomato, the disease develops rapidly and plants may die within 4–7 days of symptoms appearing (Dickstein et al., 2017). Latently infected tomato plants may wilt suddenly after fruit set. A longitudinal slice of infected stems or stolons will reveal vascular browning, visible as long, narrow, dark brown streaks (Fig. 3). In succulent young plants of highly susceptible varieties, the stem can collapse, and gray-white bacterial ooze may be visible on stem surfaces (Fig. 3) (Champoiseau et al., 2009; Dickstein et al., 2017).

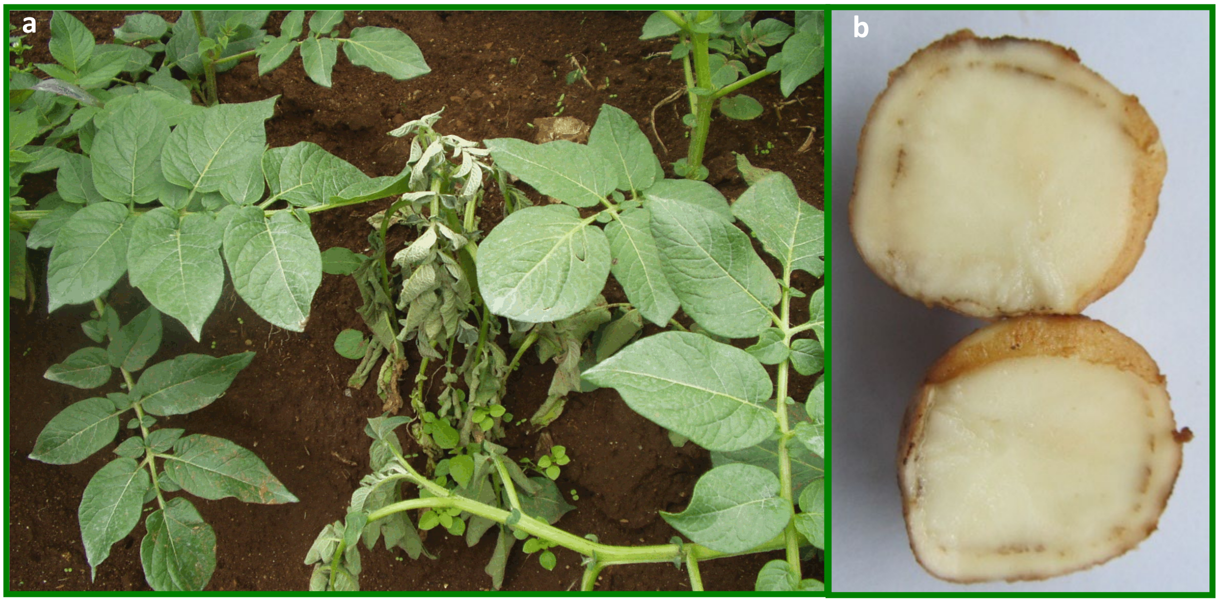

Figure 2: Wilting potato plant and grey-brown vascular ring in a tuber caused by *R. solanacearum* R3 Bvr2. Image credits: Amilcar Sanchez Perez (a) and Caitilyn Allen, University of Wisconsin-Madison (b).

Figure 3: Generalized symptoms of tomato wilt caused by *R. solanacearum* R3 Bvr2 **Left:** Wilted tomato. **Right:** Vascular browning and brown streaks observed in a tomato stem. Image credits: Clemson University - USDA Cooperative Extension Slide Series (left) and Central Science Laboratory, Harpenden Archive, British Crown (right). All photos are from [www.bugwood.org.](http://www.bugwood.org)

Figure 4: Left: A geranium showing early wilting symptoms **Right:** A geranium showing yellowing symptoms caused by *R. solanacearum* R3 Bvr2. Image credits: Wisconsin Department of Agriculture, Trade and Consumer Protection (left) and Caitilyn Allen, University of Wisconsin-Madison (right).

<u>In geranium:</u> The common name for this disease in geranium is southern wilt. Symptoms can be subtle and easily overlooked. Under favorable conditions, the disease develops rapidly, and symptoms move upwards from older to younger leaves.

Chlorosis and wilting of lower leaves usually appear first, followed by upward curling of leaf margins, which is an identifying characteristic for the disease in geranium. The leaf margins may become chlorotic and then necrotic. Wilted leaves often develop wedge-shaped areas of chlorosis that also become necrotic (Fig. 4). Vascular discoloration is visible in stems (especially at the root crown) (Fig. 5) and in the roots; these areas can blacken and eventually become necrotic (Dickstein et al., 2017; Janse et al., 2004). In late stages of disease, stems may collapse and the whole plant may desiccate and die.

Easily Mistaken Species

Symptoms of *R. solanacearum* R3 Bvr2 infection may resemble those caused by other plant pathogens or abiotic stress. A diagnosis should not be based solely on symptoms (Dickstein et al., 2017).

Other *R. solanacearum* strains that are endemic in the southern United States produce similar symptoms in the same hosts (Dickstein et al., 2017). *Xanthomonas hortorum* pv. *pelargonii* causes similar wilting symptoms in geranium (Moorman, 2014). *Clavibacter michiganensis*

Figure 5: Bacterial ooze in geranium stem caused by infection with R. solanacearum R3Bv2. Image credits: Margery Daughtrey, Cornell University, Bugwood.org

subsp. *sepedonicus* produces similar vascular browning in potato (Stevenson et al., 2001). *R. solanacearum* R3 Bvr2 symptoms on potato can also be confused with those caused by *Pectobacterium* spp., *Fusarium* spp., and *Verticillium* spp. (Cook and Sequeira, 1991). Abiotic stresses, such as drought, mechanical damage to the roots, or nutrient deficiency can also produce symptoms easily mistaken for *R. solanacearum* R3 Bvr2 (Dickstein et al., 2017).

Biology and Ecology

Ralstonia solanacearum R3 Bvr2 is a gram-negative soil- and waterborne vascular bacterial pathogen (Marco-Noales et al., 2008; Swanson et al., 2007; Wenneker et al., 1999). *R. solanacearum* R3 Bvr2 can live in the roots of hosts, including inside potato tubers, in the soil matrix surrounding the roots (rhizosphere), and in plant debris (Granada and Sequeira, 1983; Janse et al., 2004; Wenneker et al., 1999). The bacterium will grow on a variety of non-selective and semi-selective media between the temperatures of 70°F and 88°F (Caruso et al., 2003; Cook and Sequeira, 1991; Marco-Noales et al., 2008; Ozakman and Schaad, 2003; Mahbou Somo Toukam et al., 2009). *R. solanacearum* R3 Bvr2 grows slowly in culture and is easily outcompeted by other microbes; individual bacterial colonies that appear in less than 36 hours at 82°F are usually not *R. solanacearum* (Cook and Floyd, 2020).

Ralstonia solanacearum R3 Bvr2 can infect new hosts in many ways because it can survive in water, soil, and within infected plants for a long period of time. The pathogen can enter xylem tissue through wounds (Milling et al., 2009), spread via infected plant cuttings and seed tubers, and invade the plant through wounds created by nematodes or emerging roots (Swanson et al., 2007). When infected plants decompose, bacteria are released into the environment. Plants will also release the bacteria from open wounds. The bacteria emerging from the wound creates a gray-white bacterial ooze made from protective polysaccharides to help it survive in the environment (Shekhawat and Perombelon, 1991; van Elsas et al., 2000). Bacterial cells easily spread via irrigation and surface runoff water, infested soil, tools and equipment (Cook and Floyd, 2020; Swanson et al., 2007).

Unlike most strains of *Ralstonia solanacearum*, *R. solanacearum* R3 Bvr2 thrives in the cool tropical highlands and in temperate zones. This bacterium is highly virulent at temperatures between 66 ºF and 82 ºF (Huerta et al., 2015). Virulence decreases with temperatures above 95 ºF or below 61 ºF (Champoiseau et al., 2009; Ciampi and Sequeira, 1980).

R3 Bvr2 is also known to be more cold-tolerant than the southeastern native/endemic species (phylotype IIC, sequevar, commonly referred to as R1 Bvr1) and may survive throughout the continental United States (Milling et al., 2009; Swanson et al., 2007; Swanson et al., 2005). In Australia, R3 Bvr2 can survive in fallow soils with temperatures in winter as low as 39°F and in potato tubers at a constant cold storage temperature of 39°F for up to 4 months (Milling et al., 2009). However, laboratory studies found that R3 Bvr2 cannot survive the repeated freeze-thaw cycles that are common in northern continental U.S. states (Scherf et al., 2010).

Surveys for R3 Bvr2 are often difficult because the bacterium can evade detection in latently infected (symptomless) hosts (Swanson et al., 2005). Under temperate conditions, this pathogen survives in deep soil (~2 ft) (Graham and Lloyd, 1979; van Elsas et al., 2000) and is known to survive up to two years in soil where affected crops have already been removed (van Elsas et al., 2000; Wenneker et al., 1999). In warmer regions of South Africa, R3 Bvr2 can persist in the soil for more than 5 years even without known hosts present (Stander et al., 2003).

Known Hosts

The host list below includes cultivated and wild plants that 1) are infected or infested by the pest under natural conditions, 2) are frequently described as major, primary, or preferred hosts, and 3) have primary evidence for feeding and damage documented in the literature. Plants are highlighted in bold if they are commercially produced and the pest causes economically significant damage.

Economically important hosts of *R. solanacearum* R3 Bvr2 include potato, tomato, and geranium. It has also been known to colonize several weed species. These latent infections play a crucial role in the dissemination of *R. solanacearum* R3 Bvr2 and significantly influence the epidemiology of the disease (Dickstein et al., 2017). In Europe, numerous outbreaks of *R. solanacearum* R3 Bvr2 have been attributed to bittersweet nightshade (*Solanum dulcamara* L.), a weed species that grows along waterways and in wet areas in N. America and Europe (Janse, 1996; Parkinson et al., 2013). In addition to its primary economic hosts — potato, tomato, and geranium —R3 Bvr2 colonizes many other plant hosts. This adaptability poses a persistent threat to subsequent planting seasons and should be considered when designing a survey.

Major Hosts

Pelargonium hortorum* (zonal geranium), ***Pelargonium* spp. (geranium)* ,** ***Pelargonium zonale* (horseshoe geranium)***, ***Solanum lycopersicum* (tomato)*,** and ***Solanum tuberosum* (potato)*** (Ciampi and Sequeira, 1980; Gutarra et al., 2017; Janse et al., 2004; Milling et al., 2009; Ozakman and Schaad, 2003; Patil et al., 2012; Swanson et al., 2005; Vasconez et al., 2020).

Weedy Hosts

Amaranthus viridis (slender amaranth)*, *Cyphomandra betaceae* (tamarillo, tree tomato), *Physalis angulata* (cutleaf groundcherry)*, *Portulaca oleracea* (little hogweed)*, *Rumex dentatus* (toothed dock)*, *Solanum cinereum* (Narrawa burr), *Solanum dulcamara* (climbing nightshade)*, *Solanum nigrum* (black nightshade)*, *Solanum phureja* (nightshade), and *Urtica dioica* (stinging nettle)* (Ciampi and Sequeira, 1980;Farag et al., 2004; Graham and Lloyd, 1978; Wenneker et al., 1999;Gutarra et al., 2017; Lin et al., 2015; Martin and Nydegger, 1982; Swanepoel, 1992).

Eggplant and pepper can rarely be infected under specific, favorable conditions (Caffier and Hervé, 1996; Martin and French, 1995})

Pest Importance

Ralstonia solanacearum R3 Bvr2 is a serious pathogen with global impacts. According to Elphinstone (2005), about $950 million is lost annually worldwide due to *R. solanacearum* R3 Bvr2.

Ralstonia solanacearum R3 Bvr2 is not known to be present in the United States but could cause significant economic losses by impacting susceptible high-value crops that are grown throughout the country. This pathogen is considered a major problem globally and is among the most destructive pathogens for potatoes (Swanson et al., 2005).

In 2021, potatoes were grown commercially on 933,000 acres in 47 states and the estimated value of the potato harvest was over $3.91 billion and tomatoes were grown on 274,000 acres, with a total value of $1.5 billion. In 2019, geraniums were grown in 47 states with a total value of over $ 217 million (USDA-NASS, 2022).

This pathogen is a select agent in the United States (Janse, 2004; Lambert, 2002; USDA-APHIS-PPQ, 2022). A select agent is a biological agent that has the potential to pose a severe threat to plant health (USDA-APHIS-PPQ, 2022). *R. solanacearum* R3 Bvr2 is also listed as a harmful organism in Canada, El Salvador, Jordan, Mexico, Panama, and Taiwan (APHIS, 2023). In addition, *R. solanacearum* is listed as a quarantine pest in EPPO A2 list (EPPO, 2022a). There would likely be serious trade implications with these countries if this pathogen becomes established in the United States.

Once R3 Bvr2 is introduced and established, it is very difficult to control (Champoiseau et al., 2009) and its lethality, ability to cause latent infections, and environmental survival have made this pathogen a serious problem where it occurs (Gorissen et al., 2004). Eradication efforts are costly, including one eradication effort in a greenhouse in the United States that cost the grower approximately $10 million (Swanson et al., 2007). Control measures are, therefore, aimed at preventing introduction and establishment of the pathogen through exclusion and early detection.

Known Vectors (or associated insects)

There is currently no evidence of *R. solanacearum* being vectored by insects.

Known Distribution

Ralstonia solanacearum R3 Bvr2 has a global distribution and is found in both temperate and tropical climates (Swanson et al., 2005).

Africa: Burundi, Cameroon, Egypt, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Nigeria, Réunion Island, Rwanda, South Africa, Tanzania, and Uganda. **Asia:** Bangladesh, China, India, Indonesia, Iran, Israel, Japan, Korea, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, Taiwan, and Turkiye. **Central America:** Costa Rica, Guadeloupe, Guatemala. **Europe:** France[†], Georgia, Greece, Hungary, Netherlands[*], Portugal, Russia, Serbia, Spain, and United Kingdom[†]. **North America:** Mexico.

[*] Under eradication

Oceania: Australia and New Guinea. **South America:** Argentina, Bolivia, Brazil, Chile, Colombia, French Guiana, Peru, Uruguay, and Venezuela (Autrique and Potts, 1987; Caruso et al., 2003; Castillo and Plata, 2016; Cellier et al., 2012; Chakraborty and Roy, 2016; Cook and Sequeira, 1991; Cruz et al., 2012; Deberdt et al., 2014; Elphinstone, 2001; Farag et al., 2004; French, 1988; Gabriel et al., 2006; Garcia et al., 1999; Guidot et al., 2009; Hemelda et al., 2019; Horita and Tsuchiya, 2001; Izadiyan and Taghavi, 2013; Janse, 2012; Janse et al., 2004; Jeong et al., 2007; Junaid and Ahmad, 2018; Khoodoo et al., 2010; Lemessa and Zeller, 2007; Mahbou Somo Toukam et al., 2009; Marković et al., 2021; Martin and French, 1995; Matveeva et al., 2003; Mwankemwa, 2015; Natural et al., 2005; Nemeth et al., 2002; Nicole et al., 1998; Parkinson et al., 2013; Perea Soto et al., 2011; Popoola et al., 2015; Pradhanang et al., 2000; Prior and Steva, 1990; Ravelomanantsoa et al., 2017; Sagar et al., 2013; Sedighian et al., 2020; Swanson et al., 2007; Thammakijjawat et al., 2001; Tomlinson and Guntber, 1986; Tusiime et al., 1998; Ustun et al., 2009; Uwamahoro et al., 2018; Van Der Wolf et al., 1998; Vasconez et al., 2020; Wang et al., 2017; Wu et al., 2011; Zayamba Kagona, 2008).

Presence in Nurseries/Greenhouses:
Europe: Belgium[†] and Germany[†] (Marco-Noales et al., 2008), and **North America:** Canada[†] (IPPC, 2020; Janse et al., 2004; Roman-Reyna et al., 2021).

Eradication
R. solanacearum R3 Bvr2 has been eradicated in the United States, Lebanon, and Sweden (Elia et al., 2017; Persson, 1998).

There are also miscellaneous records for Libya and Zambia, but these could not be verified.

Pathway
Ralstonia solanacearum R3 Bvr2 is primarily water and soilborne and can be spread in contaminated irrigation, runoff, and surface water; equipment; and soil (Caruso et al., 2003; Janse et al., 2004; Milling et al., 2009; Wenneker et al., 1999). It can spread naturally from infected roots to healthy roots of neighboring plants (Autrique and Potts, 1987), and insect and nematode damage to healthy roots can facilitate this transmission (Champoiseau et al., 2009). Transmission does not occur by leaf to leaf contact or water splashing (Swanson et al., 2005).

The pathogen is also readily disseminated through infected propagative material, including potato tubers (Wenneker et al., 1999) and geranium cuttings (Milling et al., 2009). Infected plants may remain symptomless but still shed bacteria through their roots, making runoff water an important source of infection (Swanson et al., 2005). Latently infected geranium cuttings were responsible for introduction of *R. solanacearum* R3 Bvr2 in the United States, although it was subsequently eradicated (Dickstein et al., 2017). *R. solanacearum* R3 Bvr2 persists in field soil in the absence of host plants (Elphinstone, 1996; Stander et al., 2003) and remains viable in the roots of one alternative weed host, *Solanum dulcamara*, for many years (Elphinstone, 2001).

Use the PPQ Commodity Import and Export manuals listed below to determine 1) if host plants or material are allowed to enter the United States from countries where the organism is present and 2) what phytosanitary measures (e.g., inspections, phytosanitary certificates, post entry quarantines, mandatory treatments) are in use. These manuals are updated regularly.

Agricultural Commodity Import Requirements (ACIR) manual: ACIR provides a single source to search for and retrieve entry requirements for imported commodities. https://acir.aphis.usda.gov/s/

Plants for Planting Manual: This manual is a resource for regulating imported plants or plant parts for propagation, including buds, bulbs, corms, cuttings, layers, pollen, scions, seeds, tissue, tubers, and like structures. https://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/plants_for_planting.pdf

Treatment Manual: This manual provides information about treatments applied to imported and domestic commodities to limit the movement of agricultural pests into or within the United States. https://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment.pdf

Potential Distribution within the United States

Ralstonia solanacearum R3 Bvr2 is not known to be established in the United States due to successful eradication following detections in greenhouses in several states from imported geranium cuttings (Dickstein et al., 2017; USDA-APHIS-PPQ, 2020; Williamson et al., 2002; Roman-Reyna et al., 2021; Strider et al., 1981).

Nearly every state grows at least one of the major crops that can host *R. solanacearum* R3 Bvr2 and all solanaceous crop growing areas may be at risk due to the cold tolerance of *R. solanacearum* R3 Bvr2. However, R3 Bvr2 in infected geranium or potato tuber tissue would not survive the repeated freeze-thaw cycles common in Colorado, Idaho, Maine, Michigan, North Dakota, and Wisconsin (Scherf et al. 2010).

The majority of potatoes are harvested in California, Colorado, Florida, Idaho, Maine, Michigan, Minnesota, North Dakota, Oregon, Washington, and Wisconsin (USDA-NASS, 2022), while California and Florida are the major producers of tomatoes (AgMRC, 2021). In addition, geraniums are popular landscaping plants and widely grown and distributed in the United States. Michigan, California, New Jersey, Pennsylvania, North Carolina, New York, Ohio, Connecticut, Florida, and Wisconsin are major producers of geraniums (USDA-NASS, 2020).

Survey and Key Diagnostics

For the current approved methods and guidance for survey and identification, see Approved Methods for Pest Surveillance (AMPS) pest page on the CAPS Resource and Collaboration website, at https://caps.ceris.purdue.edu/approved-methods.

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Versions

April, 2015: Updated to include the eradication from Austria.

Feb. 2023:
- Added new name to **Synonyms** section.
- Added note to **Taxonomic Position** section.
- Revised **Known Distribution** section; verified references and added new countries.
- Revised **Known Hosts** section. Verified references and added new hosts.
- Revised **Symptoms, Biology and Ecology, Pathway, Potential Distribution, and Survey Instruction** sections.
- Added **Easily Mistaken Species** section.
- Added **Pest Importance** section.

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