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

Fusarium oxysporum f. sp. *cubense* Tropical Race 4 (TR4)

Scientific Name

Fusarium oxysporum f. sp. *cubense* (E.F. Sm.) W.C. Snyder & H.N. Hansen 1940), Tropical Race 4

Synonym(s):
Fusarium oxysporum Schltdl. 1824
Fusarium cubense E.F. Sm. 1910
Fusarium oxysporum var. *cubense* (E.F. Sm.) Wollenw. 1935
Fusarium oxysporum f. *cubense* (E.F. Sm.) Snyder & Hansen 1940
Fusarium odoratissimum Maryani, L. Lombard, Kema & Crous 2018

Common Name

Fusarium wilt of banana, Panama Disease, Panama disease of banana, Fusarium wilt, vascular wilt of banana

Figure 1. A banana plant infected with *Fusarium oxysporum* f. sp. *cubense* Tropical Race 4 in Taiwan. (Miguel Dita/Bioversity International, https://promusa.org/Fusarium+wilt).

Type of Pest

Fungus

Taxonomic Position

Class: Sordariomycetes, **Order:** Hypocreales, **Family:** Nectriaceae

Notes on taxonomy and nomenclature:

Fusarium oxysporum is a species complex, made up of more than 100 special forms (*formae speciales*; abbreviated ff. spp., singular f. sp.) that cause plant vascular wilts. *F. oxysporum* f. sp. *cubense* is divided into four races (subtypes), and the most economically damaging is tropical race 4 (TR4). Some refer to *F. oxysporum* f. sp. *cubense* TR4 as the newer species, *F. odoratissimum* (Maryani et al., 2019). For simplicity, we will refer to the pathogen as TR4 in this datasheet.

Pest Recognition

This section describes characteristics of the organism and symptoms that will help surveyors recognize possible symptomatic plants 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

In-field indicators of Fusarium wilt in banana are disease symptoms, as no fungal mold or sporulation will be visible to surveyors. Grown in the lab, *Fusarium* species appear mold-like on general nutrient media and cannot be distinguished on appearance. *Fusarium oxysporum* grows at moderate to warm temperatures and produces three different types of microscopic, asexual spores: microconidia, macroconidia, and chlamydospores. Micro- and macroconidia allow *F. oxysporum* f. sp. *cubense* to move with water uptake inside infected banana plants, while the hardier chlamydospores function in infecting new hosts via infested soil or water movement. *Fusarium oxysporum* f. sp. *cubense* is not known to sexually reproduce (Ploetz, 2000; Ploetz, 2006). In addition to banana, *F. oxysporum* f. sp. *cubense* can infect common weeds, though these may not show symptoms (Catambacan and Cumagun, 2022); (Hennessy et al., 2005).

TR4 is a subset of strains of *Fusarium oxysporum* f. sp. *cubense* that cause Fusarium wilt in all varieties of banana, grown in all environmental conditions. This includes ‘Cavendish’ varieties, which are resistant to other *Fusarium oxysporum* f. sp. *cubense* races and were widely adopted as a crop-saving solution (Ploetz, 2015a). Another subset of strains, subtropical race 4 (SR4), can cause wilt in ‘Cavendish’ varieties, but only in challenging conditions, such as cold temperatures or waterlogged soil (Ploetz, 2015a).

Significant time, labor, and expertise is needed to differentiate TR4 from other Fusarium wilt strains affecting banana. While TR4 are the only strains that infect ‘Cavendish’ grown in ideal conditions, host range studies confirming their identity require months of work (Widinugraheni et al., 2018). Faster lab tests based on TR4 biology have been developed, using growth-based vegetative compatibility groupings (VCGs) or fungal gene identification, but these have limitations. Both VCG testing and fungal gene identification can identify close relatives of reference TR4 strains, but may miss strains with slightly different biology that also infect ‘Cavendish’ grown in ideal conditions (Dita et al., 2010); (Munhoz et al., 2024). Thus, conclusively identifying TR4 relies on combined testing undertaken by specialists.

Symptoms

Yellow, wilted leaves are the most obvious Fusarium wilt symptom (Fig. 1, 3A). Older (closer to the ground) leaves are affected first, then disease progresses to younger leaves. As the disease continues, edges of yellow leaves will turn brown, and the leaf may split or shred. Diseased leaves may be upright or collapse and hang down along the pseudostem, appearing as a skirt around the base of the plant (Fig. 1, 3A). The pseudostem may also split at the base (Fig. 2) (Queensland Government, 2024). Because the fungus blocks water and nutrient movement, external visual symptoms on plants may remind surveyors of water or nutrient deficiencies. Symptoms often become

most obvious during formation of fruit bunches (Pegg et al., 2019), anywhere from 2 to 9 months after infection (Rueda and Ploetz, 2020).

Figure 2. A split pseudostem in a banana plant affected by Fusarium wilt. Courtesy of Miguel Dita/Bioversity International, http://www.promusa.org/.

Internally, TR4 causes breakdown and death of water-moving tissue (xylem) in banana roots, rhizomes (the main horizontal underground stem), and pseudostems, resulting in reddish-brown discoloration of these tissues. This may occur in localized columns or among multiple columns of xylem and will only be visible if pseudostems or rhizomes are cut (Fig. 3B, C, D).

Fusarium wilt in banana fields usually develops in a clumped pattern (Heck et al., 2021b). Based on how TR4 is introduced and spread, the source of the initial infection may be an epicenter, where a single or a few plants were initially infected and disease has not been present long. Alternatively, symptomatic plants may occur simultaneously over a larger area such as down a row where contaminated soil was spread, areas where groups of infected transplants were established, or areas that have been flooded (Pegg et al., 2019).

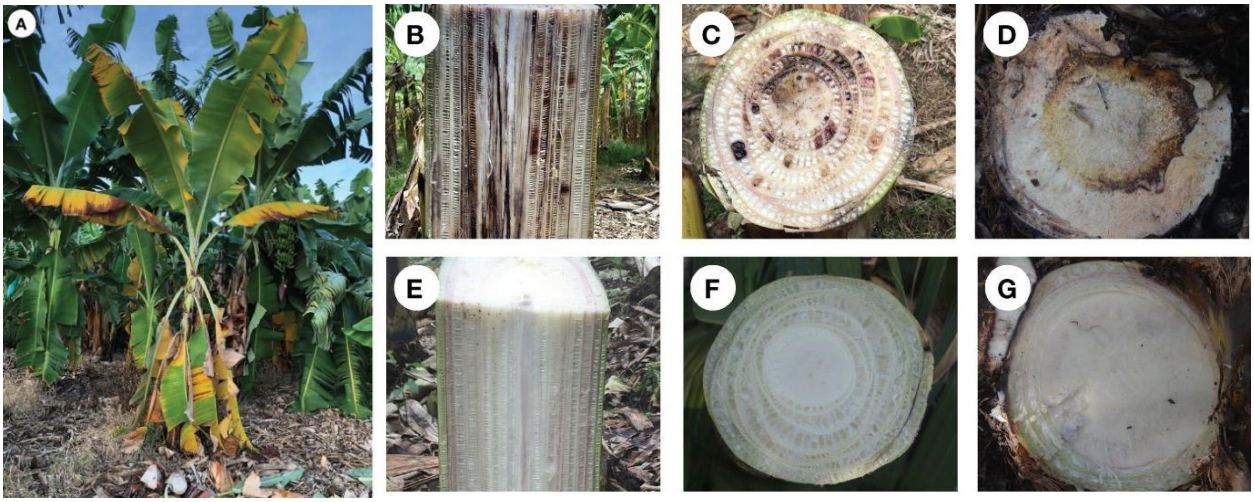

Figure 3. (A) Banana plant affected by TR4, with skirt-like leaves around base of pseudostem. **(B, C)** Banana pseudostems with dead and dying vascular columns, caused by TR4. **(D)** Banana rhizome with internal dying ring of xylem, caused by TR4. **(E, F)** Healthy banana pseudostems and **(G)** healthy banana rhizome. Photos from (Munhoz et al., 2024); Creative Commons Attribution License (CC BY 4.0).

Easily Mistaken Species & Conditions

TR4 strains cause identical symptoms as *Fusarium oxysporum* f. sp. *cubense* strains already present in Florida (Munhoz et al., 2024), Hawaii (Shipman and Tian, 2024), and Puerto Rico (Garcia et al., 2018). Lab testing is necessary to differentiate domestic strains from TR4.

Three other banana diseases appear similar to Fusarium wilt, but importantly, these are not found in the United States as of 2024. Three different bacteria cause blood disease, 'Moko,' and Xanthomonas wilt, respectively, which all cause leaf yellowing, vascular discoloration, and wilting symptoms in banana (Rincón-Flórez et al., 2022); (Tripathi et al., 2009).

Symptoms similar to those caused by Fusarium wilt - such as leaf yellowing - may be caused by abiotic factors, including water stress and nutrient deficiencies. Glyphosate damage on banana can also resemble yellowing and wilting from Fusarium wilt (Magdama, 2025).

Commonly Encountered Non-targets

The approved method for TR4 survey is visual inspection and collection of symptomatic plant material followed by molecular identification.

Any of the pathogens/abiotic factors mentioned in the Easily Mistaken Species section could be encountered during survey and are difficult to distinguish. In most cases, any symptomatic material should be collected for testing.

Fusarium wilt can most easily be distinguished from bacterial wilts if the plant is cut, as cut surfaces will ooze cloudy, white or yellow fluid within 15 minutes if infected with

bacteria. Additionally, Fusarium wilt does not affect fruit, but bacterial diseases cause oozing rot symptoms inside cut bunches (Queensland Government, 2024); (Rincón-Flórez et al., 2022); (Tripathi et al., 2009).

Abiotic factors will not cause vascular discoloration (similar to symptoms in Fig. 3B, C), so cutting into the internal trunk to look for vascular discoloration is one way to preliminarily distinguish Fusarium wilt from abiotic factors (CABI, 2021).

Biology and Ecology

Fusarium wilt disease starts in plant roots, then progresses upward. As feeder roots grow outward searching for water and nutrients, they encounter hardy *Fusarium* spores (chlamydospores) that infect them first. After the fungus grows into the plant, reddish-brown discoloration of the xylem develops. Asexual spores assist in the movement of TR4 through the xylem to other plant parts. The discoloration symptoms expand to side roots and progress to the rhizome (the main underground stem) over weeks to months. In the rhizome, discoloration will be most noticeable where the central stele joins the cortex surrounding it (Fig. 3D). As the fungus grows, the discoloration spreads internally up the pseudostem (Fig. 3B, C). More leaves wilt and turn yellow as more xylem is affected. Eventually, the youngest leaves wilt and collapse until the entire canopy consists of dead or dying leaves (Ploetz, 2006). Usually, young banana suckers (less than about 4 months) will not have visible symptoms of Fusarium wilt, even if the main stem is affected. Diseased banana plants may not set fruit, or if they do, bunches will be small but otherwise without symptoms (Queensland Government, 2024). The time period between infection to disease development can vary based on environmental conditions, from a few months to over a year (Queensland Government, 2024).

The major way TR4, and all banana Fusarium wilt strains, spread internationally is by humans moving infected planting material, contaminated machinery, and tracking contaminated soil on shoes (Dita et al., 2018; Ploetz, 2015a; Stover, 1962). Hardy chlamydospores develop in infected tissue as the plant breaks down, most of which end up in soil (Groenewald, 2005). Other ways the fungus spreads are flooding water, animal tracking, or potentially by root grafting (Dita et al., 2018; Heck et al., 2021b; Pegg et al., 2019); Ploetz and Pegg, 2000; (Queensland Government, 2024); (Stover, 1962); (Su et al., 1986). Chlamydospores of the Fusarium wilt fungus remain infectious in soil for 20 years, and up to 40 years is reported in extreme cases (Ploetz et al., 2015b).

In addition, the banana root borer *Cosmopolites sordidus* vectors *F. oxysporum* f. sp. *cubense* externally and internally (Guillen Sanchez et al., 2021). Unmanaged weevil infestations (*C. sordidus* and *Metamasius hemipterus*) increase levels of Fusarium wilt in the field (Heck et al., 2021a). TR4 can grow in common weeds without causing symptoms (Catambacan and Cumagun, 2022); Hennessy et al., 2005) and ornamental *Heliconia* spp. (Martínez-de la Parte et al., 2024), which suggests other plants may assist its survival and, indirectly, its spread.

Known Hosts

Fusarium oxysporum f. sp. *cubense* TR4 is economically damaging to banana and plantain (*Musa* spp.) commercial production (Stover, 1962). *Musa* spp. should be the primary target for any surveys. Weedy or ornamental hosts (Table 1) are only candidates for sampling if growing near symptomatic banana or plantain.

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.

Preferred hosts

***Musa* spp. (banana, plantain)** (Stover, 1962). The 'Cavendish' banana variety has resistance to non-TR4 races; however, all varieties are susceptible to TR4.

The ornamental plant, *Heliconia rostrata* (false bird of paradise) hosts TR4 and develops symptoms in the rhizome but not foliage (Martínez-de la Parte et al., 2024).

Asymptomatic hosts

Hosts listed in Table 1 become infected with TR4 but do not develop symptoms. Sampling these is only suggested if found growing near symptomatic banana or plantain plants.

Table 1. Asymptomatic hosts of *Fusarium oxysporum* f. sp. *cubense* Tropical race 4 (TR4).

Scientific Name	Common Name	Type/Use	References/Notes
Chloris barbata	Swollen fingergrass	Weed	(Hennessy et al., 2005)
Cyanthilium cinereum	Little ironweed	Weed	(Hennessy et al., 2005)
Eleusine indica	Indian goosegrass	Weed	(Catambacan and Cumagun, 2022)
Euphorbia heterophylla	Mexican fireplant	Weed	(Hennessy et al., 2005)
Heliconia latispatha	Expanded lobsterclaw	Ornamental	(Martínez-de la Parte et al., 2024)
Heliconia psittacorum	Parakeet flower	Ornamental	(Martínez-de la Parte et al., 2024)
Musa coccinea	Scarlet banana	Weed	(Martínez-de la Parte et al., 2024)
Musa textilis	Abaca	Weed	(Martínez-de la Parte et al., 2024)
Musa velutina	Hairy banana	Weed	(Martínez-de la Parte et al., 2024)
Tridax procumbens	Coatbuttons	Weed	(Hennessy et al., 2005)

Pest Importance

Fusarium oxysporum f. sp. *cubense* TR4 is the worst threat to sustainable banana production worldwide and would impact over 40% of the world's banana production if it were widely spread (Ploetz, 2015b). Yield losses due to TR4 epidemics may be 90% or greater (Pérez Vicente et al., 2014). Internationally, TR4 could destroy food stability and the income of millions of farmers while simultaneously threatening U.S. banana imports (Ploetz and Churchill, 2011). In 2023, U.S. banana imports were worth $2.04 billion (Karst, 2024).

Domestic U.S. banana production values are much smaller than imports. In 2022, Puerto Rico was the largest production area with 5,161 acres, followed by 1,433 acres in the rest of the U.S., over 1,000 of which is in Hawaii (NASS, 2023). Puerto Rico's industry is worth over $27 million, while banana industry values in Hawaii and Florida are reported as $6.3 million and $2 million by state specialists, respectively (Evans and Ballen, 2024); (HDOA, 2024); (NASS, 2023).

As of 2024, *Fusarium oxysporum* at the species level is listed as a harmful organism in the following countries: Bangladesh, Canada, Colombia, French Polynesia, Israel, Mexico, Nepal, Panama, Syrian Arab Republic, and Viet Nam. At the *forma specialis* level, *F. oxysporum* f. sp. *cubense* is listed as a harmful organism in: Cambodia, China, Ecuador, Egypt, Honduras, Morocco, Nicaragua, Oman, Pakistan, Qatar, Samoa, South Africa, South Korea, and Zambia. Most specifically, *F. oxysporum* f. sp. *cubense* race 4 is listed as a harmful organism by Brazil, Costa Rica, Guatemala, New Caledonia, and Peru; Costa Rica also lists *Fusarium odoratissimum* as a harmful organism (PExD, 2024). In 2024, TR4 was moved from EPPO's Alert list to categorization as an A2 pest (EPPO, 2024). There may be trade implications with these countries if TR4 becomes established in the United States.

Known Vectors (or associated insects)

Banana root borer *(Cosmopolites sordidus)* can carry *F. oxysporum* f. sp. *cubense* both externally and internally for several days after feeding on infected plants, and the fungus can cause banana disease after weevil excretion (Guillen Sanchez et al., 2021). In addition, unmanaged infestations of banana root borer and cane weevil *(Metamasius hemipterus*), sometimes known as the false banana weevil, worsen Fusarium wilt epidemics (Heck et al., 2021a). Both weevils occur in Puerto Rico, and banana root borer also occurs in Florida and Hawaii (GBIF, 2024). The cane weevil is a quarantine pest for Hawaii, which is the only APHIS PPQ weevil designation in the risk areas (ARM, 2024).

Known Distribution

Table 2. Countries where *Fusarium oxysporum* f. sp. *cubense* TR4 is known to occur.

Continent	Country	References/Notes
Africa	Mayotte	Aguayo et al. (2021)
	Mozambique	IPPC (2013)
Asia	China	Zheng et al. (2018)
	India	Damodaran et al. (2019)
	Indonesia	Maryani et al. (2019)
	Israel	Maymon et al. (2018)
	Jordan	García-Bastidas et al. (2014)
	Laos	Chittarath et al. (2018)
	Lebanon	Ordóñez et al. (2015)
	Malaysia	Ploetz and Pegg (2000)

Asia	Myanmar	Zheng et al. (2018)
	Oman	Dita et al. (2018)
	Pakistan	Ordóñez et al. (2015)
	Philippines	Molina et al. (2009)
	Taiwan	Su et al. (1986)
	Thailand	FAO (2019)
	Turkey	Özarslandan and Akgül (2019)
	Vietnam	Hung et al. (2018)
Oceania	Australia	Dita et al. (2010)
South America	Colombia	García-Bastidas et al. (2020)
	Peru	Acuña et al. (2022)
	Venezuela	Mejías Herrera et al. (2023)

There is a record of TR4 from a bio-dome grown banana plant in the United Kingdom (Warmington et al., 2019).

Pathway

TR4 is primarily introduced to new global areas through the movement of asymptomatic planting material (Dita et al., 2018; Stover, 1962); (Warmington et al., 2019; Zheng et al., 2018). Most *Musa* spp. are vegetatively propagated from cuttings or suckers, and plants may take up to two years for symptoms to develop (Pegg et al., 2019). Genetic analyses indicate TR4-affected bananas in Myanmar, Vietnam, and Laos likely originated via planting material from China, while similar approaches showed bananas from Pakistan and the Philippines also shared a source (Zheng et al., 2018).

Since 1990, *Musa* spp. planting material have been intercepted coming into the United States from at least eight countries with TR4 (AQAS/ARM, 2024). Commodity Import Requirements for these countries specify that *Musa* and *Ensete* spp. plants for planting have been derived from tissue culture (ACIR, 2024), so interceptions indicate unpermitted shipments (AQAS/ARM, 2024). Tissue-culture plantlets do not pose a risk of spreading TR4 (Ploetz, 2015a; Ploetz et al., 2015b).

Based on its host range, there is potential for TR4 to also enter the U.S. via select *Heliconia* spp. ornamental plants (Martínez-de la Parte et al., 2024). Nonquarantine weeds included in shipments from countries with TR4 pose little to no risk based on Commodity Import Requirements as of 2024 (ACIR, 2024). Banana root borer (*C. sordidus*) may be another potential pathway, as it is nonreportable for all of the U.S. and can vector *F. oxysporum* f. sp. *cubense* for several days after its last feed (Guillen Sanchez et al., 2021). Contaminated soil on foreign travelers' shoes is also a risk, but only if those travelers have visited TR4-affected areas.

Use the PPQ Commodity Import and Export manual 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. This manual is 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/

Potential Distribution within the United States

Bananas are grown commercially in Puerto Rico, Hawaii, Florida, and Texas, with scant acreage also reported from Alabama, California, Georgia, Louisiana, and South Carolina (NASS, 2023). 'Cavendish' varieties are commercially grown in Puerto Rico and Hawaii, but smaller plantings may also be present in other areas of the United States (Evans and Ballen, 2024); (Garcia et al., 2018). Hawaii, Puerto Rico, and southern Florida are most vulnerable to establishment of TR4 due to these areas' larger banana industries.

Weeds and ornamental plants that may serve as alternate TR4 hosts are present in the U.S., especially tropical areas of Puerto Rico, Hawaii, and Florida. These include *Chloris cinereum*, *Heliconia latispatha*, *H. psittacorum*, *H. rostrata*, *Musa velutina*, and *Tridax procumbens* (NRCS, 2024). Weedy hosts in tropical and subtropical U.S., parts of the Southeast, and southwestern U.S. states are *C. barbata* and *Ensete heterophylla* (NRCS, 2024). *E. indica* is the most broadly distributed weedy host, occurring in all U.S. states except AK, ID, MT, WA, and WY (NRCS, 2024).

Survey and Key Diagnostics

Approved Methods for Pest Surveillance*:

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://approvedmethods.ceris.purdue.edu/.

Human and Animal Pathogens Transmitted:

Not known to transmit any human or animal pathogens.

Pest is vectored by:

Fusarium oxysporum f. sp. *cubense* is associated with banana root borer (*Cosmopolites sordidus*). Cane weevil (*Metamasius hemipterus*) damage is also associated with Fusarium wilt of banana.

Approved survey method

The approved survey method is general visual inspection followed by collection of symptomatic plant material for molecular testing.

Method Notes:

Surveys for tropical race 4 should occur in banana and plantain.

Because symptoms are similar for all races of *Fusarium oxysporum* f. sp. *cubense*, surveys in more susceptible varieties (i.e., not 'Cavendish' types) are likely to detect non-targets, including non-TR4 strains already established in Florida, Hawaii, and Puerto Rico.

Survey Recommendations:

Symptoms:

On plants that are more than four months old, yellow and wilted leaves are typical symptoms of Fusarium wilt of banana. The yellowing typically progresses from the older to the younger leaves. The yellow leaves may remain erect, split longitudinally, or collapse at the petiole and hang down along the pseudostem. The base of the pseudostem may also split. Symptoms become most obvious during formation of fruit bunches.

Banana suckers that are less than four months old are unlikely to show visible symptoms. Banana fruit do not show any specific disease symptoms.

The major way to differentiate Fusarium wilt from other causes of yellowing and wilting is by cutting into the banana pseudostem. There, the major internal symptom is a reddish-brown discoloration of the xylem, which may be restricted to one or a few columns or present in a partial ring. TR4 does not produce sporulation that would be externally visible to surveyors.

Time of year to survey:

There is not a specific time for survey in established plantations. However, symptoms may become most apparent when a new pseudostem is established as the leader, or during bunch formation, which is 9-13 months after planting. If pathogen load is high in soil, new banana plantlets will die after a few weeks or months.

Survey Design:

On the field scale, banana plants may develop symptoms in groups. Banana farms with poor biosecurity practices, such as frequent imports of international planting material and those with high non-worker foot traffic, may be good targets for survey.

Visual Survey

Visually inspect host plants throughout the survey site for yellowing banana plants with yellowing and wilting leaves. Wilted plants infected with *F. oxysporum* f. sp. *cubense* Tropical race 4 will have reddish-brown internal discoloration in cut pseudostem tissue.

Survey Site Selection:

Survey for symptoms of *Fusarium oxysporum* f. sp. *cubense* Tropical race 4 in banana planted in the United States. Non-TR4 strains may occur in plantings of varieties other than ‘Cavendish’ types.

Sample collection instruction:

Collect 3 to 5 pseudostem samples of at least one square inch from plants with internal vascular discoloration. Ensure tissue is fresh, not soft and rotted. Place samples in paper bags, envelopes, or glass vials (NOT plastic bags). Spray samples with 1-2% ascorbic acid (vitamin c) solution to prevent further tissue darkening that may mask original symptoms.

Approved diagnostic method

The approved diagnostic method is lab-based conventional PCR. As of 2025, several in-field methods using isothermal equipment are in development, but their specificity is still being confirmed.

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Versions

June 2015: Datasheet completed (Version 1)

May 2025 (Version 2)

- Added *Fusarium odoratissimum* information to **Synonyms** and **Taxonomic details**
- Simplified language and provided more detail in **Pest Recognition**
- Added where Cavendish is grown in **Easily Mistaken Strains**
- Added statements about common weeds and *Heliconia* spp. in **Biology and Ecology, Known Hosts,** and **Pathway**
- Added statements about banana weevil vectors in **Biology and Ecology, Known Vectors,** and **Pathway**
- Added more detail about domestic banana production and countries listing TR4 as a Harmful organism in **Pest Importance**
- Updated country listing in **Known Distribution**
- Added minor details in **Survey Recommendations** based on contemporary literature
- Updated **Additional Resources** section.

Reviewer(s)

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