EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION
ORGANISATION EUROPEENNE ET MEDITERRANEENNE POUR LA PROTECTION DES PLANTES

24-29386 (24-29191)

Report of a Pest Risk Analysis for

Fusarium oxysporum f. sp. *cubense* Tropical race 4 (Ascomycota: Nectriaceae)

Cavendish plantation severely affected by Fusarium TR4 in the Philippines Burnt spots display places where plants were eliminated.
Courtesy: Fernando A. Garcia Bastidas - EPPO Global Database (EPPO Code: FUSAC 4)

This summary is based on:

a French PRA for Guadeloupe, Martinique, Guyane, Réunion et Mayotte (ANSES, 2018)
an EFSA pest categorisation (EFSA, 2022)
French opinions regarding measures for banana fruit (ANSES, 2015) and vitro-plants (ANSES, 2021)
IPPC Secretariat prevention, preparedness and response guidelines (IPPC, 2023).

The EFSA pest categorisation covers the European Union. The French PRA focuses on the overseas territories Guadeloupe, Martinique, French Guyana, Mayotte and La Réunion (thereafter 'French territories concerned'). Information in these documents partly apply to other part of the EPPO region. Certain elements do not apply though, such as the overall risk (and pest risk management options proposed) for the French territories concerned (all situated in tropical conditions and with banana production of major economic and social importance). Additional literature searches have been conducted to update the PRA with more recent scientific articles and to make it more representative to the whole EPPO region. The text was further developed during subsequent discussions in the Panel on Phytosanitary Measures (hereafter 'the Panel').

Probability of entry, establishment, spread and potential impact, with associated uncertainties, have been based on the above-listed documents, and adapted by the EPPO Secretariat and the Panel for the EPPO region. As in ANSES (2018), a five-level scale was used for likelihoods and a three-level scale for uncertainties.

Pest: *Fusarium oxysporum* f. sp. *cubense* Tropical race 4
PRA area: EPPO region at February 2024.
Note that French overseas territories are not covered in this PRA report, while Spanish and Portuguese territories are (Canary Islands for Spain, Azores and Madeira for Portugal).
Assessors: FR PRA: Comité d'experts spécialisé Risques Biologiques pour la Santé des Végétaux, Groupe de travail Panama

EFSA pest categorization: EFSA Panel on Plant Health for the EU
FR additional documents: ANSES (collective)
IPPC guidelines: selected experts worldwide under the coordination of the IPPC Secretariat with the oversight of the IPPC Implementation and Capacity Development Committee (IC).
PRA report: prepared by the EPPO Secretariat with input from B. Delarue (FR), H. Ertas (TR), B. Martinez Martinez (ES), M. Özarslandan (TR), EFSA EWG for the EFSA categorisation on *F. oxysporum* f. sp. *cubense* TR4 (P. Reignault, I. Vloutoglou, Q. Migheli, E. Stefani) and EFSA staff (V. Kertész, A. Maiorano and A. Gobbi).
With subsequent discussions in the Panel on Phytosanitary Measures.

Date: FR PRA: 2018; EFSA pest categorization: 2022; FR additional documents: 2015, 2021; IPPC Guidelines: 2023. The Panel on Phytosanitary Measures discussed the document in 2024-03.
EPPO Working Party on Phytosanitary Regulations and Council agreed that ***Fusarium oxysporum* f. sp. *cubense* Tropical race 4** should be added to the EPPO A2 List of pests recommended for regulation as quarantine pests in 2024.

Cite this document as:
EPPO (2024) Report of a pest risk analysis for *Fusarium oxysporum* f. sp. *cubense* Tropical race 4. EPPO, Paris.
Available at https://gd.eppo.int/taxon/FUSAC4/documents

Based on this PRA report, *Fusarium oxysporum* f. sp. *cubense* Tropical race 4 was added to the EPPO A2 List of pests recommended for regulation as quarantine pests in 2024. Measures for plants for planting of *Musa* spp. (except tissue cultures and pollen), as well as soil and growing medium are recommended.

STAGE 1: INITIATION	
Reason for doing PRA:	*Fusarium oxysporum* f. sp. *cubense* causes a severe fungal disease of banana. Four races have been designated based on their pathogenicity to different reference varieties under field conditions. Within *F. oxysporum* f. sp. *cubense* Race 4, the tropical race 4 (TR4) was identified in South-East Asia infecting a wide range of banana cultivars, including Cavendish clones. TR4 was later reported from Africa (Mozambique in 2013) as well as Latin America where approximately two thirds of the world banana trade originate (first record for Colombia in 2019) (EPPO, 2023). In the EPPO region, TR4 has been reported as present with a restricted distribution in Jordan and Türkiye, and transient in Israel (under eradication) (EPPO, 2024). *Fusarium oxysporum* f. sp. *cubense* TR4 was added to the EPPO Alert List in 2023. The Panel decided that a PRA report should be prepared based on the EFSA pest categorization (EFSA, 2022), the French PRA (ANSES, 2018), and the IPPC Secretariat prevention, preparedness and response guidelines (IPPC, 2023).
Taxonomic position of pest:	Ascomycota, Sordariomycetes, Hypocreales, Nectriaceae, *Fusarium*, *Fusarium oxysporum* f. sp. *cubense* Tropical race 4 (thereafter 'TR4'). In 2019, it was proposed to consider TR4 as a distinct species, *Fusarium odoratissimum*, but this is still being debated (EPPO, 2023; 2024). TR4 is one of two distinct sub-races within *F. oxysporum* f.sp. *cubense* race 4, the second is ST4 (subtropical race 4) (ANSES, 2018; EFSA, 2022). ST4 infects Cavendish cultivars where plants are exposed to stress conditions (EFSA, 2022, ANSES, 2018) and is considered to have lower importance. TR4 can be differentiated from other races of *F. oxysporum* f. sp. *cubense* using PCR methods and further analysis to confirm the vegetative compatibility group (VCG) of the isolate. All isolates of TR4 belong to the VCGs 01213-01216 (EFSA, 2022). IPPC (2023) mentions that complete genome sequencing can be used instead of VCG determination. EFSA (2022) notes that PCR on its own may generate false positives, and therefore notes an uncertainty on TR4 distribution when the VCG has not been determined. Issues with several PCR tests are mentioned in EFSA (2022) and Maymon *et al.* (2020). A combination of phylogenetic analysis, VCG testing, sequence analysis and pathogenicity tests should be adopted for the unambiguous identification of the pathogen (EFSA, 2022 citing Magdama *et al.*, 2019).

STAGE 2: PEST RISK ASSESSMENT

PROBABILITY OF INTRODUCTION

Entry

Geographical distribution: (Source: EPPO Global Database last consulted 2024-01-19, details on distribution are available in Global Database)	**AFRICA**: Comoros, Mayotte, Mozambique. **AMERICA**: Colombia, Peru, Venezuela. **ASIA:** China, India, Indonesia, Israel (transient; under eradication), Japan, Jordan, Laos, Lebanon, Malaysia, Myanmar, Oman, Pakistan, Philippines, Taiwan,

Thailand, Vietnam.
OCEANIA:
Australia, Micronesia, Tonga.
EPPO REGION:
Israel, Jordan, Türkiye.

EFSA (2022) notes uncertainty on the distribution of TR4, because reliable identification requires determination of the VCG (or alternatively complete genome sequencing according to IPPC, 2023).

The identity of the pathogen in Israel, Jordan and Türkiye is confirmed (Maymon *et al.*, 2020; Ploetz *et al.*, 2015; Özarslandan & Akgül, 2020; M. Özarslandan, pers. comm.).

In Mayotte, the pest is under official control (B. Delarue, pers. comm.; see 'Eradication').

Major host plants or habitats:

Musa acuminata (major host), *Musa* (host), *Chloris barbata*, *Cyanthillium cinereum*, *Euphorbia heterophylla*, *Tridax procumbens* (all four, wild/weed hosts), *Eleusine indica* (experimental host) (Source: EPPO Global Database last consulted 26-02-2024; references on host status are available in Global Database).

The genus *Musa* is generally considered susceptible to TR4 (EFSA, 2022, ANSES, 2018, IPPC, 2023). Similarly to EFSA (2022), this PRA report focuses on cultivated *Musa* spp.

M. x paradisiaca, *M. schizocarpa* and *M. textilis* are also listed in EFSA (2022, citing Stover, 1962).

Musa acuminata and several genetic groups (triploids) arising from *M. acuminata* (AA) and *M. balbisiana* (BB) are hosts, in particular the Cavendish subgroup (AAA) that is widely cultivated for dessert bananas. TR4 was also found associated with several other subgroups within AAA, AAB and ABB (ANSES, 2018 citing others; Mostert *et al.*, 2017). Ornamental *Musa* (used as plants or cut flowers - such as *M. ornata*, *M. basjoo*, *M. velutina*) are assumed to be covered in both assessments, and therefore in the present report.

Weeds and grasses can be alternative hosts of TR4 but they do not usually show symptoms (IPPC, 2023 citing Ploetz, 2015).

Which pathway(s) is the pest likely to be introduced on:
(see EFSA, 2022, ANSES, 2018, IPPC, 2023. All pathways have been reworded according to the categories defined in the guidance document for EPPO Standard PM 5/5[1])

TR4 has already entered the EPPO region. No information was found on pathways for these introductions. The present report discusses pathways covered in EFSA (2022) and ANSES (2015, 2018), and mentioned in IPPC (2023). OIRSA (2019) provides an illustrated description of pathways.

Elements that apply to many pathways:
The following life stages may be associated with:

- above-ground plant parts: microconidia, macroconidia and mycelium.
- underground plant parts: chlamydospores and mycelium.
- soil/growing medium (if *Musa* plants were grown in the soil/growing medium, or closeby and transported with water): chlamydospores and sclerotia

The likelihood of association is increased by a higher inoculum density in

[1] https://www.eppo.int/media/uploaded_images/RESOURCES/eppo_standards/pm5/guidance_pm5-05.pdf

soil. In addition plants may be asymptomatic (ANSES, 2018). TR4 may have a long incubation period (2-6 months) (EFSA, 2022 citing Rishbeth, 1957). TR4 survives saprophytically for long periods in debris in the soil (EFSA, 2022), up to 30 years according to ANSES (2018).
There is uncertainty about the distribution of TR4 in areas of production of plants for planting, and the susceptibility of various *Musa* species to TR4 (ANSES, 2018).
From areas where the pest is present, the likelihood of association is lower from areas where strict measures against TR4 are implemented (exclusion, and destruction of infested plants) compared to areas where such measures are not applied (ANSES, 2018). Such measures appear to be widely applied where TR4 is found in order to contain the disease.

- **Host plants for planting (except tissue cultures and pollen)**

This pathway covers plants for planting with or without roots (ANSES, 2018), accompanied or not with soil or growing medium, including corms (i.e. rhizomes) and suckers. It also covers *in vitro* plants pre-acclimated in nursery on growing medium (ANSES, 2018). Ornamental banana plants are also covered.
No life stages of the fungus are associated with pollen, which is therefore not covered. Tissue cultures are discussed further down.Weeds associated with plants in soil may carry the pest, but this is not further assessed.
In the EU, existing specific requirements for plants for planting of *Musa* relate to *Ralstonia* species (EFSA, 2022), and would not ensure freedom from TR4.
TR4 would survive during transport and storage (ANSES, 2018), and multiplication may happen. Transfer would occur as the pathogen could develop on the infested plant. If the pathogen is in soil associated with banana plants, it could infest other host plants.
No specific trade data was found, and it is not known if there is a trade from infested areas.
For Türkiye, it is mentioned that planting relies on suckers for open field, and tissue cultures for protected conditions (Gubbuk *et al.*, 2018). Galán Saúco (2020) mentions that Israel and Egypt are the only countries in the subtropics (they cover all EPPO countries with banana cultivation for fruit as part of the subtropics) using almost exclusively tissue culture plants for commercial planting, while others use both *in vitro* plants and conventional planting materials (suckers or rhizomes).
No information was sought on ornamental *Musa* plants for planting.
Plants for planting could also be transported by travellers.

Plants for planting (except tissue cultures and pollen) are a potential pathway for entry.

- **Tissue cultures of *Musa* sp.**

Tissue cultures of *Musa* spp. are considered unlikely to carry the pathogen (EFSA, 2022), because they are produced in strict conditions, and the plant material used would not carry the fungus. Similarly, ANSES (2018) considered association with *in vitro* plants produced in the laboratory on artificial media as very unlikely.

For the EPPO region, tissue cultures are considered a very unlikely pathway.

- **Host fruit**

Externally, fruit may be contaminated with soil or plant debris carrying TR4 (ANSES, 2015, 2018). Internally, it was shown that the pathogen can invade the fruit peduncle via the xylem vascular bundle, causing discoloration, and that isolates from discoloured peduncles are able to infect Cavendish banana

plants (EFSA, 2022 citing Bai *et al.*, 2020). EFSA (2022) therefore considered that imported fresh banana bunches with peduncles may be a risk, as they may carry part of the potentially infected peduncle. *'However, uncertainty exists on the ability of TR4 to invade xylem vessels in the terminal clusters and in the banana fingers (fruits).'*

The EU quality standards for banana fruit (EU, 2011) provide that bananas may be imported in the form of hands, clusters (parts of a hand) or fingers (individual fruits, parts of a cluster). Amongst other requirements, bananas should be: *clean, practically free from visible foreign matter; with the stalk intact, without bending, fungal damage or dessication*; *practically free from pests and from damage caused by pests*; *hands and clusters (parts of hands) must include* a *sufficient portion of crown of normal colouring, sound and free from fungal contamination*. No information was found on whether such measures exist for import into other EPPO countries.

Routine procedures such as described in Australian Government (2004) may be applied in international trade to ensure the quality of bananas, such as washing (hosing fruit bunches with water), immersion of de-handed fruit in water treated with chlorine and alum, and sponging and brushing of visibly contaminated fruit. This would limit contamination with soil or plant debris.

There is a massive trade of bananas from countries where the pest occurs, at least into the EU, with over 1.3 million tons in 2020 (fresh or dried), mostly from Colombia (over 1.2 million tonnes), Peru (over 100 000 tonnes) and small quantities from other countries (EFSA, 2022). Galán Saúco (2020) mentions that in Türkiye and Israel, respectively high taxes and strict phytosanitary requirements hinder import of banana fruits.

EFSA (2022) states that transfer to *Musa* plants for planting in the EU via fresh fruits traded in clusters with peduncle will depend on the volume and frequency of imported commodities, their final destination (e.g. retailers, packinghouses), the proximity to the banana hosts and the management of fruit/leaf waste. The management of waste would also influence transfer of TR4 as a contaminant on fruit.

Banana fruit contaminated with soil or plant debris carrying TR4, and banana bunches with peduncles are a potential pathway. There is an uncertainty on whether TR4 can infest individual fruit. This pathway is relevant mostly where import and production happen in the same facilities/areas (e.g. waste dumped in banana plantations), but there is an uncertainty on whether this happens in the EPPO region.

- **Fresh cut plant parts of hosts: cut foliage (banana leaves), cut flowers**

Fresh leaves of *Musa* have become popular for cooking, food wrapping and food serving (EFSA, 2022). ANSES (2018) also mentions cut flowers. These may be ornamentals or for experimental use in genetic improvement programmes (OIRSA, 2019). The conditions of transport are not known, and therefore whether they are conducive to survival. No specific data on trade was found. EFSA (2022) states that transfer to *Musa* plants for planting in the EU via fresh banana leaves will depend on the volume and frequency of imported commodities, their final destination (e.g. retailers, packinghouses), the proximity to the banana hosts and the management of fruit/leaf waste. This would also apply to cut flowers.

Cut leaves and cut flowers are theoretically pathways. This pathway is relevant mostly where import and production happen in the same facilities/areas (e.g. waste dumped in banana plantations), but there is an uncertainty on whether this happens in the EPPO region. However, there is a high uncertainty associated with this pathway (volumes of trade, survival of the pathogen on this material).

- **Other commodities from banana plant parts**

These include:
- manufactured/processed commodities made from banana leaves (such as ropes, bags, baskets, products made from banana leaves - ANSES, 2018, - handicrafts - IPPC, 2023)
- stored products (dried banana fruit).

There is a high level of uncertainty as to whether TR4 can be associated with and survive on such commodities.

In any case, entry on these pathways is unlikely because of transfer.

- **Soil and growing medium on its own**

This pathway covers soil and other growing media, incl. substrates such as coco fiber, potting media (ANSES, 2018). In the EU, the introduction of soil on its own from third countries other than Switzerland is prohibited (EFSA, 2022), and such prohibitions likely apply to many EPPO countries. Import of used growing media seems unlikely. Transfer from soil may happen if imported soil or growing medium is used for cultivation of banana plants. EFSA (2022) considers that soil and other substrates represent a potential pathway of entry of the pathogen into the EU territory.

For the EPPO region, soil and growing medium on its own is considered a pathway with a low likelihood of entry. There are uncertainties on the trade of such commodities, and transfer would require that they are then used to grow banana.

- **Natural spread**

EFSA (2022) considers that TR4 is unlikely to enter the EU through natural spread. Within EPPO, the pathogen is likewise unlikely to reach new countries from current outbreaks by natural spread. However natural spread may be relevant for spread locally.
The only exception may be between Jordan and Israel where there are banana plantings close to each other, but with uncertainties as to whether growing conditions (protected conditions, drip irrigation) favour natural spread (see Spread further down).

- **Contamination by soil or plant debris carrying TR4 of**
  - **Non-host plants for planting/plant parts with associated soil/growing medium**
  - **Used machinery, vehicles, farm equipment and tools**
  - **Traveller's footwear**
  - **Shipping containers**

These pathways are covered in ANSES (2018) and IPPC (2023). Transfer is unlikely unless planted in/used/visiting banana production areas/places/sites at destination, or contaminated soil is disposed of in banana production areas/places/sites at destination.

For the EPPO region, these are considered overall as unlikely pathways, but there may be specific circumstances of imports from infested areas into banana production areas/places/sites, which may make transfer possible. Many uncertainties are associated with these pathways, such as whether non-host plants are produced in infested soils, whether specific banana machinery is used and traded internationally, the part of the infested area subject to containment plans (which would imply measures mitigating association).

Overall, most of the risk of TR4 entering the EPPO region is with banana plants for planting (except tissue cultures and pollen).

Entry with host fruit and fresh cut plant parts of hosts is less likely, as well as on various pathways carrying contaminated soil. For all pathways, there are uncertainties on the trade into the EPPO region from infested areas.

Establishment

Plants at risk in the PRA area:

Musa spp., especially cultivars of the Cavendish groups, which are the most grown for fruit production also in subtropical areas (Galán Saúco, 2020). Cultivation of banana for fruit production is limited to warm areas of the EPPO region. In some areas of the EPPO region, different types of *Musa* may be grown in gardens for fruit consumption. In addition, in subtropical areas, greenhouse production of bananas occurs in Morocco, Türkiye, Israel and Spain (Canary Islands) (Galán Saúco, 2020). Ornamental bananas may be grown in other parts of the EPPO region. Some ornamental *Musa* spp. are cold tolerant (e.g. *M. basjoo* to – 15°C; Anonymous, 2024).
In areas where fruit or ornamental *Musa* are not grown outdoors, there may be limited presence under protected conditions.

Areas harvested for bananas (fruit) in EPPO in 2022 (FAOStat, 2024).

country*	**harvested area (ha)**
Türkiye	14203
Spain	8892
Morocco	8482
Israel	3351
Portugal	1160
Jordan	826
Cyprus	210
Greece	100
Algeria	10

* FAO Stat (2024) also provides data for France, but this corresponds to overseas territories, which are not covered in this EPPO PRA report.

- In Türkiye, banana is grown on the south-eastern Mediterranean coast (mainly Antalya and Mersin provinces, also Hatay and Adana – Özarslandan, 2022). In 2016, two-thirds of the production (at the time about 4000 out of 6200 ha) was under protected cultivation. The area cultivated with bananas has increased from 1725 ha in 2000 (Gubbuk *et al.*, 2018) to 14200 ha in 2022 (FAOStat, 2024).
- In Spain, banana is grown commercially mostly in the Canary Islands (in 2022, out of 8892 ha in total, 1942 ha in Gran Canaria and 6950 ha in Tenerife) (Spanish NPPO, pers. comm.).
- In Portugal, banana is grown mostly on Madeira and Azores (Galán Saúco 2020). In 2018, out of a total acreage of 1045 ha, there were 758 ha on Madeira and 287 ha on Azores (DREM, 2019; SREA, 2019). EU (2011) makes provisions regarding banana production in Algarve, but this probably relates to small areas.

TR4 can survive in the soil for many years. ANSES (2018, citing Ploetz, 2015) mentions that in the absence of banana, other plants may allow multiplication of TR4, however, this has not been demonstrated to date.

All areas where banana is cultivated are considered favourable to establishment.

Climatic similarity of present distribution with PRA area (or parts thereof):

Under *in vitro* conditions, TR4 grows in a range of temperatures between 9°C and 38°C, with an optimum growth between 23°C and 27°C. Usually, the disease is more intense during the warmer and wetter months of the year (EFSA, 2022 citing Pérez-Vicente *et al.*, 2014).

TR4 is widely present under subtropical and tropical climates.

Climatic zones where the pathogen is present are comparable to some climatic zones within the EU (based on Köppen Geiger – EFSA, 2022). The temperate climates illustrated on the map below are present in very limited areas of some countries where TR4 has been found (EFSA, pers. comm.), but there is no specific data on the presence of TR4 under these climate types.

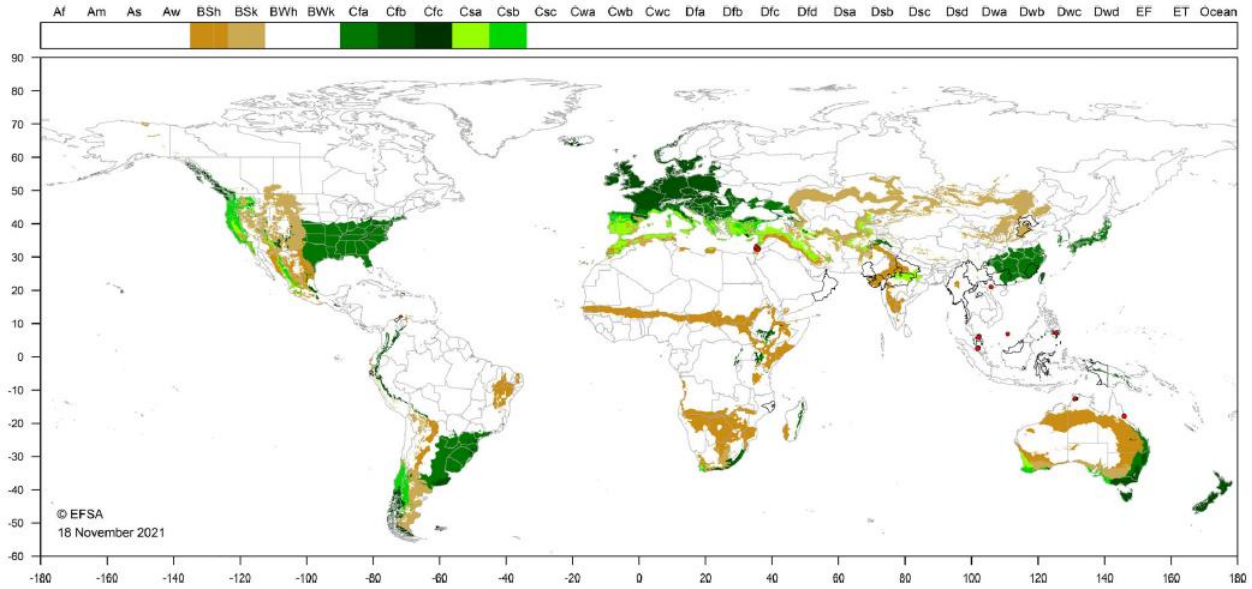

Fig. 1. TR4 climate suitability analysis based on the Köppen-Geiger climate classification. Regions with black borders indicate countries/regions where the pest is present. Red dots indicate point locations where the pest was found (EFSA, 2022).

EFSA (2022) concludes that climatic conditions in some parts of the EU (mainly in southern Member States) are favourable for the establishment of TR4 outdoors. In addition EFSA (2022) does not exclude that TR4 may also establish under protected conditions at higher latitudes in the EU, and that climate change may lead to 'northward expansion of tropical crops'.

In the EPPO region, the areas of climatic suitability overlap the areas of commercial cultivation of banana. There is an uncertainty as to whether TR4 could establish outdoors under temperate climatic conditions (where mostly ornamental *Musa* spp. are grown).
TR4 could establish on banana under protected conditions throughout the EPPO region.

Characteristics (other than climatic) of the PRA area that would favour establishment:

- No current sanitary practices would prevent establishment (ANSES, 2018)
- Vegetative reproduction favours establishment: chlamydospores ensure long-term survival and there is an abundant production of conidia (ANSES, 2018).

Which part of the PRA area is the area of potential establishment:

The part of the EPPO region where *Musa* spp. are grown, outdoors and in protected conditions.

Spread

Briefly describe each mode of spread (natural, human assisted)

Spread rates in terms of plants infested in plantations have been reported from some tropical countries. In Taiwan, TR4 was reported on Cavendish in 1967, and the number of infested plants increased to 5536 within 3 years, and to approximately 500 000 by 1976, i.e. 1200 ha (EFSA, 2022 citing Hwang & Ko, 2004). In one site in Malaysia, the incidence of the disease reached over 50% plants within 3 years in a 300 ha plantation (ANSES, 2018 citing Ong Kim Pin, 1996). Finally, in Laos there was a '*rapid epidemic development*'

within 5 years in the 3 northern provinces (ANSES, 2018 citing Chittarath *et al.*, 2018, de Lapeyre *et al.*, 2017).

In the EPPO region, an hypothesis was made of spread between Jordan and Israel because some contaminated plots in Israel were close to contaminated plots in Jordan (1-10 km); spread may have been due for example to workers, soil, wild pigs or agricultural products (Maymon *et al.*, 2020). However this has not been confirmed. Within Jordan, the pathogen may have been present since at least 2005, but only some production areas were reported infested in surveys conducted by Ploetz *et al.* (2015).

TR4 can spread through the following mechanisms:

- at long and short distance, human-assisted spread *'(e.g. asymptomatic, albeit infected, rhizomes/suckers used as planting material; fresh fruits commercialised in bunches with the peduncle and collected from infected plants, farm tools and machinery, clothes, footwear, tools, containers, etc., which have been used in Foc TR4-infested areas)* (EFSA, 2022).
  Plants for planting may be a major spread mechanism, at least within a country, and if there is movement of propagating material of banana between EPPO countries.
- at short distance: mat to mat (plant to plant) spread, water run-off incl. irrigation water, animal movement or contaminated soil (EFSA, 2022) as well as contaminated waste (ANSES, 2018). Such spread is likely to occur within and between production places. In Jordan, contamination at the borders of plantings was observed, in one case adjacent to a former banana planting that had been eliminated by TR4 (Ploetz *et al.*, 2015). Finally, cut banana leaves can be used locally to feed livestock, and may contribute to spread (Spanish NPPO, pers. comm.).

The role of wind-blown rain in the dispersal of TR4 is uncertain, as there are no studies confirming this means of spread, although in the Caribbean countries, which are frequently affected by hurricanes, strong wind accompanied by heavy rain causing flooding is considered as an important means of TR4 dissemination (EFSA, 2022 citing Pérez-Vicente *et al.*, 2014).

Run-off water may ensure some spread according to ANSES (2018); however, the French territories concerned are in tropical areas, while in most of the EPPO region, banana is grown under irrigation in areas where rainfall - and run-off- would be more limited. Galán Saúco (2020) notes that, while in Azores rainfall is appropriate for banana cultivation, all other countries in the subtropics use irrigation. Drip irrigation is preferred in Israel, Morocco, Türkiye and the Canary Islands due to water scarcity. In parts of Madeira, flood irrigation is also used.

Animals can carry spores to other banana plants, such as nematodes and weevils (IPPC, 2023), wild and domestic animals, or the banana weevil *Cosmopolites sordidus* (ANSES, 2018). However, at least *C. sordidus* was assessed to have a very minor role for the speed of spread in the French territories concerned (ANSES, 2018).

ANSES (2018) assesses that, once TR4 is established in an area, spread is very likely. Infested plants for planting and soil contaminating tools, vehicles or footwear would ensure the most rapid spread. They estimate a rapid spread at the global scale. For the French territories considered, within 5 years, TR4 would establish in 50% to 100% of the area of potential establishment. This relates to areas where banana is grown outdoors under tropical climates. It is not clear if similar spread would also occur in the EPPO region. There is no evidence that this has happened in the Middle East where banana is grown

under irrigation, partly under protected conditions.

POTENTIAL ECONOMIC CONSEQUENCES

How much economic impact does the pest have in its present distribution:

In its current distribution, TR4 affects a wide range of banana cultivars, including Cavendish cultivars, which are commonly grown in large monocultures, including for export. TR4 can destroy the entire crop, i.e. causing significant economic impact to commercial banana growers and exporters (EFSA, 2022 citing Mostert *et al.*, 2017). Impact on banana production can be massive (ANSES, 2018).

Within 5 years, TR4 causes high levels of mortality on Cavendish cultivars, but also others. Banana cropping is not possible during many years in areas found infested (pathogen persistent up to 30 years in contaminated soil; ANSES, 2018). In Malaysia, the annual loss due to this fungus was calculated as 14.1 million USD, in Indonesia 121 million USD, and on 'Cavendish' bananas in Taiwan 253.3 million USD (EFSA, 2022 citing others).

In the EPPO region:

- In Jordan, impact was reported in the Shooneh Janoobiyeh district, where the disease was prevalent. Producers had observed losses of banana plants since at least 2005. In some infested areas, many banana fields were abandoned or showed high percentages of symptomatic plants, while production was still ongoing in other infested areas (Ploetz *et al.*, 2015).
- In Türkiye, surveys were conducted in 2018-2019 in part of the banana production areas of the provinces of Adana, Antalya, Hatay and Mersin. TR4 was detected in 8 out of 117 plantations (total 5 ha), with severe symptoms in 3 plantations and no noticeable symptoms in others (Özarslandan, 2022). Infected plants were removed and destroyed. The limited detection of TR4 in Türkiye is because these areas are protected-plastic greenhouses, closed to free access from outside, and the plants are watered with drip irrigation. Preventative measures have also been implemented since 2019. In addition, producing bananas in disease-free soil and using banana seedlings propagated in tissue culture from disease-free rootstocks is recommended. Regular surveys are conducted in banana production areas, to monitor spread, identify infested areas, and detect potential sources of infection. Collaboration with banana growers is ensured, and information on measures to be taken against the disease is provided. (M. Özarslandan, pers. comm.).

Control efforts worldwide currently focus on the development of resistant cultivars, but no alternative commercial banana clones resistant to the pathogen exist to date (Maymon *et al.*, 2020). Current management methods include:
- destruction of banana plants in a large area around infested ones.
- confinement of outbreaks and farms (ANSES, 2015).

The magnitude of impact in the current distribution overall is considered very high with a low uncertainty (as in ANSES, 2018).

Describe damage to potential hosts in PRA area:

On susceptible plants, TR4 causes leaf yellowing followed by wilting of leaves and of the entire canopy, leading to plant death. This may be accompanied with stem splitting and vascular discoloration. TR4 has a long term impact due to long term contamination of soil (persistence up to 30 years; using different cultivars is not possible; reconversion between crops or abandonment of soil for agricultural purposes can happen) (ANSES, 2018).

How much economic impact would the pest have in the PRA area:	TR4 is considered as 'the biggest threat to banana production' (IPPC, 2023). At the scale of the EPPO region, banana is not a major crop over the whole potential area of establishment. However, it has economic and social importance in some countries and at a local scale. Bananas in the EPPO region are mostly destined for the national market or local use (Galán Saúco, 2020). For the EU, the economic impact on the European banana production would be devastating should the pathogen be introduced and spread (EFSA, 2022). In the rest of EPPO, Türkiye has the largest area of banana cultivation. TR4 may have high economic impact in some countries and territories, especially where the environmental and production conditions are favourable to TR4. TR4 may also have social impacts, in particular where local communities are heavily reliant on banana production (for jobs and food). In its current distribution, including Jordan, TR4 has caused abandonment of banana fields (ANSES, 2018 citing Molina *et al.*, 2009; Ploetz *et al.*, 2015). Relocation of banana production has been reported in part of TR4 distribution, but in the EPPO region limited areas present the conditions necessary for banana cultivation. From information from EPPO countries where the pest was introduced, some impact was observed in Jordan and Türkiye. Conditions in part of the EPPO region are similar to these countries. TR4 could have economic and social impact in the EPPO region.

CONCLUSIONS OF PEST RISK ASSESSMENT

Summarize the major factors that influence the acceptability of the risk from this pest:

Estimate the probability of entry:	*High with a moderate uncertainty.* Plants for planting of *Musa* spp. (except tissue cultures and pollen) are the main pathway. Transfer is a limiting factor for other pathways. There are uncertainties affecting the assessment.
Estimate the probability of establishment:	*Very high with a low uncertainty.* The pest has already established in the EPPO region, and additional areas with suitable conditions (host and climate) exist in the EPPO region.
Estimate the magnitude of spread:	*High with moderate uncertainty.* There is no information on spread from the current outbreaks in the EPPO region. However, a number of mechanisms, natural and human-assisted, would contribute to spread. The magnitude of spread may be higher if TR4 was introduced into an area that provides propagating material to other areas of the EPPO region, especially if it was not detected early. Spread with water is more likely in areas where there is abundant run-off water, compared to dry areas where drip irrigation is used.
Estimate the potential economic impact:	*High with a moderate uncertainty for the potential area of establishment.*
Degree of uncertainty:	From EFSA (2022), the uncertainties on host range, whether banana fresh fruits (fingers) commercialised in clusters is a pathway and geographic distribution do not affect the conclusions of the pest categorisation. For the current PRA report, if fruit (fingers) can be infested, this may change

the likelihood of entry (considering the massive trade of bananas) and the need for measures.

In addition,
- uncertainty about the host status of many *Musa* spp. would affect the conclusions of the current PRA report for cut fresh plant parts.
- uncertainty about the origin and amount of trade of planting material in EPPO countries.
- uncertainty about potential impact in the EPPO region where banana is grown under irrigation.

OVERALL CONCLUSIONS TR4 may enter, establish, spread and cause impact in areas of the EPPO region that are currently free from the pest. It poses a risk to the EPPO region and risk management options should be considered.

TR4 has been considered by EFSA to satisfy all the criteria that are within its remit to assess for it to be regarded as a potential Union quarantine pest (EFSA, 2022).

STAGE 3: PEST RISK MANAGEMENT

IDENTIFICATION OF THE PATHWAYS

Evaluation of the need for management measures for the different hosts:
Measures are recommended for the genus *Musa*.

Management measures are proposed for:
- Plants for planting of *Musa* spp. (except tissue cultures and pollen)
- Soil and growing medium

General recommendations are also made for banana fruit, non-host plants for planting/plant products with associated soil or plant debris, shipping containers, used machinery and used vehicles, and travellers' footwear entering a banana area/place/site of production.

No management measures (phytosanitary measures) are required for fresh cut plant parts of hosts due to unlikely transfer. If measures are deemed necessary, they could be based on those for plants for planting.

It is noted that the risk as evaluated in ANSES (2018) for French overseas territories leads to recommending prohibitions from areas infested by TR4 for: bananas, suckers, bulbs and tubers ('for consumption and planting'), cut flowers, rooted plants for planting, soil and growing media. Such prohibition is later mentioned as not feasible, and eventually the recommended prohibitions apply to bananas, bulbs and tubers, and plants from planting from infested areas. These were not retained here.

IDENTIFICATION OF POSSIBLE MEASURES

Possible measures for plants for planting of *Musa* (except tissue cultures and pollen)
Measures related to the crop or to places of production:
- PFA (EFSA, 2022)

ANSES (2018) considered that a PFA is not possible due to natural spread, to the difficulties in implementing containment plans, and to the heterogeneous distribution of the pathogen in banana plantations (leading to not detecting the pathogen because of non representative sampling). However, PFA was kept in this PRA report (as in EFSA, 2022).
- Pest-free production site/pest free place of production established according to EPPO Standard PM 5/8 Guidelines on the phytosanitary measure 'Plants grown under physical isolation'.
- Pest-free production site (EFSA, 2022)

Considering natural spread, especially with water, only isolation was mentioned (above).
- Certification scheme (production in a certification scheme may also be equivalent to PFPS/PFPP established according to Standard PM 5/8).

Measures related to consignments:
None

Measures upon entry of the consignments:
- Post-entry quarantine for at least 6 months with inspection and testing of pseudostems with representative sampling

The incubation period may be 2-6 months (see above). The feasibility of keeping *Musa* plants for planting in post-entry quarantine for 6 months should be considered.

Possible measures for soil and growing medium
- Originating from a PFA
- Treatment (in the framework of a bilateral agreement)

TR4 could be eliminated from growing media (chemical, heat, irradiation) (ANSES, 2018 citing McNamara *et al.*, 2003 et Zhang *et al.*, 2016), but there is no specific data for this pest.

EVALUATION OF THE MEASURES IDENTIFIED IN RELATION TO THE RISKS PRESENTED BY THE PATHWAYS

The pest could be difficult to eradicate or contain if introduced therefore measures should be taken to prevent its further entry and spread in the PRA area.

Degree of uncertainty	Uncertainties in the management part are: Host plants. Whether fruit can be infected.

IDENTIFICATION OF POSSIBLE MEASURES

Pathway	Measures
Plants for planting of *Musa* spp. (except tissue cultures and pollen)	Pest free area (ISPM 4, ISPM 29)[1] (see requirements below) **OR** Growing in a pest free place of production/production site[2] for TR4 established according to EPPO Standard PM 5/8 *Guidelines on the phytosanitary measure 'Plants grown under physical isolation*[3] **OR** Post-entry quarantine for at least 6 months (in the framework of a bilateral agreement)
Soil and growing medium on its own	PFA (ISPM 4, ISPM 29)[1] (see requirements below) **OR** Treatment (in the framework of a bilateral agreement)

[1]*: PFA may be recognized under a bilateral agreement in accordance with ISPM 29 (IPPC, 2017).*
[2]*: The choice between PFPP and PFPS is a decision to be taken by the NPPO based on the operational capacities of the producers and biological elements.*
[3]*: A certification scheme accompanied with measures to prevent entry of the pathogen in the facilities would fulfil* EPPO Standard PM 5/8 *Guidelines on the phytosanitary measure 'Plants grown under physical isolation'.*

In addition to phytosanitary measures to be implemented by exporting countries, the Working Party encourages importing EPPO countries to implement the following measures:
- Non-host plants for planting and plant products entering an area/place/site of production of banana plants/fruit should be free from infested soil and plant debris (e.g. washing, replacement of growing medium).
- Used shipping containers, machinery, vehicles and equipment, traveller's footwear entering an area/place/site of production of banana plants/fruit should be cleaned/disinfected.
- Fruits should not be stored or repacked at destination in (or in the vicinity of) areas/facilities that also grow banana plants.

Finally, public awareness is recommended in EPPO countries, especially in areas with places/sites of production of banana plants/fruit.

It is noted that phytosanitary requirements relating to absence of soil inside and outside shipping containers are applied, for example in Martinique for containers from Colombia (Préfet de la Martinique, 2020).

Requirements for establishing a PFA:
• If TR4 is known to occur in the country, a PFA can be established in another area only if a response plan containing all provisions of IPPC (2023) is implemented in outbreak areas, including surveillance, zoning and phytosanitary measures. There should be no risk of movement of TR4 through natural or human-assisted causes.
• To establish and maintain the PFA, a general surveillance in the area in the 2 years prior to establishment of the PFA and continued every year may be sufficient. Specific surveys for TR4 should also be carried out in the zone between the PFA and known infestation to demonstrate pest freedom. These surveys should be based on visual examination of banana plants in commercial facilities and in other settings (including gardens) and on testing of banana pseudostems at suitable sampling intensity (due to the heterogeneity of the distribution in plantations – ANSES, 2018). If the pest is present in the country, the sampling and testing programme should cover all commercial facilities.
• Surveys should include all high risk locations, such as places where potentially infested banana material may have been imported/introduced.
• All *Musa* plants for planting entering the PFA should be tested. They should be free from infested soil and plant debris (e.g. washing, replacement of growing medium).
• Non-host plants for planting and plant products entering a PFA should be free from infested soil and plant debris (e.g. washing, replacement of growing medium).
• Used containers; machinery, vehicles and equipment; traveller's footwear entering a PFA should be cleaned/ disinfected
• Public awareness campaigns should be conducted

Requirements for a pest-free place/site of production established according to EPPO Standard PM 5/8 Guidelines on the phytosanitary measure 'Plants grown under physical isolation
EPPO Standard PM 5/8 applies. In particular, the following elements should be taken into account:
- All the host plants for planting for production that enter the structure should be free of the pest concerned, and freedom should be verified prior to introduction.
- Growing media or any material (e.g. tools, equipment, vehicles, footwear etc.) likely to carry the pest which are introduced into the structure should also be free from the pest
- Water should be free from the pest
- In the case of production of in vitro plants, all mother plants should be subject to regular testing.

Eradication. IPPC (2023) states that eradication is not technically feasible due the long-term survival of the fungus in the soil.
In Mayotte (French overseas territory covered by the French PRA, ANSES, 2018), following the detection of TR4 in 2019, several outbreaks were found and management measures applied (removal and destruction of infested banana plants). Eradication is not considered possible as the fungus remains in the soil, but annual surveys are conducted (B. Delarue, pers. comm.).
In Israel, a first outbreak (detected in 2016) was declared eradicated in 2018, a second outbreak was detected in 2019 and is still under eradication (EPPO, 2024). The infected sites were confined and placed under strict supervision of the NPPO. Affected banana plantations were fenced off, access restricted and entry allowed under strict quarantine conditions only. The spread of fungal spores in rainwater was restricted by ditches that were dug around fenced affected areas (Maymon *et al.*, 2020). ANSES (2018) mentions that the first outbreak was in a particular situation of dry soil which is not favourable to survival of TR4. Amongst measures, suspension of irrigation (EPPO, 2018) may have allowed avoiding the absence of dispersal with water.

Containment is challenging and can include measures such as the following (from IPPC, 2023).
- control points of entry and exit to the affected areas;
- destruction of infected and neighbouring plants;
- prohibition of the movement of planting materials;
- controls and/or restrictions on the movement of people, equipment, soil and water in the affected area;
- wash and disinfect vehicles, equipment and tools, machinery and footwear, and manage water and soil residues;
- use of exclusive tools on the farm for cultural practices;
- regulation of agricultural practices, such as irrigation.

Measures may necessitate establishing and maintaining different zones (fully described in IPPC, 2023).

Early detection is essential to contain and delay spread (IPPC, 2023). For detection, there should be intensive sampling. Heterogeneous distribution of the pathogen in a plantation may lead to not detecting the pathogen (ANSES, 2018). Other races, and ST4, are present in parts of the PRA area, and a new outbreak may be confused for one of those. Appropriate methods should be used for identification.
Containment measures can delay spread, but where TR4 is present, disease management needs to be developed and implemented (IPPC, 2023).

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