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Banana
Tropical race 4 (TR4) fusarium wilt

What we really know about this disease and its impacts

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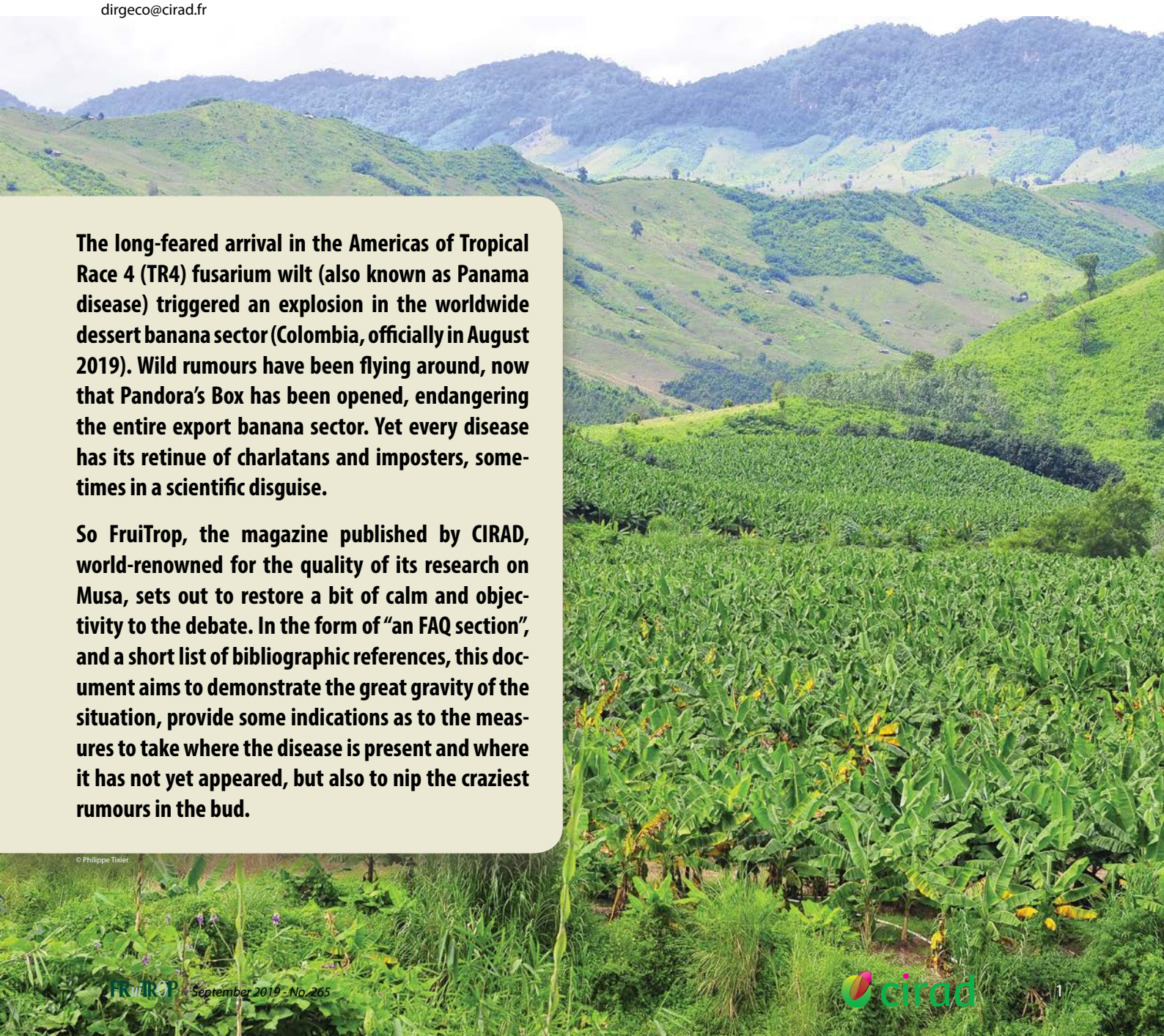

The long-feared arrival in the Americas of Tropical Race 4 (TR4) fusarium wilt (also known as Panama disease) triggered an explosion in the worldwide dessert banana sector (Colombia, officially in August 2019). Wild rumours have been flying around, now that Pandora's Box has been opened, endangering the entire export banana sector. Yet every disease has its retinue of charlatans and imposters, sometimes in a scientific disguise.

So FruiTrop, the magazine published by CIRAD, world-renowned for the quality of its research on Musa, sets out to restore a bit of calm and objectivity to the debate. In the form of "an FAQ section", and a short list of bibliographic references, this document aims to demonstrate the great gravity of the situation, provide some indications as to the measures to take where the disease is present and where it has not yet appeared, but also to nip the craziest rumours in the bud.

1. The basics on TR4

What is TR4 and what damage does it cause?

Fusarium wilt (also known as Panama disease) was first identified in 1874 in Australia on the banana (race 1). It is now found in nearly all tropical and subtropical banana production zones. The pathogenic agent responsible for the disease is a soil fungus: *Fusarium oxysporum* f. sp. *cubense* or FOC. Various races of this fungus (races 1, 2, 3, subtropical race 4 or SR4 and tropical race 4 or TR4) have been identified. Apart from race 3, which attacks only Heliconiaceae (a family closely related to Musaceae), they all cause major vascular damage under certain conditions (soil, climate, cropping intensification, drainage, etc.) in various varietal groups, making them unproductive. Race 1, for example, decimated the Gros Michel variety in the 1960s. What has just been identified in North-East Colombia is TR4. Having appeared in the 1990s, it is currently booming in South-East Asia. It attacks Cavendish and other varietal groups (including cooking bananas) under all tropical conditions. Studies are in progress to measure the sensitivity of the various varietal groups to the disease.


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External symptoms
Yellowing of the leaves and "flaring" of the pseudo-trunk

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What are the symptoms of fusarium wilt?

- **One of the most characteristic external symptoms** is gradual yellowing of the stock plant leaves (absence of initial symptoms on the shoot leaves), from bottom to top; so it is the oldest leaves which are affected first. These yellowed leaves end up completely drying out, and bend, leading to "flaring" of the pseudo-trunk.

- **The most characteristic internal symptom** is the dark red to brown coloration adopted by the inside of the leaf sheaths forming the pseudo-trunk (observable by means of a cross-section cut of the pseudo-trunk). This vascular tissue reaction proceeds from bottom to top, and from the exterior to the centre of the pseudo-trunk. The further the infection progresses, the more the tissue is affected.

Internal symptom
Coloration of vascular tissue

Photos © Philippe Tixier

How does this disease work?

This soil fungus infects the roots, and then the tissues of the bulb and pseudo-trunk. The banana reacts to this invasion by producing gums which obstruct the progression of the fungus into the plant. Hence this obstruction disrupts water and mineral transport in the banana plant. Finally, the plant dies from a kind of asphyxia.

What are the detection methods for the disease?

The presence of the disease can be visually guessed at through observation of uncertain symptoms on banana plants, but it needs to be confirmed by laboratory analyses, which take around three weeks. In fact, these analyses often require the fungus from the infected plant to be isolated, and then cultured in the laboratory. Faster molecular detection methods (based on infected banana fragments) have been developed in France. Others are under development by CIRAD, to offer a quick and less expensive tool (LAMP, loop type tool, etc.), which firstly will be able to analyse hundreds of samples quickly (banana, soil, water), and secondly detect the disease at a very early stage (before the appearance of external symptoms on the banana plants).

We can only lament that big banana exporter countries such as Colombia, Ecuador, Costa Rica and even Guatemala have not developed detection and sample analysis capabilities, though the threat of introduction of TR4 has been looming for years. The private sector, the very essence of its activity now being called into question with the arrival of TR4, must finally invest in a minimum of R&D, based specifically on State services. At present, three laboratories (European, Australian and South African) are technically able to confirm the presence of the disease, and provide its genetic filiation (type and origin of strains).

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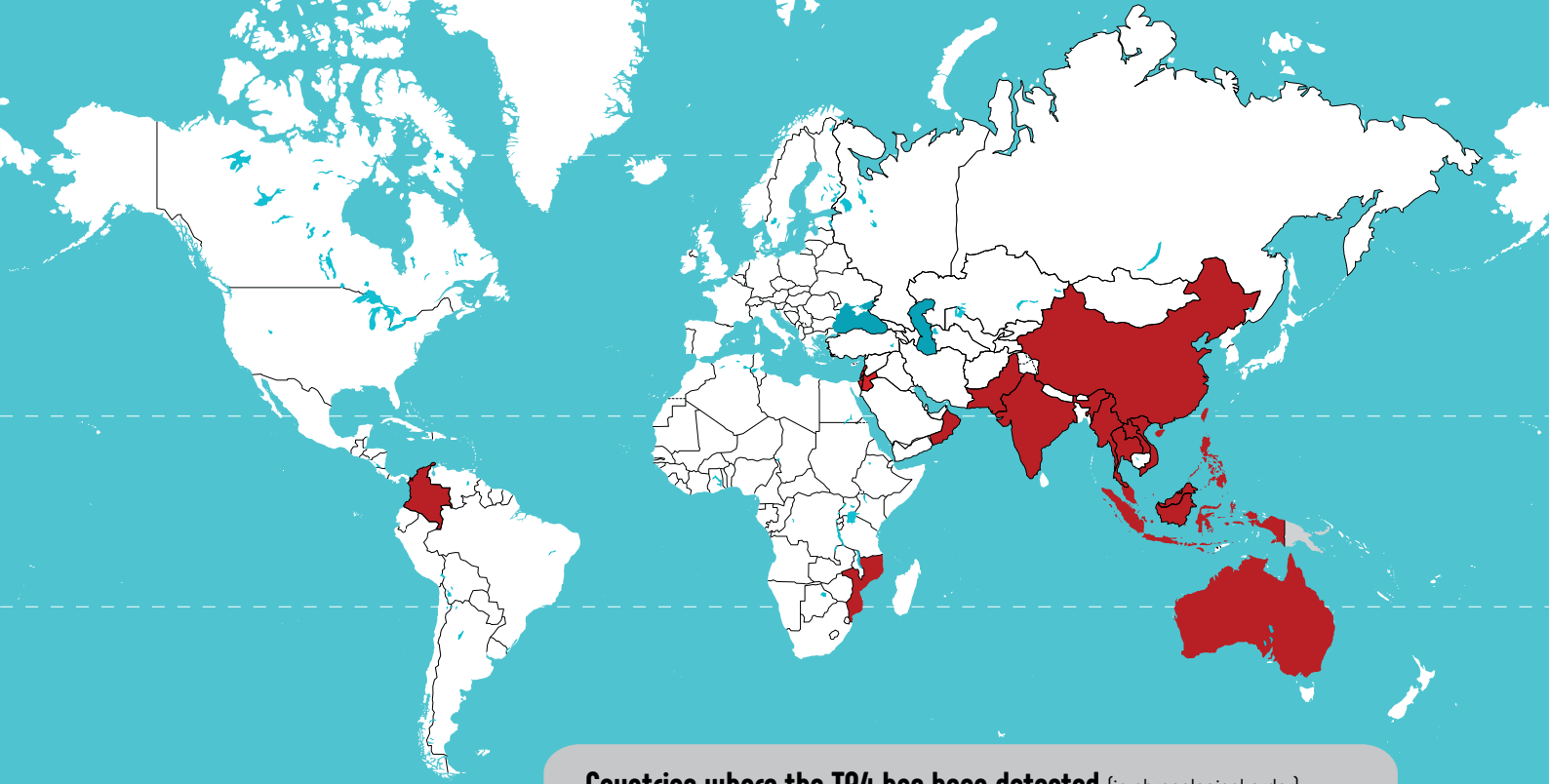

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Countries where the TR4 has been detected (in chronological order)

Taiwan (1970s)
Indonesia (1990s)
Malaysia (1990s)
Australia (1997)
Indonesian Papua (2000)
China (2001)
Philippines (2005)
Jordan (2013)
Mozambique (2013)
Pakistan (2015)
India (2015)
Oman (2015)
Lebanon (2015)
Australia (2015)
Israel (2016)
Laos (2017)
Vietnam (2017)
Myanmar (2018)
Thailand (2019)
Colombia (2019)

2. Extension and propagation of the disease

Where is the disease present today?

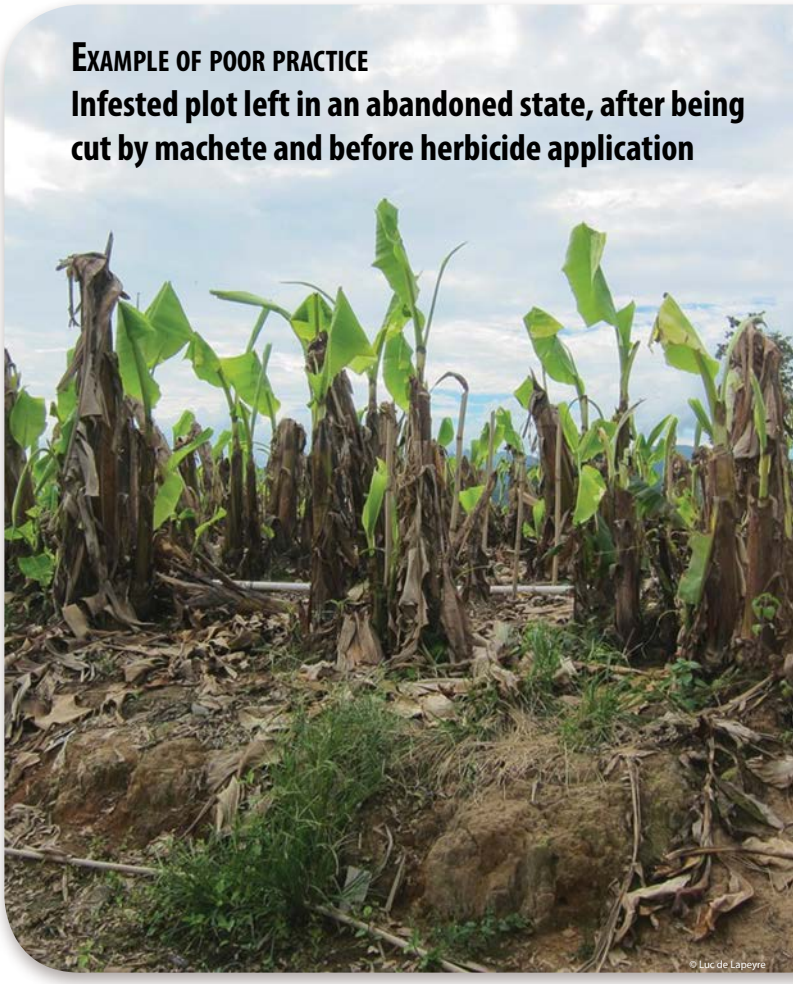
After being detected in the 1990s in Asia (Taiwan, Indonesia, Malaysia, South China, Philippines), Australia and more recently (2014) in Pakistan, it has come to the fore since its discovery from 2012 in the Middle East (Oman, Jordan, Lebanon) and above all for the first time on the African continent in Mozambique (2013), on a new Cavendish banana industrial plantation dedicated to the export sector, and shut down since. It has now crossed the ocean, having been identified for the first time in August 2019 in Colombia (north-eastern region of La Guajira).

Is it present in Africa?

Only in Mozambique. Fusarium wilt has never been reported and described in Central and Western Africa. The banana production project in Mozambique is highly restrained, and has been completely closed down and placed under surveillance, (no banana or plantain planting), especially by its immediate and not-so-immediate neighbours, such as South Africa.

Example of poor practice

Infested plot left in an abandoned state, after being cut by machete and before herbicide application



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How does this disease spread?

The main cause of large-scale dissemination of the disease is due to **human action** (visitors, labourers, local residents), whether by movements of **plant material** from sensitive and infected plantations (shoots and clumps, other host plants and substrates), by **direct contact** with infected ground on shoes/boots or tools (leaf cutters, machetes, shovels/spades, etc.). **Animals** circulating from plantation to plantation may also be involved. The micro fauna (e.g. weevils) are apparently involved in disseminating the disease. **Water** is also a vector for the fungus (rainwater run-off, drainage channels), but contamination by this route is very slow. Conversely, wind has little impact.

Can the disease be transmitted by other plants from infested production zones?

YES. The fungus can also be introduced by importing other host plants able to accommodate it. Great uncertainty remains over the range of hosts, but some asymptomatic hosts, such as ornamental plants and fruit trees, have been described. Plant substrate is also a source of transmission.

Can the disease be transmitted by fruit (bananas) from infested production zones?

NO, seemingly, but further studies are required. Although the fungus is not present in the fruit, or on banana skins, the crowns could host it asymptomatically. So the fruit is not completely without risk for the production zones.


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3. Prevention, eradication and contingency measures

Can the disease be eradicated?

NO. There is no treatment to eradicate this fungus once it has become established in the soil. Treatment products, the effectiveness of which is yet to be confirmed, are used to disinfect tools, vehicles, labourers' shoes, etc. For proof of the impossibility of eradication, Israel, where an outbreak appeared in 2016 and was quickly announced as extinct, is finally still fighting the disease (March 2019 - https://gd.eppo.int/reporting/article-6489).

Can diseased banana plants be uprooted and replaced with healthy ones to get rid of the disease?

NO, for Cavendish. Once present, the fungus eliminates any possibility of replanting Cavendish in an already infected zone for decades. It persists in the soil thanks to preservation and survival structures known as chlamydospores, and in particular has the ability to persist asymptomatically on plants other than the banana, including weeds. In so doing, it maintains its pathogenic capacity for decades, after being cut from its host plant – the banana – and despite adverse conditions (water stress, etc.). The Cavendish banana can no longer be grown for many years in zones already infested.

How to prevent propagation of the disease to other zones?

This involves stepping up **prevention** and information campaigns in countries not yet affected. This includes disseminating information, training the professionals (in agriculture, tourism) and the general public in the phytosanitary rules inherent in transporting plant material, and disinfecting equipment, shoes and substrates from infected countries.

Are prevention methods effective?

YES, if they are actually applied. As is often the case for any prevention policy against diseases or invasive pests, the implementation of the preventive actions and compliance with the phytosanitary rules are key factors for success. Furthermore, it needs to be applied for the long haul, yet very often over time alertness wanes and bad habits quickly take over, especially since this disease can quickly establish itself and spread via a host of propagation channels: plant material and contaminated soil particles, shoes and tools belonging to people working in banana plantations, wheels of agricultural machinery, wild and/or domestic animals, other host plants, surface water (and irrigation channels). Hence the risk needs to be managed at various levels: international, regional, national and local. The tension in Latin America is such that it is easy to find codes of good practice published by the industries themselves, or by the national authorities of each country.

Are contingency measures effective?

Not as yet. Current management methods (destruction of diseases plants and adjacent plants, setting up outbreak and plantation containment measures, disinfection of vehicles and personnel shoes, foot baths, etc.) are not able to eradicate the disease, but can slow it down and contain its expansion. Contingency measures become less effective as natural dissemination channels come into play, especially via the water cycle: high run-off, floods, irrigation channels, animal transit, etc.

To prevent its propagation to other zones, should the entry of all plant material from infested zones be prohibited?

YES. The entry of all plant material in any form from infested zones must be prohibited, by all means.

In disease exclusion zones, the only phytosanitary guarantee is to use vitroplants produced and acceptance-tested in a sterile medium (also providing a guarantee against any other sanitary risk), whose stock plants are certified as originating from countries officially free from the disease. For even greater security, it is preferable to obtain a sanitary certificate stating that the plants are pathogen-free (analysis based on indexing on symptom-free plants = sanitary guarantee by accumulation of proof).

Any other plant material must be excluded, particularly vitroplants in detached form (not in a sterile medium), whether with bare or clumped roots (any earth or any other substrate must be excluded).

Furthermore, since other species (cultivated or wild) have been identified as asymptomatic hosts of the disease, they must not be sampled and transported outside of the infested zone. Similarly, soil contamination of tools, containers (pots, vessels, etc.) or agricultural machinery must be prevented.

However it is vital to show discernment within a country, to refrain from generalising and take into consideration only the affected zones. For example, in Colombia, the zone concerned is La Guajira, and no suspicions have been proven true anywhere else in the country.

4. Impact of the disease

What is the impact of this disease?

There are major economic and social impacts in the affected production zones. Management of the disease is costly. Losses due to death and destruction of banana plants cause producers significant economic losses. There are still not much data regarding the economic impact of TR4. We can for example read that on a given plot, after five years, 50 % of plants are infected. On top of these yield losses, there are additional losses due to the destruction of infected plants and adjacent plants (planned destruction in management protocols for infestation outbreaks). Hence the production base may be profoundly altered in the zones concerned, in particular because of the disappearance of many small growers incapable of managing the disease and coping with revenue loss. Conversely, the big and high-tech plantations have demonstrated that they are more resilient.


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5. Some "fake news"

Can the disease be transmitted to humans?

NO. TR4 (like race 1) attacks only plants. It cannot be transmitted to humans. The fungus is not present on or inside the fruit. We reiterate that it is a fungus that lives and develops in the soil. The allegations of possible transmission and effects on humans that are emerging, including in the form of scientific publications, do not relate to this fusarium wilt.

Is this the end of the export banana?

NO. There are several countries living with the disease. This has been the case with the Philippines since 2008, yet the country has remained in the leading pack of world banana exporters. However, to achieve this, both producers and the various links in the industry have had to adapt, innovate and invest in less sensitive Cavendish varieties or in new production zones. This probably means an increase in production costs.

Hence crazy as it may seem to need to spell it out, this does not mean the end of the export banana sector in Colombia, especially since the disease has been identified in a marginal and isolated production zone (relatively far removed from Magdalena, and even further from the big Uraba production area – see Colombia country file), and the authorities have taken drastic measures to contain its possible extension to other zones. This should calm fears in the supermarket sector, which was already contemplating adjusting their supply in favour of competing origins.

6. Avenues for research

What are the avenues for research?

Efforts have largely turned toward the creation and selection of resistant or tolerant varieties (conventional hybridisation or genetic modification). Yet as ever, candidate varieties must also meet the requirements of the producers (productivity, formation of clusters, etc.) and of the markets (shape, taste, green life, etc.). A Taiwanese laboratory (Taiwan Banana Research Institute – TBRI) created several Cavendish mutants tolerant to TR4, yet most seem incompatible with the requirements of the current international market (productivity, compliance, etc.). The clone GCTCV-218, also known as "Formosana", is currently being cultivated in some countries affected by the disease (NB there are several accessions which vary in their response to the disease). Similarly, the French vitro-culture laboratory VITROPIC has a Cavendish variety which has demonstrated fairly good tolerance in laboratory conditions. Its response is under assessment in natural infestation conditions. In addition, this variety presents particularly beneficial agricultural and commercial characteristics. Furthermore, CIRAD has developed dessert banana hybrids (different from the Cavendish), exhibiting very good resistance to TR4.

7. Links to find out more

More information on the disease

ProMusa: http://www.promusa.org/Tropical+race+4+-+TR4

World Banana Forum Task Force on TR4: http://www.fao.org/world-banana-forum/disease/fusarium-tr4/en/

ICA – Colombia (in Spanish): https://www.ica.gov.co/areas/agricola/servicios/epidemiologia-agricola/fusarium-raza-4-tropical

ANSES report (in French): https://www.fruitrop.com/Articles-par-theme/Agronomie/2018/Analyse-de-risque-phytosanitaire-pour-les-departements-d-outre-mer-TR4

Video published by the Costa Rican Ministry for Agriculture & Corbana (in Spanish): https://www.youtube.com/watch?v=JGXQx512QIE

Good practice

Recommendations to prevent the entrance of diseases for the banana (in French and English): https://www.fruitrop.com/en/Articles-by-subject/Direct-from-the-markets/2019/Recommendations-to-prevent-the-entrance-of-diseases-for-banana

Good practice kit against TR4 for growers. Queensland Government, Australia: https://www.publications.qld.gov.au/dataset/panama-disease-tropical-race-4-grower-kit

Contingency Plan published by OIRSA – Organismo Internacional Regional de Sanidad Agropecuaria (in Spanish): https://www.oirsa.org/contenido/2018/Sanidad_Vegetal/Manuales%20OIRSA%202015-2018/Plan_conting_FOC_R4T_2017-V2-Final-FEB18-2017.pdf

Professional releases / Press bulletins / Regional alerts

OIRSA alert: https://www.oirsa.org/contenido/2019/ALERTA%20Foc%20Raza%204%20T%20publicacio%CC%81n%2010.07.2019.pdf

Regional Statement by the Ecuadorian Ministry of Agriculture: https://www.agricultura.gob.ec/wp-content/uploads/2019/08/Declaracio%CC%81n_Encuentro_Regional.pdf

Instituto Colombiano Agropecuario – ICA: https://www.ica.gov.co/noticias/presidente-ivan-duque-dirige-pmu-santamarta

Augura press bulletin: http://www.augura.com.co/wp-content/uploads/2019/07/ICA.-Boletin-Prensa-13.07.pdf

TR4 in Israel: https://www.fruitrop.com/en/Articles-by-subject/Direct-from-the-markets/2018/Panama-disease-TR4-in-Israel-presence-confirmed-since-2016