

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

Article ID: 37064

Diksha Sinha¹

¹Department of Plant Pathology, CSK HPKV, Palampur (H.P.), India.

Fusarium oxysporum f.sp. *cubense* (Foc) is one of the most devastating soils borne fungal pathogens of banana worldwide. Foc strains that infect Cavendish group bananas, and belong to the unique vegetative compatibility group (VCG) 01213 have been termed tropical race 4 (TR4). The pathogen has currently been renamed *F. odoratissimum*. *Fusarium oxysporum* f.sp. *cubense* tropical race 4 (Foc TR4, TR4) is one of the only six strains of *F. oxysporum* f. sp. *cubense* (Foc) that attack Cavendish bananas (AAA genome). Cavendish cultivars are the most popularly grown and exported bananas worldwide today, due to their resistance to 'Panama disease' caused by the soil-borne fungus *Fusarium oxysporum* f.sp. *cubense* (Foc) race 1.

TR4 is considered one of the most destructive Foc strains because it has a wider host range than other strains, attacking the important cultivar Cavendish, but also all the other cultivars that are sensitive to Foc. In recent years, the local incursion, widespread detection of the pathogen and continuous dissemination in India, which is the largest banana producer worldwide and establishment of the pathogen in Africa and the Middle East has caused much alarm.

Taxonomy and Nomenclature

Fusarium oxysporum f. sp. *cubense* (Foc) has been divided into pathotypes ('races') on the basis of their pathogenicity on different cultivars. Populations of Foc that affect Cavendish bananas are designated race 4. There are two subgroups within race 4: tropical race 4 (TR4) which causes disease on hosts in the tropics, and subtropical race 4 (SR4) which affects plants in the subtropics exposed to predisposing abiotic factors such as cold stress. Foc strains have also been classified into vegetative compatibility groups (VCGs), with TR4 classified as VCG 01213.

Description

The *Fusarium oxysporum* species complex is made up of similar filamentous fungi, some of which, including *Fusarium oxysporum* f. sp. *cubense* (Foc), are plant pathogens. TR4, a strain of Foc, produces three types of spores: oval-shaped microconidia, larger macroconidia and round, thick-walled asexual spores called chlamydospores. These spores can survive for up to 30 years in plant debris and soil. The spores enter a plant host through its roots, and grow long hyphae, which extend and grow in to the plant's xylem vessels. The xylem vessels become discoloured and blocked, disrupting the supply of water around the plant, and causing it to wilt.

Distribution

TR4 was first identified in Taiwan in 1989, causing Fusarium wilt in banana. Since then, it has spread to many countries in Asia, as well as Australia. Recently, the pathogen disseminated to India, Pakistan, Oman and Mozambique (Africa) and was also identified in the South American continent in Colombia in 2019.

Spread

TR4 can cause severe damage and so the spread must be contained. The fungus is commonly spread in infested suckers and rhizomes, as well as soil, water and farm machinery. Its ability to survive without its host for up to 30 years and its wider host range than other Foc strains gives TR4 great potential for spreading to new locations.

TR4 produces micro and macroconidia which can spread via surface water, rivers and streams. Vector Transmission (Biotic) Spores of TR4 can be carried by domestic animals (pigs, sheep, etc.) moving from an

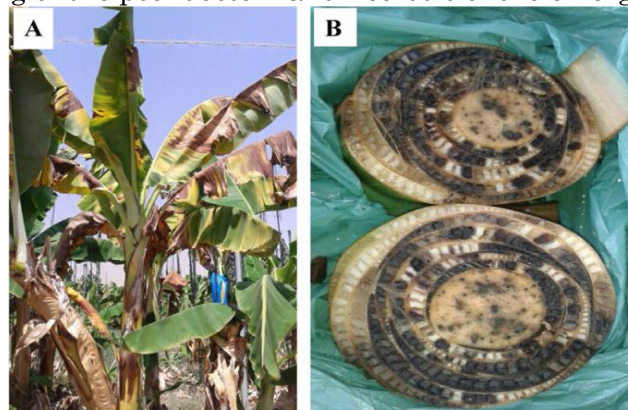
infected plantation to a plantation of healthy plants. The conidia can also be carried on the exoskeleton of insects such as the black banana weevil. A common means of dispersal is the planting of infected asymptomatic suckers in a healthy field. Infected soil attached to plant material, farm machinery and tools, vehicles or footwear is also a source of the fungus.

Hosts/Species Affected

The main hosts of TR4 are species of *Musa* and *Heliconia*. TR4 is strongly pathogenic to the commercially important banana variety Cavendish (AAA) of species *Musa acuminata*, but affects many other varieties and species than the other strains of Foc.

Symptoms

The first symptom of TR4 on banana is yellowing at the margins of older leaves, beginning at the base of the petiole. The discoloration spreads as the disease progresses and begins to appear on younger leaves over the course of 1-3 weeks. Eventually the leaves lose rigidity and wilt so much that they collapse at the petiole. At this point the leaves hang downwards. The plants will eventually die and the plant does not produce any fruit bunches. TR4, like other Foc strains, also causes vascular discoloration. The colour begins as a pale-yellow discoloration and as the disease advances, this darkens and appears dark red to dark brown to almost black. The discoloration eventually spreads throughout the pseudostem and fruit stalk, and is most pronounced in the dense vascularization of the rhizome. TR4 may also cause other symptoms, including bulging and splitting of the pseudostem and necrosis of the emerging heart leaf.



Impact

TR4 affects a range of banana varieties, including the economically important Cavendish banana, which is commonly grown in large monocultures. The spread of TR4 to these plantations can impact the whole crop, causing significant financial impact to commercial banana growers and exporters. The annual loss due to TR4 has been calculated to be 121 million USD in Indonesia. Bananas, the main hosts of TR4, are an important staple food in many countries, particularly in the least developed countries, and *Fusarium* wilt is one of the most devastating biotic constraints to its production. As well as affecting the availability of bananas for the farmers own consumption, TR4 is also a major concern for bananas that are exported, which are usually the susceptible Cavendish variety. Losses due to TR4 can therefore have a large impact on income and employment of farmers.

Detection and Inspection

External symptoms of TR4, starting with the yellowing of older leaves, are visible in the field. One of the more characteristic symptoms of TR4 is vascular discoloration which requires the cutting open of the pseudostem or rhizome. The wilt and leaf discoloration symptoms are similar to symptoms caused by moko disease (*Ralstonia solanacearum* race 2) and banana blood disease (blood disease bacterium) but these two diseases also cause discoloration of the fruit, whereas TR4 does not. Symptoms caused by TR4 are the same as those caused by other Foc strains, the only ways to differentiate TR4 from other Foc strains are through PCR-based diagnostic tests or analysis of the fungus to determine whether it is part of VCG 01213. One of the recommended molecular tools currently available is the FWB-TR4 test which detects VCGs 01213 and 0121.

Prevention and Control

Due to the limited control options for TR4, the most effective form of management is prevention. Therefore, it is important to limit as much as possible the translocation of the pathogen to uninfected areas via infected hosts, soil, machinery and tools. In countries at risk, it should be ensured to include TR4 on the national list of quarantine pests for proper monitoring on incursions. Like other Foc strains, there is currently no effective method to control TR4 in a plant that is already infested. Moreover, because the pathogen is soil borne and produces chlamydozoospores that can survive dormant in the soil, cultural control and sanitary measures might prove effective.

Several measures have been studied for the management of TR4:

- a. Crop rotation with cassava (*Manihot esculenta*) or garlic chives (*Allium tuberosum*)
- b. Soil suppression using bioorganic fertilizer that altering the microbiota of soil
- c. In the case of infected farms, farm machinery and tools should be thoroughly disinfected to prevent spread.
- d. Wherever possible, movement of people, machinery, tools, planting material and animals between fields should be minimized.
- e. Host Resistance: There is a great deal of research going in to TR4-resistant banana varieties, and many cultivated bananas have been screened for resistance to TR4, as well as wild species, such as *Musa basjoo* and *M. itinerans* are important for banana breeding programmes. In Taiwan, varieties called Giant Cavendish Tissue Culture Variants, which have intermediate resistance to TR4 are being grown.

Thus, prevention and management strategies at national and international levels must be implemented against this destructive disease that seriously threatens the global banana industry. To date, no effective TR4 management methods are known and no alternative commercial banana clones resistant to the pathogen exist, although transgenic clones transformed with a gene from TR4-resistant diploid bananas and a nematode-derived antiapoptosis gene remain disease free, while silencing of vital fungal genes have been shown to confer efficient resistance against disease.

Reference

1. García-Bastidas FA. et al. (2019) First report of Fusarium wilt Tropical Race 4 in Cavendish bananas caused by *Fusarium odoratissimum* in Colombia. *Plant Dis.* <https://doi.org/10.1094/PDIS-09-19-1922-PDN>.
2. Ploetz RC. (2015) Management of Fusarium wilt of banana: a review with special reference to tropical race 4. *Crop Prot.* 73:7–15.
3. Thangavelu R et al. (2019) First detection of *Fusarium oxysporum* f.sp. *cubense* tropical race 4 (TR4) on Cavendish banana in India. *Eur. J. Plant Pathol.* 154: 777-786.
4. Zheng SJ. et al. (2018) New geographical insights of the latest expansion of *Fusarium oxysporum* f.sp. *cubense* tropical race 4 into the greater Mekong subregion. *Front. Plant Sci.* 9: 457.