Background

The banana industry is threatened by a new race of *Fusarium oxysporum* f. sp. *cubense*, the soil-borne fungal disease Fusarium wilt. The disease, also known as Panama disease, kills banana plants by invading and blocking the xylem vessels that transport water from the roots to the leaves; effectively, the plants die of drought. In the 1950s, it wiped out previous commercial banana plantations because the main cultivar at the time, Gros Michel, was susceptible.

The current dominant cultivar, Cavendish, is resistant. In the 1990s, however, a new race of *Fusarium oxysporum* f. sp. *cubense* appeared. This race, called Tropical Race 4 (TR4), can infect and destroy Cavendish and other banana cultivars resistant to the older races of Fusarium wilt and poses a major threat.

Spores of Panama disease can survive up to 30 years in the soil and the disease can spread via infected plants and contaminated soil, water, machinery, implements and people.

Prevention and containment are thus very important control measures, but in the long term, resistant cultivars will be one effective way to overcome the problem.

Our approach

Bioversity International collaborated with many China-based and Bioversity International *Musa* Germplasm Transit Centre (ITC), research partners to study banana genetic resources.

Almost 200 different accessions of banana were ‘challenged’ in greenhouses and in the field by directly inoculating them with TR4 spores and assessing the progress of the disease. In addition, researchers looked at the DNA of the cultivars to identify genes that...
might be associated with resistance to TR4, which could then be used to carry out marker-assisted selection of resistant varieties.

Our progress

Resistance to TR4

The protocol for assessing resistance to TR4 in the greenhouse was developed in collaboration with the Yunnan Academy of Agricultural Sciences.

To monitor the infection process, by which spores germinate and then infect the roots and stems, researchers used spores that had been modified to express a fluorescent pigment. That made it easier to see the spores and track their development with a suitably equipped microscope.

Microscopic investigation revealed that while the spores can attach to the surface of roots and root hairs and germinate there, the fungus mostly penetrates the xylem vessels through wounds and moves further into the plant through the xylem.

Three resistant lines were selected for a more detailed greenhouse study: Baxi, Guijiao No. 1 and Yunjiao No. 1. Researchers visually evaluated the progress of the disease in leaves and stems and also by looking in the plant material for TR4 DNA.

Of the three varieties, Yunjiao No. 1, was the most resistant, then Guijiao No.1 and finally Baxi.

The amount of TR4 in the soil did not change this finding. In the corm (the base of the plant from which the leaves and roots emerge) the number of TR4 spores was significantly lower in Yunjiao No. 1 than in Guijiao No. 1.

Identification and origin of TR4

Details of the fungus were examined with researchers from the Guangdong Academy of Agricultural Sciences. This revealed the presence of 11 different types of Panama disease in southern China.

An in-depth look at their DNA showed that all forms of TR4 have evolved from a single ancestor, and all strains can be identified thanks to their possession of specific DNA sequences.
This information will help to combat the spread of the disease by allowing close monitoring of the fungus.

Wild bananas as a source of resistance

Although ultimately new varieties bred to take advantage of traits from wild bananas are expected to offer a long-term response to TR4, very little is known about resistance in wild species of banana.

Bioversity International and the South China Botanical Garden have begun to fill this knowledge gap. Only one species, *Musa itinerans*, is native to Guangdong Province. A new species, *M. ruiliensis*, was found among previous collections of wild banana species, 16 of which were introduced to the South China Botanical Garden and grown there for further study. Two species, *M. basjoo* and *M. itinerans*, proved most resistant to TR4. Four others were slightly susceptible in greenhouse conditions but resistant in the field.

The group sequenced the genome of the resistant species *M. itinerans*: information that will be a valuable resource for future breeding efforts.

An even more detailed analysis compared genetic information from *M. acuminata* ssp. *burmaniioides* – a resistant ancestor of the cultivated banana – with susceptible varieties. This showed that some genes that modify the structure of the cell wall are more active in the ancestral species, along with other genes believed to play a part in resistance. This and other genomic hints could help breeders to narrow the search for resistant new varieties.

Looking ahead

The threat of TR4 continues to imperil banana production and is the target of much research around the world. In China, Bioversity International and its partners are focusing on:

- Developing and implementing guidelines to prevent the spread of TR4 into non-infected areas and to contain the disease in infected areas
- Continuing the evaluation of diverse banana germplasm for resistance to TR4 and using tissue culture to multiply highly resistant individuals so that they can be used in breeding efforts

![Figure 2 – Genotypes of *Musa* spp. tested for resistance to *Fusarium oxysporum* f. sp. *cubense* Tropical Race 4 (Brazilian and Goldfinger are cultivars, the others are wild genotypes). A: Brazilian; B: Goldfinger; C: *Musa balbisiana*; D: *Musa acuminata* ssp. *burmaniioides*; E: *Musa yunnanensis*; F: *Musa nagiensium*; G: *Musa velutina*; H: *Musa ruiliensis*; I: *Musa itinerans* and J: *Musa basjoo*. Photo credits: South China Botanical Garden, CAAS/X Ge](image-url)
• Exploring the relationship between TR4 and soil characteristics, evaluating the survival and germination of TR4 spores in relation to soil pH, organic matter, salt levels, local microbiome and other factors

• Deciphering the TR4 resistance mechanism in plant-pathogen interactions and applying results to sustainable banana production.

**Partners**

• Yunnan Academy of Agricultural Sciences, Kunming, Yunnan

• Guangdong Academy of Agricultural Sciences, Guangzhou, Guangdong

• South China Botanical Garden of Chinese Academy of Sciences, Guangzhou, Guangdong

**Related publications**


**For more information, see:**

**Factsheet 9: Site visit – Disease resistance in banana**

Cross-section of the pseudostem showing the reddish to dark brown discolouration typical of Fusarium wilt. Credit: A. Javellena

Electron microscopy of *Fusarium oxysporum* f.sp. *cubense* invading the cortex of a banana root. Credit: CENA/M.Lanzoni Rossi

Scanning electron microscopy photo of the mycelium of the fungus *Fusarium oxysporum* f. sp. *cubense*. The mycelium consists of a mass of branching, thread-like hyphae through which the fungus absorbs nutrients. Credit: CENA/M.Lanzoni Rossi