Clone Wars: How Fusarium Fungi Control the Banana Industry

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How does the Gros Michel banana taste? Unfortunately, most people have missed the opportunity to form an opinion: the fungus *Fusarium oxysporum* rendered this cultivar commercially extinct in the 1950s by causing a fatal disease called *Fusarium* wilt or "Panama disease." Today, a new—less flavorful—banana cultivar called Cavendish occupies Gros Michel's place at the grocer. For a brief time, this variety enjoyed resistance to *Fusarium* wilt. However, by the 1960s, *F. oxysporum* with a serious taste for the Cavendish banana was found in Taiwan. This fungus has not yet spread worldwide, but the precarity of Cavendish clones provides a window into the ongoing assault of fungi on our food security.

A banana plant of the Gros Michel variety in Costa Rica attacked by *Fusarium* wilt in 1919.
Source: https://commons.wikimedia.org/wiki/File:Banana_wilt_(1919)_(20166670479).jpg

Send in the Banana Clones

The domestication of bananas has enabled their devastation by *Fusarium* wilt. Seeds are not compatible with selling bananas for consumption because their seeds are very hard and embedded within the fruit, so they

can't be easily removed. The bananas that we eat are triploid, which results in the production of fruits without seeds (known as parthenocarpy). Without seeds, these domesticated bananas can only be propagated asexually as clones.

Cross-sections of wild and domesticated bananas demonstrating the large, embedded seeds of wild bananas that are absent in domesticated bananas. Source: Adapted from Wikimedia Commons

Unappetizing as they are, the seeds of wild bananas benefit them in 2 ways: they aid in natural dispersal and, as the product of sexual reproduction, each seed is genetically unique. This variety is important because genetic diversity buffers the banana population from stress, like a fungal infection, by allowing for different phenotypes among the plant population. This diversity means that under attack by a pathogen, some plants may survive and others may not, which allows for adaptation and survival of the population. Without variation, if a stressor is lethal to one banana, it is lethal to them all.

However, genetic variation is not compatible with industrial agriculture, which relies largely on fields full of one variety of plant (a monoculture). Monoculture standardizes the needs of a field, making it easier to care for. Growing bananas without seeds requires transferring a corm, an underground winter survival organ similar to a bulb. That corm is a clone of the parental banana plant. As a result, plantations are full of bananas plants that are clones of each other. Each clone in these plantations represents a domino carefully stacked by modern agriculture that *Fusarium* could topple.

Wilting from *Fusarium*

Fusarium wilt, the disease caused by *F. oxysporum*, is common and not specific to bananas. This fungus also causes trouble for melon- and tomato-growers. The progression and challenges of *Fusarium* wilt are similar across the diverse plants that are susceptible to it. *F. oxysporum* typically infects plant roots in the soil and grows into the plant until it reaches the xylem, part of the plant's vascular system that works like an elevator to carry water and soil-derived nutrients up the plant. The fungus grows within the plant xylem, blocking it (either physically or through a plant response), then sends spores up the xylem where they germinate and further prevent water flow. Ultimately, this makes plants thirstier and thirstier, resulting in a slow and general decline where the plant yellows, wilts and dies.

Cross section of a Koa e' Kea variety banana plant showing wilt and xylem necrosis from *Fusarium oxysporum* f. sp. cubense Tropical Race 1.
Source: https://www.flickr.com/photos/scotnelson/24629834448/

F. oxysporum is common in soil and can survive on decaying plant material. Furthermore, the fungus produces multiple spore types, including thick-walled chlamydospores that persist for long, stressful periods in the soil. This waiting game that the fungus plays makes it nearly impossible to control once it's established.

The *F. oxysporum* species is further divided into "special forms" (*formae speciales* or f. sp.), each evolved to infiltrate a preferred plant host. Bananas are susceptible to the *F. oxysporum* f. sp. cubense. This special form is further divided into at least 4 races, depending on which cultivars of banana they can infect. Clones share susceptibility, so a field of clones can be open season for a fungal pathogen. *F. oxysporum* f. sp. cubense Tropical Race 1 (TR1) wrought destruction on Gros Michel bananas, but Cavendish cultivars were naturally resistant. A new race called TR4 has, since 1967, set off alarms for the Cavendish industry.

The Modern Fungal Threat to the Banana Industry

TR4 has led to an anxious anticipation for banana growers: there is an ominous lack of cultivars that *Fusarium* cannot wilt. Not only is the multi-billion-dollar banana industry under threat, but so is the health of those who rely on bananas for vitamins and fiber.

This global biosecurity situation has been taken incredibly seriously. The Australian department of Agriculture and Fisheries has a Panama TR4 Program to track and report on this fungus. The discovery of the fungus in 2015 at a plantation in Queensland "warranted destruction of all banana plants on the property," according to a review commissioned by the Biosecurity Queensland. TR4 is now present in Australia, Asia, Africa and South America. It was most recently reported in Peru.

The Uncertain Banana Future

Fusarium wilt paints a dark future for bananas. It has toppled this same industry once before. Once TR4 is discovered, swift removal of any material associated with infected plants is necessary. There is no effective treatment. Once the fungus is in the soil, it survives for years as chlamydospores and resists fungicides, making it incredibly difficult to remove. Fortunately, understanding of *F. oxysporum* f. sp. cubense and its pathogenesis has advanced since TR1. TR4 is already being tracked and has triggered a coordinated global response. Only time will tell if the Cavendish will go the way of Gros Michel. The world may one day know the taste of a TR4 resistant cultivar or a Cavendish engineered to resist this fungal threat.

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