

Editorial: fusarium wilt of banana, a recurring threat to global banana production...

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Editorial on the Research Topic

Fusarium Wilt of Banana, a Recurring Threat to Global Banana Production

The Topic

This Research Topic contains a selection of papers dealing with Fusarium wilt of banana (FWB), also known as Panama disease, that investigate (i) the epidemiology, distribution, infection biology, and diversity of the pathogen, (ii) management practices, and (iii) ways to identify and screen for resistance. The Research Topic arose from the increasing spread and the growing global impact of FWB, affecting a wide range of banana production systems worldwide.

During the inception of this Research Topic an increased understanding of genetic diversity of *Fusarium oxysporum* f. sp. *cubense* (Foc), traditionally considered as the causal agent of FWB, emerged and showed that Foc comprises several different Fusarium species ([Ploetz, 2006](#) ; [Maryani et al., 2019](#)). The so-called Tropical Race 4 (TR4) was found to be genetically distant from other FWB causing species and was described as *Fusarium odoratissimum* ([Maryani et al., 2019](#)).

Different strains of this Fusarium species have affected banana production worldwide. Prior to the 1960s, the spread of FWB was primarily caused by so-called Race 1 strains that caused severe losses in the production and export trade in Latin America, which was based almost entirely on the highly susceptible cultivar Gros Michel. The failing management of FWB in Gros Michel eventually convinced the export companies to convert the business to resistant Cavendish cultivars.

TR4 first emerged in Southeast Asia ([Ploetz, 1990](#)) and its current rapid spread was analyzed by [Ordóñez et al. \(2015\)](#) . Subsequent studies showed that the TR4 strain is extremely virulent toward many banana cultivars, including Cavendish cultivars grown in large-scale monoculture plantations for export markets and many banana varieties important for food security and domestic consumption. There are no readily available solutions to manage this disease. Moreover, this global threat connects export trade, strongly dependent on the susceptible Cavendish cultivars, to local production systems wherein a range of banana varieties contributing to food security are also impacted.

This Research Topic aims to provide a platform for information exchange and knowledge sharing. The contributions demonstrate an active research community in search of effective control of FWB. Taken together, the papers provide an overview of our current understanding of the biology and epidemiology of TR4, its management and how integrated and innovative solutions are required and need to be embraced by all stakeholders in an effort to build a sustainable banana industry for the future.

Background

Bananas evolved in Southeast Asia and are globally the most traded fruit, currently grown throughout the (sub-)tropics. Annual global production of banana and plantain combined is 155 million metric tons (FAOSTAT 2020; data for 2018). Over 400 million people rely on bananas and plantains for food security and for income. Banana and plantains are consumed as fruits or as a starchy food staple and are an important ingredient of local diets.

Other uses include; beer brewing, packaging and food wrapping, fibers for clothing and handicrafts, transport pallets and animal feeds and dried sheaths for binding ropes, thatching materials, mulching material and traditional medicines.

Banana production takes place under diverse agro-ecological and social-economic conditions where disease pressure varies significantly.

Approximately 84% of the crop is cultivated by smallholders and delivered to domestic markets. The international trade represents about 16% of the global banana production consisting of just over 25 million metric tons which are exported from tropical areas to mainly countries in the temperate zones (FAOSTAT 2020; data for 2018). The latter bananas are almost exclusively of the “Cavendish” variety grown in monoculture in large plantations for export. Cavendish cultivars are also important for domestic markets and represent ~50% of the global banana production. They are resistant to Race 1 strains, but susceptible to TR4. The threat posed by Race 1 was countered by replacing the susceptible Gros Michel with the resistant Cavendish, particularly in export-oriented production systems in tropical lowlands.

Refrigerated transport enabled the export industry to be developed in the 20th century based on the banana variety Gros Michel. This hardy and highly popular variety however turned out to be susceptible to FWB Race 1. After invading Central America Race 1 continued to spread to other banana growing countries and destroyed Gros Michel plantations putting pressure on the export industry in Central and South America ([Simmonds, 1966](#)).

Despite large scale and expensive efforts to manage FWB in large

monoculture plantations, effective control was never achieved. For the first half of the 20th century the industry tried to hold on to “ Gros Michel” by shifting cultivation to escape the pathogen with great environmental and socio-economic consequences ([Marquardt, 2001](#) ; [Soluri, 2005](#)). The banana export industry only gradually adopted Cavendish as a replacement for Gros Michel as it required changes to the logistic supply chain. The introduction of cardboard boxes enabled shipment of the more fragile and easily bruised Cavendish fruit, and improved temperature control through refrigeration and artificial ripening, enabled delivery of bananas to Western markets in an acceptable quality. The change in variety as response to Race 1 necessitated major adjustments in logistics and marketing, but the large-scale and uniform production systems based on one single cultivar remained.

Since the 1960's global banana production has expanded significantly due to increased global demand. Cavendish turned out to be highly productive in intensively managed plantations and acceptable to international and domestic markets resulting in contributing approximately 50% of global production and 99% of export markets. The downside of relying on a single cultivar at a global scale is genetic vulnerability which has become evident by the rapid spread of Race 1, and black leaf streak disease, or black Sigatoka ([Marin et al., 2003](#) ; [De Bellaire et al., 2010](#)) in Central and South America and more recently by the emergence and dissemination of TR4. The TR4 epidemic started in the 1960s in Taiwan, and apparently expanded into South East Asia and China and subsequently emerged in the Middle East, Africa, the Indian subcontinent, and most recently in Colombia ([García-Bastidas et al., 2020](#)). The spread of TR4 around the world has increased

significantly and causes severe damage to the highly susceptible “Cavendish” cultivars planted in huge monocultures as well as backyard gardens.

The Scope of the Research Topic

The papers in this Research Topic cover a wide range of issues in an effort to capture the biology and epidemiology of the pathogen (Zheng et al. ; Dita et al. ; Warman and Aitken ; Liu et al. ; Pegg et al.), the impact and management of the disease (Montiflor et al. ; Carvalhais et al. ; Bubici et al. ; Staver et al., 2020), identification and screening for resistance (Chen et al. ; García-Bastidas et al.) and the socioeconomic approaches to engage all stakeholders in coordinated efforts to contain the spread and to exchange knowledge under circumstances of uncertainty and unfamiliarity (Montiflor et al. ; Staver et al., 2020).

The export sector represents the more salient part of the worldwide banana sector; however, the consequences of TR4 for banana producers, traders and consumers in local food provisioning systems is also severe. Therefore, the Research Topic aims to connect the two distinct domains, of export trade and local food security ([Oosterveer et al., 2014](#)). This multiplicity enables spread of the pathogen and complicates tailoring of disease management to different circumstances. Yet, the truly global nature of TR4 may be conducive to linking the resources and knowledge of the export-oriented industry with the problem-solving capacities and livelihood strategies of banana producers in diverse agro-ecological and socio-economic contexts.

The Research Papers

Infection and Spread of the Pathogen

The paper by Pegg et al. deals with the epidemiology of FWB. The paper provides a complete introduction to the FWB problem and this Research Topic. The authors review the body of evidence with regard to the origin, spread and infection of the pathogen and the mechanisms of colonization of the banana plant leading to expression of disease symptoms. The authors outline the evidence for the survival of TR4 in the soil either as chlamydospores or as an asymptomatic endophyte in a wide range of different non-host plants. Issues which prevent effective management of FWB, are discussed in detail. Some crucial points, such as the long incubation period, are highlighted which substantiate the observation that a lack of symptoms may not be a good indication of the presence or absence of the pathogen. In fact, it may be several years before the pathogen present in the soil infect the banana roots and FWB occurrence become evident.

Several fundamental epidemiological issues are brought to the forefront including the long established observation that all infections by *Fusarium* originate from the roots ([Wardlaw, 1961](#)). Banana root exudates stimulate the germination of chlamydospores present in the soil and the initial advancement of the pathogen through the roots is slow but once the pathogen enters the pseudostem it can spread rapidly through the formation of microconidia in the xylem vessels. The authors hypothesize that when *Fusarium* microconidia in the xylem vessels are confronted with a perforation plate they germinate and the resulting mycelium grows through the perforation plate to form microconidia at the other side, progressing the co-

lonization of the pseudostem. In banana varieties resistant to FWB the defenses of the host arrest pathogen colonization in the rootlets, roots or at the root base while in susceptible plants the colonization of the xylem continues unabated. Symptoms expressed as wilting are a result of impaired water movement due to vascular clogging, significantly reducing the transpiration levels. In the final phase of colonization, the pathogen moves from the xylem into the parenchyma and cortex of the plant where an abundance of chlamydospores and conidia are produced in the degrading plant tissue. The paper also gives a pertinent overview of the areas that are insufficiently covered in contemporary research efforts such as; completing the disease cycle, investigating in detail the host pathogen interaction, development and application of effective containment measures, detection of affected plants, destruction of infected plant material, soil treatments to reduce the inoculum load, the process of colonization of the pseudostem and the nature of resistance in Cavendish to Race 1.

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