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Bacterial Disease in Plantain (*Dickeya paradisiaca*): symptoms, epidemiology, and management elements

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Abstract

Context: Fungal diseases, commonly known as black Sigatoka (*Mycosphaerella fijiensis* Morelet), and Fusarium (*Fusarium oxysporum* f. sp. *cubense*) wilt, have always been considered the major worldwide diseases in plantain and banana, therefore they have received more attention. However, bacterial diseases cause significant impacts on yields, and management practices are not always well known.
Aims: I. To describe and illustrate the symptoms that correspond to pseudostem wet rot in a plantation of plantain, observed in the premises of a farm located in Santo Domingo, province of Villa Clara, Cuba, in September 2019. II. To study the state of the art of the main bacterial wilt affecting plantain and banana today. To offer elements that contribute to the adoption of biosafety practices on the farms, in order to manage pseudostem wet rot, and rhizome rot.
Results: The symptoms of the disease were described after confirming the attack of the pathogen in a particular production area. Besides, aspects related to the epidemiology and management of the bacterial disease are updated.
Conclusions: The success of management strategies depends largely on the development of capacities and systematic activities for elimination and sanitation.

Key words: Musaceae, diseases, pseudostem wet rot, management.

Introduction

Plantain (*Musa* spp.) is the most important crop in the world, in terms of production and sales volume (FAOSTAT, 2017). Although this is an important staple food in Africa, Asia, and Latin America, only 13% of the fruit produced is sold internationally (Lescot, 2015). Sixty-two percent of the production of bananas and plantain in Latin America and the Caribbean (20 million tons), is consumed locally, which indicates its importance in the diet and food safety across the region (Dita Garming, Van den Bergh, Staver & Lescot., 2013).

In Cuba, the production of bananas and plantain is highly regarded as part of the production of vegetables, since they account for more than 32% of this indicator annually. The implementation of a local self-supply program for crop productions is intended to meet the supply requirements of 6.8 kg (15 pounds) of crop vegetables, in which 40% correspond to plantain and bananas, with high nutritional values, and part of the traditional feeding habits of the Cuban population (MINAG, 2018).

Regardless of the region and the production system, pests and diseases have been responsible for most yield losses, and low plantain productivity. Fungal diseases commonly known as black Sigatoka (*Mycosphaerella fijiensis* Morelet), and Fusarium (*Fusarium oxysporum* f. Sp. *cubense*) wilt, have been considered by farmers as important threats to plantations. However, bacterial diseases cause significant impacts on yields worldwide, and management practices are not always well known (Blomme et al., 2017).

The bacterial diseases of banana and plantain can be classified into three groups: i) diseases associated to Ralstonia (Moko/Bugto`k disease caused by *Ralstonia solanacearum* (Smith) Yabuuchi, and banana blood disease, caused by *Ralstonia syzygii* subsp. *Celebesensis*); ii) Banana xanthonomas wilt, caused by *Xanthomonas campestris* pv. *musacearum*; and iii) Erwinia-associated diseases (bacterial head rot or pin-rot disease (*Erwinia carotovora* ssp. *carotovora* and *E. chrysanthemi*), bacterial rhizome rot, pseudostem wet rot (*Dickeya paradisiaca* previously *E. chrysanthemi* pv. *paradisiaca*). Other, less important, bacterial diseases include: Javanese vascular wilt, abaca bacterial wilt, and bacterial fingertip rot (probably caused by *Ralstonia* spp., unconfirmed). Bacterial wilt in banana is becoming more frequent in different regions of the world, reducing yields, and raising crop management costs (Blomme et al., 2014).

The purpose of this communication is to describe and illustrate the symptoms observed in the premises of a farm located in Santo Domingo, province of Villa Clara, in September 2019; to study the major bacterial wilts that are currently affecting plantain and bananas; and to provide elements that contribute to the adoption of biosafety practices on the farms, in order to cope with pseudostem wet rot and rhizome rot, following confirmation of the appearance of the pathogen.

Causal agent of the originating bacterial disease, geographical distribution, and economic relevance.

Pseudostem wet rot was first reported in Valle del Cauca, Colombia (Llanos, 1967; Fernández & López, 1970), causing severe losses in almost 2000 hectares of plantain. This disease is widely spread in plantain and banana, in Guatemala (Wardlaw, 1972), Cuba (Rivera, 1978), Jamaica (Shillingford, 1974), Haití, Venezuela (Ordosgoitti et al., 1974), Colombia (Fernández, 1967); Ecuador and Perú, and Nicaragua, Panamá and República Dominicana (Dita et al., 2013). In the1970s, the disease caused severe damage to plantain in Cuba, with up to 75% affectation in some areas. Today, the disease is seriously affecting plantations in El Salvador, Nicaragua, Panama, and The Dominican Republic (Dita et al., 2013)

Taxonomy and genetic diversity of the causal agent

The bacteria associated to plantain soft rot have been described as *D. paradisiaca* (previously *E. chrysanthemi*; Dickey & Victoria, 1980.

Dickeya paradisiaca (Fernández & Lopez, 1970) Samson et al., 2005, belongs to the Enterobacteriaceae family, Gammaproteobacterium class. It is an aerobial pathogenic bacterium, with peritrichous flaggella, which comes alone or in pairs forming spores. It is characterized to positive proctopectinase, amylase, reductase nitrate, lecitinase, and catalase; negative amylase, urease, and gellatinase, producing gas from glucose. It does not grow in 5% NaCl, but can grow at 40 °C (Rivera, 1978; Rivera & Ezavin, 1989). The colonies in nutritional agar are white-light gray after 48 h, with irregular edges, thin granular growth, and after 4 days, they show a well-defined rising core. The data on the genetic diversity of *D. paradisiaca* are extremely scarce, so further studying should be done as the disease increases.

Quite large changes have been observed in the taxonomy of this group, where the species that affect banana and plantain pseudostem have been grouped or named as *Dickeya chrysanthemi* (*Erwinia chrysanthemi*) and *Dickeya* sp. (*Pectobacterium chrysanthemi*) (Samson et al., 2005).

Epidemiology

According to Belalcázar, Cayón & Arcila (1998), the disease is endemic, explaining why it is widely spread in all the regions where musaceae are cultivated. Bacteria causing soft rot may develop and maintain their activity at a wide range of temperatures. The minimum, optimum, and maximum temperatures for disease development are 5 °C, 22 °C, and 37 °C, respectively. The bacteria die at around 50 °C (Agrios, 2006).

The bacterium enter the plant thorough wounds, and occasionally through the lenticels. It is spread by infected seeds, tools, water, insects, vectors, and nematodes, which cause injures in the roots, making their entry easier (Agrios, 2006); INFOAGRO (2012).

The pathogen may remain latent in ornamental plants, plantain, carnation, chrysanthemums, dahlia, maize, potato, onion, *Philodendrum*, and phanerogams from the arum family (Araceae); it can propagate through seeds, such as in the musaceae.

Agrios (2006) commented that the main cause of the disease is nutritional unbalance, particularly of potassium and boron, during long dry periods, alternating with heavy rains, as factors that increase the severity of the disease. These drastic changes are a predisposing factor for the entry of bacteria, possibly due to the stress conditions withstood by the plants.

Spreading

One of the causes of dissemination of the disease is seed selection, the lack of tool disinfection and wound cleaning caused to the pseudostem during

weeding (Fernández & López, 1970). Farmers are the main spreaders of the bacterium, resulting from the absence of proper practices, such as the elimination of the pseudostem after harvest.

Immediate removal of the pseudostem rules out water and nutrient recirculation in the plants harvested, to the offspring for the next production cycle (Belalcázar, Cayón & Arcila (1998), but supports the approach of this research in relation to pest and disease management, since the pseudostem cannot become the source or reservoir of inoculate causing major economic phytosanitary problems, such as pseudostem wet rot, and black and striped weevils.

Ploetz, Kema & Ma (2015) claim that tools like the machetes used for pruning, as well as other materials infected are effective vehicles to spread the disease.

Belalcazar, Rosales & Pocasangre (2004) note that the high incidence of insects like *Metamasius hemipterus* increases the dispersion of the bacterium in the field. The removal of leaves using infected cutting tools, and the wounds caused to the pseudostem during weeding are the most commonly found factors that help increase phytosanitary problems in the crop. The preservation of highly infected plants, and maintaining the pseudostem after harvest increase the attack of *M. hemipterus*, which spreads the disease.

Symptoms of pseudostem wet rot of plantain on a farm from Armando Perera CSS, in Santo Domingo

The description of symptoms through photos taken by the authors of this paper illustrates them for better understanding and diffusion within the scientific community. (Figures 1 - 5)

The initial symptoms of the disease consists of aqueous-like yellowish spots, located on any part of the stem of the plant. Then, these spots turn brown-reddish, and spread all over, until the leaf pods are partially or totally covered.

Eventually, the affected parts become dark, and a smelly fluid comes from the affected part when the surrounding tissue is pressed.

Fig. 1. Affected plant parts with a dark coloring; the presence of a smelly fluid was observed when the tissue of the affected part was pressed. Note the soft rot inside that begins from the outside and into the interior.

Rot advances progressively to the base of the stem, while penetrating the tissue of the healthy internal pods.

The symptoms of diseases caused by bacteria in banana may be summarized as wilt, plant collapse, rhizome and pseudostem rot, and fruit (Buregyeya et al., 2014).

Wilt begins when the density of pathogens increases in the plant, which prevents water to reach the leaves in sufficient amounts, due to vascular dysfunction (Buddenhagen & Kelman, 1964; Denny, Carney & Schell, 1990).

Fig. 2. Plantation of INIVIT PV 06 30 (ABB) plantain in premises of Santo Domingo municipality, Villa Clara, affected by pseudostem and rhizome rot.

Fig. 3. Experts of the Faculty of Agricultural Sciences from the Central University of Las Villas and INIVIT inspect the affected areas, and recommend the farmer how to manage the bacterial disease.

Fig. 4. Characteristic symptom contrasting the collapse caused by nematodes and the black weevil, respectively. The rot caused by bacteria takes place at some distance, above the pseudostem base.

Fig. 5. Adult INIVIT PV 06-30 plantain affected, the weight of bunches contributes to bend the plant down. Note that the fruits have not completed their development, producing bunches with poor commercial value, and high losses to the farmer.

The severely infected plants can develop chlorotic young leaves, with necrotic edges, and stunted shoots. The severely affected young plants do not flower (Stover, 1972, and Rivera, 1978). An additional symptom observed in Cavendish (AAA) plants mainly, is the rot of pods showing beige-dark brownish coloring at the soil level, which later turns into a necrotic cavern in the rhizome (Rivera & Ezavin, 1989), similar to the one caused by *Cosmopolites sordidus* Germar. The plants that grow with infected rhizomes have slow growing chlorotic and flaccid leaves, as well as rotting that extends upwards, from the base to the rest of the pseudostem. These plants can eventually collapse and die (Rivera & Ezavin, 1989).

D. paradisiaca infects the plant through openings and wounds produced during the sanitation of senescent leaves affected by black Sigatoka, and shoot pruning (Rivera, 1978; Thwaites, Eden-Green, & Black,., 2000). Plantain cultivars (AAB), and plantain for cooking (ABB) are more likely to suffer pseudostem wet rot than Cavendish cultivars. Severe epidemic outbreaks are commonly observed after long periods of water shortage, during the warm and dry seasons in Central America. These conditions are associated to deficient sanitation practices, which lead to serious symptoms, including the collapse of the plant.

Management

Farmers must be alert on the presence of symptoms produced by this bacterial disease, and keep in mind that the first line of defense is preventing their introduction; that is, through exclusion.

Pérez (2003) notes that sanitation programs performed in Cuba based on the systematic use of tissue culture plants by ELISA succeeded in the removal of necrotic rhizome rot in Cavendish plantations.

Because *D. paradisiaca* grows well in meristem culture medium, any infected plant material undetected during the diagnostic can be easily removed during the process of multiplication, making it disappear from the system after six steps of multiplication.

The utilization of clean culturing material, and proper sanitation procedures must always be linked to timely diagnostic, and quarantine methods.

Some ammonia-based disinfectants have proven their effectiveness to remove bacteria from farming tools, adding the advantage that they are not corrosive, biodegradable, and are more stable than sodium hypochlorite. (Pérez-Vicente & Martínez de la Parte, 2015)

Fernández, Chavarría, Brown & Dita (2013) made contributions by evaluating different treatments to manage the disease in plantain, in Rivas, Nicaragua.

In the absence of effective bacterial control measures, rural farmers have to destroy infected plantations, leave the affected soil free of crops for months, and sterilize the area before planting new healthy crops (Blomme et al., 2017). These farmers will face substantial economic losses if wilt spreads throughout the plantation (Shimwela et al., 2016).

Ramírez, Jaraba & Burriticá (2014) said that new management strategies of *Dickeya* sp. can be associated with other tools, in order to design an integrated plan, and offer solutions to treat sick plants, so removal is not the only mechanism available.

After a comprehensive evaluation of the state of the art of the major wilts caused by bacteria, which affect plantain and bananas, several elements are presented to adopt management practices based on

epidemiological aspects, and specific actions that contribute to disease management in premises of Armando Pereira CCS, in the municipality of Santo Domingo.

The success of management strategies largely depended on the development of collective capacities that helped increase knowledge on the disease, along with systematic activities of removal and sanitation.

Monitoring and intervention

Diagnostic is a first critical step in managing bacterial diseases. The observation of the disease in plants affected by bacteria can be done by checking the plant in the plantation between 5 and 7 days.

Permanent monitoring of the disease in the crop is important to find the above-mentioned symptoms. As soon as pseudostem wet rot is detected in a crop, the following measures should be taken:

1. To employ conventional healthy seeds from healthy and strong plantations, whose corms show no signs of rot at all. This aspect is essential, since the bacterium can move through the tissues of leaf sheaves to the basal portion of the cormos. The utilization of seeds produced by *in vitro* culture is an excellent propagation material.

2. To apply fertilization correctives, especially potassium and boron, if necessary.

3. To implement proper irrigation and draining management.

4. To remove the sick plants, chopping the stem in small chunks to help with decomposition, and to spread quicklime on the residues.

5. To implement crop rotation with non-host species.

6. To disinfect the tools from plant to plant, since this is a vascular disease, and should not be spread over the plantation. To disinfect the tool used in infection sites, using a disinfecting solution (2% formol or 20% sodium hypochlorite). To put disinfectant in the machete sheaths, which is also a viable practice.

7. To set traps to control the presence of the weevils, since the insect can be an important vector of the disease.

Conclusions

1. The presence of the bacterial disease consisting of pseudostem wet rot, and rhizome rot in plantain caused serious damage in the premises of a farmer in the municipality of Santo Domingo, province of Villa Clara, and demands the attention to bacterial diseases in plantain and bananas.

2. A significant effort is needed for training at different levels (farmers, technicians, and developers), as a way to identify the disease, the epidemiology, and perform biosafety practices on farms. The implementation of these actions in a broad area, systematically, based on epidemiological parameters, can ensure sustainable management.

Author contribution

Lilian M. Morales Romero: research planning, bibliographic review, description of symptoms, design of the management plan of the bacterial disease on plantain, analysis of results, manuscript redaction, final review.

Felipe Lidcay Herrera Isla: research planning, bibliographic review, description of symptoms, design of the management plan of the bacterial disease on plantain, analysis of results, manuscript redaction, final review.

Maryluz de la Caridad Folgueras Montiel: design, research planning, manuscript redaction, final review.

Conflicts of interest

Not declared.

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