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Cultural Practices for Banana Bunchy Top Disease Management: A Sustainable Option for Burundian Smallholders?

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Abstract

Banana bunchy top disease (BBTD) was reported for the first time in Burundi in 1987. Ever since, the disease has continued its spread throughout the Rusizi valley, reaching ever-higher altitudes, as no specific measures are being taken for its control. Management of BBTD through symptom and vector identification and good cultural practices was evaluated during a 1-year period in an on-farm, research-led trial at Munyika (Cibitoke Province) in a predominant monocrop system of 'Yangambi Km 5' (AAA). In addition, a "new start" demonstration trial consisting of *in vitro* 'FHIA-03' (AAAB), 'FHIA-17' (AAAA) and 'FHIA-23' (AAAA) plantlets was established 80 m away from existing plantations. In parallel, two contrasting control sites (no awareness raising and no cultural practices) within Cibitoke were identified (Mparambo II, 'Yangambi Km 5' monocrop and Muyange, 'Igitsiri'/'Igisahira' (AAA-EA) intercrop). BBTD incidence and severity were recorded quarterly in all three sites. Results indicate that initial BBTD incidence varied from one site to another, with lower incidence in 'Igitsiri'/'Igisahira' intercropping systems (8.6%) compared to 'Yangambi Km 5' monocropping systems (30.9%). Furthermore, in the pilot village Munyika, disease incidence was higher in the vicinity of households (26.2%) versus in recent plantations (2.7%). Data collected in Munyika show that when appropriate cultural practices are applied and adhered to, within a year, BBTD incidence can be reduced to economically acceptable levels in an existing plantation (26.2% to 8.2%) and in new plantations (2%, FHIA trial). Moreover, severity is equally reduced, highlighting that farmers are presently familiar with initial symptoms and regularly scout fields to eradicate diseased plants. However, low adherence to proposed management practices underlines that most farmers – despite awareness raising - are reluctant to uproot the entire mat (100% of farmers) or the diseased corm (78% of farmers) when a single plant manifests visible symptoms. Refusal to conform to proposed practices might prove to be a limiting factor to sustainable management of BBTD in Burundi.

INTRODUCTION

Bananas (banana and plantain, *Musa* spp.) are considered as key food security and income-generating crops for millions of people in East and Central Africa. In Burundi, they

are considered as the most important cash and staple crop (FAO, 2009) and are traditionally intercropped by smallholders as a backyard crop in plots rarely reaching 1 ha. Among the numerous constraints that exist, reduced soil fertility levels, aged plantations, and pest and disease pressure reduce banana production levels in Burundi. Banana bunchy top disease (BBTD) is identified as a major factor reducing both bunch size and number, not only in Burundi, but also in other banana producing regions of Africa, Asia and the Pacific (Dale, 1987).

Symptoms of BBTD are readily distinguished from those of other viral diseases and are easily observable in advanced infections, manifested by leaf margin chlorosis, leaf dwarfing and a bunchy top appearance of the foliage. Subtle symptoms of early stages of infection include dot-dash streaking of leaf veins, mid ribs, petioles and bracts (Magee, 1927).

Bunchy top is caused by a phloem-invading, aphid-vectored, virus commonly known as *Banana bunchy top virus* or BBTV (genus *Babuvirus*, family *Nanoviridae*) (Magee, 1927; Vetten et al., 2005). Spread of the disease occurs solely by infected planting materiel or locally via the winged aphid vector *Pentalonia nigronervosa*, naturally associated with banana (Magee, 1927, Dale, 1987). The fact that the virus is not transmitted mechanically implies that virus-contaminated tools used for the routine management of plantations will not act as a source of infection. The virus is transmitted by the aphid vector in a persistent circulative and nonpropagative manner, with descendants acquiring the virus only after having fed on infected plants (Ng and Perry, 2004). Recent work carried out by Foottit et al. (2010) and Bhadra and Agarwala (2010) suggests that the host range of *P. nigronervosa* is limited to *Musa* spp., no longer encompassing members of the Zingiberaceae and Araceae (Wardlaw, 1961) which harbor a new distinct species termed *P. caladii*. Confirmation if this new species plays an active role in BBTD epidemiology is warranted. Allen (1978) demonstrated that 99% of new infections vectored by the banana aphid occur within 86 m of the primary source of inoculum, with favorable wind currents increasing the distance for wind-borne aphids. Moreover, on average, the interval between infection of a plant and movement of aphids from this plant to another was equivalent to the time taken for 3.7 new leaves to emerge (with the average leaf emergence rate being one leaf per week, dependent on temperature and other growing conditions). When establishing a new plantation either next to or 50-1000 m from an existing diseased field, Allen and Barnier (1977) determined that the chance of spread of bunchy top to the new plantation is reduced from 88% to 27% within the first 12 months.

Experience in BBTD management is reported among others for Australia (Magee, 1927), Hawaii (Hooks et al., 2009) and the Philippines (Molina et al., 2009) and is based on three major components: use of clean planting material, eradication of infected plants, and exclusion of infected plants from unaffected areas (quarantine). Depending on local conditions, management is either based on a strict national exclusion/eradication program and adapted legislation, awareness raising and integrated collaborative management based on use of insecticides and herbicides or participative rehabilitation promoting the use of virus-indexed tissue culture-derived planting material and an annual to 2-year production system. However, whether these control measures are applicable to developing countries such as Burundi where resource-limited smallholders produce bananas has yet to be evaluated.

Despite BBTD being in the region for over four decades and in Burundi since 1987 (Sebasigari and Stover, 1988), farmers are unfamiliar with symptoms (particularly initial stages), modes of transmission, possible management options, quarantine measures and reporting mechanisms (Niyongere et al., 2011). Moreover, traditionally, Burundian farmers exchange suckers as planting material and devote little time and labor to the maintenance of their ageing banana plantations with mats easily containing more than 20 stems. This encourages the pullulation of aphids vectoring the disease from plant to plant and allowing it to reach ever-higher altitudes as no specific measures are being taken for its control or to limit expansion. The present study focuses on assessing farmers' awareness of BBTD epidemiology, BBTD management options available/accessible to them, the impact of such options on disease incidence, and the abundance of winged vector populations. This constitutes, to our knowledge, the first study of the effect of cultural practices on BBTD management in a small-scale agricultural setting in sub-Saharan Africa.

MATERIALS AND METHODS

Management of BBTD through awareness-raising and good cultural practices was evaluated in an on-farm, research-led trial at Munyika (BBTD hotspot, 933 masl, Rugombo commune, Cibitoke Province) in a predominantly monocrop system of 'Yangambi Km 5' (AAA, beer). Nineteen farmers, with adjacent plots, were surveyed using a structured questionnaire on their general knowledge on banana and BBTD before being trained and followed-up during a 1-year period (December 2009 to December 2010) on bunchy top symptom and vector identification, management options and cultural practices. During the initial training, each farmer was supplied with an awareness-raising pamphlet covering bunchy top identification, transmission and proposed control options. Farmer group and individual meetings were organized quarterly, allowing the follow up of each farmer's adherence to proposed management options, identification of eventual constraints to adherence and a chance to refresh their knowledge of the disease and its management. In parallel, two contrasting control sites where no awareness-raising or cultural practices were carried out were identified: Mparambo II, 933 masl, Rugombo commune, 'Yangambi Km 5' monoculture and Muyange, 1,170 masl, Mugina commune, 'Igitsiri' (AAA-EA, beer)/'Igisahira' (AAA-EA, cooking) intercrop with maize, bean and taro.

BBTD incidence and severity (CIALCA scale ranging from 0 to 5; 0: no symptoms, 1: dark green streaks on leaf lamina, 2: dark green streaks on petiole, 3: chlorosis of leaf margin, 4: reduction in leaf size, 5: bunchy top appearance) were recorded quarterly at all three sites. Based on information collected during the initial survey in the pilot village Munyika, data were subdivided in two to reflect the natural characteristics of existing plantation typology. The first 120 m of banana plantations (from the road) consist of aged plantations surrounding households whereas the subsequent 120 m are more recent plantations.

A "new start trial" containing 40 'FHIA-03' (AAAB), 30 'FHIA-17' (AAAA) and 30 'FHIA-23' (AAAA) *in vitro*-derived plants was established in a farmer's field in the pilot village, 80 m away from existing banana plantations (windward or leeward depending on the time of day). In addition, each of the 19 farmers included in the pilot village received 5 plantlets of each hybrid for their personal plots. Recommended plantation establishment and

maintenance was demonstrated in the new start trial prior to farmers establishing their own plots, in order to promote and assess adherence to proposed practices (i.e.; choice of site, hole preparation, use of organic fertilizer, use of mulch, dry season irrigation, protection against goats, etc.).

Occurrence of winged *P. nigronervosa* populations was recorded from April to November 2010 on each site using yellow metallic traps placed approximately 45 cm above soil level and filled with soapy water to prevent insects from crawling out. Two traps were placed in each plantation typology (i.e., Munyika household, Munyika recent plantations, FHIA new start trial, Mparambo II and Muyange). Aphids were collected three times a week and the soapy water replenished once a week. Collected insects were stored in 70% ethanol pending identification.

RESULTS AND DISCUSSION

Farmers' Awareness of BBTD and its Control Options

Data suggest that all surveyed farmers in Munyika pilot village use suckers as planting material, with no previous experience with tissue culture. Suckers are obtained from their own plantation (68%) or from neighbors (32%), either as gifts or by exchange, within a 1-km radius of their plot. Plantations surrounding households were established more than a decade ago in 58% of the farms surveyed. The predominant cropping system is monoculture with random stands of taro (42% of farms), bean (32%), maize (21%), oil palm (21%) or mango (10%). Desuckering is not practiced, leading to clusters encompassing up to 63 stems. In the subsequent 120 m, planting material is obtained either from the household plot (67%) or from close neighbors (33%), and plots were established 3 to 5 years ago in 83% of the cases. Intercropping is typically practiced with sweet potato (33% of farms), taro (25%), manioc (25%), maize (17%), bean (17%) and cotton (8%) predominating as associated crops. During cropping season B (February to May, locally known as *Impeshi*), intercropping is mainly carried out with beans. Absence of desuckering is also observed with mats counting up to 18 pseudostems depending on time of plantation establishment. Main varieties grown by farmers in the pilot village are 'Yangambi Km 5' (100% of farmers), 'Igisahira' (53%), 'Mugomozi' (ABB, beer) (37%) and 'Gros Michel' (AAA, dessert) (16%) with 'Yangambi Km 5' representing 95% of mats in the farms. Farmers state that all varieties are susceptible to BBTD with 'Mugomozi' being the most tolerant.

With regards to BBTD identification and transmission, all farmers are aware of advanced symptoms (reduced leaf size) and 95% are familiar with the bunchy top aspect of affected plants. Conversely, none of the farmers was aware of initial symptoms caused by the virus (i.e. green streaks on leaf lamina or petiole), neither the role of *P. nigronervosa* as a vector nor the transmission of the disease through infected suckers. For farmers, the origin of infection is thought to be through the soil (47%) or by large ants known in the region as "*Imitotezo*" (42%). Several local names have been given to the disease such as "*Gipfizi*" (11%) and "*Kimasa*" (5%), with "*Sindika*" being used by all farmers. It should be noted that "*Sindika*" is a generic term referring locally to banana diseases in general. Approximately half (53%) of the interviewed farmers declared that BBTD incidence is not a function of season and 74% state that BBTD was observed for the first time within 10 km of their home.

Around half (47%) of the farmers noticed that it takes less than a year for symptoms to appear on neighboring mats and that the production span of an infected mat is less than a year. Surprisingly, 42% of respondents plant collected suckers randomly within an existing plot, not taking into account proximity of infected mats.

Awareness on BBTD management is clearly lacking, with all farmers declaring that they are not informed of control options. In practice, none of the farmers uproot an entire mat when a single plant is infected and only 21% take into account the disease when selecting suckers as planting material. Symptomatic plants within a mat are cut down by 74% of farmers.

Results confirm data obtained in a similar survey carried out on a larger scale (Burundi, Rwanda and Democratic Republic of Congo) by Niyongere et al. (2011), highlighting the lack of knowledge of farmers with regards to bunchy top and that sustainable management passes through awareness raising. Moreover, despite the fact that most farmers report not taking into account the disease when selecting/planting suckers, abnormally low levels of infection were observed in new plantations (0 to 15% in December 2009). This suggests that farmers, unknowingly, are selecting BBTD-free suckers when planting new fields.

Adherence to BBTD Control Options and Recommended Cultural Practices

At the end of the 1-year trial, adherence to proposed cultural practices by pilot farmers was evaluated. Sixty-three (63)% of the participants declared scouting their fields bimonthly with all but one farmer regularly deleafing their plantations and systematically cutting down symptomatic plants during inspection rounds. Also, 84% now take into account the disease when collecting suckers for establishing new fields. However, only 22% removed the corm of an infected plant, and none of the farmers uprooted entire mats when a single stem manifested symptoms. Random intercropping was practiced by 58% of the farmers and 76% attended the group meetings.

With regards to cultural practices demonstrated in the new start trial using FHIA tissue culture plantlets, none of the farmers adhered to establishing new plantations at least 30 m from existing plantations, use of organic fertilizer or proper planting hole preparation. Only 5% of farmers protected their plants from goats (especially in the dry season), 16% mulched the newly planted bananas and 58% irrigated their plots during the dry season. This resulted in a very poor survival rate of farmer plantlets (mean 24%, highest 73%, lowest 0% due to loss at planting, goat damage, BBTD incidence and weed competition) compared to the demonstration plot (88% - 53% - 50% survival rate at planting for respectively ‘FHIA-03’, ‘FHIA-17’ and ‘FHIA-23’; 2% BBTD incidence). The poor survival rate at planting in the demonstration plot resides in the fact that establishment was carried out towards the end of the rainy season with reduced access to irrigation during the dry season. In addition, the ‘FHIA-17’ and ‘FHIA-23’ plantlets were not yet fully weaned at the time of field planting.

In this study, the regular scouting of fields and implementation of proposed eradication measures, have been stated as major constraints by farmers. This can be explained given that farmers do not have a habit of regularly tending to their banana and are unsure of being provided with replacement material (ideally certified in vitro). Moreover, from their experience, they have been able to harvest bunches within BBTD-infected mats.

This could be due to the fact that corms are not always interconnected within the large banana clusters present in aged plantations. These observations underline the complexity of managing a disease that necessitates collective measures in a smallholder setting where banana plantations form a continuum and no legislation is enforced. In addition, the role of all stakeholders is still to be defined and the linkage between private tissue-culture companies and farmers to be optimized.

BBTD Incidence and Severity

Results in Table 1 indicate that the initial BBTD incidence (evaluated in December 2009) varied from one site to another, with lower incidence in 'Igitsiri'/'Igisahira' intercropping systems in Muyange (8.6%) compared to 'Yangambi Km 5' monocropping systems in Mparambo II (30.9%). Furthermore, in Munyika where 'Yangambi Km 5' predominates, disease incidence was higher in the vicinity of households (26.2%) versus recent plantations (>120 m, 2.7%). Data collected in the pilot village shows that when cultural practices are applied and adhered to, BBTD incidence can be reduced within a year to acceptable levels in an existing plantation (26.2% to 8.2% in December 2010) and in a new plantation (2%, new start FHIA trial). Severity is equally reduced (4.5 to 2.9), suggesting that farmers regularly scout fields to eradicate diseased plants and are presently familiar with initial BBTD symptoms. Differences in incidence were observed between pilot farms throughout the trial, with initial incidence varying from 13% to 67% at the beginning of the trial (i.e. December 2009) and from 1% to 40% in December 2010.

Furthermore, incidence and severity was reduced significantly during the study in the intercrop control site of Muyange (8.6% to 3.5%, 4.4 to 2.0). This could be due to the fact that, stimulated by scientists' frequent visits to their fields, farmers spontaneously and independently started eradicating diseased plants and removed senescent leaves without having been trained or informed on control practices. Why BBTD incidence is reduced in intercropped systems such as Muyange compared to other sites in Cibitoke is unknown. This could be linked to varietal preference of aphids for 'Yangambi Km 5', a negative effect of intercrop or low suckering ability of 'Igitsiri'/'Igisahira' on aphid populations, age of plantations, altitude or something else.

Six months after the end of the trial, severity and incidence was evaluated once again and revealed a general increase in all plots (Table 1). However, a handful of farmers had continued to manage their fields and kept incidence levels constant. These results emphasize the importance of a continuous follow up of farmers by trained authorities if BBTD management is to be adhered to and integrated in daily farm activities. The relatively higher incidence of bunchy top around households could be attributed to the advanced age of plantations and the corresponding large clusters of plants or to the high soil fertility resulting in rapid leaf emission and therefore symptom expression. It is also thought that aphids have a preference for vigorous and healthy plants. In addition, Burundian farmers traditionally plant their bananas at higher densities in fertile soils, creating therefore a more confined space, optimal for aphid multiplication.

Seasonal Variation of Winged *Pentalonia nigronervosa*

Overall, banana aphid flight activity varied over time with peak captures in the months of April, July and October (data not shown). Reduced numbers of *P. nigronervosa* were caught during the months of June and August on all sites, with an all-season low in June for the intercrop control site of Muyange and in August for the remaining sites. Winged banana aphid populations in the new start FHIA trial differed from other sites by their absence in October and November 2010. Overlap of aphid captures with mean monthly precipitations suggests a direct correlation with lowest levels of rainfall in August and high precipitations in April and September-October. Within the FHIA trials, aphid preference and high BBTD incidence was clearly observed on 'FHIA-03' and could be attributed to the light green color of its pseudostem, as for plantain (Kumar and Hanna, 2008; Niyongere et al., 2011). Moreover, the peak in aphid flight appears to coincide with the main planting season (October), therefore putting at risk newly established plantlets.

Several constraints were encountered while collecting the data and include the difficulty in finding a responsible technician for regular data collection and foraging cows and/or goats during the dry season (the animals use the yellow traps as a source of drinking water). Future research could explore further varietal preference, effect of intercropping and altitude on aphid presence and abundance.

CONCLUSION

The key to the success in reducing BBTD incidence and severity on small-scale farms in Munyika, Burundi to economically acceptable levels resides in the (i) training of farmers, extension officers and authorities on symptoms, transmission and control options; (ii) regular follow up of farmers by competent authorities; (iii) regular scouting of fields by farmers; (iv) prompt eradication of infected plants/mats; (v) control of planting material movement and increased vigilance in non-affected bordering regions and (vi) supply of disease-free replacement planting materials in a timely manner.

This study highlights that despite the fact that farmers did not completely adhere to the proposed control options (no complete uprooting of infected mats) and that no direct action on aphid populations was taken (no use of insecticidal soaps or kerosene), BBTD incidence can be reduced to acceptable levels. While BBTD will most probably never be totally eradicated, the sustainability of its management is subject to question if authorities do not recognize the disease as a major production constraint for farmers and if no concerted efforts are taken for its management. An effective partnership between the government, National Agricultural Research Institutes, local/international NGOs and private tissue culture laboratories is essential. Refusal of farmers to conform to proposed practices might prove to be a limiting factor to long-term management of BBTD in Burundi, and incentives or a bylaw are warranted if the disease is to be managed in a sustainable manner. In the future, quantification of the benefits of management on yield and income could be used to stimulate further adoption by farmers and authorities. Furthermore, now that banana bacterial wilt (caused by *Xanthomonas campestris* pv. *musacearum*) is equally present in Burundi (N. Niko, pers. commun.), a novel approach to BBTD management is to be designed and adapted to the local context of small-scale resource poor farming.

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Tables

Table 1. Evolution of mean incidence and severity (in parentheses) of BBTD in farmers' fields in pilot and control sites recorded from December 2009 to Mai 2011. Incidence is given in terms of a percentage of mats affected, while severity was scored using the CIACLA scale ranging from 0 to 5[1].

	Pilot site Munyika (household, Yangambi Km 5 monocrop)	Pilot site Munyika (>120m, Yangambi Km 5 intercrop)	Control site Mparambo II (Yangambi Km 5 monocrop)	Control site Muyange (AAA-EA intercrop)	FHIA new start trial[2]
Dec 2009	26.2 (4.5)	2.7 (4.5)	30.9 (4.4)	8.6 (4.4)	ND
Apr 2010	12.5 (3.0)	2.0 (2.8)	31.0 (4.3)	9.3 (3.5)	ND
Aug 2010	9.0 (3.2)	3.8 (3.4)	28.4 (4.1)	4.8 (3.6)	2 (3)
Dec 2010	8.2 (2.9)	1.9 (2.8)	27.9 (4.0)	3.5 (2.0)	0 (0)
Mai 2011	15.1 (3.0)	3.9 (2.9)	ND	ND	0 (0)

[1] 0: no symptoms, 1: dark green streaks on leaf lamina, 2: dark green streaks on petiole, 3: chlorosis of leaf margin, 4: reduction in leaf size, 5: bunchy top appearance

[2] ND = No data