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Assessing the Spread and Seasonal Influence of Fruit Peel Disease and Banana Bunchy Top Disease in South Kivu, Eastern DR-Congo

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ABSTRACT

Baseline studies and subsequent diagnostic surveys carried out in south Kivu, DR-Congo by the Consortium for improving agriculture-based livelihoods in Central Africa (CIALCA) revealed that banana is severely affected by several diseases in the region, especially in Nyangezi and Kamanyola. Two major diseases are observed on the crop; banana bunchy top disease (BBTD) and a fruit peel disease of unknown origin. Studies of the two diseases were carried out by the Université Catholique de Bukavu in order to assess disease spread and seasonal influence. Survey results indicate that both diseases are well known by farmers and BBTD is more prominent at lower elevations (<1,300 masl), while the fruit peel disease is only present at higher elevations (>1,700 masl). The fruit peel disease (locally named 'Cibojo') has been reported in the region for over 50 years and infections mainly appear in fields were the disease has been observed previously. The symptoms start off as tiny reddish-brown specks on the fruit peel which enlarge to become irregularly shaped reddish-brown lesions. These lesions can eventually cover the whole fruit peel, leading to the splitting of the fruit in the terminal stage of the disease and rendering bunches unsuitable for human and animal consumption. An increase in severity of symptoms is observed during the rainy season (especially during weeks of heavy rains) whereas symptoms are limited to small blemishes on the peel during the dry season, unaffecting fruit pulp. The causal agent still awaits formal identification. In the Kamanyola area (1,000 masl) banana is severely affected by BBTD. The disease has been present in this region for over 20 years and although all varieties are susceptible, the beer banana 'Nakasimbu' or 'Yangambi Km5' (*Musa* AAA group) is most affected, while 'Gros Michel' (*Musa* AAA group) is least affected.

Keywords: anthracnose fruit rot, Banana bunchy top disease, brown spot, diamond spot, distribution, farmer awareness, incidence, leaf speckle, severity

INTRODUCTION

In the eastern Democratic Republic of Congo (DR-Congo), banana is cultivated primarily for human and animal consumption, but also for beer brewing and banana fibre handicrafts production. The biotic and abiotic constraints in banana and plantain cultivation in eastern DR-Congo are numerous and comprise fungal diseases (e.g., Fusarium wilt, Sigatoka), viral diseases (e.g., Banana bunchy top virus), bacterial diseases (e.g., Xanthomonas wilt), lack of improved *Musa* varieties, declining soil fertility and climatic changes (Gatsinzi 1987; CIALCA 2007).

Baseline studies and subsequent diagnostic surveys carried out in south Kivu, DR-Congo by the Consortium for improving agriculture-based livelihoods in Central Africa (CIALCA) revealed that banana and plantain are severely affected by diseases, especially in Nyangezi and Kamanyola. BBTD and a novel fruit peel disease are prominent in the region. The observed fruit peel disease is characterized initially by tiny reddish-brown specks on the fruit peel that enlarge to become irregularly shaped reddish-brown lesions (**Fig. 1A, 1B**). These lesions can eventually cover the whole

Fig. 1 (**A**) Fruit peel disease symptom progression: first tiny reddish-brown specks appear on the peel (right) and gradually enlarge to irregular shaped lesions that can eventually cover the entire fruit and make it rot and/or crack (left). Premature ripening of fruits is also observed; (**B**) Reddish-brown spots covering the whole fruit peel surface; (**C**) Severely affected bunches become un-consumable once the pulp is affected.

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fruit peel, leading to the splitting of the fruit in the terminal stage of the disease and rendering bunches inconsumable (**Fig. 1C**). Previously described pre- and post harvest fungal fruit peel diseases include anthracnose fruit rot [*Colletotrichum musae* Berk. & Curtis Arx. (syn. *Gleosporium musarum* Cooke & Massee)], brown spot and diamond spot caused respectively by *Cercospora hayi* Calpouzos and a complex of fungi in which *C. hayi* is the primary pathogen followed by *Fusarium solani*, *F. pallidoroseum* and other opportunistic fungi, fruit freckle [*Guignardia musae* Racib. (anamorph *Phyllosticta musarum* (Cooke) vander Aa], and sooty mold [*Cladosporium cladosporioides* (Friesen) De Vries] (Ploetz *et al.* 1994; Jones and Stover 2000). On the other hand, BBTD is transmitted by an aphid vector (*Pentalonia nigronervosa*). Leaves of BBTD-infected plants become smaller, both in length and in leaf lamina width and often have chlorotic, upturned margins. The leaves become brittle and stand more erect, giving the plant a rosetted or "bunchy top" appearance (Thomas and Iskra-Caruana 2000) (**Fig. 2A, 2B**). Infected plants rarely produce a bunch after infection and most lateral shoots develop disease symptoms (Thomas and Iskra-Caruana 2000).

To date, the fruit peel disease has been reported in a village in Muleba district, Kagera, Tanzania (Mgenzi Byabachwezi pers. comm.), and has been occasionally observed in south-western Uganda (since the 1950s) (Eldad Karamura pers. comm.), in north Kivu and in western Rwanda bordering Lake Kivu. BBTD surveys, conducted so far in Central Africa, have shown that the disease is spreading to north Kivu and to higher altitudes in the hills around the Rusizi valley (CIALCA 2009). Banana fruit peel disease and especially BBTD could potentially become a regional problem.

Studies of the two diseases were carried out in south Kivu, eastern DR-Congo by the Université Catholique de Bukavu in order to assess disease spread and seasonal influence. In addition, BBTV aphid vector incidence was recorded.

MATERIALS AND METHODS

The surveys and field studies were carried out in Nyangezi and Kamanyola in South Kivu province, eastern DR-Congo. These areas were previously identified, via a CIALCA baseline study and a diagnostic survey, as being disease hot spots. Nyangezi is located 23 km south of Bukavu, on the Uvira-Bukavu axis, at an elevation of >1,700 masl, while Kamanyola is located in the Rusizi plain at a lower elevation (<1,000 masl). Nyangezi belongs to the 'CW' climate type according to the Köppen climate classification, with an annual total rainfall of 1,500 to 2,000 mm. In contrast, Kamanyola belongs to the 'AW4' climate type and has an annual total rainfall of only 763 mm (Lubarika 2003).

Disease incidence was monitored during the rainy season (March to May, 2007) and the dry season (June to August, 2007) in severely affected villages and fields. In order to avoid any possible confusion, color photographs of both diseases were used during the surveys. A total of 14 and 59 villages were assessed in a first stage for the presence and spread of BBTD and the fruit peel disease in the Kamanyola and Nyangezi areas, respectively.

Subsequent in-depth BBTD surveys were carried out randomly on 40 BBTV infected farms in 20 villages in Nyangezi (2 farms per village) and 20 BBTV infected farms in 10 villages in Kamanyola (2 farms per village). Further studies on the seasonal influence on BBTD severity and incidence were carried out on 12 BBTV-infected (seeing as no viral isolations were made, only symptom observation was carried out) farms located in 4 severely affected villages (3 farms per village). In addition, fruit peel disease surveys were carried out on 60 fruit peel disease infected farms in 20 villages in Nyangezi (3 farms per village). Further studies on the seasonal influence on disease severity and incidence were carried out in 8 severely affected villages (3 farms per village, in all 24 farms).

No fruit peel disease surveys were carried out in Kamanyola as the disease had not been observed during the CIALCA baseline and diagnostic surveys, and during the preliminary evaluation of disease presence in all the villages of both areas.

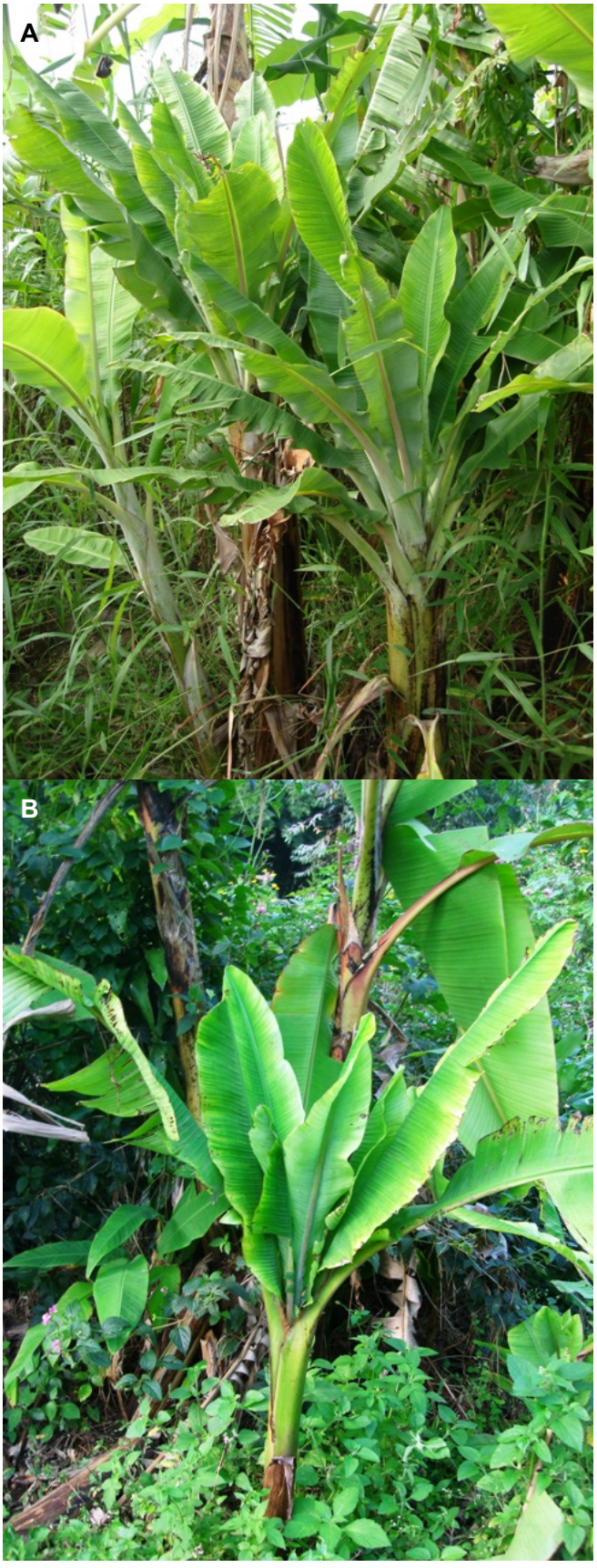

Fig. 2 (**A**) The leaves of BBTD-infected plants become brittle and stand more erect, giving the plant a rosetted or "bunchy top" appearance. (**B**) Lateral leaves showing chlorotic leaf margins.

The surveys assessed the most common *Musa* cultivars grown on farm and their use, age of the farm, origin of planting material, type of cropping system, farm maintenance status, date of appearance of the disease, origin of the disease, cause of the disease,

Table 1 The most common *Musa* cultivars in Nyangezi and Kamanyola and their use.

Area	*Musa* cultivars	Use
Nyangezi	Nakasimbu or Yangambi km5, Nabushi[§], Cisukari, Cisubi	Beer
	Kamaramasenge[#], Gros Michel, Kamara ka Rwanda[*#], Malaya	Dessert
	Musheba, Binyamunyu[ǂ]	Cooking
Kamanyola	Nakasimbu or Yangambi km5, Kisubi, Cihanda, Mushikazi[§]	Beer
	Cindege, Kamara[#], Gros Michel	Dessert
	Kisamunyu[ǂ], Musheba	Cooking

*originated in Rwanda
[#], [§] and [ǂ]: variety name synonyms

Table 2 Banana farm characteristics in Nyangezi and Kamanyola.

Farm characteristics	Nyangezi (farms with fruit peel disease present)		Nyangezi (farms with BBTD present)		Kamanyola (farms with BBTD present)	
	N° farms	%	N° farms	%	N° farms	%
Age of the farm						
Below 10 years	2	3.3	0	0	15	75
10-30 years	6	10	1	2.5	5	25
30-50 years	10	16.6	0	0	0	0
More than 50 years	42	70	39	97.5	0	0
Total	60	100	40	100	20	100
Origin of the planting material						
Own farm or exchange with neighbors	57	95	40	100	20	100
From far away	3	5	0	0	0	0
NGOs or government	0	0	0	0	0	0
Total	60	100	40	100	20	100
Cropping system			NA*		NA	
Sole crop	10	16.6				
Banana-beans	41	68.3				
Banana-coffee	7	11.6				
Banana-other crops	2	3.3				
Total	60	100				
Maintenance status						
Bad	50	83.3	10	25	5	25
Good	10	16.7	30	75	15	75
Very good	0	0	0	0	0	0
Total	60	100	40	100	20	100

*: NA: not assessed

most infected cultivars, suitable season for disease development and control measures practiced by the farmers.

The incidence (percentage of diseased plants over the total number of plants) and severity of both diseases were evaluated during both the dry and rainy season using a scoring system. The scoring system for the fruit peel disease comprised: 1) no symptoms (on the fruit peel); 2) reddish-brown specks (on the fruit peel); 3), reddish-brown spots (on the fruit peel) and 4) reddish-brown spots covering the whole fruit peel surface and/or longitudinal cracks in the fruit peel and/or pulp slightly affected. The scoring system for BBTD comprised: 1) no symptoms; 2) moderate symptoms [dark green streaks in the leaf veins] and 3) severe symptoms [chlorosis of leaf margins and/or dwarfing of leaves and/or plant has a rosetted or "bunchy top" appearance] (CTAHR 1997).

A preliminary study was conducted to assess aphid vector incidence using yellow colored traps which were positioned 80 cm about ground level in heavily BBTD-infested fields in 4 villages in the Kamanyola area during May 2008 (4 weeks) and in 8 villages of Nyangezi during June 2008 (4 weeks). Aphids were collected from the yellow traps at a frequency of three times per week and identified using reference photographs (Remaudière and Autrique 1985)

Two batches of bananas collected from 4 *Musa* varieties ('Cisukari', 'Nakasimbu', 'Mushikazi' and 'Kamaramasenge') affected by the fruit peel disease were sent off to the Global Plant Clinic (GPC) in the UK (www.globalplantclinic.org) for isolation and identification. The first batch of eighteen samples consisted of large mature fruits at an advanced stage of the disease (scoring stage 3 and 4). The second batch included 3 samples of immature fruits with only tiny reddish-brown specks on the fruit peel (scoring stage 2).

RESULTS AND DISCUSSION

Most common *Musa* cultivars (in Nyangezi and Kamanyola)

In Nyangezi the most common cultivar was 'Nakasimbu' (also known as 'Yangambi Km5'; *Musa* AAA group) (83.8%), followed by 'Gros Michel' (*Musa* AAA group) (6.1%) and 'Kamaramasenge' (*Musa* AAB group) (5.3%) (**Table 1**). The variety 'Kamara ka Rwanda' originated in Rwanda, while 'Nabushi' or 'Mushikazi' is the oldest variety. Synonyms in variety names were recorded (**Table 1**).

Banana farm characteristics (in Nyangezi and Kamanyola)

Most of the banana plantations in the Nyangezi area are over 50 years old (**Table 2**). Farms are inherited and planting materials are obtained from own farm or through exchange between neighbors. This practice is ideal for disease spread.

Banana is mainly intercropped with bush beans and mulch and manure application is rare (**Table 2**). Only backyard or home gardens receive organic kitchen/house refuse/waste. Overall farm management in the old plantations in Nyangezi is poor. In contrast, field maintenance was relatively good in the Kamanyola area where most farms were established in the last 10 years (**Table 2**). Currently banana cultivation in the Kamanyola area is resuming after the crop was nearly totally abandoned due to the devastation caused by BBTD over the past two decades.

Table 3 Overview of the number and percentage of villages affected by BBTD and the fruit peel disease in Nyangezi (>1,700 masl) and Kamanyola (<1,000 masl).

Disease	Nyangezi		Kamanyola	
	N° villages	%	N° villages	%
Fruit peel disease	59/59	100	0/14	0
BBTD	59/59	100	14/14	100

Distribution of banana fruit peel and banana bunchy top diseases in Nyangezi and Kamanyola areas

In Nyangezi the fruit peel disease has the local name 'Cibojo' which means 'crack in the fruit'. 'Cibojo' is widespread in the Nyangezi area but is unknown in the Kamanyola area (**Table 3**). As most cultivars are present at both locations an altitude effect (temperature and/or humidity and/or rainfall) on the incidence of fruit peel disease can be suspected.

On the other hand BBTD is present both in Nyangezi and Kamanyola (**Table 3**) and is locally known as 'Syndicat' or 'Sindika'. Most of the farmers (92%) declared that they were capable of identifying BBTD. The disease has been most devastating in Kamanyola with 'Nakasimbu' (or 'Yangambi Km5') being most severely affected. This variety however has resistance to nematodes and leaf fungal diseases (Fogain and Gowen 1998). On the other hand 'Gros Michel' and 'Pisang Awak' or 'Kayinja' (*Musa* ABB group) seem less affected by BBTD, in line with reports by Thomas and Iskra-Caruana (2000).

Farmer awareness and perception of the fruit peel disease and BBTD

The two diseases are well known in both locations (**Table 4**). However, most farmers are unaware of the origin of these diseases. The farmers who acquired planting materials from neighboring villages or countries stated that the fruit peel disease arrived with these introduced planting materials. Moreover, a large number of farmers think that insect stings on the fruit peel cause the fruit peel disease (**Table 4**) whereas others think that infected soil may be the origin. However, for the moment, no findings confirm these suggestions.

The cause of BBTD is, on the other hand, unknown to most farmers. The BBTD aphid vector is relatively small and hides in between the leaf sheaths. According to Thomas and Iskra-Caruana (2000) aphid vectors can spread the disease over more than 80 meters from the nearest source of infection. The distance over which infection can occur will also be determined by prevailing winds.

Incidence and severity of the fruit peel disease and BBTD during the rainy and dry season

The incidence of the fruit peel disease was slightly higher during the rainy season, 17% against 14% during the dry season (**Table 6**) challenging farmers' claims that the rainy season was far more suitable for disease development (**Table 4**). There was a 5% increase in disease incidence during the rainy period between the months of March and April 2007, while the incidence remained more or less constant during the entire dry season. This reflects the influence of the seasons on the evolution of the disease. However, there were no significant differences in severity between the rainy and dry season, probably due to low rains observed

Table 4 Farmer awareness and perception of the fruit peel disease and BBTD.

Farmer awareness and perception	Nyangezi (farms with fruit peel disease present)		Nyangezi (farms with BBTD present)		Kamanyola (farms with BBTD present)	
	N° farms	%	N° farms	%	N° farms	%
Date of appearance of the disease						
Less than 10 years ago	0	0	0	0	0	0
10-30 years ago	0	0	0	0	0	0
30-50 years ago	9	15	0	0	0	0
More than 50 years ago	29	48.3	35	87.5	18	90
Unknown	22	36.7	5	12.5	2	10
Total	60	100	40	100	20	100
Origin of the disease						
Neighbouring villages	10	16.6	0	0	0	0
Neighbouring countries	7	11.7	0	0	0	0
Unknown	43	71.7	40	100	20	100
Total	60	100	40	100	20	100
Cause of the disease						
Insect stings	36	60	0	0	0	0
Infected soil	20	33.3	8	20	0	0
Unknown	4	6.7	32	80	20	100
Total	60	100	40	100	20	100
Most infected cultivar						
Nakasimbu	60	100	40	100	17	85
Gros Michel	0	0	0	0	3	15
Kamaramasenge	0	0	0	0	0	0
Total	60	100	40	100	20	100
Suitable season for disease development						
Rainy season	60	100	0	0	0	0
Dry season	0	0	0	0	0	0
Both	0	0	40	100	20	100
Total	60	100	40	100	20	100
Control measures practiced by farmers						
Cut infected plant	7	11.6	10	25	15	75
Cut infected plant and remove plant debris	0	0	1	2.5	0	0
Replant with clean planting material	53	88.4	0	0	0	0
None	0	0	29	72.5	5	25
Total	60	100	40	100	20	100

Table 5 Incidence (%) and severity of BBTD during the rainy (March till May) and the dry season (June till August).

Time of assessment		Villages											
		Nyamurhambi			Lukananda			Cijingiri			Kabiganda		
		Scoring system*			Scoring system			Scoring system			Scoring system		
Mar-07		1	2	3	1	2	3	1	2	3	1	2	3
	N[#]	2	47	11	28	38	4	30	28	2	24	30	6
	I		97%			60%			50%			60%	
	S		2.2			2.0			2.1			2.2	
Apr-07	N	5	48	7	23	35	8	27	32	1	18	36	6
	I		92			65			55			70	
	S		2.2			2.2			2.0			2.1	
May-07	N	3	51	6	26	29	5	22	40	4	28	29	3
	I		95			57			67			53	
	S		2.1			2.2			2.1			2.1	
Mean during the rainy season	I		**95**			**61**			**57**			**61**	
	S		**2.2**			**2.1**			**2.1**			**2.1**	
Jun-07		1	2	3	1	2	3	1	2	3	1	2	3
	N	8	42	10	18	33	9	12	44	4	42	10	8
	I		87			70			80			30	
	S		2.2			2.2			2.1			2.4	
Jul-07	N	12	40	8	27	29	4	8	46	6	13	45	2
	I		80			55			87			78	
	S		2.2			2.1			2.1			2.0	
Aug-07	N	10	49	1	16	36	8	20	30	10	12	39	9
	I		83			73			67			80	
	S		2.0			2.2			2.3			2.2	
Mean during the dry season	I		**83**			**66**			**78**			**63**	
	S		**2.1**			**2.2**			**2.2**			**2.2**	

*1: no symptoms; 2: moderate symptoms [dark green streaks in the leaf veins, plant with fruit] and 3: severe symptoms [chlorosis of leaf margins and dwarfing of leaves, plant with stunted fruit]
[#]: N: number of plants ; I: incidence (in percentage); S: severity

Table 6 Incidence (%) and severity of the fruit peel disease during the rainy (March till May) and the dry season (June till August).

Month		Villages																												Mean	
		KAMISHI				BULENGA				KAMINA				MUSHEGO				CIBIMBI				KALENGERA				MUNYA				MULENDE			
		Scoring*				Scoring				Scoring				Scoring				Scoring				Scoring				Scoring				Scoring			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	I	S
March	N[#]	89	11	0	0	90	8	2	0	73	20	7	0	83	15	2	0	87	12	1	0	89	11	0	0	86	12	2	0	86	14	0	0	14	2
	I		11				10				27				17				13				11				14				14				
	S		2				2.2				2.3				2.2				2.1				2				2.1				2				
April	N	87	9	4	0	80	17	3	0	70	19	10	1	80	16	2	1	80	18	0	0	84	10	6	0	82	10	2	2	80	13	4	0	19	2
	I		13				20				30				19				18				16				15				18				
	S		2.3				2.2				2.4				2.2				2				2.4				2.4				2.2				
May	N	87	9	4	0	79	18	3	0	70	19	7	4	79	16	3	1	80	16	2	0	84	10	6	0	80	11	2	3	80	12	4	0	19	2
	I		13				21				30				20				18				16				17				17				
	S		2.2				2.1				2.5				2.1				2.2				2.4				2.2				2.3				
Mean	I		12				18				29				19				18				14				14				18				17	2
	S		2.2				2.1				2.4				2.1				2.1				2.2				2.2				2.2				
June	N	89	9	2	0	90	10	0	0	73	27	0	0	84	14	2	0	90	10	0	0	86	12	2	0	91	9	0	0	85	15	0	0	14	2
	I		11				10				27				16				10				14				9				15				
	S		2.2				2				2				2.1				2				2.1				2				2				
July	N	84	9	1	0	90	10	0	0	73	24	1	0	81	16	3	0	89	9	0	0	86	10	3	0	90	10	0	0	85	15	0	0	14	2
	I		11				10				26				19				9				13				10				15				
	S		2.1				2				2				2.2				2				2				2				2				
August	N	83	10	0	0	88	12	0	0	73	22	1	0	81	16	3	0	82	11	1	0	84	12	2	0	90	10	0	0	85	15	0	0	15	2
	I		11				12				24				19				13				14				10				18				
	S		2				2				2.04				2.15				2.08				2.42				2				2				
Mean	I		11				11				26				18				11				14				10				16				14	2
	S		2.1				2				2				2.1				2				2.2				2				2				

*: 1= no symptoms on the fruit peel, 2= tiny black spots on the fruit peel, 3= enlarged black spots on the fruit peel 4= black spots covering the whole fruit peel surface; longitudinal cracks in the fruit peel; pulp slightly affected.
[#]: N: number of plants ; I: incidence (in percentage); S: severity

during the rainy season. Farmers stated that the disease is most severe during weeks of heavy rain with production losses attaining up to 100%. Although the incidence and severity of the fruit peel disease is low (**Table 6**) badly infected bunches are no longer consumable by humans or animals and beer processed from diseased bunches is undrinkable.

With regards to BBTD, symptoms are omnipresent at both locations during both the rainy and dry season (**Tables 4, 5**). The highest mean disease incidence of BBTD was recorded in Nyamurhabi village (95%) (**Table 5**). Disease severity was similar during both seasons. Although the severity score is low, infected plants will not produce bunches (or only very small ones) and lateral shoots will most likely develop disease symptoms.

Isolation and identification of micro-organisms associated with fruit peel disease

Banana samples collected in three distinct locations (Cibimbi, Kamina, Munya) manifesting initial and severe stages of the fruit peel disease were sent to the Global Plant Clinic

Table 7 List of bacteria and fungi isolated from fruit peel disease affected fruits at the Global Plant Clinic (UK).

Location	Cultivar	Symptom status	Microorganism present
Cibimbi	Kamaramasenge	Severe symptoms	*Cladosporium musae*; *Phoma herbarum*; *Phoma* sp.
	Nakasimbu	Initial symptoms (specks)	*Alternaria* sp.; *Cladosporium cladosporioides*; *Cladosporium* sp.; *Colletotrichum musae*; *Colletotrichum.* sp.; *Pantoea sp. (bacteria)*; *Phoma* sp.
Kamina	Cisukari	Severe symptoms	*Cladosporium musae*
	Kamaramasenge	Severe symptoms	*Cladosporium musae*; *Idriella bolleyi*; *Phoma pomorum*
	Mushikazi	Severe symptoms	*Cladosporium musae*
	Nakasimbu	Initial symptoms (specks)	*Colletotrichum musae*; *Fusarium solani*
	Nakasimbu	Severe symptoms	*Alternaria alternata*; *Colletotrichum musae*; *Mycosphaerella musicola*; *Periconia bessoydia*; *Phoma herbarum*
Munya	Mushikazi	Severe symptoms	*Colletotrichum musae*
	Nakasimbu	Initial symptoms (specks)	*Alternaria tenuis*; *Cladosporium cladosporioides*; *Cladosporium musae*; *Epicoccum* sp.; *Fusarium solani*; *Pythium ultimum*
	Nakasimbu	Severe symptoms	*Leptodontidium* sp.; *Phoma herbarum*; *Phoma nebulosa*

Table 8 Number of banana aphids (*P. nigronervosa*) collected in yellow traps in 4 sampled villages of Kamanyola during May 2008 and in 8 sampled villages of Nyangezi during June 2008.

Local area	Village	1st week	2nd week	3rd week	4th week	Mean
Kamanyola, May 2008	Ihindiro	13	12	15	11	13
	Kashenyi	14	12	14	12	13
	Migina	13	15	15	12	14
	Kambara	14	12	11	10	12
	Mean	14	13	14	11	
Nyangezi, June 2008	Nyamurhabi	10	13	11	9	11
	Kabiganda	12	8	12	6	10
	Lukananda	12	10	11	8	10
	Chijingiri	13	11	9	6	10
	Kalwa	13	11	9	6	10
	Tendera	10	7	8	3	7
	Munya	9	9	7	4	7
	Chibimbi	11	10	8	4	8
	Mean	11	10	9	6	

(UK) for isolation. Morphological analyses revealed the presence of numerous microorganisms that are listed in **Table 7**.

Colletotrichum musae, causal agent of anthracnose fruit rot, was isolated from four out of the 11 samples analyzed; revealing its presence on cultivars 'Nakasimbu' (Cibimbi and Kamina) and 'Mushikazi' (Munya) in all three locations. It was isolated as a sole colonizer in one out of the four samples (Munya cv. 'Mushikazi'). *Cladosporium musae*, causal agent of leaf speckle, was identified from fruits in five out of eleven samples on cultivars 'Cisukari' (Kamina), 'Kamaramasenge' (Cibimbi and Kamina), 'Mushikazi' (Kamina) and 'Nakasimbu' (Munya) in all three locations. The fungus was surprisingly isolated as a sole colonizer in two distinct samples despite the fact that it is not reported in the literature as affecting fruit. *Fusarium solani* was isolated on cultivar 'Nakasimbu' in two locations (Kamina and Munya) and always in association with other fungi.

Anthracnose fruit rot, also known as wound anthracnose, is reported as an important postharvest banana disease, but has equally been reported to cause lesions on immature bunches (Jones and Stover 2000). Symptoms appear under high humidity and temperature conditions and through wounding, causing premature ripening and/or rotting of fruit. A hypersensitive reaction manifested as red-brown flecks on the peel is induced when green fruit are infected. The infection remains latent until the fruit ripens causing sunken, necrotic spots to develop from the initial flecks. A salmon colored conidial mat covers lesions when conditions are optimal for sporulation.

Based on the GPC analyses and literature reports, it is likely that the fruit peel disease observed in South Kivu is caused partly by *Colletotrichum musae*. However, the fact that *Colletotrichum musae* was not isolated in a majority of the samples and that other pathogens such as *Cladosporium musae* were isolated in equal ratios restricts the assimilation of the fruit peel disease to anthracnose. Moreover, studies clearly identifying the entry point of the pathogen (no wound, insect wounds, etc) and artificial lab inoculations using purified strains of *Colletotrichum musae*, *Cladosporium musae* and *Fusarium solani*, solely or in combination, need to be carried out to fulfill Koch's postulate, unambiguously identifying the fruit peel disease's causal agent.

Assessing the aphid populations at both locations

Trapped winged aphids were morphologically identified as being *Pentalonia nigronervosa* using reference plates (Remaudière and Autrique 1985). A slightly higher number of aphids was recorded in the Kamanyola area (**Table 8**) where the disease has devastated the crop in the past decades. Additional aphid assessments are needed during both the dry and rainy season to better understand aphid population dynamics. In Burundi, aphids have been found in all banana growing regions from the Rusizi valley (890 masl) to Gitega (>1,600 masl). Less aphids were collected from the yellow traps during the rainy season compared to the dry season at the ISABU Mparambo research station, Burundi (893 masl) and at the IRAZ research station in Gitega, Burundi (1,645 masl) (Célestin Niyongere pers. comm.).

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REFERENCES

Anonymous (1998) *Les Bananas*, CIRAD et INIBAP, 13 pp

Berg LA (1968) Diamond spot of bananas caused by *Fusarium roseum* 'Gibbosum'. *Phytopathology* **58**, 388-389

CIALCA (2007) *Summary Progress Report*, 02 September 2005-April 2007, 28 pp

CIALCA (2009) Consortium for Improving Agriculture-based Livelihoods in

Central Africa. Summary Technical Report, Final report phase 1, Jan 2006 – Dec 2008. Supported by the Directorate General for Development Cooperation (DGDC), Belgium, 91 pp

CTAHR (1997) Cooperative Extension Service, Plant disease, December 1997. College of Tropical Agriculture and Human Resources (CTAHR), University of Hawaii, Honolulu, Hawaii, 4 pp. Available online: http://www.ctahr.hawaii.edu

Fogain R, Gowen S (1998) 'Yangambi km5' (*Musa* AAA, Ibota subgroup): a possible source of resistance to *Radopholus similis* and *Pratylenchus goodeyi*. *Fundamental and Applied Nematology* **21 (1)**, 75-80

Gatsinzi F (1987) Les principales maladies et ravageurs du bananier au sein de la CEPGL. Séminaire sur les maladies et ravageurs des principales cultures vivrières d'Afrique centrale. Bujumbura, 16-20 fevrier 1987. IRAZ et ISABU, 554 pp

Jones DR, Stover RH (2000) Fungal diseases of banana fruit: pre-harvest diseases. In: Jones DR (Ed) *Diseases of Banana, Abaca and Enset*, CABI Publishing, City, UK, pp 183-185

Kaiser WJ, Lukezic FL (1966) Influences of certain environmental conditions on spore dispersal and survival of *Cercospora hayi* from banana. *Phytopathology* **56**, 1290-1293

Lubarika WK (2003) Introduction à la recherche sur les nématodes chez le bananier à bière en basse altitude dans la province du Sud Kivu, cas de la Plaine de la Ruzizi. Mémoire, U.C.B., 38 pp

Lukezic FL, Kaiser WJ (1966) Aerobiology of *Fusarium roseum* 'Gibbosum' associated with crown rot of boxed bananas. *Phytopathology* **56**, 545-548

Ploetz RC, Zentmeyer GA, Nishijima WT, Rohrbach KG, Ohr HD (1994) *Compendium of Tropical Fruit Diseases*, ANS Press, St. Paul, Minnesota, USA, 111 pp

Remaudière G, Autrique A (1985) Contribution à l'écologie des aphids africains. Etude FAO, Production végétales et Protection des Plantes, 64, Rome, FAO, 214 pp

Stover RH (1972) *Banana, Plantain and Abaca Diseases*, Commonwealth Mycological Institute, Kew, Surrey, UK, 316 pp

Thomas JE, Iskra-Caruana MI (2000) Diseases caused by viruses: Bunchy top. In: Jones DR (Ed) *Diseases of Banana, Abaca and Enset*, CABI Publishing, City, UK, pp 241-253