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The changing spread dynamics of banana Xanthomonas wilt (BXW) in Uganda

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Abstract

Banana Xanthomonas wilt still remains a serious threat to banana production in Uganda. Although the desired long term control strategy would have been use of resistance, no sources of resistance have been found. Further the transgenic resistance under development will only be deployed in the long run. In the meantime, cultural control, remains the driver of BXW management strategy in Uganda. This requires continuous effort by the farmers and other stakeholders. It is imperative that disease spread information be continuously updated to sustainably control BXW. The study was conducted to update the status of BXWto inform the continuous refinement of the control strategy of BXW control in across all the epidemics zones in Uganda. BXW incidence increased from about 1% between 2005 and 2006 to about 3.8% in 2010 in the threatened areas. The BXW prevalence increased from below 5 to 34.4% in the same period. Meanwhile, the incidence and prevalence of BXW in the endemic areas reduced to below 10% and about 40%, respectively, from over 50% between 2006 and 2010. The high prevalence of BXW indicates that BXW is widely spread but the low incidence shows that BXW is at initial linear phases of disease epidemic across all zones. There are also a few clusters of infection with infected fields at various phases of the disease progress curve. This suggests that it is no longer feasible to classify Uganda's banana growing areas in different epidemic zones. Consequently the strategies to control BXW across the zone are similar.

Key words: *Banana Xanthomonas wilt,* control, incidence, prevalence, stakeholder mobilisation

Introduction

Banana (*Musa* sp.) is the fourth most important global food crop after rice, wheat and maize in terms of gross value of production(Sharrock and Frison, 1999). It is a major staple food, supplying up to 25% of the carbohydrates for over 14 million people in Uganda (Karamura, 1993). Xanthomonas wilt (*Xanthomonas campestris* pv. *musacearum* (*BXW*)) has continued to threaten banana production in Uganda, endangering the livelihoods of poor, small-holder farmers. Many stakeholders now regard it as a major priority constraint to banana production, overtaking weevils, nematodes, and fungal and viral diseases. The latter constraints have, however, been managed using cultural practices that exploit the differences in cultivars' resistance/ tolerance on farm (Tinzaara *et al.*, 2009). Thus, farmers suffered reduced productivity, but maintained a reasonable level of food and income security. The arrival of banana *Xanthomonas* wilt in Uganda in 2001 entire crop holdings were wiped out in some areas (Tushemereirwe *et al*., 2004). It was reported that Uganda would lose US$ 295 million worth of bananas at farm gate price annually, an equivalent of US$ 200 of food and income per household (Kalyebara *et al*., 2006). BXW also

erodes banana genetic diversity and disrupts the ecological stability in banana plantations (Kubiriba *et al*., 2012).

It would have been desirable to control BXW using resistance; however, no source of resistance to BXW has so far been identified in the Musa germplasm (Ssekiwoko *et al*., 2006). The transgenic resistance currently under development can only be deployed in the long run. Therefore cultural control remains the main driver of BXW control strategy in the meantime. This necessitates continuous engagement of the farmers and other stakeholders. It in-turn requires continuous information update of BXW spread to inform the control strategy.

There have been unconfirmed reports of BXW spread to new areas. Additionally, there are other unconfirmed reports of BXW occurrence in areas where it had been controlled. Although, BXW status in Uganda, has been reported before (Tushemereirwe *et al*., 2004; Kagezi *et al.,* 2006), this may have changed over the years. It is, therefore, important to update BXW status and accordingly inform and reinforce the control strategy for BXW in Uganda. This paper presents data on the incidence and level of control of BXW between 2005 and 2010 in Uganda.

Materials and methods

In response to the BXW outbreak, a National Banana Xanthomonas Wilt Control Initiative was established in 2005. This divided the country's banana growing areas into three epidemic zones to be able to better target control activities in 2005 (Tushemereirwe *et al*., 2006). The zones included the endemic, frontline and threatened areas. The frontline zone constituted areas that stretch from L.Victoria to the Mt. Rwenzori (districts of Mpigi, Mityana, Mubende, Kiboga, Kyenjojo and Kabarole) at the edge of BXW epidemic at the time. Endemic zone constituted areas where BXW was considered established in more than 50% banana fields and were in the northern part of the frontline. They included the Bunyoro region, Luwero, Kayunga, Eastern and Northern Uganda. These are also areas that produce less than 15% of Uganda's bananas. The other zone was the threatened zone, south of the frontline. It constituted most banana growing areas of South Western Uganda, which were largely free of BXW at the time. These are areas where more than 80% of Uganda's bananas are produced (Kalyebala *et al*., 2006).

Sampling procedure

Data were collected on1080 households that were sampled using a multistage random sampling procedure. The sample was representative of major banana growing areas in the three epidemic zones and those with recent reported but unconfirmed outbreaks. Sampling was stratified according to spread dynamics of BXW to represent what was previously classified as endemic areas, frontline areas and threatened areas (Tushemereirwe *et al*., 2006).

In the 2005 survey, at least two districts were selected to represent each epidemic zone. Two sub-counties were randomly selected from which two parishes were selected. Three villages were selected per parish and 15 farms were selected from each village. In total, 1080 farms were sampled. Largely, the sampling frame used in 2005 was also used in the surveys of 2006, 2008 and 2010. However, a few more districts were added or removed to accommodate the changing BXW spread dynamics over time. In 2010, additional data was collected from new outbreak areas. Atleast 15 fields were sampled in each of the 2 villages in a district. Three districts represented the endemic areas; 2 districts the frontline areas and 5 districts the threatened areas totaling to 348 fields.

Data collection and analysis

Data were collected in 2005, 2006, 2008 and 2010. Data were directly collected on 30 mats by moving diagonally through the banana fields. Data were recorded on presence of BXW on the sampled mats, number of banana bunches sold at the different BXW epidemics

events; before BXW attack (at the onset of the BXW attack), peak of attack (time the fields were most affected; with most affected plants and least banana harvests or sales) and time of data collection. The BXW key epidemic events above were vivid in the farmers' minds because of their dramatic nature of destruction and spread. Data on the proportion of fields on which BXW had been effectively controlled was derived as follows:

X-Y/X where, X is the number of fields that were ever affected with BXW and Y is the number of banana fields affected at the time of data collection.

Descriptive statistics were used to obtain mean BXW incidence (proportion of infected plants) and prevalence (proportion of affected fields). Data about fields that once had BXW infection were derived from responses of farmers and the BXW status on the farm recorded by the Research team.Percentage banana sales recovery in areas previously affected by BXW was computed as follows:

C-B/A-B where A is the number of banana bunches sold at time of data collection, B is the number of banana bunches sold at the peak of the epidemic and C is number of banana bunches sold the the onset of BXW. Data on number of banana sold per month were analysed by the General Linear Model (GLM) that suits the unbalanced treatments and means separated by Student – Newman Keul (SNK) test (SAS, 1997).

Results

BXW incidence

The results in Table 1 show a marked difference in the incidence of BXW between the three epidemic zones. All the districts in the endemic zone had a higher incidence of BXW, followed by those in the frontline zone

Table 1. BXW incidence in three epidemic zones over time

Epidemic zone	District	% of infected plants			
		2005	2006	2008	2010
Threatened	Bushenyi	1	1	3	5.9
	Ntungamo	1	1	3	1.2
	Mbarara	-	-	-	3.6
Mean for the threatened areas		**1.0**	**1.0**	**3.0**	**3.6**
Frontline	Kiboga	-	40	23	-
	Mubende	2	19	16	6.7
Mean for the frontline		**2.0**	**29.5**	**19.5**	**6.7**
Endemic	Luwero	43	57	49	-
	Kayunga	59	64	45	4.6
	Masindi	71	72	58	-
	Kamuli	50	57	67	5.2
	Mbale	67	67	41	7.4
	Bududa	-	-	-	5.0
	Manafa	-	-	-	2.1
Mean for Endemic areas		**58.0**	**63.4**	**52.0**	**4.9**

and least in the threatened zone. In the threatened areas (South Western Uganda), BXW incidence slightly increased from 1% between 2005 and 2006 to about 3.6% between 2008 and 2010. On the frontline, BXW incidence increased over time up to about 30% and then reduced to below 10% in 2010. BXW incidence in the endemic areas was higher than in the threatened or frontline areas in 2005, 2006 and 2008. BXW incidence reduced from over 50% in 2006 and 2008 to below 10% in 2010 even in the endemic areas.

BXW prevalence (proportion of infected banana fields)

In the endemic areas, prevalence of BXW reduced from over 60% in 2005 and 2006 to about 40% in 2010 (Figure 1). BXW prevalence in the threatened areas, however, increased from under 5 to 34% in 2010 in the same period. The data also shows that there is decreased BXW prevalence to about 50% from the proportion of banana fields ever affected with BXW in endemic areas and decreased BXW prevalence to 36.5% the proportion of banana fields ever affected with BXW in threatened areas. BXW prevalence in 2010 is lower for the endemic and frontline areas and about 6 fold higher for the threatened areas compared to that of 2005 -2006. Other additional data collected from new outbreak areas confirms new BXW reports in Kisoro, Sembabule, Rakai and Kanungu (Figure 2).

Level of BXW control

Level of control of BXW was considered to be the proportion of the farms that cleared BXW infection off their fields, and had had no BXW infection for more than 3 months. BXW infection was cleared on more than 30% of the previously affected fields in areas with previously unconfirmed outbreaks. In areas such as Sembabule and Kabale, BXW infection was cleared on about 60% of the previously affected fields. It is only in Kisoro, Kamwenge and Bundibudyo, where BXW infection was cleared on 26, 15.6 and 9.1% of the affected banana fields, respectively (Figure 2).

BXW was effectively controlled on most of the affected farms (90%) in threatened areas in both 2006 and 2008. The proportion of affected fields where BXW infection was cleared drastically reduced to about 45% in

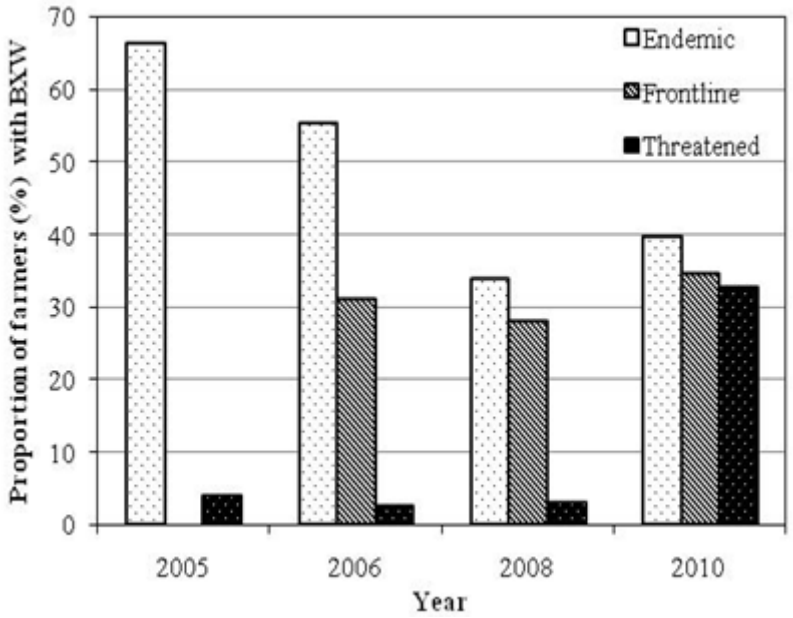

Figure 1. BXW prevalence in the three epidemic zones over time.

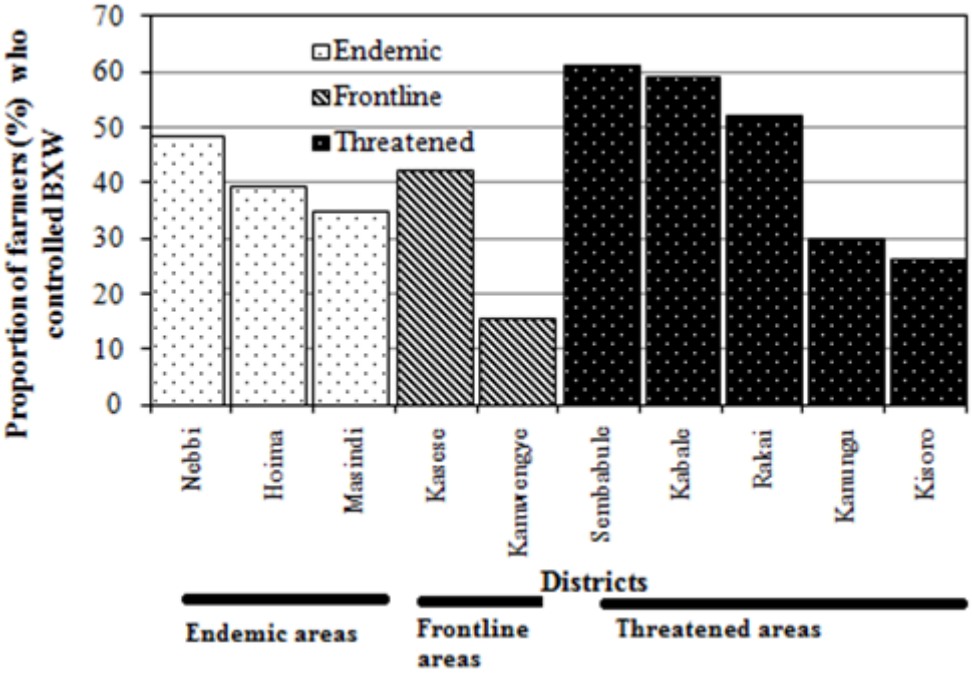

Figure 2. Level of BXW control in new outbreak areas.

2010 (Figure 3). In the frontline areas, BXW was effectively controlled on 60% of the affected fields in 2006; which increased to about 70% in 2008 and then reduced to about 40% in 2010. There was an increase of previously infected fields where BXW was effectively controlled in endemic areas from 21.5% in 2006 to about 50% in 2008 and 54.3%.

Banana sales recovery

Most farmers sold bananas ranging from 20 to 38 bunches per acre per month before BXW onset (Table 2). Mean number of banana bunches sold significantly reduced to lowest level at the peak of BXW infection ranging from 9 to 23 bunches per acre per month. Although, mean number of banana bunches sold per month at the time of data collection did not largely differ significantly from that at the peak of infection, there were indications of banana sales recovery up to 40%. There was also bananasales recovery from new outbreak areas of up to 29.6%.

Discussion

By 2006, BXW had been reported in areas covering half of Central Uganda, Bunyoro and most of Eastern and Northern Uganda and a few areas in thereatened areas (Tushemereirwe *et al.*, 2006). On the frontline, BXW occurred in scattered pockets. Kagezi *et al*. (2006) reported that BXW was poised to spread to the threatened areas, where more than 80% of Uganda's bananas are produced. However, BXW at the time had been reported in the Districts of Bushenyi, Mbarara, Ntungamo and Kabale in the threatened areas.

Data in this paper show that BXW incidence (proportion of infected plants) was below 10% in all the three epidemic zones in 2010 indicating that BXW infection is generally reduced at field level. However, BXW prevalence (proportion of affected fields) increased in the threatened areas almost 6-foldto levels comparable to that in frontline and endemic areas. BXW prevalence remained

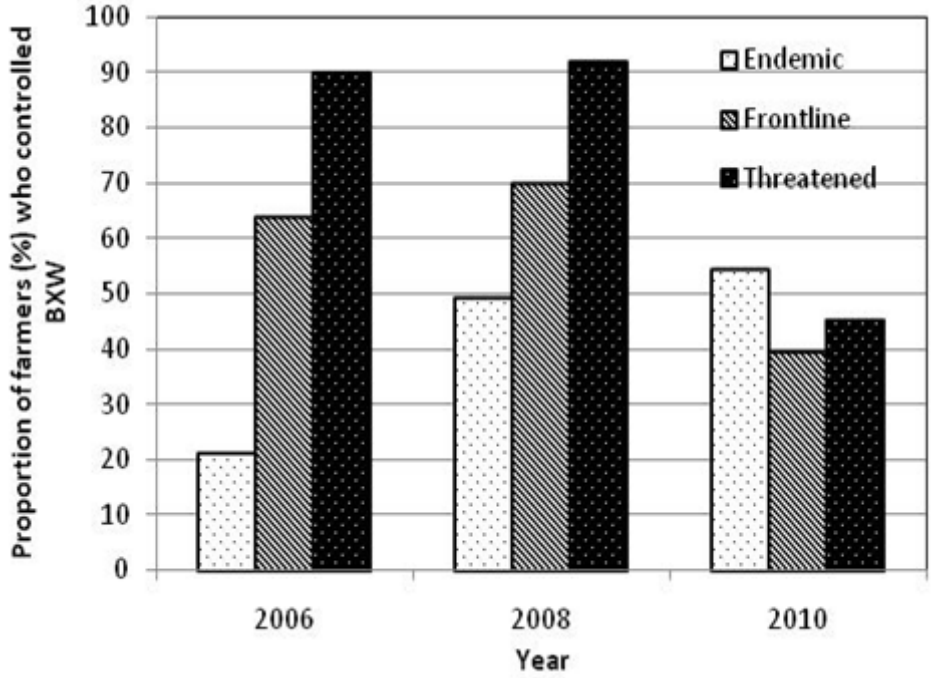

Figure 3. Level of BXW control in the three epidemic zones over time.

Table 2. Mean number of bunches sold per acre per month at different BXW epidemic levels in new outbreak areas

Districts	Before BXW	At BXW epidemic Peak	Current (August 2010)	Percentage sales (%) recovery
Hoima	19.3a	6.2b	7.9b	9.3
Masindi	22.3a	6.6b	8.3b	13.6
Nebbi	9.7a	4.5b	4.5b	0
Kamwengye	21.8a	12.7b	16.3ab	39.8
Kasese	26.7a	10.4b	9.0b	16.0
Kabale	33.1a	16.5b	17.3b	5.0
Kanungu	27.4a	9.9b	12.5b	15.3
Kisoro	22.2a	8.7b	7.0b	-
Rakai	34.6a	12.3b	19.9b	33.8
Sembabule	38.4a	21.0b	22.7b	9.7

Means with the same letter in the same row are not significantly different (P> 0.05) by SNK

around 30% on the frontline and significantly reduced to about 40% in the endemic areas. Data collected from formerly areas with unconfirmed infection revealed that BXW occurred in areas of Sembabule, Rakai, Kisoro and Kanungu with high prevalence of up to 60% in some districts. BXW has spread to more fields and areas in 2010 as compared to 2006 especially in the main banana growing areas of the South Western Uganda

(threatened areas) and on the frontline areas. This suggests that the front of BXW spread in Uganda seems to have disappeared. This has implication on the recommendations for BXW control. For example, the focus of the control strategy of BXW in threatened areas may have to shift from largely preventive to proactive measures.

Low BXW incidence (<10%) but high BXW prevalence (30-45%) presents two scenarios; i) BXW occurs in many fields, each field, with a few plants infected with BXW. This scenario is representative of an epidemic with initial focal points of diseaseinocula (Zadoks, and van den Bosch, 1994). These are the spring boards for developing the disease epidemic into exponential phase (Nutter *et al*., 1997). This could be the case where the disease has recently been introduced on the fields. These are characteristically caused by infected planting material where there are massive new plantings or insect vectored spread (Thresh, 1980) through the malebuds since flowered plants are randomly distributed. Traders who harvest bananas from farm to farm using the same machetes may also cause this kind of spread. For BXW epidemic in South Western Uganda, the most likely causes are the insect vectored spread and traders. The few infected plants can easily be removed by the individual farmers and if backed with suspension of using cutting tools in those fields, this type of infection may be controlled within atleast 4 months (Tushemereirwe *et al*., 2006). ii) The other scenario is one where, there are pockets of BXW, i.e., few widely affected villages or parishes, each with sometimes up to 300 affected banana fields, also referred to as hotspots. This is a situation where the BXW is at different epidemic phases of the disease progress curves (Nutter, 1997). On some fields, it may be at the initial linear phase, others in exponential phase (rapid spread) and others in the declining phase (most of plants are already affected). It is also common to find fields where banana plants have been completely destroyed. This is a scenario of an advanced disease epidemic, which requires more effort for control. The pockets of BXW infection need to be identified and then communities around these infection pockets be mobilised to control them using participatory approaches (Tushemereirwe *et al.*, 2006). Such infection has been reported to be controlled within at least 9 months (Kubiriba *et al*. under review).

The BXW status reported in this paper has implication in the control strategy of the disease. The disease control goal in the threatened zone was be to keep it disease-free and to stop the further advance of the disease into unaffected areas and to control it in the advancing edge of BXW spread (Tushemereirwe *et al.*, 2006). Accordingly, different control options were recommended for the different epidemic zones. For example disposal of infected banana refuse from affected fields was to be buried in the threatened areas, while they were left to rot on the ground in frontline areas. This was to keep a high level of BXW control with goal of eradicating the disease and preventing it from further spread in those areas. Similar strategies (previously described in this paper) will now be used to control BXW across the epidemic zones since BXW incidence and prevalence are comparable.

Data in this paper also show that some farmers were able to effectively control BXW on their fields, resulting in recovery of banana sales. This seems to indicate that technologies recommended for BXW control are still effective if well implemented. Tushemereirwe *et al*. (2006) reported effective control of outbreaks from whole sub-counties in threatened areas. Even, the advancing front of BXW spread had slowed down and the disease control programme was effective where it was implemented.

Data presented in this paper show that the situation described by Tushemereirwe *et al*. (2006) obtained for up to 2008. During this period, BXW incidence and prevalence remained below 5% in the threatened areas. This was attributed to effectiveness of the recommended practices; the pathogen limited ability to survive outside the host (Mwebaze

et al., 2006) but also the level of engagement of the farmers in BXW control. Successful control of BXW required effective extension and supportive local leaders in the mobilisation of farmers (Tushemereirwe *et al*., 2006). It is still possible to control the current upserge of BXW infection using a similar or slightly modified system depending on stakeholders' input.

It can be concluded that BXW spread dynamics have greatly changed across the banana growing areas in Uganda. BXW prevalence in the threatened areas that also produce more than 80% of Uganda's bananas increased 6 fold This is probably due to reduced level of engagement of the different stakeholders in BXW control since the recommended cultural control practices seem to still be effective. There is need to reactivate the BXW control machinery of stakeholders, review the control strategy in light of the current situation and mobilize both human and financial resources to support the control programme to reduce the impact of BXW on banana production in the country.

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