Vol.11(7), pp. 128-138 July 2019
DOI: 10.5897/JAERD20198.1000
Articles Number: 80E2A3261374
ISSN: 2141-2170

http://www.academicjournals.org/JAERD

ACADEMIC JOURNALS
expand your knowledge

Journal of Agricultural Extension and Rural Development

Full Length Research Paper

Effectiveness of learning and experimentation approaches for farmers as a community based strategy for banana xanthomonas wilt management

William Tinzaara[1*], Fred Ssekiwoko[2], Enoch Kikulwe[1] and Eldad Karamura[1]

[1]Bioversity International, Kampala Offices, P. O. Box 24384, Kampala, Uganda.
[2]National Agricultural Research Organization, Bulindi Zonal Agricultural Research and Development Institute, P. O. Box 101, Hoima, Uganda.

Received 1 December, 2018; Accepted 20 February, 2019

Banana Xanthomonas wilt (BXW) is a devastating disease for banana and enset in east, central and Horn of Africa since 1968. The disease has spread to all banana growing countries in the region in the last decade, causing yield losses of up to 80 to 100%. Several efforts have been undertaken to develop and implement technologies for BXW management and their effective deployment with varying successes. This paper presents a new participatory approach for managing BXW named Learning and Experimentation Approaches For Farmers (LEAFF) and describes how it was implemented, tested and evaluated among 220 farmers across two agroecological regions, central and South-western Uganda. Results showed that there was a general reduction in the number of infected plants, corresponding to 7% increase in productivity of banana among the LEAFF compared to the non LEAFF participating farmers. The findings suggested that scaling out LEAFF to different parts in the region can significantly contribute to effective and sustainable adoption of BXW management technologies, and in turn, can lead to improved productivity and smallholder farmers' livelihoods.

Key words: Accountability group, community mobilization, farmer record management information system (FARMIS), learning and experimentation approaches for farmers (LEAFF), Single Diseased Stem Removal (SDSR).

INTRODUCTION

Banana Xanthomonas wilt (BXW) caused by *Xanthomonas campestris* Pv. *musacearum* (*Xcm*, Yirgo and Bradbury, 1974), or *Xanthomonas vasicola* Pv. *musacearum* (Aritua et al., 2007) is the most important biotic constraint to banana production in East and Central Africa. Firstly, it threatens the livelihoods and food security of over 80 million people in sub saharan Africa. Secondly, while the disease incubation period ranges from 10 days to 16 months (Ssekiwoko et al., 2006; Ocimati et al., 2013a) depending on inoculum load and route of entry, most affected plants quickly wilt, die and rot away, often making it impossible to realize any

*Corresponding author. E-mail: w.tinzaara@cgiar.org.

harvests from any single affected plant including those attacked post fruiting through the inflorescence. Thirdly, all cultivated varieties lack resistance against the pathogen (Ssekiwoko et al., 2006) and are all affected. Fourthly, the disease spreads very fast and is currently widely distributed in all banana growing areas within the region including Ethiopia (Yirgo and Bradbury, 1974), all parts of Uganda (Tushemereirwe et al., 2004), in eastern Democratic Republic of Congo (Ndugo et al., 2006), northern Rwanda (Reeder et al., 2007), areas around lake Victoria zone of Tanzania, western Kenya and Burundi (Carter et al., 2010).

Over the years, research has come up with a number of technological recommendations for disease management including: cutting and burying whole infected mats as Xcm survival under rotting condition within soil was very limited (Mwebaze et al*.,* 2006), destruction of infected plants by use of herbicides such as 2, 4-dichlorophenoxyacetic Acid (2,4-D) and Glyphosate (Okurut et al., 2006; Blomme et al., 2008), removal of male buds (de-budding) by twisting with a forked stick to deny transmission by foraging stingless bees, birds and bats on banana inflorescence and fruits (Buregyeya et al., 2014; Tinzaara et al., 2006), use of escaping varieties that have persistent bracts and flowers (Ocimati et al., 2013b). Single Diseased Stem Removal (SDSR) as Xcm exhibits incomplete systemicity (Ssekiwoko et al*.,* 2010; Ocimati et al*.,* 2013a; Ocimati et al*.,* 2013b) and use of resistant transgenic varieties carrying a plant ferredoxin-like protein (*Pflp*) and a hypersensitive response assisting protein (*Hrap*) genes from sweet pepper (Tripathi et al., 2010; Namukwaya et al., 2012; Muwonge, 2016). These technologies for BXW management have been deployed with varying successes across landscapes and countries in the region.

These technologies have been deployed through a number of approaches including: (i) eradication and containment, (ii) Community sensitization for action, (iii) Participatory Development Communication (PDC), (iv) Community action and (v) Farmer field school (FFS).

Eradication and containment

This was deployed in the early days of the epidemic (2001-2007) in Uganda, Rwanda and DR. Congo where localized outbreaks would be identified; then teams would be dispatched and paid to cut and burry the affected mats (Mwangi and Nakato, 2009).

Community sensitization for action

This was practiced in Ethiopia and Uganda and it involved printing and distribution of information leaflets, fact sheets, brochures and posters about BXW. It was deployed with an assumption that this would trigger action by farmers on their farms but it was later noted that despite the over 85% awareness, less than 30% were actually practicing (Bagamba et al*.,* 2006; Tushemereirwe et al*.,* 2006).

Participatory development communication (PDC)

This approach involved mobilization of community stakeholders to explore available and potential solutions to BXW problem which they constituted into an action plan detailing what needs to be done, when to do it, where to do it, how to do it, who would take what responsibility and mechanisms for monitoring and evaluation. Application of PDC showed a drop in BXW prevalence from 88 to 18% (Kubiriba and Tushemereirwe, 2014) but limited by dependence on external PDC resource person and thus unsustainable.

Community action

It involved mobilization of community stakeholders to explore available and potential solutions to BXW problem which they constituted into an action plan detailing what needs to be done, when to do it, where to do it, how to do it, who would take what responsibility and mechanisms for monitoring and evaluation but most importantly, the plan also included mechanism for enforcing agreed actions (such as by-law enforcement). Implementation of community action approach showed a drop in BXW prevalence to 68% and a banana yield recovery of 22% (Kubiriba et al., 2012) but this approach is also limited by dependence on external resource person and thus unsustainable.

Farmer field school (FFS)

This approach involved mobilization of community stakeholders for participatory discovery, decision making, problem solving and stimulating local innovation while using the field as their learning school under guidance of a technical facilitator (Ochola et al., 2015). Implementation of FFS approach in Uganda in 2006-2008 (Kubiriba et al., 2012) showed a drop in BXW prevalence by 43% compared to 15% with other approaches ever used in the same area (Kubiriba and Tushemereirwe, 2014) but it is limited by encouraging one way flow of information (facilitator to farmers).

Given the limitations associated with these approaches, the Learning and Experimentation Approaches for Farmers (LEAFF) was developed with the aim of fostering sustainable Community Based Management of BXW. Specifically the approach would foster a two way learning from both facilitators and farmers who already had their own innovations and were presented with an opportunity to systematically validate them.

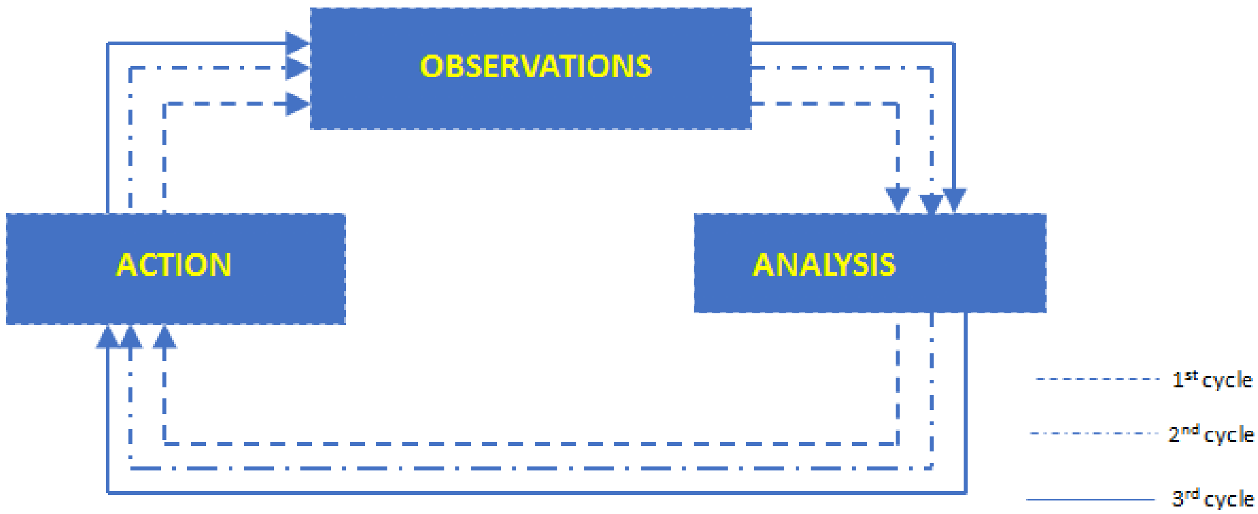

Figure 1. The learning and experimentation cycle.

This study was conducted from 2014 to 2016 (3 years) to evaluate the effectiveness of using the LEAFF tool in the management of BXW and its out scaling would significantly contribute to effective and sustainable adoption of BXW management technologies for improved banana productivity. The effect of the approach on community awareness, disease incidence, banana yields was evaluated within the participating banana communities of Kiboga and Bushenyi districts.

LEAFF concept and development

LEAFF is one of the community mobilization approaches for action. It focuses on increasing knowledge and deployment of agro-ecologically sensitive approaches with respect to pest/disease management, nutrient flows and sustainability of the production systems. It fosters better understanding of the variability within and between farms and landscape by farmers so as to match interventions with variability in the production and agro-ecological systems. The approach strengthens skills for observation, analysis and decision making and tap into farmer knowledge and experiences to promote farmer innovation and strengthening horizontal interactions and promote quality engagement within and between partner groups (Figure 1). These were achieved through repeated experimentation, learning and knowledge sharing, then deployment of best-bet practices. The approach is an innovation that was conceived after noticing that many agricultural recommendations to small holder farmers (including disease management) are in most cases made without considering the variability in production systems, agro-ecologies and socioeconomic situation of different regions. This has had an effect of causing low adoption and discouraging farmers from using indigenous knowledge yet farmers have knowledge of the variability within and between farms and sites with respect to biotic, abiotic and socioeconomic diversity especially the gender attributes which can be exploited to promote farmer-researcher experimentation and learning experiences. This approach was designed to empower farmers to not only be recipients but also originitors of knowledge and technology.

LEAFF is composed of a basic unit called an accountability group (AG), normally of 5-10 farmers who have mutually agreed to set priorities, share plans and lessons to address common objectives on a landscape. The members of AG informally/mutually consent to visit each other's farms and make observations considering the socio-cultural and gender perspectives. Within the AG, one member assumes responsibility as a contact person for the group and becomes the preliminary link with other AG's on a landscape and beyond. AG fora are used to identify short and long-term needs and priorities, with respect to technology and/or information while also capturing feedback. After priority setting by different AGs, experimentation objectives are developed, experiments established, and observations made, recorded, analyzed and interpreted (in participatory manner usually with support of technical persons). Interpretation influences implementation of next agreed actions for next experimentation cycle. In this approach, practices such as integrated pests and disease management (IPDM) only become an integral part of activities but with flexibility for farmers to validate them through experimentation. In addition to experimentation and learning, LEAFF exploits modern communication tools/platforms (including internet and mobile phones) to facilitate farmers to access and use improved technologies while enhancing horizontal linkages between farmers and communities across landscapes.

LEAFF is similar to the FFS approach in that both are group-based adult learning approaches that teaches farmers how to experiment and solve problems independently. LEAFF however attempts to involve farmers in the development of the control measures through farmer action research networks which support experimentation and learning, value chain strengthening, enterprise development and knowledge sharing. The designs of LEAFF provide for farmers to be exposed to experimentation skills and processes, including constraint identification, prioritization, hypothesis setting and testing, data collection and analysis, participatory monitoring and evaluation and reporting/feedback with emphasis on the specific application to BXW management, while tapping into their existing experiences. This increases farmer-to-farmer interactions to enhance the sharing of experiences and skills in the quest to increase the effectiveness of the control measures. LEAFF farmers are connected through mobile phones and internet thus increase within group and between group interactions which lack within FFS and other community approaches.

MATERIALS AND METHODS

Sites descriptions

The study was conducted in Bushenyi Benchmark site (in western Uganda, about 300 km from Kampala) and in Kiboga District (mid-western Uganda, about 120 km from Kampala). Bushenyi is characterised by the East African Highland banana system while Kiboga is mainly Kayinja based system. In Bushenyi, diversity is low with pure stands of commercially grown banana covering much of the agricultural land and producing 344,369 Mt per year compared to 58,564 Mt in Kiboga. In all two landscapes, diseases, declining soil fertility, poor market access and unreliable rainfall are the major constraints to production. Agricultural development is encroaching on natural wetlands in Bushenyi, and is a driver of bush burning in Kiboga, potentially leading to a loss of habitat for biodiversity and locally valuable ecosystem services. While agriculture is the main economic activity in these study sites, it is practiced mainly by smallholders and the average household farm holding is just 1.1 ha. Kiboga is characterized by high farm diversity relative to other landscapes, comprising mixed crop and crop-livestock systems dominated by maize and beans. The bananas are grown for both subsistence and sale.

Baseline and endline data collection

Both baseline and endline data were collected from LEAFF and non LEAFF farmers through interviews and measurements on: banana production levels and productivity including area under banana, number of banana mats and productivity including the number of bunches harvested, consumed or marketed, number of disease free bunches; BXW awareness levels and sources of information, number of affected plants, level of debudding and level of destruction of infected plants. All farmers whose baseline data were collected but were not selected for participation in the LEAFF activities were considered to be non-LEAFF farmers.

Farmers' selection and training

Following trainings, 100 farmers and another 120 farmers were self -selected (with the guidance of community leaders) from Bushenyi and in Kiboga respectively to participate in the project. The farmers selected to be in a group were those who were in the same landscape, sharing a common concern (BXW disease problem), willing to work together as a team and share ideas and mutually agreed to share plans and lessons to address common objectives on their different landscapes. Farmers were organized into 10 accountability groups (AG) (10 farmers of mixed gender per group) in Bushenyi and 12 AGs in Kiboga .

The process of LEAFF testing/implementation

Initial planning and priority setting meeting

Following baseline survey data collection and analysis, a meeting with AGs was organized to provide an opportunity for AG members to comment on household, farm and landscape summaries and review constraints as they come out. This was then followed up by a general feedback workshop where AGs and other farmers used the data summaries to prioritize the constraints and develop management targets and/or research questions. In this meeting, capacity needs of the AGs were identified which would be incorporated into the training of the trainers programme.

Training for LEAFF

Farmers in the AG along with their leaders in the landscape were first trained in field BXW diagnosis, disease spread and control. This was followed by training in general banana management/ agronomy (from planting to harvesting). Two lead persons per group were trained and empowered to train members of the respective groups. They were trained in banana as a business; formation of a network, farmer record management information system (FARMIS) for information exchange (information on banana markets, disease outbreak and weather data), basics about banana phenology, nutrition and yields and attendant factors such as pests, diseases, nutrient cycles and healthy products. In addition, they were exposed to experimentation skills and processes, including constraint identification, prioritization, hypothesis setting and testing, data collection and analysis, participatory monitoring and evaluation and reporting/feedback with emphasis on the specific application to BXW management, while tapping into their existing experiences.

Experimentation and data collection

Following the training and under technical guidance, the selected farms were each considered as an experimental garden (replicate) and each farmer made observations on changes in prevalence of BXW having applied various treatments including: debudding and single diseased stem removal (SDSR). After a field wide application of these particular treatments to particular well labeled mats within their fields with the exception of 5 mats for each treatment as controls, farmers would monitor and record BXW symptoms development on such a mat. They would then rate the treatment as effective in preventing or reducing BXW prevalence in comparison to the controls. In addition, farmers were asked to carry out the following general field wide practices including disinfecting tools

Table 1. Farmer percentage obtaining BXW awareness information from various sources in 2014.

Source of information	% respondents
Extension	5
From my children	2
Observation	23
Radio	33
Trainings and workshops	33

with fire and sometimes jik, establishing new gardens with clean planting materials, avoidance of corm removal, avoidance of digging with a hoe in the banana plantation, avoidance pruning but cutting dry parts only, Avoidance of dumping rubbish in the farm then give an opinion of their effectiveness in controlling BXW. They would then also rate these treatments as effective in preventing or reducing BXW prevalence. Proportion of farmers giving a specific rating was recorded. In addition, general data on changes in banana production levels and productivity including area under banana, number of banana mats, bunches and leaves harvested, BXW awareness levels and sources of information was also subsequently collected in a participatory manner over a period of 3 years: 2014, 2015 and 2016 by participating farmers, a contact AG member who had under gone training and a technical field assistant. Necessary tools for data collection and recording including the weighting scales and a data collection booklet were given to every farmer for recording of data/observation.

Farmers would share notes through visits to each other's fields and through monthly meetings organized at AG level. The AG contact persons would also collect information via an internet-connected phone (through whatsApp or Facebook) and shares it with other AG contact persons who in turn shared it with members of the AG and other partners in the network. To promote horizontal interactions among farmers, exchange visits to other banana growing areas were organized for group members.

Data analysis

Data from LEAFF and Non-LEAFF farmers were summarized as means and frequencies/proportions were compared using student t and chi squared tests where applicable. Results were presented in tables and graphs over the years then shared with the communities.

RESULTS

BXW awareness levels and sources of information

At project initiation in 2014**,** it was established that most of the farmers (91%) were aware of BXW. This high level of awareness was found to have been majorly achieved through radio messages (33%), trainings attended (33%) and personal observation in their fields (23%) (Table 1).

Changes in BXW incidence and prevalence among LEAFF and non-LEAFF farmers

There was a general observable rduction in the number of infected plants per farm over the three year study period (Table 3) although by close of 2016, there were still recordings of presence of infected plants on farmer field among both the LEAFF and non LEAFF participating farmers (Figure 2). Further analysis showed a significant difference in the percentage of farms with BXW among the LEAFF and non LEAFF participating farmers in 2015 (Table 4), where 31% of the LEAFF participating farmers and 57% of the non LEAFF participating farmers still had BXW on their farms.

Further analysis also showed significant degrees of success in preventing outbreak of BXW among the farms that did not have BXW among the LEAFF compared to non LEAFF participating farmers in 2015 (Table 5). In at least 6 months, 86% of the LEAFF participating farmers and 64% of the non LEAFF participating farmers had not registered any BXW outbreak on their farms suggesting successful control.

Farmer rating of effectiveness of various BXW control options as judged from their experimentation trials also were consistent with above changes in incidence and prevalence (Table 2). They highly rated the effectiveness of avoidance of corm removal (100%), avoidance of pruning (100%), cutting off only dry parts (100%), cutting and burying (79%), debudding (73%) and disinfection of tools in Jik or sodium hypochloride (78%) in reducing the prevalence of BXW on their farms. They however rated having many tools and restricting them for use in specific areas of plantation (33%), avoidance of dumping rubbish in the farm (50%), removal of diseased part only (59%), pouring a liquid mixture of urine, ash and hot pepper on the cut suckers (67%), restricting animals (67%) and avoidance of digging with a hoe in the banana plantation (67%) as not effective in reducing the prevalence of BXW on their farms.

Changes in banana production and productivity

At project initiation in 2014, land holding, area under banana, were not significantly variable among the study communities. On the other hand, banana yields were significantly variable among the study communities (Table 6). Land holding averaged around 5.49 acres among the

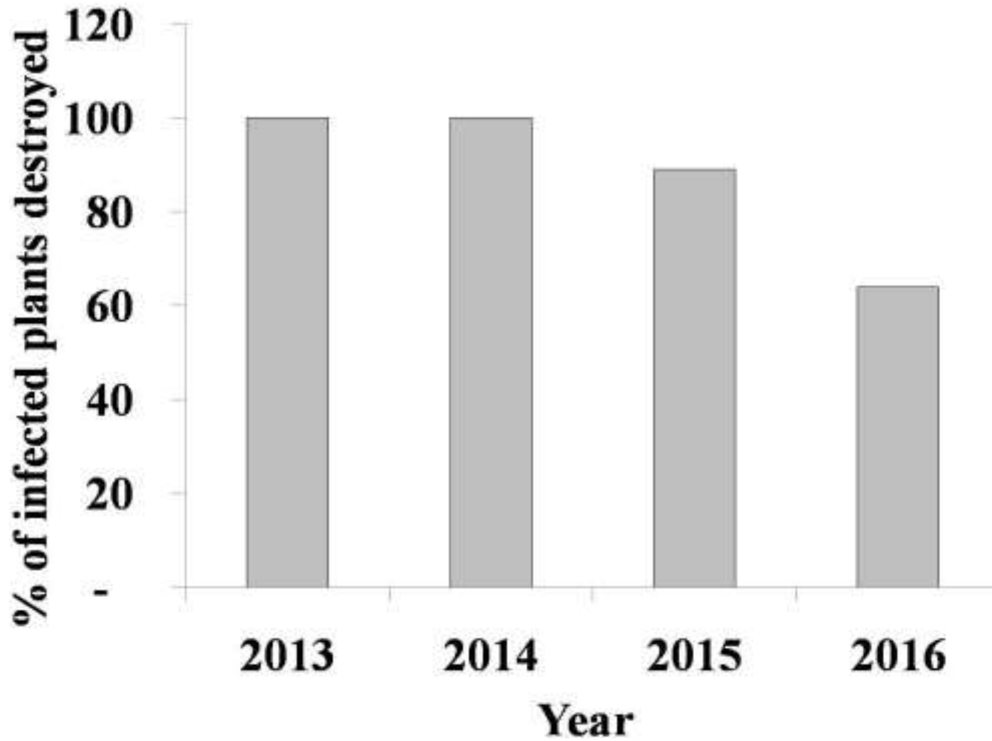

Figure 2. Changes in proportion (%) of BXW infected banana plants destroyed over the years among LEAFF participating farmers.

Table 2. Percentage of LEAFF participating Farmers variously rating the effectiveness of their BXW management practices.

Farmers' BXW management practice	Prevented	Reduced
Debudding	5	73
Removing diseased part	41	59
Pouring a liquid mixture of urine, ash and hot pepper on the cut suckers	-	67
Disinfection of tools in sodium hypochloride	4	78
Disinfection of tools with fire	17	67
Avoid corm removal	-	100
Avoid digging with a hoe in the banana plantation	-	67
Avoid pruning	-	100
Avoid dumping rubbish in the farm	-	50
Burning the diseased part	-	100
Cutting and burying	-	79
Cutting dry leaves and fibres only	-	100
Having many tools and restricting them for use in specific areas of plantation	-	33
Restricting animals	-	67

LEAFF and at 6.24 acres among the non LEAFF participating farmers. Area under Matooke averaged around 1.98acres among the LEAFF and at 2.68 acres among the non LEAFF participating farmers. Area under Kayinja averaged around 3.31acres among the LEAFF and at 1.16 acres among the non LEAFF participating farmers.

Similarly, Matooke yields averaged around 59.02 bunches among the LEAFF and at 65.2 bunches among the non LEAFF participating farmers while Kayinja yields

Table 3. Mean number of infected plants per farm over the years.

Farmer type	Mean No. infected mats per farm per year (S.E)		
	2014	2015	2016
LEAFF	27.6(3.1)	6.3(0.51)	4.4(0.34)
Non LEAFF	21.4(1.56)	7.4(0.9)	5.7(0.44)
t-test	1 NS	0.6 NS	0.8 NS

Table 4. Percentage of farms with BXW among the LEAFF and non LEAFF participating farmers.

Farmer type	% affected farms(S.E)
LEAFF	31(3.4)
Non LEAFF	57(9.4)
X^2 test	3.42^{xxx}

*** significant P< 0.001.

Table 5. Percentage of farms without BXW outbreak in at least 6 months among the LEAFF and non LEAFF participating farmers.

Farmer type	% farms controlled (no outbreak in at least 6 months)
LEAFF	81.5
Non LEAFF	64
X^2 Test	7.05^*

*Significant, P<0.05.

Table 6. Mean land hold, area under banana and banana yields in 2014.

Farmer type	Mean land hold (acres) (S.E)	Mean area under Matooke (acres) (S.E)	Mean area under Kayinja (acres) (S.E)	Mean Matooke yields (bunches) (S.E)	Mean Kayinja yields (bunches) (S.E)
LEAFF	5.49(0.45)	1.98(0.09)	3.31(0.41)	59.02(5.33)	41.0(3.54)
Non LEAFF	6.24(2.0)	2.68(0.74)	1.16(0.12)	65.2(18.61)	34.82(4.8)
T- test	0.5NS	1.28NS	1.58NS	0.44NS	0.30NS

NS means not significant at (P <0.05).

averaged around 41.0 bunches among the LEAFF and at 34.8 bunches among the non LEAFF participating farmers. This observation suggested that banana production was possibly equally important among the LEAFF and non LEAFF participating farmers. After project initiation, while land holding neither increased nor was it significantly variable among the study communities, there were observed changes in area under banana (Table 7). In comparison to the baseline values in 2014 (Table 6), by the year 2015, there was a general decrease in area under banana which averaged at 1.7 and 2.4 acres among non LEAFF and LEAFF participating farmers respectively for Matooke and at 3.6 and 0.7 acres among LEAFF and non LEAFF participating farmers respectively for Kayinja. By 2016 however, although area under Matooke had stagnated at 1.7acres, that under Kayinja had significantly increased from 0.7 to 5.4 acres among the LEAFF participating farmers. On the other hand however, area under banana had decreased from 2.4 to 2.3 acres for Matooke and from 3.6 to 1 acre for Kayinja among the non LEAFF participating farmers

Similarly, in comparison to the baseline values in 2014, by the year 2015 banana yields had generally decreased though there was observed recovery by 2016 (Table 8). Among LEAFF farmers, yield recovery was generally lower among matooke AGs (7.2%) compared to Kayinga

Table 7. Changes in banana acreage among LEAFF and Non LEAFF farmers over the years.

Farmer type	Mean area under Matooke (acres) (S.E)		Mean area under Kayinja (acres) (S.E)	
	2015	2016	2015	2016
LEAFF	1.7(0.1)	1.7(0.1)	0.7(0.1)	5.4(1.4)
Non LEAFF	2.4(0.7)	2.3(0.72)	3.6(0.8)	1.0(0.09)
t-testt	1.13NS	1.00 NS	0.65NS	1.15NS

NS means not significant at (P <0.05).

Table 8. Changes in banana yields among LEAFF farmers over the years.

Year	Mean Matooke yields (No. bunches) (S.E)	Mean Kayinja yields (No. bunches) (S.E)
2015	31.1(3.6)	5.0(0.6)
2016	33.1(2.43)	9.2(1.5)
% recovery	7.2	11.7

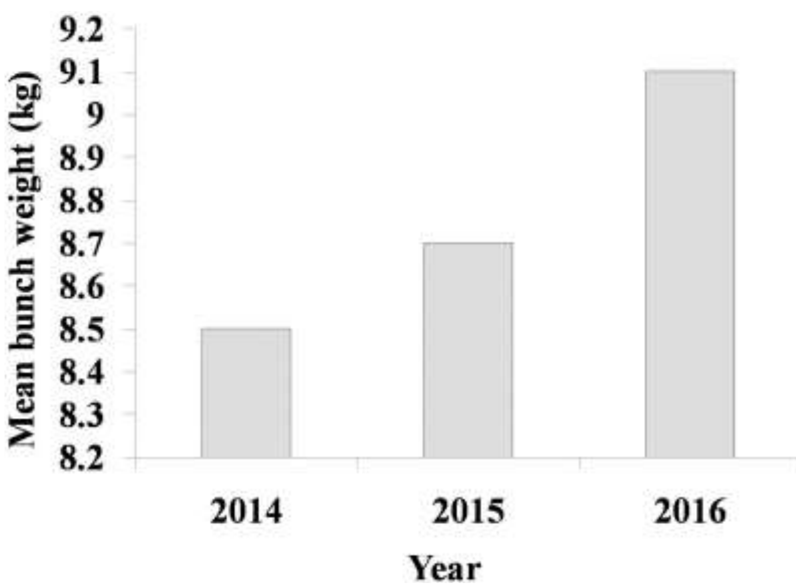

Figure 3. Changes in bunch weights over the years among LEAFF participating farmers.

AGs (11.7%). The number of bunches harvested and sold over the years among LEAFF participating farmers declined over the years (Figure 2) while their mean weight (Figure 3) and number of fingers (Figure 4) increased.

DISCUSSION

BXW awareness levels and sources of information

The observed high level of BXW awareness is consistent with other studies dating back in 2006 in Uganda which showed that by that time, over 85% of farmers had been aware of BXW symptoms and available control options (Bagamba et al., 2006; Tushemereirwe et al., 2006) although they had not been implementing them. This observation further highlighted the need for a more robust approach to cause implementation of the control options. It therefore follows that the observed incidence and prevalence of BXW at the beginning of this study in 2014 cannot be attributed to lack of awareness but due to other factors. It had been noted earlier that many farmers did not appreciate the rationale for these control options. This justified the need for farmers to validate these control option together with their other related innovations for

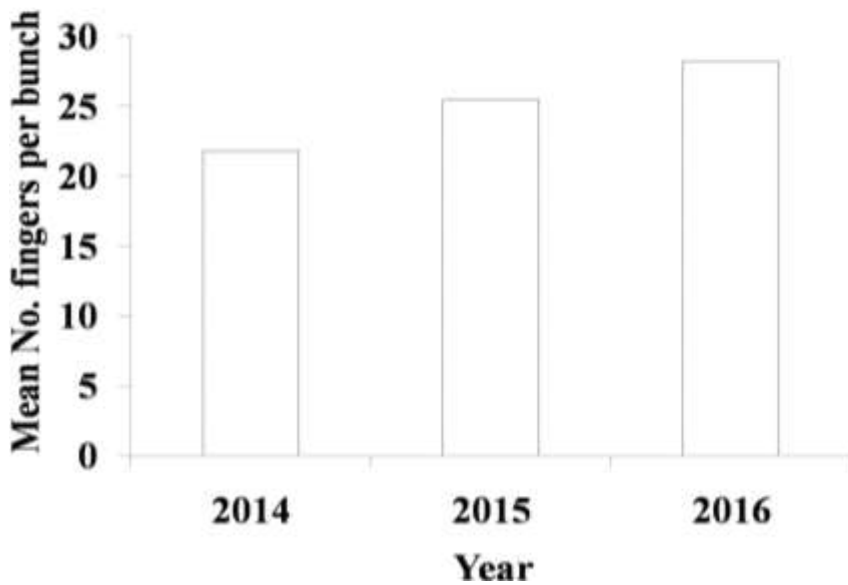

Figure 4. Changes in mean number of fingers over time.

BXW management.

Changes in BXW incidence and prevalence

It was noted from the farmer managed control practices validation experiments that while some LEAFF participating farmers reported a prevention of outbreak and reduction of BXW prevalence on their farms, others also reported that some practices such as simply having many tools and restricting them for use in specific areas of plantation, avoiding dumping rubbish in the farm, removing diseased/symptomatic part only and pouring a liquid mixture of urine, ash and powdered hot pepper on the cut suckers were not very effective in disease reductions. Pruning with contaminated tools is an established transmission mode (Buregyeya et al., 2010) and while farmers had imagined that they could control BXW by restricting specific tools to specific areas of the plantation, they discovered that this was not practical and in some way they only caused further disease spread within field thus was not effective as they eventually rightly observed.

The low farmer rating of the effectiveness of avoiding dumping of rubbish in farm is expected especially that this is only a means of preventing disease introduction into the field but would not in any way prevent disease spread within the field from the already infected plants. Also, the low farmer rating on the practice of removal of only symptomatic part is expected especially that Xcm infection is systemic (Ssekiwoko et al., 2010; Ocimati et al., 2013a; Ocimati et al., 2013b). By simply removing only symptomatic part would not render other deeper parts where Xcm has migrated free of the pathogen and it would only be a matter of time when symptoms appear in another adjacent part.

The observed reduction in the number of infected plants per farm and the total number of infected plants over the landscape over the years was attributed to active destruction of infected plants. Further, the persistent presence of infected plants on their farms even by 2016, despite all efforts, was attributed to the laxity on the part of farmer who had actually reduced on destruction efforts as shown in Figure 2 and this further justifies a need for a continuous and more sustainable engagement of farmers.

Nevertheless, application of LEAFF caused a reduction in prevalence of BXW from 57% to 30% and subsequent eradication of the same in up to 82% of the farms that once had the disease compared to 64% where such approach was not applied. The relatively high level of disease eradiacation among non LEAFF farmers was attributed to spillover effects. In addition, it should be noted that other previously promoted approaches were still active in these communities and this result only illustrates the superiority of LEAFF over such other approaches such as Community sensitization for action which is largely universally applied in all banana growing areas of Uganda. LEAFF performance is however comparable to Participatory Development Communication approach (PDC) that caused a drop in BXW prevalence from 88 to 18% (Kubiriba and Tushemereirwe, 2014), Community action which caused a drop in BXW prevalence to 68% (Kubiriba et al., 2012) and FFS approach which caused a drop in BXW prevalence by 43% compared to 15% with other approaches before it

(Kubiriba and Tushemereirwe, 2014).

Changes in banana production and productivity

Observed initial values in area under banana and the yields suggested that banana production was possibly equally important among the LEAFF and non LEAFF participating farmers. This is further supported by the observed lack of significant variability in Matooke acreage among LEAFF and non LEAFF participating farmers. Further, maintenance of Matooke acreages over the years seems to suggest that regardless of presence of BXW and implementation of LEAFF approach, households were already operating at optimal acreages and that there had been sufficient efforts to manage effects of BXW in Matooke fields. In addition, field devastation by BXW to cause reduction in acreage is usually less pronounced in Matooke fields. This is clearly evident in our results that showed reduction in Kayinja acreage among the Non LEAFF participating farmers. The observed increase in Kayinja acreage among LEAFF participating farmers further emphasizes the significance of LEAFF approach. Further, the observed higher Matooke yields also emphasize the significance of LEAFF approach. It is however not very clear why there was a greater banana yield recovery among the non LEAFF participating farmers than among LEAFF participating farmers, but since there had been an increase in banana acreage among the LEAFF participating farmers; it is most likely that most plants at the time of assessment had not yet bore fruits to contribute to yield recovery as they are likely to have just been planted. Note that it is more common to continuously plant matooke unlike for Kayinja. In addition, the banana acreage was generally lower among the LEAFF compared to the non LEAFF participating farmers.

The observation that reduction in BXW prevalence on farms did not necessarily correspond with increase in yields together with a general drop in the number of bunches harvested and sold (Figure 3) among the LEAFF participating farmers is attributed to the time requirement for ecosystem recovery which this approach also emphasizes. Disease infection together with roguing reduces the plant cover and yields directly but they also expose the soil to degradation resulting in reduction in bunch weights. But towards 2016, it was noted that bunch weights and general number of fingers were beginning to recover and improve (Figure 4).

CONCLUSION AND RECOMMENDATIONS

LEAFF has been found to be a powerfull approach in mobilizing for community action against BXW where when applied in the study areas it caused a reduction in disease prevalence from 57 to 30% and subsequent eradication of the same in up to 82% of the farms that once had the disease compared to 64% where such approach was not applied. Given this approach's superiority over others previously used in East and central Africa, it is recommended for scalling out to other areas within this region.

FUTURE PERSPECTIVE IN BXW MANAGEMENT

While LEAFF has been proved effective in increasing farmers adoption of options for BXW management and consequently lead to increased yields, it lacks provisions for handling the increased produce which would negatively affect their sustainable use. More over all the participatory approaches so far used for BXW management, focused on the need to control this diaese as the main entry point. Indeed the main challenge was BXW but for the implementers, it was assumed that BXW challenge and the need to controll it per se would its self act as an incentive for farmers to invest time to learn, share and inovate for sustainable control. There is need to consider a new perspective where farming households today are nolonger focusing on food sufficiency only but use their farms as a source of income and will invest time if there is a threat to their income or there is a potential to improve their income if they engage. Otherwise they will make BXW control secondary and rather focus on other income generating activities only returning to BXW control activities during their free time. Each farming household is a trading entity of some sort and trade strengthening to maximise profits from their agricultural activities should be the driver/ incentive for action. Research therefore needs to explore the incentives and benefits/success that would come along when the above participatory aproaches are organised around whole value chains, intergrating marketing and strengthening agricultural trading for better incomes. It is envisaged that through such, other practices such as environmental management, ecosystem sustainability and management of epidemics such as BXW should be an intergral part to protect and improve their incomes and in this way, it shall be more sustainable.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Aritua V, Parkinson N, Thwaites R, Heeney JV, Jones DR, Tushemereirwe W, Smith J (2007). Characterization of the Xanthomonas sp. causing wilt of enset and banana and its proposed reclassification as a strain of *X. vasicola*. Plant Pathology 57:170-177.

Bagamba F, Kikulwe E, Tushemereirwe WK, Ngambeki D, Muhangi J, Kagezi GH, Green S (2006). Awareness of banana bacterial wilt control in Uganda: Farmers' perspective. African Crop Science Journal 14(2):157-164.

Blomme G, Turyagyenda LF, Mukasa H, Eden-Green S (2008). The effectiveness of different herbicides in the destruction of banana Xanthomonas Wilt infected plants. African Crop Science Journal 16(1):103 -110

Buregyeya H, Kubiriba J, Tusiime G, Kityo R, Ssekiwoko F, Tushemerierwe WK (2014). Role of birds and bats in long distance transmission of Banana Bacterial Wilt in Uganda. International Journal of Agriculture Innovations and Research 2(4):636-640.

Buregyeya H, Tusiime G, Tushemerierwe WK (2010). Evaluation of the contribution of birds, bats and farm tools in the long distance transmission of Banana Bacterial Wilt in Uganda. Msc. Dissertation. Makerere University.

Carter BA, Reeder R, Mgenzi SR, Kinyua Z M, Mbaka J N, Doyle K, Smith JJ (2010). Identification of Xanthomonas vasicola (formerly *X. campestris* pv. *musacearum*) , causative organism of banana xanthomonas wilt, in Tanzania, Kenya and Burundi. Plant Pathology 59(2):403-403.

Kubiriba J, Tushemereirwe WK (2014). Approaches for the control of banana Xanthomonas wilt in East and Central Africa. African Journal Plant Science 8(8):398-404. DOI: 10.5897/AJPS2013.1106.

Kubiriba J, Karamura EB, Jogo W, Tushemereirwe WK, Tinzaara W (2012). Community mobilization: A key to effective control of banana Xanthomonas wilt. Journal Development of Agricultural Economics 45(5):125-131.

Muwonge A (2016). Evaluation of expression of Hrap and Pflp gene in transgenic banana plants for resistance against *Xanthomonas campestris* pv. *musacearum*. PhD Thesis, University of Pretoria.

Mwangi M, Nakato G (2009). Key factors responsible for the xanthomonas wilt epidemic on banana in East and Central Africa. Acta Horticulture 828:395-404

Mwebaze J, Tusiime G, Tushemereirwe WK, Kubiriba J (2006). The Survival of Xanthomonas campestris pv. musacearum in Soil and Plant Debris. African Crop Science Journal 14(2):121-127.

Namukwaya B, Tripathi L, Tripathi JN, Arinaitwe G, Mukasa SB, Tushemereirwe WK (2012). Transgenic banana expressing *Pflp* gene confers enhanced resistance to Xanthomonas wilt disease. Transgenic Research 21(4):855-865

Ndugo V, Eden-Green S, Blomme G, Crozier J, Smith JJ (2006). Presence of banana Xanthomonas wilt (*Xanthomonas campestris* pv. *musacearum*) in the Democratic Republic of Congo (D,RC). Plant Pathology 55(2):294-294.

Ochola D, Jogo W, Tinzaara W, Odongo M, Onyango M, Karamura BE (2015). Farmer Field School and Banana Xanthomonas Wilt Management: A Study of Banana Farmers in Four Villages in Siaya County, Kenya. Journal. Agricultural Extension Rural Development 7(12):311-321.

Ocimati W, Ssekiwoko F, Butibwa M, Karamura E, Tinzaara W, Eden-Green S, Blomme G (2013a). Systemicity and speed of movement of *Xanthomonas campestris* pv. *musacearum*in the banana plant after garden tool-mediated infection. In: Blomme G, Vanlauwe B, van Asten P, eds. *Banana Systems in the Humid Highlands of Sub-Saharan Africa: Enhancing Resilience and Productivity*. Wallingford, UK: CAB International 101-108.

Ocimati W, Ssekiwoko F, Karamura E, Tinzaara W, Eden-Green S, Blomme G (2013b). Systemicity of *Xanthomonas campestris* pv. *musacearum* and time to disease expression after inflorescence infection in East African highland and Pisang Awak bananas in Uganda. Plant Pathology 62(4):777-785.

Okurut AW, Tushemereirwe WK, Aritua V, Ragama PE (2006). Use of herbicides for the control of banana bacterial wilt in Uganda. African Crop Science Journal 14(2):143-149

Reeder RH, Muhinyuza JB, Opolot O, Aritua V, Crozier J, Smith J (2007). Presence of banana bacterial wilt (*Xanthomonas campestris* pv. *musacearum*) in Rwanda. Plant Pathology 56(6):1038-1038

Ssekiwoko F, Turyagyenda LF, Mukasa H, Eden-Green S, Blomme G (2010). Spread of Xanthomonas campestris pv. musacearum in banana (Musa spp.) plants following infection of the male inflorescence. Acta Horticuture (ISHS) 879:349-356.

Ssekiwoko F, Batte M, Tushemereirwe W, Ragama PE, Kumakech A (2006). Reaction of Banana Germplasm to Inoculation with *Xanthomonas campestris* pv. *musacearum*. African Crop Science Journal 14(2):151-155.

Tinzaara W, Gold CS, Ssekiwoko F, Bandyopadhyay R, Abera A, Eden-Green. S (2006). Role of insects in the transmission of banana bacterial wilt. African Crop Science Journal 14(2):105-110.

Tripathi L, Mwaka H, Tripathi JN, Tushemereirwe WK. (2010). Expression of sweet pepper *Hrap* gene in banana enhances resistance to *Xanthomonas campestris* pv. *musacearum*. Molecular Plant Pathology 11:721-31.

Tushemereirwe WK, Okaasai O, Kubiriba J, Nankinga C, Muhangi J, Odoi N, Opio F (2006). Status of banana bacterial wilt in Uganda. African Crop Science Journal 14(2):73-82.

Tushemereirwe W, KangireA, Ssekiwoko F, Offord LC, Crozier J, Boa E, Smith JJ (2004). First report of *Xanthomonas campestris* pv. *musacearum* on banana in Uganda. Plant Pathology 53(6):802-802.

Yirgou D, Bradbury J (1974). A note on wilt of banana caused by Enset wilt organism, *Xanthomonas musacearum*. East Africa. Agricultural Forestry Journal 40:111-114.