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ECONOMIC IMPORTANCE OF THE BANANA BACTERIAL WILT IN UGANDA

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ABSTRACT

A study was conducted to estimate the economic value of the likely loss due to banana bacterial wilt (BBW) if not controlled; and the potential benefits of implementing the short-term control. Using survey data from 8 districts of Uganda and banana production data from the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) a logistic regression was used to estimate the effect of control measures over time and exponential growth model was used to simulate data over 15 years. The result shows that if BBW is not controlled, Uganda stands to lose an estimated 295 million dollars worth of banana output valued at farm gate prices. This translates into an annual 200 dollars of food and income per household at stake. Adoption of recommended sanitation methods would result in saving over 40% of the loss due to BBW on matooke; much less on beer types because of their low market value, low adoption, and high cost of adopting sanitation measures compared to matooke. In the long run developing resistant cultivars is the most sustainable option. Although the value of loss of output from beer types is relatively low compared to matooke the crop remains very critical in areas where beer is main source of income. The control of BBW in beer growing areas is equally important to reduce reservoirs of inoculum that will remain a nuisance to otherwise well managed matooke plantations.

Key Words: Economic loss, logistic regression, *Musa* sp.

RÉSUMÉ

Une étude était conduite pour estimer la valeur économique des pertes due au virus de flétrissement bactérien de la banane si pas contrôler, et le bénéfice potentiel d'implantation des contrôler a court termes. En utilisant les données de sondage de 8 districts de l'Ouganda et les productions de la banane du Ministère d'Agriculture, Elevage, Industries et Pêche (MAAIF) une régression logistique était utilisée pour estimer les effets de mesures de contrôle dans le temps et la modèle de croissance exponentielle était utilisé pour simuler les données pendant 15 ans. Les résultats montrent que si le BBW n'est pas contrôlé, l'Ouganda perdra 295 millions de dollars pour les bananes achetées au prix des paysans. Ceci se convertirai a 200 dollars de nourriture et revenu par ménage perdu. L'adoption des recommandations sanitaires résultera à une épargne de 40% de perte causée par BBW sur le matooke, et un peu moins pour la banane destinée à la boisson pour leur faible prix, leur faible adoption, et le coût élevé d'adopter les mesures sanitaires comparée au matooke. Le développement à long terme d'une variété résistante est l'option la plus durable. Même si les pertes des productions de la banane destinée à la boisson sont relativement faibles par rapport a celle destinée à la cuisson, la plante reste très critique dans des endroits ou la bière est la source principale des revenues. Le contrôle de BBW dans la région de production de la bière est aussi important pour réduire le réservoir de l'inoculum qui restera nuisible à des plantations bien gérées.

Mots Clés: Perte économique, régression logistique, *Musa* sp.

INTRODUCTION

Uganda produces 10 million tones of bananas (*Musa* sp.) annually (UBOS, 2004). Cooking bananas (*Matooke*) account for 80% of total output; which is equivalent to approximately 440 million U.S dollars at the average farm gate price. Over 90 percent of the output is mainly consumed locally, with an estimated per capita consumption of 220 – 460 kg per year (IITA, 1995). It is estimated that 75% of Ugandan farmers grow the banana crop. In terms of rural revenue, the banana is one of the most important cash crops in Uganda, contributing up to 22% of national agricultural rural revenue (Embrechts *et al.*, 1996). Over 7 million people including 65% of the urban population depend on the crop as their staple food (Karamura and Karamura, 1994).

Field studies conducted in Uganda revealed that all banana varieties are susceptible to BBW (Tushemereirwe *et al.*, 2001; MAAIF, 2002). The disease spreads very fast and results in total yield loss within a year. Studies showed that in the field where the disease was first observed, the incidence increased to over 70% in a period of one year. Apart from loss in yield, the wilt also causes serious loss in fruit quality. Even in cases of late mild infection of mature bunches, the fruit rots and cannot be consumed. This has posed a serious threat to the banana industry, and the export potential that was starting picking up. This devastating effect of BBW on banana in so far 33 out of 56 districts in the country has contributed to decreased household and national food security; reduced incomes for banana farmers and traders.

Efforts are underway to control the spread of BBW and reduce its impact on livelihoods of farmers and other beneficiaries. As part of the information to inform decision makers and stakeholders who are considering investing resources in controlling BBW, it is necessary to evaluate the potential impact of the disease; and the expected recourse from research and control programmes. In order to clearly understand the implications of BBW on the economy and livelihoods, it is imperative to evaluate the private cost of the threat on farm incomes and food security, and the social cost on the country likely to result from loss of export revenues, loss of staple food, and effect on poverty. Determining the economic value of the loss needs to establish the incidence and severity of the disease in all banana growing areas in the country; the likely loss in food production and incomes; and implications on poverty and food security for those who depend on banana as the main source of livelihood.

Following the outbreak, the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and other stakeholders put in place an action plan aimed at controlling the disease, and preventing its spread to new areas. The strategy recognizes that research outputs leading to formulation and validation of improved disease management practices will take time to develop and proposes more immediate coping measures. The strategy recommends a control driven Research and Development (R and D) strategy. The measures put in place include: crop sanitation measures, plant quarantine, and mass mobilization for short-term containment and control of the disease. However, for long-term control of the diseased the option being pursued is to incorporate resistance into preferred banana cultivars (Tripathi *et al.*, 2004). This has proved to be challenging given that the East African Highland banana is female sterile, with limited seed production, and there are no known sources of resistance within the banana group yet. Also the breeding programme will cost millions of dollars. Thus policy makers have had to consider allocating more resources to the BBW control strategy. It is important to critically assess the cost of the strategy against potential benefits likely to result if BBW is controlled. It is necessary to evaluate various scenarios such as the loss avoided using short-term control measures; and the likely benefits from developing resistant cultivars. It will take over 10 years to develop resistant cultivars. In this study we provide estimates of the economic value of the likely loss due to BBW if not controlled; and the potential benefits of implementing the short-term control.

METHODOLOGY

Data sources. Due to uncertainty about the long-term effects of BBW on banana production and the likely effectiveness of control strategies it is very difficult to make an accurate estimate of the expected loss. Country-wide empirical information is still lacking on incidence over time and space, the likely effect of control measures on yield loss reductions, and probability of adoption by different farmer classes.

Data on disease incidence, yield losses, and adoption of recommended control measures was obtained from a farm level survey conducted in 8 districts during January – April 2005 (Kagezi *et al.*, 2006). This survey covered 360 farm households randomly selected from 8 districts representing Eastern, Central, Western, and South-Western Uganda (Table 1). Districts were selected based on duration they have been exposed to BBW. The resulting data shows the prevalence of BBW over the period 2000 to 2005.

The baseline scenario is defined as the value of banana output at the prevailing farm gate price if there is no BBW infection. Banana output has been growing at an average rate of 2% per annum for the last 5 years prior to the year 2000 (UBOS, 2004). It is assumed that *ceteris paribus* banana acreage would continue to grow at a rate of 1% per annum for the next 10 years if BBW was not present. Estimation of the economic impact of BBW without and with control interventions put in place is based on available information provided by NARO scientists and the MAAIF. Assumptions about the expected yield loss, adoption levels, and the rate of growth of the epidemic were based on a combination of data and estimates by scientists working on BBW. Results from pathogenicity trials by scientists indicate that BBW inoculation with BBW leads to 100% loss of infected mats within one month (W.Tinzaara, person. comm.). Its spatial rate of spread is not well known. However it is estimated that if the disease is not controlled, it will spread throughout an average plantation in 6 months, and result in 100% loss within a year. It is so far known that BBW is spread from plant to plant by stingless bees collecting sap from fresh wounds left when male bracts/flowers fall off (male bud cushion wounds), infected cutting tools used by traders. Bees have been observed to move more than one kilometre in a day; and harvesting tools are used by traders on average of 5 to 10 farms per day in a village per season. It is also known that the wilt caused pathogen multiply very fast within host tissue. Thus if no control measures are adopted, it appears realistic to assume that BBW progress would assume an exponential or similar growth pattern through farms and over time.

Data analysis and model assumptions. The incidences of BBW over time were estimated from survey data as the number of farms infected per year for the 8 districts. A logistic model fitted on data collected in 8 districts over 6 years as follows using SAS (SAS instate Inc., 1997):

$$Y_i = \frac{1}{1 + \exp(-X_i\beta)} \qquad (1)$$

Where Y_i is the cumulative proportion of total banana acreage affected by BBW in a given year in district i, X_i is a vector of explanatory variables that predict change in disease incidence over time, and β is a vector of parameters including a constant to be estimated. Y is regressed against time (t = duration in years of the presence of BBW), exposure to BBW control measures (X = 1 if exposed, 0 otherwise), and the proportion of matooke in each district (M = 33 if less than 33%, 66 if 33 - 66%, and 100 if >66). The fitted model is defined in equation 2 where Y is replaced by the annual prevalence of BBW.

$$\ln \frac{y_i}{1-y_i} = \beta_0 + \beta_1 t + \beta_2 X_i + \beta_3 M_i + e \qquad (2)$$

The analysis requires information on spread rate of BBW, which unfortunately is limited. Therefore at this stage we rely on literature on epidemiology of similar diseases, and the experience from research on BBW over the past 4 years. The expected behaviour of the pathosystem is based on Vanderplank's theory of polycyclic diseases. A polycyclic nature implies that inoculum production increases based on the inoculum produced by the previous cycle, as well as current inoculum production in present cycle – i.e. both the initial inoculum and its offspring immediately multiply into other propagules in a very short time, resulting in a compounding effect within a given cycle. Exponential, Logistic, and Gompertz models have been recommended for modelling the behaviour of such diseases. Based on experience with BBW, the following behavioural assumptions are made for the pathosystem:

i) Infections occur continuously
ii) Disease progress is very rapid - once a plant is infected all the tissues die within a month
iii) Newly infected host tissue becomes infective immediately (the incubation period is about two weeks)
iv) Spatial disease spread is not random, but systematic, mainly dependent on movements of honeybees, bats, birds and human beings with tools or diseased materials.

Disease progress is described by a differential equation (3) derived by taking the first derivative of equation (1) with respect to time, t. This gives us a variable rate of disease spread over time.

$$\frac{\partial y}{\partial t} = \beta_I y\,(1-y) \qquad (3)$$

The rate of the epidemic is simulated over time and the likely loss if the disease was not controlled determined from predicted incidence levels. It is noted that the sample used by Kagezi *et al.* (2005) was based on the data that was collected in central Uganda where BBW has been prevalent for six years. The disease was only well established in central Uganda and predominantly in matooke growing areas of South Western Uganda were relatively free of the disease. An attempt to extrapolate the results is based on the following assumptions:

i) The same underlying factors driving disease epidemic occur in the frontline and disease free areas.
ii) The rate of disease spread is the same for specific cultivars in both affected and disease free areas if no control measures are adopted.
iii) There are major inter-cultivar differences in tolerance to BBW so as to cause a major inter-regional differences in disease progress over space and time.

Definition of counterfactual and intervention scenarios. Since the first time BBW was observed in 2000 the Banana Bacterial Wilt Initiative reported that the disease has spread to 33 out of the 56 districts. However incidence varies across the districts. The reported incidence from the sample survey is used to estimate the number of infected mats, and the loss of output per year is computed as a product of the average yield per hectare per year, and the proportion of mats affected by BBW. In order to forecast future losses we needed data on the rate of loss of output per year. Thus a projection of incidence and associated output loss was estimated for the period 2000 – 2019 using a logistic growth function. The year 2015 is the earliest when scientists are expected to come up with a variety that is resistant to the disease, the extra 5 years are added to account for likely variation in the research lag.

The total loss of output due to BBW for year t (Y_{it}), is estimated for each of the 8 districts as a product of the district total banana acreage (A), the share of the area affected by BBW (I), the yield loss per hectare (γ), the average district yield (x), and the farm gate price (p) (Table 10):

$$Y_{it} = A_{it} I_{it} \gamma_{it} x_t p_t \qquad (4)$$

The annual values for the simulated period (t=2000...2019) are discounted to present (2005) values at the rate of 15%. This represents an estimated loss at stake if BBW is not controlled. However, in some of the areas farmers were already using recommended control measures to curb the disease. The expected benefit from implementing the control package (B) is calculated as a product of the expected total loss if BBW is not controlled (Y), the share of the loss avoided if recommendations are adopted (z), the expected adoption level (A), less the farmers' cost of implementing the control package (C) at time t.

$$B_{it} = Y_{it} z_{it} A_{it} - C_t \qquad (5)$$

In calculating benefits from short term control, we use a result from on-farm research which indicated that adopting the disease Avoidance, Breaking off male buds, Cutting out diseased plants and Cleaning cutting tools (ABCC) package fully will result in a yield loss saving of 80 to 100%. However the package is not expected to be fully adopted by farmers, hence the expected loss saved was adjusted using expert opinion to 40 -

80% depending on the region. Thus without further research input it is expected that some level of banana output can be sustained if farmers maintain yields through crop sanitation and replanting. However the ABCC package entails some costs including labour to cut and bury diseased plants, chemical for disinfection, and costs of replanting destroyed bananas. No concrete data exists on the actual costs incurred by farmers, and costs are expected to vary from farm to farm. After consultation with researchers the most common practice observed was cutting and chopping infected plants, removal of male buds with a forked stick, and disinfecting tools using fire flame. The main cost item is labour, which was estimated at 40,000 UShs hectare^{-1}. The total cost to a farmer of applying recommended cultural control measures was estimated at 60,000 Ushs per hectare.

The ABCC intervention however is unlikely to reduce the disease to economic levels. It is expected that adoption will level off at some point; and the disease will remain endemic in all banana growing areas. This is likely to result in reduced yields due to continuous curling of infected mats, increased production costs due to demand for labour and materials for crop sanitation, and reduction or total elimination of major sources of inoculum especially the beer types, and Kivuvu. Not withstanding the loss of biodiversity, the disease is also likely to reduce the banana beer industry. The maximum likely adoption level was estimated from previous monitoring studies conducted by banana researchers to range from 40% to 95% (Table 7). Adoption is expected to be lowest in beer growing areas due to known poor management of beer types.

RESULTS AND DISCUSSION

Estimation of Disease Incidence and Progress. The logistic regression results indicate that both the duration of exposure to BBW (i.e. time), exposure to information on control measures, and the proportion of total district banana acreage under matooke were significantly different ($P \leq 0.05$) by X^2 on BBW incidence (Table 2). The signs for the coefficients on duration of exposure to BBW were positive showing increase over time and exposures to control measures were negative. Exposure of farmers to PDC has a strong negative influence on disease incidence,

TABLE 1. Incidence of BBW (% of mats infected) in 2005

District	Matoke	Kayinja	Kisubi
Kamuli	0.27	0.60	0.56
Kayunga	0.24	0.66	0.50
Masindi	0.21	0.71	0.23
Luwero	0.18	0.32	0.10
Mbale	0.12	0.44	1.00
Bushenyi	0.00	0.00	
Mubende	0.00	0.02	0.00
Ntungamo	0.00	0.04	0.00

Source: NBRP Survey (these proceedings)

TABLE 2. Parameter estimates for logistic function

Parameter	Estimate	Std Error	Wald Chi-Sq	Pr>Chi-Sq
Intercept	-3.414	0.193	314.06	<.0001
No. of years BBW is present	0.578	0.038	226.72	<.0001
Exposure to PDC	-1.006	0.112	80.39	<.0001
Proportion of Matooke	0.006	0.003	3.99	0.05

indicating that the various control efforts have had a significant impact on combating disease levels and spread.

Use of the proportion of matooke as regressor is intended to capture regional differences in disease incidence as far as the model is concerned. Within this regional stratification there is an implicit recognition of differences in major cultivars grown. In areas where matooke is less important the main bananas grown are beer types (mainly Kayinja and Kisubi). As a result adoption of removal of male buds and sanitation is less than in commercial matooke growing areas. Until 2005, BBW was absent in major matooke producing areas. The exception is Mbale where the matooke acreage is high relative to beer banana. Reported BBW incidence in Mbale has been as high as in major beer banana growing areas. This model result can also be explained on *apriori* grounds: once infected, disease incidence and spread are expected to be high in major matooke growing areas due to a relatively high mat density per unit area, and a high frequency of using cutting tools by farmers and traders due to more banana trade in these areas. Use of infected cutting tools has been identified as the main mode of transmission responsible for rapid spread of BBW in Mbarara district in a recent study by NARO (NBRP, 2006).

Without any intervention the BBW epidemic would spread very fast and devastate the banana industry in a very short time. The model predicts that in any given district, the entire banana crop would be infected in five years, irrespective of the type of cultivar grown (Table 3). There would be no major differences in the rate of spread of BBW across regions. This estimate is reasonable in lieu of available evidence in central Uganda areas where the disease is known to wipe out a plantation in a year. During any given day there are high possibilities of infection at any one point across the country due to widespread use of infected tools, movement of bees and human beings; and interregional movement of inoculum by traders and farmers through exchange of banana materials.

Economic value of potential loss due to BBW with and without intervention. It is estimated that it would take approximately 10 to 15 years to develop and release a consumer acceptable BBW resistant cultivar. During this period, the estimated total loss of banana output if BBW is not controlled is estimated to be 5.6 billion U.S dollars (4.1 billion for matooke and 1.5 billion for beer). This is equivalent to an annual loss of a source of livelihood equivalent to 295 million dollars. The average loss per household per year is approximately 200 dollars worth of output valued at farm gate prices (Table 11). It is therefore estimated that about 1.5 million households are threatened by the disease. From previous studies it was determined that on average 35% of banana output is sold, and in some western districts banana is the main source of income. Therefore loss of bananas as a cash crop would severely affect household income in these districts. In addition, bananas play a major role in environmental conservation. Bananas have become an integral part of sustainable agriculture whereby they provide a good soil cover that reduces soil erosion on steep slopes and are a principle source of mulching material for maintaining and improving soil fertility (INIBAP, 1986; Karamura, 1993).

TABLE 3. Predicted incidence of BBW without intervention

Predicted cumulative incidence	Importance of matooke in the district		
Year	Low Matooke	Medium Matooke	High Matooke
0	0.00	0.00	0.00
1	0.07	0.08	0.10
2	0.18	0.21	0.26
3	0.30	0.35	0.41
4	0.47	0.55	0.63
5	0.71	0.80	0.90
6	1.00	1.00	1.00

TABLE 4. Estimated impact of BBW by cultivar group and region

Cultivar group	Region	Loss If BBW is NOT controlled (USD 2005)
Matooke	Central	617,950,767
	Eastern	337,099,185
	Western	3,056,221,262
	Miscellaneous[7]	77,862,748
	Total	4,089,133,961
Beer (Kayinja, Kisubi, FHIA)	Central	266,821,993
	Eastern	51,178,247
	Western	184,792,046
	Miscellaneous	1,013,711,170
	Total	1,516,503,455
Total	Central	884,772,760
	Eastern	388,277,431
	Western	3,241,013,308
	Miscellaneous	1,091,573,918
	Total	5,605,637,416

TABLE 5. Cultivar share of total national banana area for major Districts, and Score of Importance of Matooke

District	Importance of Matooke Production	Share of national banana area - Matooke	Share of national banana area - Beer (Kayinja, Kisubi, FHIA)
Bushenyi	High	0.126	-
Hoima	Low	-	0.013
Iganga	Low	0.013	0.013
Kabale	Low	0.010	-
Kabarole	High	0.084	0.020
Kamuli	Low	0.005	-
Kayunga	Low	0.014	-
Kibaale	Low	0.013	0.013
Kiboga	Medium	0.019	0.009
Luwero	Low	0.013	0.015
Masaka	Medium	0.048	-
Masindi	Low	0.003	-
Mbale	Medium	0.065	-
Mbarara	High	0.162	0.010
Mpigi	Low	0.021	0.021
Mubende	Medium	0.042	0.013
Mukono	Low	0.024	0.012
Ntungamo	High	0.064	-
Rakai	Medium	0.027	-
Rukungiri	Medium	0.035	-
Sembabule	Low	0.007	-
Others		0.043	0.351

Table 6. Cultivar Share of National Banana Area by Region

Cultivar group	Region	Cultivar Share of National Banana Area
Matooke	Central	0.215
	Eastern	0.083
	Western	0.497
	Misceleneous	0.043
	Total	0.838
Beer (Kayinja, Kisubi, FHIA)	Central	0.071
	Eastern	0.013
	Western	0.055
	Misceleneous	0.023
	Total	0.161

TABLE 7. Model data for exposure to control measures and expected adoption

Matooke	Year BBW was 1st reported	Years of Exposure to ABCC by 2006	Expected Maximum Adoption of ABCC Package (%)	Adoption of ABCC package (%) in 2006	Share of loss avoided if ABCC package is adopted (%)
Bushenyi	2005	1	0.95	0.32	0.8
Iganga	2003	2	0.60	0.40	0.4
Kabale	2005	1	0.60	0.20	0.4
Kabarole	2005	2	0.70	0.47	0.6
Kamuli	2003	2	0.60	0.40	0.4
Kayunga	2001	5	0.60	0.60	0.4
Kibaale	2004	2	0.60	0.40	0.4
Kiboga	2004	2	0.60	0.40	0.6
Luwero	2004	3	0.60	0.60	0.4
Masaka	2005	1	0.80	0.27	0.6
Masindi	2004	2	0.60	0.40	0.4
Mbale	2003	2	0.70	0.47	0.6
Mbarara	2005	2	0.95	0.63	0.8
Mpigi	2004	2	0.60	0.40	0.4
Mubende	2004	2	0.60	0.40	0.4
Mukono	2001	5	0.60	0.60	0.4
Ntungamo	2005	1	0.95	0.32	0.8
Rakai	2005	1	0.80	0.27	0.6
Rukungiri	2005	1	0.80	0.27	0.6
Sembabule	2005	2	0.60	0.40	0.4
Others	2005	2	0.60	0.40	0.4
Beer Banana					
Hoima	2004	2	0.60	0.40	0.4
Iganga	2003	2	0.60	0.40	0.4
Kabarole	2005	2	0.70	0.47	0.6
Kibaale	2004	2	0.60	0.40	0.4
Kiboga	2004	2	0.60	0.40	0.6
Luwero	2004	3	0.60	0.60	0.4
Mbarara	2004	2	0.95	0.63	0.8
Mpigi	2004	2	0.60	0.40	0.4
Mubende	2004	2	0.60	0.40	0.4
Mukono	2001	5	0.60	0.60	0.4
Others	2005	2	0.60	0.40	0.4

Table 8. Average yields for major districts

Matooke	Average Yield (MT/Ha)
Bushenyi	19
Iganga	5
Kabale	5
Kabarole	10
Kamuli	5
Kayunga	5
Kibaale	5
Kiboga	7
Luwero	5
Masaka	7
Masindi	5
Mbale	7
Mbarara	19
Mpigi	5
Mubende	5
Mukono	5
Ntungamo	19
Rakai	7
Rukungiri	7
Sembabule	5
Others	5
Beer (Kayinja, Kisubi, FHIA)	26

TABLE 9. Incidence of BBW (% of mats infected) in 2005

District	Matoke	Kayinja	Kisubi
Kamuli	0.27	0.60	0.56
Kayunga	0.24	0.66	0.50
Masindi	0.21	0.71	0.23
Luwero	0.18	0.32	0.10
Mbale	0.12	0.44	1.00
Bushenyi	0.00	0.00	
Mubende	0.00	0.02	0.00
Ntungamo	0.00	0.04	0.00

Source: NBRP Survey, 2005 (Kagezi *et al.*, 2006)

Implications for the national BBW control strategy. The western region is likely to benefit most from adoption of available control measures (Table 4). This is mainly due to relatively high priorities attached to matooke in the region and high expected maximum adoption. Despite apparent major differences in the impact arising out of differences in matooke concentration, the national control strategy cannot afford to be 'region biased' because of the fact that beer banana plantation appears to be more susceptible and are likely to remain as reservoirs of innoculum of BBW.

TABLE 10. Mean farm gate prices for an average bunch (25 Kg) as by December 2006

Cultivar group	Region	Farm Gate Price (UShs/KG)
Matooke	Central	120
	Eastern	120
	Western	103
Beer (Kayinja, Kisubi, FHIA)	Central	31
	Eastern	31
	Western	31

Source: NBRP, 2006

It needs to be noted here that these estimates of impact are based on maximum (potential) benefits. However it is known that current adoption levels in terms of the area of bananas where recommended practices are applied is very low. The implication therefore is that the BBW strategy has a target adoption to achieve. This will be achieved through intensifying dissemination efforts as well as implementing other measures such as bye-laws.

CONCLUSIONS AND RECOMMENDATIONS

If BBW is not controlled, Uganda stands to lose an estimated 295 million dollars worth of banana output valued at farm gate prices. This translates into an annual 200 dollars of food and income per household at stake. Although the value of loss of output from beer types is relatively low compared to matooke, the crop remains very critical in areas where beer is main source of income. The control of BBW in beer growing areas is equally important due to the aspect of leaving infected beer bananas as reservoirs of inoculum that will remain a nuisance to otherwise well managed matooke plantations.

Current losses are very high in endemic districts because this is where BBW is concentrated, however, over 75% of the potential loss will be incurred by farmers in frontline districts in western region where the disease is currently headed for.

Table 11. Estimated Annual Economic Losses with and without Intervention

Year	Loss If BBW is NOT controlled (USD 2005)	Loss if ABCC is adopted (USD 2005)
2,000	0	0
2,001	2,506,660	2,732,612
2,002	4,509,878	4,563,088
2,003	13,512,297	13,600,690
2,004	30,108,824	30,419,187
2,005	137,605,308	129,510,853
2,006	204,532,511	159,306,130
2,007	274,388,276	168,336,522
2,008	365,611,044	199,109,127
2,009	453,769,274	251,619,347
2,010	689,802,425	366,013,547
2,011	605,826,477	321,455,376
2,012	532,073,689	282,321,678
2,013	467,299,501	247,952,083
2,014	410,410,866	217,766,612
2,015	360,447,804	191,255,894
2,016	316,567,202	167,972,568
2,017	278,028,586	147,523,733
2,018	244,181,627	129,564,322
2,019	214,455,168	113,791,274
Total	5,605,637,416	3,144,814,644
Average	295,033,548	165,516,560

Despite the inclination to concentrate efforts in major matooke producing areas to curb the epidemic there due to the more significant implications on social and economic welfare, it is not recommended to have a regional bias in the BBW control strategy.

Successful realisation of the potential impact from short term control would heavily depend on achieving the projected maximum adoption levels in terms of maximising numbers of adopting households and ensuring uniform application of recommended practices across farms. It is important to intensify dissemination, but also to promote adoption of bye-laws and operationalise the revised policy on control of crop pest and disease epidemics.

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REFERENCES

Bagamba, F., Kikulwe, E., Tushemereiwe, W.K., Ngambeki, D., Muhangi, J., Kagezi, G. Ragama, P.E. and Eden-Green, S. 2006. Farmers' awareness of banana bacterial wilt and its control in Uganda. *African Crop Science Journal* 14:157-164.

Bradbury, J. F. 1970. Isolation and preliminary study of Bacteria from plants. *Pathology* 49: 213-218.

Bradbury, J. F. 1986. Guide to plant pathogenic bacteria. CAB International, Wallingford, UK. 332pp.

INIBAP, 1986. International Network for Improvement of Banana and Plantain (INIBAP). A Preliminary Study of the Needs for Banana Research in Eastern Africa. INIBAP. Montpellier.

Kagezi, G.H., Kangire, A., Tushemereirwe, W., Bagamba, F., Kikulwe, E., Muhangi, J., Gold C.S. and Ragama, P. 2006. Field assessment of banana bacterial wilt incidence in Uganda. *African Crop Science Journal* 14:83-91.

Karamura, D.A. and Karamura, B.E. 1994. A Provisional Checklist of Banana Cultivars in Uganda. INIBAP, Montpelier.

Karamura, E.B. 1993. The strategic importance of bananas/plantains in Uganda. In: Gold, C.S. and Gemmil, B. (Eds.), pp.384-387. *Proceedings of a Research Coordination*

Meeting for Biological and Integrated Control of Highland Banana and Plantain Pests and Diseases. Cotonou, 12-14 November 1991. IITA, Cotonou, Benin.

Koenning, S. 2000. Bacterial blight (Angular leaf spot) of cotton. Cotton disease information note No. 3. Plant pathology extension. North Calorina State University.

Korobko, A. Wondimagegne, E. and Dilbo, C. 1987. Survey and identification of bacterial diseases on banana in Ethiopia. In: *Scientific Phytopathological Laboratory of the State Agro-Industrial Committee of the USSR.* Progress Report for the period 1986/87. Ambo, Ethiopia. pp. 387-390.

Lazo, G.R., Roffe, R. and Gabreil, D.W. 1987. Pathovars of *Xanthomonas campestris* are distinguishable by Restriction Fragment Length Polymorphism. *International Journal of Systematic Bacteriology* 37:214-221.

Poplawsky, A. R. Urban, S. C. and Chun, W. 2000. Biological role of Xanthomonadin Pigments in *Xanthomonas campestris* pv *campestris*. *Applied and Environmental Microbiology Journal* 66:5123-5127.

SAS Institute Inc., 1997. SAS/STAT software: Changes and Enhancements through Release 6.12. Cary, NC, USA. 1167pp.

Thangavelu, R., Sundaraju, P., Sathiamoorthy, S., Reghuchander, T., Velazhahan, S., Nakkeeran, S and Palansamy, A. 2001. Status of Fusarium wilt of banana in India. In: Banana fusarium wilt management: Towards sustainable cultivation. In: Molina, A.B., Nik Masdek, N.H and Liew, K.W (Eds.). *Proceedings of the International workshop on the banana fusarium wilt disease*. Genting Highlands Resort, Malaisia, 18-20 October 1999.

Thwaites, R., Eden-Green, S.J. and Black, R. 2000. Diseases caused by bacteria. In: Jones D.R (Ed.), pp. 213-226. *Diseases of bananas, abaca and Enset.* CABI Publishing, UK.

Tripathi, L., Tripathi, J.N. and Tushemereirwe, W.K. 2004. Strategies for resistance to bacterial wilt disease of bananas through genetic engineering. *African Journal of Biotechnology* 3:688-692.

Tushemereirwe, W, Kangire, A., Smith, J., Nakyanzi, M., Kataama, D. and Musiitwa, C. 2001. An out-break of banana bacterial wilt in Mukono district: A new and devastating disease, National Agricultural Research Organisation (NARO), National Banana Programme, Kawanda Agricultural Research Organisation (KARI).

Wondimagegne, E. 1981. The role of *Poecilocarda nigrinervis* (Stal), *Pentalonia nigronervosa* (Coquerel) and *Planoccocus ficus* (Signoret) in the transmission of enset wilt pathogen, *Xanthomonas musaceurum* sp. n. in Wollaita, Ethiopia, Msc Thesis, College of Agriculture, Alenmaya. 41 pp.

Wondimagegne, E., Korobko, A. and Dilbo, C. 1987. Serological properties of *Xanthomonas musaceurum*. In: Scientific Phytopathological Laboratory of the State Agro-Industrial Committee of the USSR. Progress Report for the period 1986/87. Ambo, Ethiopia. pp. 384-386.

Wondimagegne, E., Korobko, A. and Dilbo, C. 1987. The modes of transmission of bacterial wilt of enset. In: *Scientific Phytopathological Laboratory of the State Agro-Industrial Committee of the USSR.* Progress Report for the period 1986/87. Ambo, Ethiopia. pp. 375-382.

Yirgou, D. and Bradbury, J.F. 1974. A note on wilt of banana caused by the enset wilt organism *Xanthomonas musacearum*. *East African Agricultural and Forestry Journal* 40: 111-114.

Yirgou, D. and Bradbury, J.F. 1968. Bacterial wilt of enset *(Ensete ventricosum)*, incited by *Xanthomonas musacearum*. *Phytopathology* 59:111-112.

Yi-Wei Tang, Procop, W. and Persing, D. H. 1997. Molecular diagnostics of infectious diseases. American Association for Clinical Chemistry, Inc. 43:2021-2038.