CROP PROTECTION PROGRAMME

Promotion of control measures for cassava brown streak disease

R8404 No (ZA 0632)

FINAL TECHNICAL REPORT

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Executive Summary

The purpose of the project was to promote the adoption of CBSD-tolerant varieties developed in earlier phases of the project, to improve food security and decrease the economic impact of the disease on commercialisation of cassava as a source of flour. This short extension to the project has added-value by further distribution of CBSD-tolerant varieties, evaluating the impact of CBSD on commercialisation of cassava and surveyed the extent of disease spread following a new outbreak of CBSD in Uganda.

Activities were carried out in Tanzania [Southern Zone and Eastern Zone], Malawi and Uganda. In Tanzania tolerant varieties were evaluated, multiplied and distributed. The adoption of tolerant varieties and the impact on processing into flour was assessed. In Malawi local and improved varieties were evaluated for reaction to both CBSD and CMD, on-station and on-farm. In Uganda, in response a new outbreak of CBSD the project funded a nation-wide survey to determine the extent of disease spread and the varieties affected.

The main physical outputs of the project are the CBSD-tolerant varieties and supporting communication media about CBSD recognition and control. An information leaflet and poster were produced and distributed in Southern Tanzania during the reporting period. Tolerant varieties have now been identified in Tanzania and Malawi [also Mozambique in earlier projects] and widely distributed in Tanzania, where they are available to about 2 million farmers but as varieties become more widely disseminated, up to 4 million households could benefit in the areas affected by CBSD in Tanzania, Mozambique and Malawi. Adoption rates of tolerant varieties in surveyed villages was between 45% and 70%.

The main research findings were that CBSD root necrosis is highly detrimental to the production of high quality flour and even a severity score of 2 is sufficient to discolour the flour produced. It has been difficult to identify varieties resistant to both CBSD and CMD but one variety in Malawi was free of both diseases at all sites in 2005.

Some varieties previously thought to be resistant to CBSD began to show symptoms in 2004 and one of these, NAL 34 showed severe root necrosis at both sites in eastern Tanzania, while remaining CBSD-free in Mtwara. This and other aspects of the relationship between environment and symptom expression, needs further research.

In Malawi one local and one improved variety were highly resistant to CBSD but only the improved variety ‘Sauti’ was also resistant to cassava mosaic disease.

In Uganda where cassava was free of CBSD until 2004, we have recorded a severe outbreak of the disease. The project was initially the only source of funding for an emergency survey to determine the extent of the CBSD outbreak in Uganda. Surveys supported by the project and carried out by NARO scientists have shown that two improved varieties, now widely released are highly susceptible to the disease and are infected at high incidence at many locations. This is a serious occurrence potentially affected another 4 million households that depend on cassava for food security, and is causing concern at the highest level in Uganda.

Background

Cassava plays a vital role in sustainable livelihoods in the coastal districts of eastern and southern Africa, where it is the preferred staple. Cassava brown streak disease [CBSD] is a virus disease present at high incidences in the coastal areas of Kenya, Tanzania and Mozambique, as well as the Lakeshore areas of Malawi. These are among the most important cassava producing areas in the region. CBSD is the most important biotic constraint to cassava production and marketing in these areas due to its direct effect on root quality. The disease is a threat to food security and to the expansion of commercial products derived from cassava such as high quality flour and related value-added products.

This project follows-on from Project R227 which promoted the control of CBSD through multiplication and distribution of tolerant cultivars and through training of trainers and dissemination of technical information on the biology and control of the disease.

The present project placed more emphasis on the role of CBSD as a constraint to the production of cassava flour and initiated research on the distribution of the disease in Uganda, where an outbreak was confirmed by us in 2004.

Project Purpose
'Ecology and epidemiology of cassava brown streak disease understood and improved control methods and strategies developed and promoted'.

Cassava is the primary staple in the areas most affected by CBSD. The disease is therefore a direct threat to food security. Much of development policy today is directed towards increasing the commercialisation of smallholder farming. A prerequisite for any household or community to engage in commercial farming is that they are food secure for at least most of the year. Anything which decreases food security will all decrease commercial farming activities in the affected communities. IITA has been focusing its activities around the promotion of cassava as a source of cash income from flour and value-added products derived from cassava flour. CBSD directly affects root quality and is therefore a constraint to this development.

This project addresses CBSD both as a constraint to food security and commercialisation of cassava production by promoting locally adapted varieties that we have identified as tolerant to the disease and by ensuring that extension workers and farmers have access to information on the biology and control of the disease.

Research Activities
The Project activities were conducted in three countries in eastern and southern Africa but the main activities were different in each country.

In Tanzania the research focus was on the implications of CBSD for the utilisation of cassava in marketing and agro-processing. We continued to multiply and distribute the CBSD-tolerant cvs to address both food security and the constraint posed by the disease to the development of cassava marketing. An experiment was conducted to determine the effect on flour quality of each of the 5 severity grades for CBSD root necrosis.

Also in Tanzania, we added to and improved upon our previous communication media for information on ten biology and control of CBSD.

In Malawi, where CBSD research is at an earlier stage, the research focus was on-farm evaluation of varieties that might have some tolerance to CBSD and which were screened on-station in the previous project.

Uganda is a new area for project activities and where the previous project identified CBSD as the cause of a disease outbreak in 2004. It was necessary quickly to undertake a survey to determine how far the disease had spread in Uganda. The outbreak of CBSD in Uganda came after the proposal for the present project was written. Because of the importance of this outbreak, proposed work in Mozambique was replaced with the activities in Uganda and this was agreed with CPP [Dr Kimmins].

Outputs
All Outputs were achieved as outlined in the PMF [with the modification to Output 2, due to the unexpected outbreak of CBSD in Uganda]

OUTPUT 1: CBSD-tolerant cvs promoted for improved quality of cassava flour from small-scale and 'cottage' processors.

Distribution of CBSD-tolerant varieties to farmers
The project has developed two cassava multiplication sites of 2 ha and 3 ha in southern Tanzania which are the primary source of CBSD-tolerant planting material. This is used as a source to supply contact villages with planting material. In November 2005 a total of 740 bundles of 50 stems each were distributed to farmers but prison farms and rural development project run by Concern Worldwide also received material for further multiplication.

In October, 2005, farmers receiving cassava planting materials were identified by researchers in collaboration with extension staff in selected villages. In most cases planting materials were distributed to farmer groups. Due to inadequacy of planting materials, it was decided to select few villages in Mtwara rural district, Tandahimba, Newala, Masasi, Lindi urban and Lindi rural district. These villages were selected based on their potential in cassava production and most of them have never received improved planting materials. In addition, the materials were distributed to Lilungu prison in Mtwara, Namajani prison in Masasi and Nachingwea prison in Nachingwea district. Also, the CONCERN office in Lindi received improved cassava planting materials. Prisons and CONCERN Lindi wide were given planting materials due to their interest in cassava production. For prisons, they expressed their intention to produce cassava as a source of food for their prisoners. CONCERN and prisons paid a total of 10,000 Tanzanian shillings per bundle of 50 stems, while farmers were given free of charge with the condition that they have to pay back the same quantity of planting material to village authorities after harvesting in order to reinvest to another batch of farmers. This will ensure sustainability of improved planting materials in the villages. Those who received planting materials were given leaf lets on cassava brown streak disease, symptoms and control strategies.

Impact survey
A survey was conducted in three villages in S. E. Tanzania to assess the impact of CBSD-tolerant varieties. (Chisegu in Masasi district; Hiyari and Ziwani both in Mtwara rural district). Villages were selected based on their importance of cassava production and Cassava Brown Streak Disease. In each village 20 farmers were randomly selected and interviewed using a structured questionnaire. Additionally, group interview was used to evaluate the quality of various cassava based products with different levels of root necrosis (class1 – 5 where 1 indicated no root necrosis and 5 severe root necrosis). The products were cassava chips, cassava flour, doughnut and stiff porridge (*ugali*). In each village, sensory evaluation was used to assess each product separately. Furthermore, in each village about 5 kg of fresh cassava roots from each class of root necrosis (2 – 5) were prepared. Variety badi was used at Ziwani, variety Kigoma mafia at Hiyari village and Mreteta at Chisegu village. In each village, a group of 20 farmers were asked to remove non marketable

portion from each of the classes and then loss of weight from each class was recorded.

The products assessed were cassava chips, flour, ugali and doughnut with 1-5 classes of root necrosis, where 1 indicated no root necrosis and 5 indicated severe root necrosis. The products with CBSD class 1 and 2 were considered to be suitable for human consumption due to the fact that the products were relatively white in colour, which is attractive to consumers. Additionally, the products (ugali and doughnuts) were sweet and had a good flavour. Conversely, products with classes 4 and 5 were reported to be unfit for human consumption because they were bitter, bad smelling and dark brown in colour. It was further stated that the products with class 4 and 5 can not be consumed even during hunger periods. Products with CBSD class 3 was perceived as transitional from 'fit to unfit' and can only be consumed during hunger periods and when there are no alternatives. They would not be suitable for sale.

To understand losses of cassava fresh roots due CBSD, cassava was harvested in each village by group of farmers. 5 kg of cassava fresh root from each scale of root necrosis (2-5) was recorded by using a weighing balance. Variety Mreteta was used at Chisegu village, Kigoma mafia at Hiyari village and badi at Ziwani village. Farmers removed non-marketable portion by using kitchen knives and weight loss (kg) was recorded (Table 1). It was found that losses of marketable portion of fresh cassava roots increased with increasing levels of root necrosis. In class 2 of root necrosis, 54 % of fresh cassava root was fit for human consumption whereas only 16 % of fresh root could be consumed in class 5. From farmers perspective even the highest level of root necrosis (class 5) still farmers find a small portion of root suitable for human consumption.

Table 1. Losses of fresh roots (kg) due to root necrosis at various classes of the disease severity.

	Weight of non-marketable fresh roots (kg) out of 5kg sample			
Village	**Class 2**	**Class 3**	**Class 4**	**Class 5**
Chisegu	3.0	3.2	4.0	4.5
Hiyari	2.4	2.8	4.0	4.6
Ziwani	1.6	2.1	3.0	3.6
Mean	2.3	2.7	3.7	4.2

Adoption of CBSD tolerant cassava varieties

Previously Naliendele Agricultural Research Institute, Mtwara, Tanzania distributed limited quantities of CBSD tolerant cassava planting materials to a number of villages including Chisegu and Ziwani- the study area. The tolerant varieties were NDL 90/034, Kigoma red, kalulu, Namikonga and kitumbua.

The study showed that 45 % of respondents at Chisegu village, 45% at Ziwani village and 70 % at Hiyari village grow disease tolerant varieties. Overall, about 53 % of respondents in the study area grow CBSD tolerant varieties.

Farmer adoption of disease tolerant varieties is shown in Table 2. Most respondents adopted NDL 90/034, Kigoma red and kitumbua at Chisegu and Ziwani villages. However, most respondents at Hiyari village grow Kigoma red and Nachinyaya.

Table 2. Percentage of farmers growing tolerant varieties by village In the Southern Zone

	% of farmers growing tolerant variety		
Variety	**Chisegu**	**Hiyari**	**Ziwani**
NDL 90/034	35	0	35
Kigoma red	40	45	25
Kitumbua	25	0	40
Namikonga	0	15	5
Kalulu	15	0	25
Nachinyaya	0	50	5

Farmers were asked to mention decision making criteria they use in identifying suitable cassava varieties. The most important decision making criteria used by farmers to adopt suitable cassava varieties were high yielding, taste (sweet), tolerance to pests and diseases and early maturity. Other decision making criteria that mentioned were cooking quality, high dry matter content and non-fibrous. High yielding varieties are preferred in order to increase cassava productivity. Sweet varieties are desired because they can be consumed in raw form or boiled. Varieties which are tolerant to cassava brown streak disease are preferred, as the disease (root necrosis) renders cassava unsuitable for consumption and affects marketability. Early maturing varieties are preferred because they can be planted and harvested within the same year and provide food for the household.

Furthermore, 75 % of respondents at Chisegu, 70 % at Hiyari and 35 % at Ziwani village reported that, CBSD tolerant varieties have beneficial effect in processing qualities of cassava. Overall, 60% of respondents reported that disease tolerant varieties have beneficial effect in processing. Currently, Chisegu and Hiyari villages use motorized graters in cassava processing whereas at Ziwani village they use tradional method of cassava processing, as they do not have graters. It was reported that CBSD tolerant varieties do not show root necrosis. Consequently, when grated produce white chips, which are good for making good quality cassava based products such as flour and stiff porridge (ugali). Additionally, these varieties give out soft chips and hence easier for pounding, good cooking quality, less sticky and also results into real taste and smell of cassava products.

Fig. 1. Cassava chips made from cassava showing different levels of severity of CBSD root necrosis.

Table 3. Response to CBSD and CMD of cassava varieties selected for tolerance to CBSD in Southern Tanzania

Variety	Origin	Disease response*			Pest response	
		CBSD		CMD	CMB	CGM
		Above ground	Root necrosis			
Nachinyaya	Mtwara local	10	3	6	-	-
Kiroba	Rufiji local	7	4	6	-	-
Namikonga	Mtwara	0	0	1	1	2
Kitumbua	Coast	0	2	4	4	2
Chindumoto	Mtwara	3	1	3	2	2
Kibaha	Kibaha	3	4	3	2	2
Kigoma Red	Mafia Island	0	1	3	2	2
Naliendele 34	Mtwara	0	1	3	0	2
KBH 96/094	Kibaha	1	1	1	1	1

*Disease response: scored 0 – 10, where 0 = symptoms not so far observed at any location and 10 = highly susceptible to infection and sever symptoms.

Table 4: Description of cassava varieties selected for tolerance to CBSD

Variety	Maturity [months]	Yield (t/ha)	Sweetness* [score 1-5]
Nachinyaya	9-12	8.0	4
Kiroba	9-12	8.0	4
Namikonga	9-12	8.0	4
Kitumbua	9-12	8.0	4
Chindumoto	9-12	8.0	4
Kibaha	9-12	8.0	4
Kigoma Red	9-12	9.0	4
Naliendele 34	9-12	9.0	5
KBH 96/094	9-12	8.0	4

Sweetness: 1 = bitter, 5 = sweetest
NA= not available, as this variety is found in Kibaha.
Months to mature are in a range; optimum harvesting time was not determined before.
Yield figures are based on on-farm data.

2. Eastern Zone of Tanzania

Effect of CBSD on post-harvest utilisation of cassava roots

Fermentation took place in all cassava roots regardless of the level of severity of CBSD. Fermentation started almost the same time in all roots (i.e. seven days after immersing the roots in the water). This is contrary to what farmers have been reporting that even a tiny flake of CBSD can cause total fermentation failure. More studies need to be done to clarify this argument. Farmers assessment of flour and ugali are summarized in Tables 5 & 6. Flour from roots in Classes 1 (without CBSD symptoms) and 2 was considered to be good. Whereas flour from roots in Classes 4 and 5 was considered to be bad to very bad. Flour made from class 3 was less acceptable and would probably not be suitable for sale [Table 5].

Table 5 : Farmer assessment of flour qualities prepared from roots in 5 classes of severity for CBSD root necrosis

Attribute	Assessment class [1-5] for flour made from roots with CBSD severity scores 1-5.				
	1	2	3	4	5
Appearance	4.33	3.94	3.55	2.44	1.44
Smell	4.18	3.71	3.89	3.06	3.02
Acceptability	4.61	4.11	3.67	2.82	1.80
Mean	4.37	3.92	3.70	2.77	2.08

Assessment scale: Class 1 – Very bad, Class 2 – bad Class 3 – Average, Class 4 - good, Class 5 – Very good

Flour made from roots with CBSD severity scores of 4 and 5 was cleasrly unsuitable for consumption, so stiff porridge [ugali] was prepared from flour obtained from roots belonging to severity scores 1 – 3. Ugali from roots in severity score 1 and 2 was rated as good by farmers while that from roots in Class 3 was rated as bad [Table 6]. The overall results indicate that in order for processing and marketing of cassava and its products to be successful CBSD infection levels have to be kept below Class 3. Thus control of CBSD should be part of the cassava commercialization agenda.

Table 6. Farmer assessment of ugali qualities prepared from flour made from roots in 5 classes of severity for CBSD root necrosis

	Assessment class [1-5] for ugali made from roots with CBSD severity scores 1-5.		
Attribute	1	2	3
Appearance	4.45	4.27	2.27
Taste	4.40	4.20	2.40
Smell	4.64	4.27	2.55
Acceptability	4.55	4.18	2.27
Mean	4.51	4.23	2.37

Assessment scale: Class 1 – Very bad, Class 2 – bad Class 3 – Average, Class 4 - good, Class 5 – Very good

Evaluation of CBSD-tolerant varieties

Namikonga was the only variety to remain free of CBSD foliar symptoms at both Chanika Village [Table 7] and SRI [Table 8] and only very slight root symptoms were detected. Kikombe which previously was tolerant to root necrosis is now starting to show severe root necrosis at Chanika but remains tolerant at SRI. Tolerance to root necrosis has now broken-down in Naliendele. Kiroba still looks like a good option in areas with high incidences of CBSD and seems to be less susceptible than most of the other varieties to cassava mosaic disease [CMD].

Table 7. Virus disease screening [Chanika village]

Variety	Disease incidence			Yield tonnes/ha
	Foliar[%]		Root score 1 -5	
	CMD	CBSD		
Kiroba	47	79	1.1	57.7
Naliendele	95	68	2.4	22.7
Kibaha	76	71	2.0	25.3
Namikonga	54	0	1.1	25.4
Kigoma Red	62	76	1.9	19.6
Kitumbua	69	51	2.1	16.5
Kikombe	57	39	2.5	24.7
Mean	66	55	27.4	27.4
LSD	50	45	1.8	21.5

Table 8. Virus disease screening [SRI on-station]

Variety	Disease incidence			Yield [tonnes/ha]
	Foliar[%]		Root [score 1 -5]	
	CMD	CBSD		
Kiroba	4	17	1.0	18.0
Naliendele	83	50	2.1	23.3
Kibaha	65	83	1.9	13.4
Namikonga	13	0	1.1	17.4
Kigoma Red	58	38	1.5	16.9
Kitumbua	54	13	1.2	15.7
Kikombe	57	0	1.1	18.2
Mean	48	29	1.4	17.5
LSD	41	44	0.7	8.3

Impact of CBSD and adoption of CBSD tolerant varieties

In order to find out the impact of CBSD root necrosis and adoption of CBSD tolerant varieties discussions with farmers were held using a checklist as well as structured questionnaires. Discussions were made while farmers were in a group. A structured questionnaire was used to interview individual farmers. A total of 21 farmers in the village were interviewed.

Summary of the information collected:-

Cassava is the major food and cash crop at Zogowale

The village has a cassava processing machine as well as a milling machine

Varieties currently grown in the village are new. Why some varieties were abandoned?

1) They were late maturing

2) Some were low yielders

3) Others were very susceptible to CBSD

According to farmers the above three are the major reasons as to why some of the varieties are no longer being grown. It is clear from this information that CBSD has contributed in the disappearance of some cassava varieties in this village.

Most farmers (90%) said that they grow CBSD tolerant cultivars. The varieties are Muzege, Kiroba, Borakupata, Namikonga and Kalolo (Table 9). Apart from being CBSD tolerant, these varieties are said to be early bulking and high yielders. Only few farmers (5%) grow Namikonga as a tolerant cultivar. Note that one farmer can be growing 2 or more varieties but the area of each differs depending on preference. Kiroba which has been promoted by the project has been adopted by all but one of the interviewed farmers [Table 9].

Table 9. Proportion of farmers who grow different CBSD tolerant varieties.

Variety	% farmers
Kiroba	90
Muzege	57
Borakupata	57
Namikonga	5
Kalolo	60

According to majority of farmers Muzege is more tolerant to CBSD than Kiroba, thus there is a need to evaluate it in other locations in the Eastern zone. This highlights the need to be continuously collecting and screening local varieties based on farmers observations.

Information gathered from farmers indicate that CBSD has had a significant impact on food availability in the village (Table 10) where just over one third of respondents said the effect was serious. In some households CBSD infection has resulted in food shortage, this is probably because for most of the villagers cassava is mainly used for home consumption. There has apparently been no serious impact on price of cassava and quantity of processed cassava. Processing of Cassava is a relatively new activity in this village and Cassava quantities processed are very small, thus many farmers don't see the actual impact of CBSD on quantities processed. Moderate impact has been seen on marketing opportunities because most of the traders who come to buy fresh cassava in the village, reject cassava roots even if root necrosis is in class 2.

Table 10. Impact of CBSD on food availability, Market opportunities for Cassava, Price of Cassava and Quantity of processed cassava.

Issue	Proportion of farmers rating **CBSD** impact on the issue		
	Serious	moderate	Not serious
Food availability	38%	23%	39%
Marketing opportunities for Cassava	19%	57%	24%
Price of Cassava	10%	38%	52%
Quantity of processed cassava	14%	38%	48%

OUTPUT 2: CBSD-tolerant varieties evaluated in Malawi and extent of CBSD in Uganda evaluated [replaces work in Mozambique]

CBSD in Malawi

Since its introduction in Malawi, cassava *(Manihot esculenta* Crantz) has played an important role as a food security and cash crop in the country. Its importance as a food security crop was highlighted in the early and mid 1990s when annual maize production, the main staple, was reduced to almost half (0.7-0.8 Mt) of the normal production (1.7 Mt) due to drought. Of late, cassava has increasingly become an important crop for industrial use and livestock feed. However, its production is constrained by two diseases; brown streak and mosaic.

In response to this the CPP project has funded work in Malawi to screen local and improved germplasm for resistance to the two virus diseases. Screening trials were conducted on-station at Baka Research Station and using 'mother and baby' trials 'on-farm' in two villages.

Data from Baka Research Station and on-farm trials in Karonga collected 6 MAP showed that most clones succumbed to CBSD, with 82 % of the clones having foliar symptoms. However, only 41 % had root symptoms (Tables 11 and 12). Varieties Sauti, I82/000576 and Masoyabazungu did not have foliar symptoms and up to ten clones (Sauti, I82/000576, Masoyabazungu, I930330, I89/00005, I91/00439, Chitembere, 20-20, Mulanje and Nyautonga) did not have root symptoms of CBSD. Clones that have foliar but no root CBSD symptoms up to harvest time have the potential of being utilized since the root quality is not affected.

Similar results were obtained on-farm (Tables 13 and 14). Only Sauti and Masoyabazungu were free of CBSD symptoms at 3 and 6 MAP at both locations. The two clones did not also succumb to this disease at the Research Station.

In addition to CBSD, most clones also succumbed to CMD. Out of the 17 clones at Baka only Sauti, I930330 and 81/00015 did not have CMD symptoms. Similar results were obtained on-farm; out of the 10 clones under evaluation, only Sauti and Banga at Ipyana and Sauti, Banga and Mkondezi at Mwanilondo did not succumb to CMD. Sauti is a released variety in Malawi while Banga is likely to be an improved clone, originally from Mkondezi Research Station and is grown in Banga, a few kilometres from the Station, without official release.

The conclusion from the Malawi work to date is that the improved variety 'Sauti' has remained free of both CBSD and CMD. This variety should be widely promoted in areas with a high incidence of CBSD.

The local variety 'Masoyabazangu' looks as if it may be resistant to CBSD but would need to be evaluated for agronomic and culinary qualities before being further promoted. Unfortunately it showed a high incidence of CMD at Mwenilondo.

Throughout this project, very few varieties have shown resistance to both the main virus diseases affecting cassava. Those that on present evidence may be resistant to both diseases should be multiplied and more carefully evaluated.

Table 11. CBSD and CMD at 6 MAP at Baka Research Station, Karonga, Malawi

Genotype	CBSD				CMD	
	Foliar		Root		Foliar	
	Score	Incidence (%)	Score	Incidence (%)	Score	Incidence (%)
I61036	2.3	2.7	1.7	40.0	3.0	5.6
I930330	3.7	14.3	1.0	0.0	1.0	0.0
I89/00005	2.7	5.7	1.0	0.0	3.0	6.4
Mbundumali	3.3	8.0	1.3	6.7	4.0	67.7
I82/000576	1.0	0.0	1.0	0.0	1.7	1.1
Banga	2.7	9.0	1.7	20.0	1.7	1.5
Tukuyu	1.7	2.3	2.0	33.3	3.7	9.9
I91/00439	1.7	0.7	1.0	0.0	3.0	4.6
I88/00039	2.3	4.3	1.3	20.0	2.3	11.3
Chitembwere	3.0	6.0	1.0	0.0	4.0	39.7
20-20	4.0	11.7	1.0	0.0	3.7	18.2
Ngw'enyani	3.3	10.7	1.3	13.3	2.3	8.6
Mulanje	2.3	4.3	1.0	0.0	3.7	48.0
Masoyabazungu	1.0	0.0	1.0	0.0	2.3	11.8
81/00015	3.7	7.0	1.7	13.3	1.0	0.0
Nyautonga	1.7	0.7	1.0	0.0	4.0	31.9
Sauti	1.0	0.0	1.0	0.0	1.0	0.0
Mean	2.43	5.13	1.24	8.63	2.67	15.7
$LSD_{(0.05)}$	1.07	5.46	NS	32.9	1.33	14.4

Table 12. Foliar CBSD and CMD at 6 MAP at Ipyana and Mwenilondo in Karonga, Malawi

Genotype	Ipyana				Mwenilondo			
	CBSD		CMD		CBSD		CMD	
	Score	Incid. (%)	Score	Incid. (%)	Score	Incid. (%)	Score	Incid. (%)
Banga	1.0	0.0	1.0	0.0	2.3	48.7	1.0	0.0
Tukuyu	1.0	0.0	2.0	6.8	2.3	4.2	3.7	20.0
Chitembwere	2.0	8.5	3.5	16.8	1.7	2.3	2.0	4.0
Ngw'enyani	2.0	18.5	4.0	46.4	3.3	43.3	3.7	63.3
Mulanje	2.0	3.0	4.0	72.6	2.0	9.3	2.7	27.3
Masoyabazung	1.0	0.0	3.0	9.7	1.0	0.0	2.3	39.0
Masoyabahindi	2.0	4.0	3.0	23.0	1.0	0.0	3.0	15.3
Nyautonga	2.5	17.0	3.0	31.7	2.3	19.7	3.3	43.7
Sauti	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
Mkondezi	3.0	10.0	3.9	3.8	1.7	1.7	1.0	0.0
Mean	1.75	6.1	2.8	21.1	1.87	12.9	2.37	21.3
$LSD_{(0.05)}$	NS	NS	1.12	23.5	1.41	16.2	1.20	32.9

Table 13. Foliar CBSD, and CMD (1-5) at Mkondezi Research Station, Nkhata Bay, Malawi at 6 MAP

Genotype	CBSD	CMD
I61036	1.7	1.7
I930330	2.0	1.7
I89/00005	1.3	1.0
Mbundumali	1.0	3.3
I82/000576	1.0	1.7
I91/00439	1.0	1.0
I88/00039	1.0	1.0
Chitembwere	1.0	3.7
Ngw'enyani	1.0	3.7
Mulanje	1.0	3.0
Masoyabazungu	2.3	3.0
81/00015	1.0	1.0
Mkondezi	1.0	1.0
Sauti	2.0	2.0
Mean	1.3	2.0
$LSD_{(0.05)}$	NS	1.14

Table 14. Foliar CBSD and CMD scores (1-5) at 6 MAP at Chintheche (on-farm), Nkhata Bay Malawi

Genotype	CBSD	CMD
Mbundumali	1.3	3.8
Gomani	1.5	2.4
Tukuyu	1.0	2.1
Chitembwere	1.0	2.3
Masoyabazungu	1.1	2.5
Nyautonga	1.1	3.7
Sauti	1.0	1.5
Mean	1.15	2.6
$LSD_{(0.05)}$	NS	0.30

CBSD in Uganda – nation-wide survey

Cassava brown streak disease was found only in four districts out of the 18 districts surveyed countrywide between July and September 2005 (Table 4). The magnitude of the disease in the affected districts was low with prevalence ranging from 3.3-16.6% (Table 15). Three of the districts, Mukono, Wakiso and Luwero, out of the four affected are located in central Uganda. This apparently indicated that by the time of the survey, CBSD was more prevalent in the districts situated in the northern shore of Lake Victoria Crescent (Fig. 2). The fourth affected district Kaberamaido is situated in north-eastern Uganda. The material planted in Kabermaido that has showed CBSD symptoms was reportedly obtained from Mubende district which is also located in central Uganda. The risk of spreading the disease through use of infected material cannot therefore be overemphasized.

Table 15. The incidence and severity of cassava brown streak disease (CBSD), cassava mosaic disease (CMD) and whitefly abundance on cassava in 18 districts in Uganda, July-September 2005

District	CBSD			CMD		Whitefly population
	% fields infected	Incidence per field (%)	Severity (1-5)	Incidence (%)	Severity (1-5)	Adults score on lvs (scale 1-5)
Mukono	16.6	34.7	2.3	56.0	2.5	2.1
Wakiso	3.3	3.3	3.0	55.3	2.5	2.2
Iganga	0.0	0.0	0.0	71.1	3.0	2.0
Kamuli	0.0	0.0	0.0	75.5	3.1	2.2
Pallisa	0.0	0.0	0.0	34.9	2.7	2.5
Kumi	0.0	0.0	1.0	26.0	2.9	2.5
Soroti	0.0	0.0	1.0	19.0	2.7	3.0
Kaberamaido	3.3	100	2.6	65.0	3.3	2.5
Lira	0.0	0.0	1.0	84.0	3.5	2.4
Apac	0.0	0.0	1.0	76.0	3.5	2.2
Hoima	0.0	0.0	1.0	85.0	3.0	2.1
Masindi	0.0	0.0	1.0	63.0	2.7	2.0
Luwero	10.0	67.8	2.3	86.0	2.7	2.1
Nakasongola	0.0	0.0	1.0	66.0	2.7	2.1
Mpigi	0.0	0.0	1.0	61.0	2.7	2.4
Nebbi	0.0	0.0	1.0	46.0	2.7	2.0
Arua	0.0	0.0	1.0	64.0	3.0	2.1
Moyo	0.0	0.0	1.0	62.0	3.3	2.0

The disease was mainly observed on improved CMD resistant cultivars throughout the country and on only one landrace (Kabwa) being grown in Mukono (Table 16). The most affected cultivars were TME 204 and TME 14 with CBSD incidences ranging from 59 -100% and 3 - 92%, respectively. Tuberous root deformation and root necrosis were observed only in Kaberamaido district and 100% of the harvested tuberous roots were affected. The damage levels (scale 1-5) were very high with average severity score of up to 4.6 (Table 16). A colossal loss of this magnitude warrants careful choice of cassava varieties to promote if cassava production in the country is to be upheld and famine averted, especially in communities where cassava is a major source of food.

Results from the survey of 15 districts showed that CBSD was not widespread in the cassava population as a whole. However, it was present in a large proportion [exact % not given] of fields where the improved varieties TME204 and TME 14 were being grown. CBSD symptoms were found with one exception, only on these two varieties with incidences of leaf symptoms up to 100%. These two varieties have been widely distributed in Uganda due to their high yield and quality and resistance to mosaic disease.

Root necrosis was found at only one site where both TME204 and TME14 were being grown and here, root necrosis was severe. It is not known why root necrosis was confined to this one site. The source of planting material for the affected fields was in all cases Namulonge or cassava fields around Namulonge.

Table 16. The incidence and severity of cassava brown streak disease (CBSD) on cassava cultivars commonly affected in four districts in Uganda, July-September 2005

Infected cultivar	*Fields sampled	CBSD (foliar)		CBSD (roots)		Crop age (Month)
		Incidence	Severity	Incidence	Severity	
Mukono District						
TME 204	6 (2)	58.5	2.9	0.0	0.0	7
TME 14	7 (2)	26.7	2.0	0.0	0.0	7
Kabwa (landrace)	2 (1)	3.3	3.0	0.0	0.0	7
Wakiso District						
TME 14	10 (1)	3.3	3.0	0.0	0.0	7
Luwero District						
TME 14	9 (2)	91.7	2.3	0.0	0.0	6
00057 (Omongole)	3 (1)	20.0	2.3	0.0	0.0	5
Kaberamaido District						
TME 204 &TME 14	**1 (1)	100	2.6	100	4.6	8

* Numbers of fields infected by CBSD are in parentheses

** A small plot with only 10 plants of TME 204 and 1 plant of TME 14

It now seems clear from these preliminary results that the main reason for the outbreak of CBSD in Uganda is the release of CMD resistant varieties that are highly susceptible to CBSD. On the Namulonge farm CBSD symptoms are apparent on a much wider range of varieties which is probably due to the raised inoculum pressure, resulting from the presence of highly susceptible varieties and elevated whitefly populations [*B. tabaci* is the insect vector of CBSV].

Having established that some of the released TME varieties are the main source of CBSD infection and that the disease is not generally widespread, surveys should focus more on these varieties. Fields known to be growing TME varieties should be targeted and then survey the surrounding fields if CBSD is found. This would make more sense than random surveys based on a fixed mileage interval.

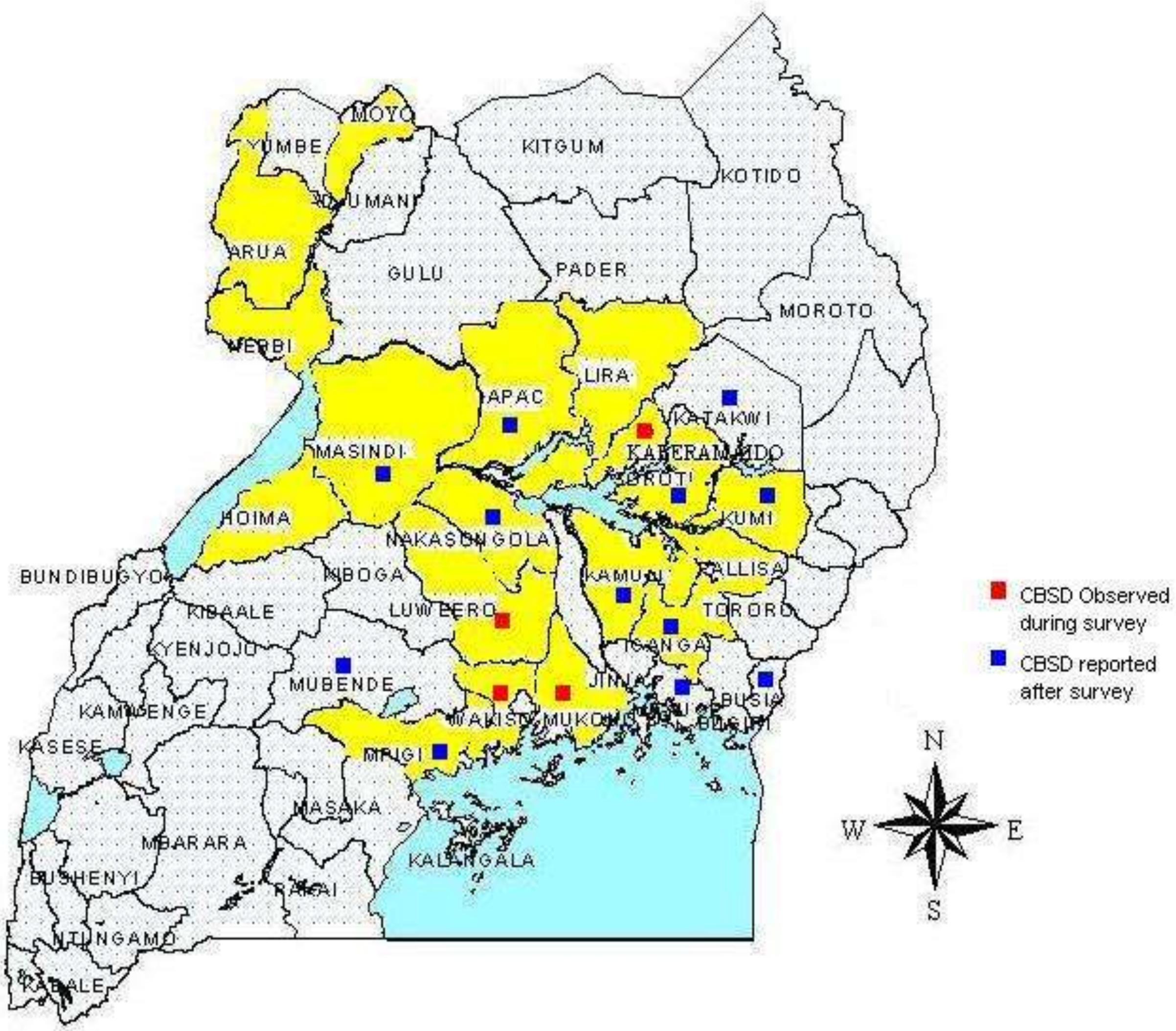

Fig. 2. Distribution of CBSD in Uganda by District in December 2005.

Management strategy for CBSD in Uganda

The first option is eradication. This would require destruction of all crops of TME 204 and 14 throughout Uganda and in neighbouring countries, as well as destruction of all cassava at Namulonge. All further distribution of the affected varieties should cease. This is not practical due to the wide distribution of the affected varieties and to elevated whitefly populations now being seen in Uganda CBSD which may already have spread the virus to other varieties.

If eradication is considered impractical at this stage, this amounts to a tacit admission that CBSD is established in Uganda and management of the disease is addressed on a long term basis through selection and breeding for resistance, as is the case in Tanzania.

Next steps

1. It is a matter of urgency that fields growing TME varieties in Rwanda, Burundi [Kenya and Tanzania?] are surveyed. Eradication may still be an option that some countries may wish to adopt, especially if the affected varieties are of limited distribution.

2. Investigations carried out into affected fields in Kaberamaido to try to determine why it is only there that root necrosis has been seen.

3. Sequential harvesting of the affected varieties to determine if root necrosis appears in older plants.

4. Initiate a screening programme at Namulonge in search of varieties resistant to CMDs that are either resistant to CBSD as well, or at least, are not prone to root necrosis.

5. Initiate investigations into the genotype x environment interactions that influence the expression of root necrosis symptoms.

Fig 3. Headlines for article in Ugandan FARMERS VOICE October 2005-12-01


Uganda Attacked By Deadly Viral Cassava Disease

OUTPUT 3: Communication strategy for information on CBSD evaluated.

In Southern Tanzania, the programme to multiply and distribute cassava varieties selected by earlier phases of the project for tolerance to CBSD is supported by an information campaign that has previously used information posters, information leaflets, training of extension officers and radio broadcasts to increase knowledge among farmers about CBSD, recognition of symptoms and control measures, particularly the availability of tolerant varieties.

Fig 4. Poster and leaflets displayed by extension officers

Visits to villages in Southern Tanzania and to extension offices indicated that our poster was not widely displayed. It seems that the number were too few and the quality high, so that individual extension officers kept the posters to use for their own training sessions. A large number of leaflets [4000] were printed but it was difficult to find individuals who had them.

On the basis of this informal survey, it was decided not to use further resources for a more detailed monitoring, but instead to produce a new poster and revise the leaflet. More care was taken this time to ensure that posters were displayed at District Extension Offices. A further 2000 leaflets were distributed to extension and villages in Mtwara Region. The text of both poster and leaflet were in Kiswahili [Fig.4.].

We distributed 12 posters to Districts Agricultural and Livestock Development Officers (DALDO) in Mtwara and Lindi Regions and Tunduru district. Each DALDO received one poster. We produced 2000 leaflets on CBSD and distributed many of them in the sites where we distributed cassava planting materials. Remaining leaflets will be distributed to farmers during implementation of on farm research in 2005/2006 cropping season. Most leaflets will be distributed in CBSD hot spot villages.

<u>Dissemination outputs</u>

Peer Reviewed Journal Papers:

ALICAI, T., OMONGO, C., MARUTHI, M. N., HILLOCKS, R. J., BAGUMA, Y., KAWUKI, R., BUA, A., OTIM-NAPE, G.W and COLVIN, J. (2006) Cassava brown streak disease re-emerges in Uganda. Plant Disease [Submitted June 2005] [Peer-Reviwed Paper]

Internal Reports:

HILLOCKS, R.J. (2005) Report of a visit to Uganda to participate in a workshop to formulate an action plan to address the problem of CBSD in Uganda, 16 May 2005. Natural Resources Institute (NRI), Chatham, UK, 2 pp. [BTOR]

HILLOCKS, R.J. (2005) Report of a project management visit to Uganda and Tanzania to review activities on cassava brown streak disease, 12 – 21 August 2005. Natural Resources Institute (NRI), Chatham, UK, 5 pp. [BTOR]

Extension literature:

ARI NALIENDELE (2005) Symptoms and control of cassava brown streak disease. Naliendele Agricultural Research Institute, Mtwara, Tanzania [Poster] [Kiswahili]. 50 copies

ARI NALIENDELE (2005) Symptoms and control of cassava brown streak disease. Naliendele Agricultural Research Institute, Mtwara, Tanzania [Leaflet] [Kiswahili]. 2000 copies

Appendices:

Appendix I: Cassava brown streak disease in Uganda. Working Paper A1150/1, Natural Resources Institute (NRI), Chatham, UK, 10 pp. (Copy of paper submitted to Plant Disease).

Appendix II: Occurrence of cassava brown streak disease in Uganda – survey report. NARO-Namulonge Agricultural and animal Research Institute, Kampala, Uganda, 17 pp.

Contribution of Outputs to developmental impact

How is the knowledge promoted benefiting the poor?

Funding during this period has allowed the project to more widely distribute the CBSD-tolerant varieties. The main areas of distribution are southern Tanzania and eastern Tanzania. In the south multiplication and distribution has been assisted this year by the NGO, CONCERN and in the east by the EZCORE extension project funded by Irish Aid. Cassava is the staple food crop in our target areas and access to these varieties increases food security and allows communities to process cassava into flour which is used as a source of income. Our communication strategy has increased awareness of the disease, how to recognise it and the availability of tolerant varieties, among farmers and extension workers.

What coverage has been achieved (numbers of farmers, institutions and production areas adopting the technology).

The implications for the research work of the project are massive as cassava is the staple crop for around 20 million people along the coast of Kenya, Tanzxnia and Mozambique and also the lake shore of Malawi. Now that we have confirmed CBSD in Uganda, the first time we have seen the disease at altitudes above 1000m, the major cassava-growing area of the Lake Victoria basin is threatened. At the end of this reporting period most of the main villages in Mtwara region are supplied with cuttings [400,000 people]. The distribution of the tolerant varieties in southern Tanzania is now sufficient to be self-perpetuating. A further 100,000 people can access CBSD-tolerant varieties through the EZCORE project.

What is the potential for wider scale impact?

The potential number of people in the region that could be affected by CBSD is around 70 million. The impact of this project and its predecessors has been huge because we were the only group working on the disease until a few years ago when IITA became interested and now recognise CBSD as one of the major constraints to cassava production and utilisation in s. and e. Africa. Wider scale impact is happening already as IITA supports breeding and selection for resistance to CBSD in the region. The actual multiplication and distribution of varieties is however, a slow process and requires large-scale support from NGOs and from government, with which we have had little success, except in Mozambique, where there was a lot of funding for disaster relief after the floods. The recent outbreak of CBSD in Uganda is an opportunity for further work there as the IITA work on CBSD [Supported by Rockefeller Foundation] does not extend to Uganda which was thought to be outside the zone affected by the disease.

What follow up action/research is necessary to promote the findings of the work to achieve their development benefit?

We have identified germplasm with tolerance to CBSD and a couple of varieties that might have true resistance. However, some varieties which we thought were tolerant have developed severe symptoms at some locations during the period of this project and its predecessors. Those that are still resistant should be collected and used in breeding programmes in the region. The ones of most interest are the few that may be resistant to both CBSD and CMD.

Further progress on breeding and selection for resistance to CBSD requires that we understand more about the expression of resistance to both above ground symptoms and root necrosis. In Uganda, root necrosis was seen at only one site during the survey although the same varieties were showing leaf symptoms at several other sites. What is particular about this site and the larger question of what environmental factors influence the expression of root necrosis. Funds need to be made available for this basic work on host response to infection and environmental influences alongside more adaptive work on resistance.

PROJECT LOGFRAME

Narrative Summary	**Objectively Verifiable Indicators**	**Means of Verification**	**Important Assumptions**
Goal			
Benefits for poor people generated by application of new knowledge on crop protection to annual and herbaceous crops in Forest Agriculture production systems	To be completed by CPP Programme Manager	To be completed by CPP Programme Manager	To be completed by CPP Programme Manager
Purpose			

Ecology and epidemiology of cassava brown streak disease understood and improved control methods and strategies developed and promoted.	To be completed by CPP Programme Manager	To be completed by CPP Programme Manager	To be completed by CPP Programme Manager
Outputs			
1. CBSD-tolerant cvs promoted for improved quality of cassava flour from small-scale and 'cottage' processors. 2. CBSD-tolerant varieties evaluated on-farm in Malawi and Mozambique 3. Communication strategy for information on CBSD evaluated.	Primary multiplication and distribution completed during 2005 Farmer groups identified at end of present project in order for trials to be in field in 2005. Farmers continue multiplying on their own 05/06 Communication strategy evaluated by social scientists and Zonal Communication [Southern zone] by October 2005	CPP progress reports SARRNET reports CPP reports INIA reports Report from Naliendele	Continued collaboration with SARRNET Continues support from SARRNET and the NARS in Malawi and INIA [and Rockefeller Project] in Mozambique
Activities	**Inputs**	**Means of Verification**	**Important Assumptions**
1.1. Multiplication and distribution of CBSD-tolerant varieties 1.2.Promotion of CBSD-tolerant varieties for utilisation in flour production	Total Budget here £69,217	Varieties distributed	Transport available for distribution Continued co-operation with EZCORE
2.1.Farmer participatory evaluation in Malawi of local varieties selected for resistance to CBSD and CMD.			Adverse weather or pest attack does not affect cassava crop
2.2. Farmer participatory evaluation in Mozambique of local varieties selected for resistance to CBSD and CMD.	As for 2.1		
3.1. Evaluation of the CBSD knowledge communication strategy.	Knowledge on CBSD among target groups assessed by September 2005		Transport available for surveys

Note: Outputs should be numbered 1, 2, 3, *etc.* Activities should relate to these outputs and be numbered 1.1, 1.2, ...2.1, 2.2, ...*etc.*

It is expected that most projects will achieve only one or two outputs and a small number of activities.

Appendix I: Draft Paper submitted to 'Plant Disease'

Cassava brown streak disease re-emerges in Uganda

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Abstract

Cassava brown streak disease [CBSD] is an important virus disease that damages the starch-bearing tuberous roots of cassava. The disease is endemic in the coastal lowlands of Eastern Africa and the coastal strip of Lake Malawi. CBSD has rarely been seen at altitudes above 1000 m above sea level, although the reason for this is unknown. CBSD is maintained through the planting of infected cuttings. It has been confirmed recently that the whitefly *B. tabaci* is a vector of CBSD, and responsible for disease spread. This insect can be found on cassava almost everywhere in Africa that the crop is grown. CBSD was first observed in Uganda in 1945 in materials introduced from Tanzania. Affected crops were destroyed and the disease was not noticed until 1994 when it was observed in a field near Entebbe. We report a new outbreak of CBSD in Uganda, more than 1000 km from the coastal areas where it is endemic and at altitudes above 1000 m. This is of great concern because the roots of the cassava plant can become unfit for human consumption due to the root necrosis associated with CBSD. The disease is a major threat to food security in areas where large numbers of people depend on cassava as their staple.

Introduction

Cassava brown streak disease [CBSD] is caused by *Cassava brown streak virus* [*Ipomovirus:Potyviridae*] [Monger *et al*., 2001]. There are a number of different symptoms in the CBSD syndrome. On the leaves the disease appears as a feathery chlorosis on either side of the smaller veins. There are several variants of this symptom, depending on variety, crop age and weather conditions (Hillocks *et a*l., 1999). The economically damaging symptom occurs on the tuberous roots as a yellow/brown, corky necrosis in the starch-bearing tissues. The necrosis begins as discrete areas but in fully susceptible varieties, it may affect most of the root (Nichols, 1950; Hillocks *et al*., 1996; Hillocks and Jennings, 2003). The history and current knowledge on CBSD has been reviewed by Hillocks and Jennings (2003).

CBSD was first reported and distinguished from the cassava mosaic disease [CMD] in Tanzania during the 1930s (Storey, 1936). Soon after, the whitefly, *Bemisia tabaci* was suggested as a possible vector (Storey, 1939). CBSD was found to be endemic in all East African coastal cassava-growing areas from Kenya to the Ruvuma River that marks the southern border between Tanzania and Mozambique. The disease also occurred at lower altitude in Malawi (Nichols, 1950). Recent surveys have confirmed that the disease occurs throughout the coastal strip surrounding Lake Malawi (Shaba *et a*l., 2003; Gondwe *et a*l., 2003). CBSD was reported to be widespread in coastal Kenya (Bock, 1994; Muga and Thresh, 2002) and in Mozambique where it occurred at high incidences (Hillocks *et al*., 2002; Thresh and Hillocks, 2003). Symptoms resembling those of CBSD have been reported from Bas-Congo and Kinshasa Provinces of the Democratic Republic of Congo (Mahungu *et al*, 2003).

Until recently, and since the speculation by Nichols (1950) that *B. tabaci* might transmit CBSD, all attempts to transmit CBSV with whitefly [and with aphids (Lennon *et al*., 1986)] have failed. Two whitefly species occur on cassava in Africa, *B. tabaci* and *B. afer* (Robertson, 1985; Munthali, 1992). Both have been suggested as possible vectors of CBSD and *B. tabaci* is the known vector of CMD (Nichols, 1950; Bock, 1994; Fishpool and Burban, 1994)). Transmission experiments with CBSD and *B. tabaci* in Kenya were unsuccessful (Bock, 1994). Transmission experiments conducted at the Natural Resources Institute, finally demonstrated that *B. tabaci* could transmit CBSV between cassava plants, but results for *B. afer* were inconclusive (Maruthi *et al*, 2005). Both whitefly species are distributed throughout Africa and there is no apparent association between whitefly occurrence and the distribution of CBSD. The reason for the restricted distribution of CBSD remains unknown. In Tanzania, *B. tabaci* is more abundant than *B. afer* and they occupy different parts of the cassava plant. *B. tabaci* adults are more abundant on the upper green leaves, while *B. afer* is more abundant on the lower semi-senescent leaves (Maruthi *et al*., 2004).

Nichols (1950) stated that CBSD could be found inland from the East African coast up to an altitude of 1000 m above sea level. Surveys conducted during the 1990s appeared to support that view (Legg and Raya, 1997; Hillocks, 1999), although the disease has been seen at low incidence at one site in Malawi at 1100 m. With the exception of one or two plants in Malawi, wherever the disease has been reported to be endemic, occurrences are confined to altitudes below 1000m, and incidence increases with decreasing altitude (Hillocks *et a*l, 1999). It has been known for some time that CBSD symptoms can be expressed at altitudes above 1000m when infected cuttings have been planted there. This happened in Uganda when infected material was taken from Tanzania in 1934, but the disease was eradicated by destroying all plants showing symptoms (Jameson, 1964). From that time until 2004, CBSD has not been recorded in Uganda, although symptoms resembling those of CBSD were seen on some plants in Uganda during the 1990s (J. M. Thresh, personal communication). The disease has also been reported from DRC that borders Uganda (Mahungu, 2003) but this has not been confirmed by PCR-based diagnostics. Although cassava is widely grown at altitudes above 1000 m in Tanzania, Malawi and Mozambique, CBSD has not been reported from these areas. A nationwide survey of Tanzania in 1993/94 recorded CMD in all parts of the country, but CBSD was absent from the cassava-growing area bordering Lake Victoria, being recorded only in regions bordering the Indian Ocean and Lake Malawi. However, *B. tabaci* was found throughout the survey area (Legg and Raya, 1998).

CBSD is a major disease of cassava and because of its direct effect on the quality of tuberous roots, the disease can be considered to be more of a threat to food security than CMD. It is therefore of great concern if CBSD is being reported at high incidences in areas outside the coastal lowlands of eastern Africa and at altitudes above 1000 m. We report a new occurrence of CBSD in Uganda at altitudes above 1000m, and its confirmation by PCR-based diagnostics following identification based on leaf symptoms.

Materials and methods

Source of test material

Cassava plants showing symptoms resembling those of CBSD were observed in demonstration fields of Mukono Agricultural Research and Development Centre (ARDC) situated near Kampala City on the northern shores of Lake Victoria. Leaves showing feathering and yellowing symptoms were collected on two diseased plants from four different varieties. Uppermost leaves showing clear symptoms were collected and these were often in the middle of the shoot. Leaves were also collected from apparently symptomless plants as negative controls. The leaves were stored in self-sealable plastic bags for preserving moisture and shipped to the Natural Resources Institute (NRI), UK for diagnoses using reverse transcriptase-polymerase chain reaction (RT-PCR).

Extraction of RNA from cassava leaves

Total RNAs were extracted from cassava leaf samples from Uganda using the CTAB (cetyl trimethyl ammonium bromide) method of Lodhi *et al*. (1994) modified by Maruthi *et al*. (2002). This method was originally described for extractions of total DNA from plant samples, however, is also found to be suitable for the extraction of total RNA with a minor modification that the samples were diluted in 100 μl of RNase-free water (supplied by Qiagen, UK) at the end of the protocol. Leaf samples collected from the CBSD and healthy cassava plants that were grown in the NRI quarantine glasshouse were used as positive and negative controls. The CBSD-affected plants at the NRI glasshouse were originally collected from the CBSD endemic area of Kibaha, Tanzania.

RT-PCR tests

The total RNAs were subjected to RT-PCR tests using the One-Step RT-PCR kit with Platinum Taq (Invitrogen, UK) following the manufacturer's instructions. The 25μl final reactions consisted of 12.5 μl of 2x reaction buffer, 0.5 μl each of 20 μm primers CBSV10 and CBSV11 (Monger *et al*., 2001b), 0.3 μl of RT/Taq mix, 1.0 μl of template RNA and the final volume was made up of RNase-free water. Reactions were run in a Gene Amp PCR System 9700 thermal cycler (Applied Biosystems, UK) under the following amplification cycles: 50°C for 30 min for the synthesis of cDNA, followed by the initial denaturation of cDNA at 94°C for 2 min, which is followed by 35 cycles of 94°C for 45 sec, 52°C for 1 min and 72°C for 1 min, and ending with 72°C for 10 min. Amplicons were electrophoresed through a 1.5% (w/v) agarose in 0.5x TBE gel and bands were visualised under UV light after staining the gel in 0.5 μg/ml ethidium bromide solution.

Survey of CBSD in three districts

A total of 120 farmers' cassava fields, 40 in each of Mukono, Wakiso and Mayuge districts were assessed to record the incidence and severity of CBSD, CMD and whitely numbers. Wakiso and Mayuge are to the west and east of Mukono, respectively, the latter being the district where the recent observation of plants with CBSD-like symptoms first occurred. In each district, 30 fields were assessed for above ground symptoms and 10 fields for symptoms on the tuberous roots. Fields were selected at regular intervals along major and feeder roads traversing the districts. The distance between sampled fields was about 7 km for above ground symptoms and

21km for symptoms on tuberous roots. Crops assessed for foliar symptoms were those planted 4-6 months previously. Only crops more than 10 months old were assessed for symptoms on tuberous roots. Within each field sampled for above ground symptoms, 30 plants along two diagonals were recorded in detail on the predominant variety. Names of other varieties also found in each sampled field were also recorded. The presence or absence of CBSD symptoms on the leaves and stems was recorded on each plant following a scale of 1 (no symptoms) to 5 (defoliation, stem lesions and dieback) (Gondwe *et al*. 2003). The same plants were also examined for CMD symptoms, recorded on a scale of 1 (no symptoms) to 5 (very severe leaf distortion, chlorosis and stunting) (Terry and Hahn, 1980). For CMD-affected plants, a distinction was made between recent infections through whiteflies (whitefly infection) and plants perpetuating CMD symptoms resulting from use of cuttings from CMD-affected plants as planting material (cutting infection). In the 'current season' infection by whiteflies, only the upper leaves show CMD symptoms, whereas in plants with cutting infection, even early-formed leaves near the ground have symptoms. It is not yet clear whether such distinction is possible for CBSD-affected plants. The presence or absence of CBSD and CMD in neighbouring fields and the proximity of such fields (adjacent, near, far or none in site) relative to the sampled field were noted. In fields sampled for tuberous root symptoms, 10 plants were uprooted and the tuberous roots transversely sliced to check for root necrosis. Root symptoms were scored on a scale of 1 (no necrosis) to 5 (>25% root necrotic) (Gondwe *et al*. 2003). The incidence of CBSD was calculated from the number of affected plants as a percentage of the total number of plants assessed in a field. In calculating mean severity per field, scores for symptomless plants were omitted. Numbers of adult whiteflies on the top five leaves of a representative shoot were counted on every other plant assessed for foliar symptoms, thus whitefly counts on a total of 15 plants per field. The altitude, latitude and longitude of each site were taken using a GPS.

Results

<u>Symptoms of cassava brown streak disease</u>

The most obvious symptom observed was chlorosis, expressed mainly on the lower older leaves. The cholorosis mainly occurred along and between the smaller veins, giving a 'feathery' appearance (Plate 1) and was different from that usually associated with CMD. Unlike typically observed for CMD and regardless of the amount of chlorosis, most symptomatic leaves had no or only mild leaf distortion. Corky brownish necrosis of tuberous roots, the other symptom usually associated with CBSD was observed also noted in some plants (Plate 2).

<u>Incidences and severities of CBSD and CMD</u>

CBSD was observed in Mukono and Wakiso districts but was not found in Mayuge district. In Mukono district, one farmer's field out of those sampled for foliar symptoms had the disease (Table 1). The field was planted with the officially selected variety TMS I 92/0057 and had incidence of 70%. In addition, the disease was present in the 8-month demonstration crop of CMD-resistant varieties at Mukono ARDC. Five out of 11 varieties in the garden had plants with CBSD symptoms. The affected varieties (and their respective CBSD incidences in brackets) were; TME 14 (64%), Nase 10 (40%), Nase 12 (22%), TME 204 (16%) and 0087 (4%). At this site, CBSD was also present in two younger crops (4 months) of the variety TME 14, one planted nearby and the other just adjacent to the old planting.

In Wakiso district, CBSD was found in two fields planted with the CMD-resistant variety TME 204. One of the fields had been assessed for above ground symptoms and had CBSD incidence of 16.7% (Table 1). The other field in which CBSD was present had been sampled for symptoms on the roots. Roots of two out of ten plants sampled had CBSD symptoms. The affected plants had both root and foliar symptoms. 92% of the roots harvested from the affected plants were necrotic and all the CBSD-affected roots were severely damaged with severity score of 5.

Overall, chlorosis (score 2) was the only above ground CBSD symptom observed and CBSD was not found among landraces. However, CMD was present in both officially bred varieties and the landraces. Mean CMD incidence among conventionally bred varieties did not exceed 24% in each of the districts, whereas that for landraces was greater than 45% (Table 1). Some individual landraces had 100% CMD incidences. Mean severities of CMD in each of the three districts were generally moderate and ranged from 2.1-2.5 in the resistant varieties and 2.8-3.1 in the landraces. Similar levels of CMD incidences and severities pooled for the overall most predominant landraces and resistant varieties were apparent (Table 2).

<u>Whitefly populations</u>

Generally moderate mean numbers of whiteflies were recorded in all the districts, ranging from 17 to 28 adult whiteflies per plant (Table 1). However, the numbers of whiteflies varied among the predominant varieties assessed, but this did not seem to be related to the level of resistance of the varieties to CMD or the occurrence of CBSD among the varieties (Table 2).

<u>PCR diagnosis</u>

All the eight diseased leaf samples obtained from the field in Mukono tested positive for CBSV. A diagnostic band size of approximately 230 bp was obtained for the diseased leaf samples (Fig. 1), which was similar to the bands obtained for the two diseased samples collected from the NRI glasshouse and used as positive controls. The bands were absent in the leaf samples from the apparently healthy samples, although two of them (samples H1 and H2, Fig. 1) had faint bands at the same height as the positive samples suggesting that these two plants had latent CBSV infections at the time of sample collection.

Discussion

When there are no previous records in a country or region, of a disease that is subsequently found to be widespread and present at high incidences, it is impossible to know if the disease was previously present but went un-noticed, or, has spread from a more recent introduction. This was the case with CBSD in Mozambique, which was unreported until 1998 when surveys, initially planned for CMD, showed CBSD to be present at high incidences throughout the northern Provinces of Nampula and Zambezia (Hillocks *et al*., 1999; Thresh and Hillocks, 2003).

There are two possibilities for the origin of the current outbreak of CBSD in Uganda. Firstly that the disease has been present for many years at a low level and occurred largely un-noticed. It is known that CBSD was once accidentally introduced into Uganda in the 1930s, before the disease had been described and was later noted in

1994 (Thresh, 2003). When the symptoms were recognised in the 1930s, all cassava plants at the affected sites of Bukalasa and Serere were destroyed. CBSD was not aggressive on the cassava varieties grown there at that time. The second possibility is that there has been a new introduction of infected material from Kenya, Tanzania, Malawi or Mozambique. The multiplication of such material or others that subsequently got affected by CBSD may have helped to perpetuate and proliferate the disease. This argument seems reasonable to the extent that in this study CBSD was mainly observed in recently introduced cassava genotypes. However, the disease was also present on varieties such as Nase 10 and Nase 12 that were introduced earlier in the mid 1990s. It may simply be the case that more recently introduced material, especially the TMS and TME varieties are highly susceptible to CBSD.

Whatever the source of infection, the elevated whitefly numbers being experienced in Uganda may be aiding the increased spread of CBSD. The spread of a new variant of CMD (caused by a recombinant begomovirus named East African cassava mosaic virus-Uganda [EACMV-UG]), has been associated with a pandemic of a severe form of the disease which spread from Uganda to affect neighbouring countries in the period between 1988 and the present day (Gibson *et* al., 1996; Deng *et al*, 1997; Legg, 1999; Otim-Nape *et al*., 2001). The pandemic was linked to unusually high populations of *B. tabaci* (Legg and Ogwal, 1998; Colvin *et al*., 2004). While there is clear evidence from Uganda of high whitefly populations and their association with the spread of EACMV-UG, it is not obvious why CBSD has not previously become endemic in the cassava areas in the interior of East Africa. This is particularly surprising given that there is considerable movement of cassava planting material within Uganda and between the East African countries and one of the vectors, *B. tabaci* is widely distributed. Clearly, CBSD is able to spread quite rapidly in the areas where it has been endemic for at least 70 years, even in areas with comparatively low whitefly numbers such as is common at the East African coast. Cassava has been regarded as not being a particularly good host for *B. tabaci* (Fishpool and Burban, 1994) and the numbers per plant in coastal East Africa, are generally much lower than is now the case in Uganda. It has been observed on the coast of Tanzania that the periods of spread of CBSD closely coincide with surges in whitefly populations (Maruthi *et al*., 2005) and little or no spread occurs in years, such as 2002, when whitefly was absent or present at levels rarely exceeding 2 - 3 per plant, counted, on the uppermost shoots. This contrasted with the 1998 season when whitefly numbers reached 50 per plant during the period February/March, when there is an abundance of new leaf growth suitable for virus infection. This resulted in almost 100% infection in a plot of 900 plants grown from virus-free cuttings with a row of CBSD-infected plants at one end of the plot (R. J. Hillocks, unpublished). Storey and Nichols (1938) estimated that *B. tabaci* transmitted CMD only to young leaves that were less than 25% of their mature length. The rate of spread of CMD has been shown to increase with increasing whitefly population (Fargette *et al*., 1985).

Nichols (1950) believed that CBSD was rarely seen at altitudes above 1000 m because low temperature induced severe symptoms in plants grown from CBSD-infected cuttings. Symptoms were so severe that plants either did not survive, or were in such poor condition that farmers would not take planting material from them. He also thought that there was no disease spread by the vector at altitudes above 1000 m. However Jennings (1960) was not happy with this explanation and examined plants grown from CBSD-infected cuttings in Tanzania, at Iringa at 1700 m and at Singida at

1500 m. Most of the plants continued to grow well despite showing symptoms of CBSD on the leaves and roots but there had been no spread of the disease to neighbouring cassava plants. Nichols hypothesis about the effect of low temperature was therefore rejected by Jennings, but he supported Nichols view that vector transmission of CBSD did not occur at higher altitudes. If it is the case that 'wild type' Tanzanian populations of *B. tabaci* are unable to transmit CBSV at high altitude, then it is possible that changes in the whiteflies associated with the mosaic pandemic in Uganda, have influenced its ability to transmit plant viruses (Maruthi *et al.,* 2002), including CBSV. Similarly changes in weather, especially the frequent occurrence of unusually prolonged hot and dry seasons in recent years may have a role in the re-emergence of CBSD in Uganda.

One factor contributing to the lack of spread of CBSD away from the coast, might be that the cassava growing areas on the coast of Eastern Africa are separated from those around Lake Victoria by a large region of central Tanzania where the staples are sorghum and millet and cassava is rarely grown. Similarly, in Mozambique and Malawi, the cassava-growing areas are separated from those in Zambia by mountains and by Zimbabwe, where cassava is not a traditional crop. This is beginning to change as Governments promote cassava in these areas to enhance food security. All these factors make it difficult to reach a conclusion on the origin of the current outbreak of CBSD in Uganda.

A problem with surveys for incidence of CBSD that are conducted only once is that the expression of leaf symptoms is fickle. It is possible to survey an area at a time when CBSD leaf symptoms are not being expressed and record no disease, but then to go back two weeks later to find obvious leaf symptoms at a high incidence. For instance, new leaves that sprout at the end of a dry spell often do not show any symptoms. Young crops newly infected following an upsurge in whitefly numbers in a neighbouring crop affected by CBSD will remain symptomless for at least 7 – 21 days. Thereafter, CBSD would be recorded, possibly at high incidence and perhaps with no, or few whiteflies present. Moreover, whitefly populations fluctuate within and between seasons (Seif, 1981). Added to this, CMD is endemic in areas where CBSD also occurs and symptoms of CMD can mask the less conspicuous leaf symptoms of CBSD. In addition, the leaves may be damaged by the feeding of the cassava green mites (*Mononychellus tanajoa*), further obscuring CBSD symptoms. The complex relationship between host physiology, environmental conditions, soil type and disease expression with CBSD are not fully understood. A survey of Zanzibar conducted in 1994, concluded that the disease was absent from the Island (Legg and Raya, 1998), although it had been known there in the 1950s. However, when the island was surveyed again in 1998, CBSD was found at high incidences (Thresh and Mbwana, 1998).

The reappearance of CBSD in Uganda, raises great concern for food security for the entire country, given that many communities have already suffered from a shortage of their staple as a result of the pandemic caused by EACMV-UG. The need for routine monitoring and diagnostics and developing varieties resistant to CBSD, CMD and whiteflies has become more urgent with this confirmation of the disease at altitudes above 1000 m.

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Table 1: The incidence and severity of cassava brown streak disease (CBSD), cassava mosaic disease (CMD) and whitefly numbers in the most predominant varieties in each of the three districts surveyed

Predominating varieties per district	[a]Fields sampled	CBSD		CMD		Adult whitefly
		incidence	severity	incidence	severity	
Mukono district						
Njule	6	0	-	37.2	2.9	7.1
Matooke	5	0	-	31.3	2.8	23.1
	4	[b]*17.5*	*2.0*	*35.0*	*2.2*	*11.1*
TMS I 92/0057						
Kabwa	4	0	-	77.5	2.6	62.5
Unnamed (local)	4	0	-	47.5	2.8	7.0
	3	*0*	-	*17.8*	*2.1*	*8.7*
TME 14						
TME 204	*3*	*0*	-	*21.1*	*2.0*	*30.4*
Nase 12	*1*	*0*	-	*0*	-	*8.4*
[c]**Mean**: Local		0	-	46.3	2.8	30.8
Resistant		*6.4*	*2.0*	*23.3*	*2.1*	*15.5*
Total		**2.3**	**2.0**	**37.9**	**2.5**	**25.2**
Wakiso district						
	9	*0*	-	*27.8*	*2.5*	*41.7*
TMS I 92/0057						
Unnamed (local)	5	0	-	54.7	2.9	16.6
	4	*0*	-	*0.8*	*2.2*	*50.4*
TME 14						
Bamunanika	4	0	-	60.0	3.0	4.4
TME 204	*3*	[d]*5.6*	*2.0*	*7.8*	*2.0*	*13.8*
Kirimumpale	2	0	-	41.7	3.1	10.1
Unnamed (resistant)	*1*	*0*	-	*3.3*	*2.0*	*19.6*
Njule	1	0	-	86.7	3.3	8.5
Kameza	1	0	-	100.0	3.7	57.1
Mean[b]: Local		0	-	60.3	3.1	14.3
Resistant		*1.0*	*2.0*	*16.5*	*2.4*	*37.5*
Total		**0.6**	**2.0**	**35.4**	**2.7**	**27.5**
Mayuge district						
Magana	10	0	-	78.7	2.9	9.2
Nase 3	*7*	*0*	-	*23.3*	*2.5*	*4.3*
Nase 2	*2*	*0*	-	*65.1*	*2.6*	*1.3*
Nase 12	*2*	*0*	-	*0*	-	*30.5*
TME 14	*2*	*0*	-	*0*	-	*154.4*
Njule	2	0	-	68.4	2.9	2.1
Unnamed (local)	2	0	-	65.7	3.1	6.1
Ebwanateraka	1	0	-	16.7	2.4	10.3
Kabwa	1	0	-	100.0	3.0	1.7
Mfumbachai	1	0	-	100.0	2.5	0.5
Mean: Local		0	-	74.8	2.9	7.1
Resistant		*0*	-	*22.6*	*2.5*	*30.9*
Total		**0**	**-**	**52.2**	**2.8**	**17.4**

CMD-resistant varieties and corresponding statistics are indicated in italics

[a] Where many varieties are grown in the same field, records were taken only on the predominant variety

[b] One field of the CMD-resistant variety TME 204 was affected by CBSD in Wakiso district with incidence of 16.8%

[c] Means for all fields sampled per district

[d] One field of the CMD-resistant variety TMS I 92/0057 was affected by CBSD in Mukono district with incidence of 70%

Table 2: Mean incidence and severity of cassava brown streak disease (CBSD), cassava mosaic disease (CMD) and whitefly numbers in the overall most common varieties of cassava grown by farmers

Variety	**Number of plantings**		**CBSD**		**CMD**		**Adult whitelies**
	Overall	**[a]Sampled**	**incidence**	**severity**	**incidence**	**severity**	
TME 14	*30*	*15*	*0*	*-*	*6.3*	*2.1*	*59.6*
TMS I 92/0057	*25*	*13*	[b]*5.4*	*2.0*	*31.6*	*2.4*	*18.0*
Magana	16	13	0	-	78.7	2.9	9.2
Njule	26	10	0	-	49.6	3.0	6.2
Nase 3	*24*	*8*	*0*	*-*	*23.3*	*2.5*	*4.3*
Kabwa	8	7	0	-	82.3	2.6	50.3
[c]Unnamed (local)	11	7	0	-	71.4	3.4	8.8
TME 204	*13*	*6*	[d]*2.8*	*2.0*	*14.4*	*2.0*	*22.1*
Matooke	9	5	0	-	31.3	2.7	53.1
Bamunanika	7	4	0	-	60.6	3.0	4.4
Nase 12	5	4	0	-	0.0	-	0.9
Kirimumpale	4	3	0	-	41.6	3.1	10.1
Nase 2	6	3	0	-	65.1	2.6	1.3
[e]Other local (n=13)	40	6	0	-	69.5	3.0	25.3
[f]*Other resistant (n=4)*	*30*	*1*	*0*	*-*	*10.0*	*2.0*	*40.9*
All local (n=30)	**121**	**49**	**0**	**-**	**60.0**	**2.9**	**18.2**
All resistant (n=10)	***133***	***41***	***2.1***	***2.0***	***20.2***	***2.3***	***29.5***
All varieties (n=40)	**254**	**90**	**1.0**	**2.0**	**41.8**	**2.7**	**23.4**

CMD-resistant varieties and corresponding statistics are indicated in italics

[a] Number of fields in which variety predominated in two or more fields

[b] One field of the CMD-resistant variety TMS I 92/0057 was affected by CBSD in Wakiso district with incidence of 70%

[c] landraces for which farmers had no names

[d] One field of the CMD-resistant variety TME 204 was affected by CBSD in Mukono district with incidence of 16.8%

[e] Landraces that predominated in one field

[e] CMD-resistant varieties that predominated in one field

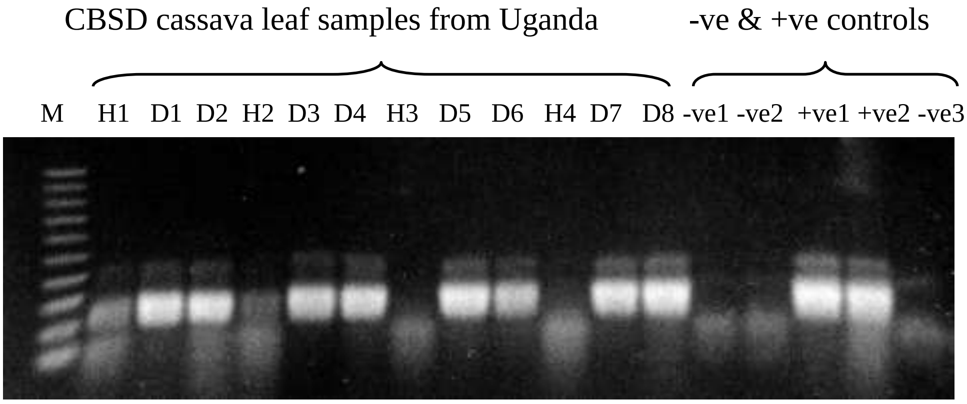

Figure 1. Gel electrophoresis photograph of RT-PCR products obtained using the CBSV10 and CBSV 11 primers for the detection of CBSV in cassava leaf samples from Mukono, Uganda. H = cassava leaf from apparently healthy plant, D = cassava leaf showing typical CBSD symptoms. –ve and +ve controls are from the healthy and CBSV-infected cassava plants grown at NRI. –ve3 is a water control. M = 100 bp molecular weight marker.

Plate 1. Leaf of CBSD-affected cassava of CMD-resistant variety TME 14 showing 'feathery' chlorosis

Plate 2: Root necrosis in the variety TME 204 due to CBSD

Appendix II: Survey Report

OCCURRENCE OF CASSAVA BROWN STREAK DISEASE IN UGANDA

PROJECT A1150

TECHNICAL REPORT

1 July 2005 – 30 November 2005

January 2006

National Cassava Programme

Namulonge Agricultural and Animal Production Research Institute,
P.O. Box 7084, Kampala Uganda

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Background

Cassava brown streak disease (CBSD) is caused by *cassava brown streak virus* (CBSV). The disease was first described in Tanzania during the 1930s and is the second most important virus disease of cassava (*Manihot esculenta* Crantz.) to-date in Africa after cassava mosaic disease (CMD). Unlike CMD which is widely distributed wherever cassava is grown in the African Continent, CBSD has been restricted mostly along the East African coastal cassava-growing regions and hence considered for a long time as a low altitude (< 1000 masl) problem.

CBSD first appeared in Uganda in the 1940s on materials introduced from Tanzania. The affected crops were destroyed and the problem was not noticed until 1994 when symptom typical of CBSD was observed in a field near Entebbe on the northern shores of Lake Victoria. A decade later symptoms of CBSD was again observed on cassava in some locations in central Uganda this time in relatively higher incidence, albeit localized, on some of the popular CMD-resistant varieties being grown countywide by farmers. This caused serious concern as cassava production in the country has just been restored through use of CMD-resistant varieties following devastation by the unusually severe CMD epidemic in the 1990s. There was therefore need to establish the prevalence of the disease in the country in order to institute corresponding mitigation strategies. An immediate intensive survey of the CBSD in the country was therefore recommended in a planning meeting convened at Namulonge Agricultural and Animal Production Research Institute (NAARI) on 16 May 2005 and attended by scientists from NARO, IITA, NRI and Root Crop Programme of Tanzania. The highlights of the survey are contained in this report.

Countrywide survey of CBSD

The survey was conducted between July 2005 and September 2005 in 18 major cassava producing districts of Uganda (Fig. 1) to assess the occurrence of CBSD in farmers' fields and to establish the status of CMD and abundance of cassava whitefly in the locality. A total of 720 cassava fields were assessed-30 for above ground symptoms and 10 for tuberous root symptoms per district. Fields were selected at regular intervals of 6-7 km for above ground symptoms and 18-21 Km for tuberous symptoms along major and feeder roads traversing the districts. Within each field sampled for above ground symptoms, 30 plants along two diagonals were examined for presence or absence of CBSD and noted. Symptom severity were recorded on the same selected plants on a scale of 1 (no symptoms) to 5 (very severe symptoms) (Table 1). Coloured pictures of CBSD foliar symptoms were presented to the field extension staff to familiarize with during and even after the survey. For the root symptoms 10 plants per field were uprooted and the tuberous roots sliced and checked for root necrosis. Root

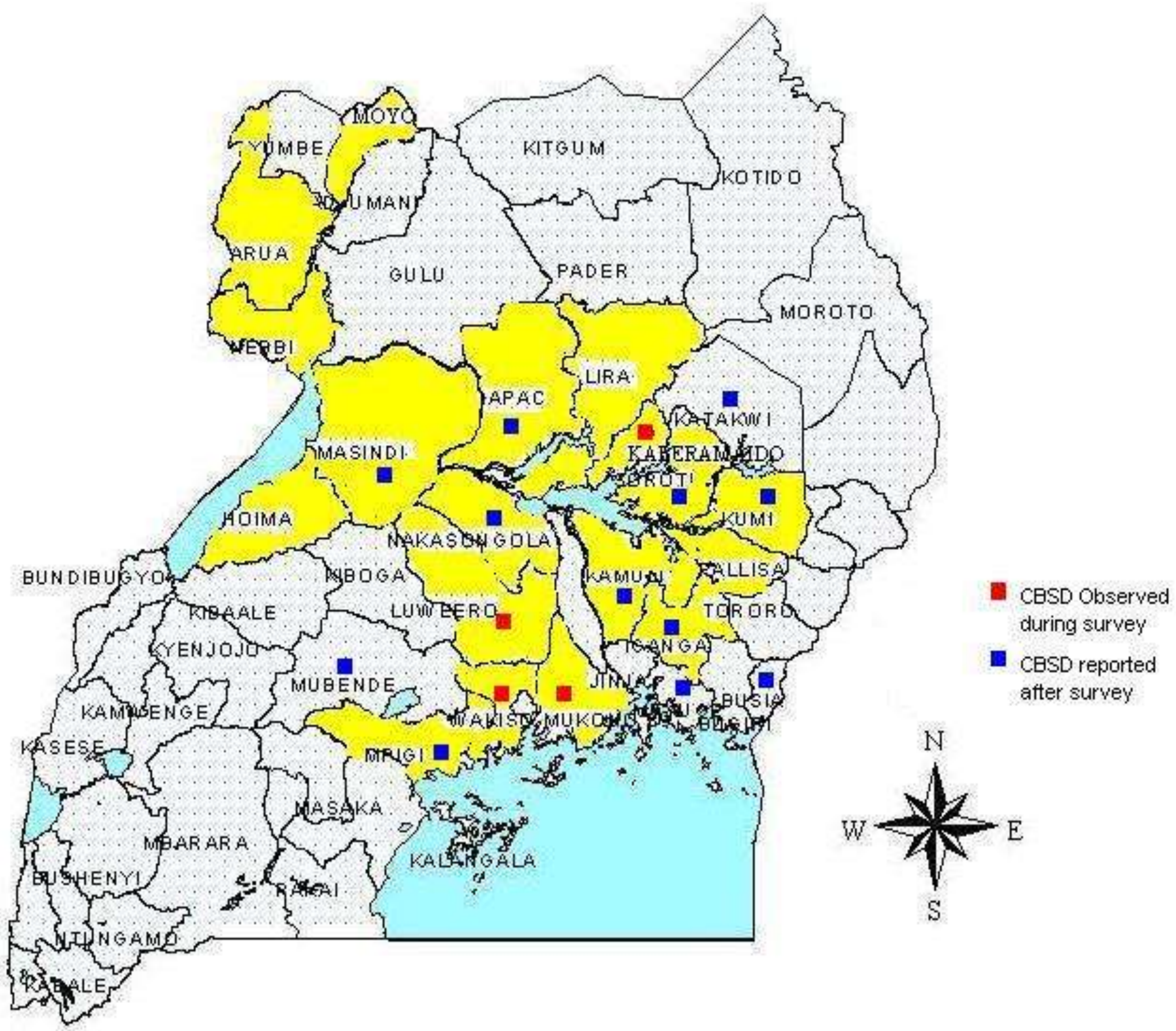

Fig. 1. Map of Uganda showing surveyed districts (yellow) and districts where CBSD was observed (red square) and reported (blue square) during and after the survey, respectively.

symptoms were scored on a scale of 1 (no necrosis) to 5 (> 25% root necrotic) (Table 2). The incidence of CBSD was calculated from the number of affected plants as a percentage of the total number of plants assessed in a field. Scores of 1 for symptomless plants were omitted in the calculation of mean severity per field.

Table 1. Scale used for CBSD foliar symptoms

Score	Description of above ground symptoms
1	No apparent symptom
2	Slight foliar mosaic, no stem lesions
3	Foliar mosaic, mild stem lesions, no die back
4	Foliar mosaic, severe stem lesions, no die back
5	Defoliation, severe stem lesions and die back

Table 2. Scale used for CBSD tuberous root symptoms

Score	Description of above ground symptoms
1	No apparent necrosis
2	Less than 5% of root necrotic
3	5-10% of root necrotic
4	10-25% of root necrotic, mild root constriction
5	> 25% of root necrotic, severe root constriction

The CMD status was assessed on the same 30 plants on which CBSD was assessed. CMD symptom severity were recorded on a scale of 1 (no symptoms) to 5 (very sever leaf distortion, chlorosis and stunting). Likewise scores of 1 for symptomless plants were omitted in the calculation of mean severity per field. For whitefly abundance adult populations were rated (see Table 3) on every other plant assessed for above ground symptoms giving a total of 15 plants per field.

Table 3. Scale used for rating whitefly populations

Score	Description of adult abundance
1	No whiteflies
2	0-20 adults per leaf
3	21-50 adults per leaf
4	51-100 adults per leaf
5	> 100 adults per leaf

Prevalence, Incidence and severity of CBSD

Cassava brown streak disease was found only in four districts out of the 18 districts surveyed countrywide between July and September 2005 (Table 4). The magnitude of the disease in the affected districts was low with prevalence ranging from 3.3-16.6% (Table 4). Three of the districts, Mukono, Wakiso and Luwero, out of the four affected are located in central Uganda. This apparently indicated that by the time of the survey CBSD was more prevalent in the districts situated in the northern shore of Lake Victoria Crescent (Fig. 1). The fourth affected district Kaberamaido is situated in north-eastern Uganda. The material planted in Kabermaido that has showed CBSD symptoms was reportedly obtained from Mubende district which is also located in central Uganda. The risk of spreading the disease through use of infected material cannot therefore be overemphasized.

The disease was mainly observed on improved CMD resistant cultivars throughout the country and on only one landrace (Kabwa) being grown in Mukono (Table 5). The most affected cultivars were TME 204 and TME 14 with CBSD incidences ranging from 58.5-100% and 3.3-91.5%, respectively. Tuberous root deformation and root necrosis (Fig. 2) were observed only in Kaberamaido district and 100% of the harvested tuberous roots were affected. The damage levels (scale 1-5) were very high with average severity score of upto 4.6 (Table 5). A colossal loss of this magnitude warrants careful choice of cassava varieties to promote if cassava production in the country is to be upheld and famine averted especially in communities where cassava is a major source of food.

Figure 2. Root constrictions and corky necrosis arising from CBSD effect

Incidence and severity of CMD

Cassava mosaic disease status varied across the districts surveyed but the incidence and disease severity were generally high, > 60% and > 2.5 respectively, in most of the districts (Table 4). CMD incidence was low (< 50%) only in Pallisa, Kumi, Soroti and Nebbi. It is clear from the present survey that CMD is still prevalent in the country. Local cassava varieties are still common in most districts (Table 6) and their continuous growing by farmers is a probable reason for the sustained high level of CMD in the country. Most of the districts surveyed had < 40% of the improved CMD resistant varieties (Table 6).

Whitefly populations

The population of whiteflies were generally low and the relative abundance ranged from 2.0 to 3.0 (scale 1-5) (Table 4). None-the-less, moderate populations (score 2.5 – 3.0) were recorded in Pallisa, Kumi, Kaberamaido, Soroti, Lira and Mpigi districts with the highest score (3.0) occurring in Soroti. The very low numbers of whitefly observed in the present survey could have been mainly due to the advanced age of the cassava since most of the crops sampled were > 6 months old. Being a phloem feeder, whitefly normally prefers younger cassava crops (1- 4 months old) which are more nutritious than the older crops.

The role of cassava whitefly in the spread of CBSD seemed to be apparent especially after the successful transmission, for the first time, of CBSV using *B. tabaci* at NRI. This scenario causes great worry especially with the current unusually high whitefly populations on cassava in Uganda.

Table 4. The incidence and severity of cassava brown streak disease (CBSD), cassava mosaic disease (CMD) and whitefly abundance on cassava in 18 districts in Uganda, July-September 2005

District	**CBSD**			**CMD**		**Whitefly population**
	% fields infected	Incidence per field (%)	Severity (1-5)	Incidence (%)	Severity (1-5)	Adults score on lvs (scale 1-5)
Mukono	16.6	34.7	2.3	56.0	2.5	2.1
Wakiso	3.3	3.3	3.0	55.3	2.5	2.2
Iganga	0.0	0.0	0.0	71.1	3.0	2.0
Kamuli	0.0	0.0	0.0	75.5	3.1	2.2
Pallisa	0.0	0.0	0.0	34.9	2.7	2.5
Kumi	0.0	0.0	1.0	26.0	2.9	2.5
Soroti	0.0	0.0	1.0	19.0	2.7	3.0
Kaberamaido	3.3	100	2.6	65.0	3.3	2.5
Lira	0.0	0.0	1.0	84.0	3.5	2.4
Apac	0.0	0.0	1.0	76.0	3.5	2.2
Hoima	0.0	0.0	1.0	85.0	3.0	2.1
Masindi	0.0	0.0	1.0	63.0	2.7	2.0
Luwero	10.0	67.8	2.3	86.0	2.7	2.1
Nakasongola	0.0	0.0	1.0	66.0	2.7	2.1
Mpigi	0.0	0.0	1.0	61.0	2.7	2.4
Nebbi	0.0	0.0	1.0	46.0	2.7	2.0
Arua	0.0	0.0	1.0	64.0	3.0	2.1
Moyo	0.0	0.0	1.0	62.0	3.3	2.0

Table 5. The incidence and severity of cassava brown streak disease (CBSD) on cassava cultivars commonly affected in four districts in Uganda, July-September 2005

Infected cultivar	*Fields sampled	CBSD (foliar)		CBSD (roots)		Crop age (Month)
		Incidence	Severity	Incidence	Severity	
Mukono District						
TME 204	6 (2)	58.5	2.9	0.0	0.0	7
TME 14	7 (2)	26.7	2.0	0.0	0.0	7
Kabwa (landrace)	2 (1)	3.3	3.0	0.0	0.0	7
Wakiso District						
TME 14	10 (1)	3.3	3.0	0.0	0.0	7
Luwero District						
TME 14	9 (2)	91.7	2.3	0.0	0.0	6
00057 (Omongole)	3 (1)	20.0	2.3	0.0	0.0	5
Kaberamaido District						
TME 204 &TME 14	**1 (1)	100	2.6	100	4.6	8

* Numbers of fields infected by CBSD are in parentheses

** A small plot with only 10 plants of TME 204 and 1 plant of TME 14

Table 6. The Prevalence of different cassava cultivars grown by farmers in 18 districts in Uganda

Sampled cultivar/landrace	Prevalence (%)	Overall prevalence (%)	
		Improved cultivar	Landrace
Mukono District			
Njule	14.3	67.7	32.3
Kabira	3.6		
Unknown (local)	3.6		
Gombolola	3.6		
Kabwa	3.6		
Mitimyero	3.6		
00056	14.0		
TME 14	25.0		
Unknown (improved)	3.6		
0067 (Akena)	3.6		
TME 204	17.9		
Nase 4	3.6		
Wakiso District			
		63.3	36.7
Njule	6.8		
Unknown (local)	13.3		
Kamesa	3.3		
Kirimupale	13.3		
0057 (Omongole)	3.3		
TME 14	26.7		
0056	26.7		
0067	3.3		
TME 204	3.3		
Apac District		20.0	80.0
Atim atim	3.3		
Unknown (local)	6.7		
Ogunu	3.3		
Derodero	23.3		
Apac apac	3.3		
Bao	33.3		
Nyaraboke	6.7		
00067	3.3		
TME 14	13.3		
Nase 12	3.3		

Lira District		16.7	83.3
Ogwang ogwang	3.3		
Aporo	3.3		
Derodero	10.0		
Gamente	3.3		
Egabu	10.0		
Apwony Ogwok	6.7		
Nyadanya	3.3		
Olibo	23.3		
Bao	3.3		
Mogo atar	3.3		
Adejo	3.3		
Bu	3.3		
Mel	6.7		
Nyaraboke	3.3		
Nase 10	3.3		
Nase 3	3.3		
TME 14	6.7		
Kumi District		90.0	10.0
Unknown (local)	6.7		
Njule	3.3		
0057	3.3		
TME 14	3.3		
TME 204	3.3		
Nase 3	80.0		
Soroti District		90.0	10.0
Unknown	3.3		
Elog elog	3.3		
0067	3.3		
Nase 3	90.0		
Kaberamaido District		46.7	53.3
Unknown(local)	6.7		
Kevina	3.3		
Egabu	43.3		
TME 204	3.3		
0067	10.0		
Nase 3	33.3		
Kamuli District		67.8	32.2
Mfumba chai	16.1		

Mutesa	3.2		
Unknown (local)	3.4		
Tereka	12.9		
Kikapa	29.0		
Bao	3.2		
TME 14	3.2		
Nase 3	22.6		
Nase 2	3.2		
TME 204	3.2		
Iganga District		30.9	69.1
Local (unknown)	17.4		
Njule	10.4		
Magana	13.9		
Budongo 29	3.4		
Tereka	3.4		
Budungoza	3.4		
Mivule	3.4		
Mfumba chai	10.4		
Bao	3.4		
Nase 3	17.3		
Nase 4	3.4		
0067	3.4		
Nase 1	3.4		
0057	3.4		
Pallisa District		100	0.0
Nase 3	93.0		
TME 204	3.5		
0057	3.5		
Nebbi District		40.0	60.0
Nyamitu	26.7		
Nyarateka	3.3		
Bisimenge	6.7		
Nyararokh	3.3		
Nyamatia	6.7		
Angaruba	3.3		
Nyarunega	6.7		
Ocola	3.3		
Nase 3	40.0		

Arua District		10.0	90.0
Ariwala	6.7		
Mabulu	3.3		
Zakayo	3.3		
Bali	6.7		
Bisimenge	3.3		
Musa	3.3		
Godiri	3.3		
Abiria	23.3		
Basumagi	6.7		
Nyarunega	6.7		
Omoo	10.0		
Gilgil	3.3		
Nyapamitu	10.0		
TME 204	6.7		
0067	3.3		
Moyo District		30.4	69.6
Unknown (local)	3.3		
Tegabanat	3.3		
Karuka	13.3		
Ebwana tereka	3.3		
Sanje	3.3		
Alfasio	3.3		
Cenje	6.7		
Joyo	6.7		
Tongolo	3.3		
Kabana	3.3		
Tikabanat	3.3		
TME 14	3.3		
TME 204	3.3		
0067	3.3		
Nase 3	13.3		
Hoima District		3.3	96.7
Unknown (local)	30		
Kidino	20		
Bukalasa	6.7		
Kirimupale	3.3		
Mulyandongo	3.3		
Nyamatia	3.3		
Nuru Kalisa	3.3		
Sibampali	3.3		
Gwalanda	6.7		

Bao	3.3		
Nyakonyako	3.3		
Jenganyumba	3.3		
Nase 12	3.3		
Masindi District		20	80
Nyakibiriti	3.3		
Kidino	3.3		
Njule	3.3		
Tongolo	6.7		
Kafefei	3.3		
Unknown (local)	6.7		
Terengule	3.3		
Nyakunyaku	3.3		
Nyaraboke	36.7		
Atim atim	3.3		
Nase 3	16.7		
00057 (Akena)	3.3		
Nakasongola District		16.7	83.3
Atim atim	6.7		
Unknown (local)	23.3		
Mpologoma	3.3		
Nylon	10.0		
Nyasaki	3.3		
Njule	3.3		
Ebwanateraka	16.7		
Myufu	3.3		
Abuut	6.7		
Bao	3.3		
Para	3.3		
TME 14	13.3		
Nase 1	3.3		
Luwero District		46.7	53.3
Kirimupale	3.3		
Bukalasa	3.3		
Bao	3.3		
Njule	3.3		
Unknown (local)	16.7		
Nyaraboke	13.3		
Omweru	3.3		
Okumu	3.3		
Muwanvu	3.3		
Nase 12	3.3		

00057	10.0		
Nase 4	3.3		
TME 14	30.0		
Mpigi District		36.7	63.3
Unknown (local)	26.7		
Njule	16.7		
Bao	6.7		
Kaalo	6.7		
Kikware	3.3		
Sakabusolo	3.3		
TME 204	6.7		
TME 14	16.7		
00057	13.3		

Post-survey reports on presence of CBSD

To date new information has emerged from District Agricultural Offices and some NGOs from 11 other districts reporting the presence of CBSD (Fig. 1). All the reported cases have been verified and confirmed by staff from the National Cassava Programme (NCP). For instance up to 12 acres of TME 204 at Loro Prison Farm in Apac district were found to have CBSD incidence of > 80 % in December 2005. The same fields were inspected during the survey in July 2005 and no CBSD symptoms were observed. It is also fascinating to note that most of the "newly" affected districts were actually part of the 18 districts surveyed earlier on and no CBSD was found. The above scenarios have just elucidated the fickleness of CBSD symptom expression and this phenomenon requires careful handling to avoid spreading the disease through use of seemingly "clean" planting material.

Conclusions and Recommendations

Results from the present survey have confirmed the re-emergence and spread of CBSD in Uganda. To date CBSD has been confirmed in 15 districts in the country majority of which are located in the central and eastern regions. This clearly indicates that the rate of spread of the disease, most probably though use of infected cuttings, is alarmingly high and must be halted. The high prevalence of CBSD on CMD-resistant cultivars indicated that the cultivars were developed with no background of resistance to cassava brown streak virus. However, the almost total lack of the disease on landraces is difficult to explain and warrants in-depth investigations. The situation currently unfolding in the country raises great concern for food security and incomes for a larger population of Ugandans who

Fig. 3. Institutional multiplication of TME 204 at Loro Prison Farm in Apac District, Uganda.

depend mostly on cassava for their livelihood. There is therefore more gloom than ever before given that the country has just recovered from an epidemic of CMD through wide promotion and distribution of CMD-resistant varieties to the farmers. Unfortunately the very popular varieties are being devastated by CBSD!.

Another dimension to the current CBSD outbreak in Uganda is its implications for the wider cassava germplasm movement in the east and central African regions. There has been open sharing of germplasm in the region under the auspices of the East Africa Root crops Research Network (EARRNET). One of the most vibrant germplasm collection and testing sites for the region is at Serere Agricultural and Animal Production Research Institute (SAARI) in Soroti district (see Fig. 1) in Uganda. There is therefore need to redesign the mode for germplasm exchange in the region.

In totality, it is imperative that a realistic strategy be developed and operated in order to avert the looming crisis from escalating. This should include amongst others:

- Capacity building at higher and lower levels to handle the problem,

- Sensitization of the population on the disease and its management,
- Regular extensive surveys to continue tracking the disease spread,
- Meticulous phytosanitary measures to rid inoculum and prevent further spread,
- Institution of aggressive quality control processes to vet and certify planting material for both local and regional use,
- And as a long term strategy embark on development of cultivars with multiple resistances to CBSD, CMD and whiteflies.

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