CROP PROTECTION PROGRAMME

Control of cassava virus diseases in eastern and southern Africa
R7563 [ZA0368]

FINAL TECHNICAL REPORT

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1. Project summary

TITLE OF PROJECT:	Control of cassava virus diseases in eastern and southern Africa
R NUMBER:	R7563
PROJECT LEADERS:	Dr Rory Hillocks, Natural Resources Institute
RNRKS PROGRAMME:	Crop Protection Programme
PROGRAMME MANAGER:	Dr. F. Kimmins
SUB-CONTRACTORS:	Ministry of Agriculture & Food Security Naliendele and Kibaha Research Institutes.
COMMODITY BASE:	Cassava
BENEFICIARIES:	Smallholder cassava farmers
TARGET INSTITUTIONS:	Naliendele Agricultural Research Institute, Mtwara, Tanzania Sugarcane Research Institute, Kibaha, Tanzania
GEOGRAPHIC FOCUS:	Tanzania and Mozambique (Malawi and Kenya)
START DATE: **FINISH DATE:**	1 January 2000 31 December 2002
TOTAL COST:	£268,136

Executive summary

The project purpose was to contribute to the sustainability of rural livelihoods in coastal areas of Tanzania and Mozambique by addressing the threat to food security posed by cassava brown streak and cassava mosaic virus diseases [CBSD and CMD]. Research activities were undertaken to develop control measures for the virus complex and these were divided into four main categories:

i] Basic research on the transmission and spread of *Cassava brown streak virus* [CBSV].
ii] Adaptive research to multiply and distribute virus-free planting material of CBSD-tolerant cultivars.
iii] Surveys to determine the incidence and severity of CBSD in parts of the Region not previously surveyed.
iv] Monitoring and evaluation activities consisting of socio-economic studies of the role of cassava in rural livelihoods and the impact of CBSD and also, an assessment of the usefulness of the recommended control measures.

All of the planned activities were undertaken and expected outputs achieved.

Vector transmission studies were conducted at the Sugarcane Research Institute at Kibaha in Tanzania and at NRI. With the exception of two single plants that developed CBSD in separate tests in the cage experiments at Kibaha, no transmission was achieved with the whiteflies, *Bemisia tabaci* and *B. afer*. While it is not possible to prove a negative, this has cast some doubt on whitefly as the vector of CBSV. Nevertheless, research at Bristol University indicated that CBSV was likely to be an ipomovirus and all known members of the genus are whitefly-transmitted. Field trials on disease spread showed that within each season, periods of rapid spread of CBSD co-incided with high whitefly populations. Whitefly populations varied in magnitude between seasons and the years when CBSD incidence was highest, coincided with years with greatest whitefly populations. This field data would suggest that either we have failed to transmit the virus with whitefly due to failings of methodology, or, there is another vector with population dynamics similar to that of the whitefly.

A number of CBSD-tolerant cultivars were identified among 'local' cassava during the previous project in both Tanzania and Mozambique. In the present project these were further evaluated for yield and reaction to the two virus diseases. Virus-free stocks were obtained and the cultivars were then multiplied and distributed for participatory on-farm testing. About eight tolerant cultivars were identified in Tanzania and five have been evaluated on-farm. Around 160 farmers in eight villages in Tanzania have received virus-free cuttings from the project. Cv. Nachinyaya has been widely disseminated by farmers themselves during the previous four years and has now almost totally replaced the CBSD-susceptible cv. Albert around Mtwara. Cv. Cv.Kiroba has proved popular around Kibaha. Kigoma Red has useful tolerance to CBSD but the most popular since 2000, has been Nal 34, an improved variety developed at Naliendele.

In Mozambique the project identified a number of local cultivars that seemed to have some tolerance to CBSD and these have been adopted by NGOs in their food security programmes. This collaboration with NGOs will allow up to 60,000 farmers to receive CBSD-tolerant planting material over the next three years. Some of these cultivars require further evaluation, as we were unable to expose them to high inoculum pressure during the project, due to having two years with very low rates of disease spread.

A country-wide survey was conducted in Malawi to determine the distribution and importance of CBSD. The disease was found at high incidences at low altitude along the shore of Lake Malawi [550 - 700 m above sea level], but was largely absent from the rest of the country. Root necrosis was found in most of the local cultivars with little evidence of useful levels of tolerance. A brief survey was conducted in coastal Kenya which showed CBSD to be present at incidences higher than reported by Bock in the 1970s. During the survey Mike Thresh found at a sub-station of Mpwapa Research Station, a collection of the CMD and CBSD-resistant lines developed by the East African Agriculture and Forestry Organisation during the 1940 and 1950s. Steps have since been taken to make this material available to cassava breeding programmes in the region with support from the Rockefeller Foundation.

Monitoring and evaluation activities found that cassava was the most important crop in the areas affected by CBSD, providing not just food security but also income for many smallholders. CBSD was often, but not exclusively, perceived as one of the main production constraints. Control measures against virus diseases were more likely to be used by the more successful farmers and there was clearly a need for more effective dissemination of knowledge about the disease and its control. The lack of disease spread during the previous two seasons, made it difficult to evaluate the success of the tolerant cultivars in farmers fields, but many farmers had retained the material for a second season and some had distributed cuttings to friends and relatives.

Background

Cassava brown streak disease was first identified in northern Tanzania in 1936. Under the East African Agriculture and Forestry Research Organisation [EAAFRO] much work was done in breeding for resistance to both CBSD and CMD. When EAAFRO moved from Tanzania to Kenya in the 1950s the work on CBSD was discontinued. When IITA took over the mandate for cassava improvement in Africa in the 1970s, their emphasis was on CMD which was important in West Africa. CBSD was more or less forgotten until the early 1990s when NRI [Mike Thresh] recognised its potential importance in coastal east Africa and approached DFID-CPP for research funds.

This project follows on from a previous project funded by CPP [R6765] which established the distribution of CBSD in the coastal areas of eastern, developed methodologies for disease assessment and identified tolerance to CBSD in local cultivars. CBSD was found at high incidences on the coast at altitudes below 500m and the disease was reported by the project in Mozambique for the first time, where incidences of 100% occurred in some fields in Zambezia Province. Because of the associated symptom of root necrosis, the disease impacts directly on yield and is a major threat to food security in areas worst affected by the disease. A rural population of some 20 million people are affected by CBSD in the affected area that extends form Kenya to the Zambezi river in Mozambique.

Project Purpose

The present project was developed to build upon the findings of the previous project to design and evaluate a management strategy for CBSD. Disease management was based largely on tolerant local cultivars, as these were already adapted to local conditions and could be quickly disseminated. Multiplication and distribution of CBSD-tolerant cvs has depended on project resources in Tanzania but in Mozambique this has been greatly facilitated by our partnership with the NGOs, Save the Children and World Vision.

Research activities

1. Vector transmission studies

Field studies in southern Tanzania to determine rates of spread at different altitudes. This was done by planting plots of virus-free cuttings and recording the appearance of CBSD symptoms over time. Screenhouse studies were conducted at Kibaha Research Station to try to demonstrate transmission from infected plants to virus-free seedlings with whiteflies. Cages were placed within a screenhouse and whitefles collected from the field were introduced into cages containing young cassava plants infected by CBSD to act as the virus-donor. The cage also contained a virus-free plant grown from seed as the virus-recipient.
Cuttings taken from plants of cv. Kibaha showing CBSD symptoms were used as the virus donor. Plants to serve as the test host were grown from seed of cv. Albert. This is a highly CBSD-susceptible cv. and seed was used on the basis that it would be virus-free. The experiment consisted of six treatments replicated twice:

Treatment 1. Infected donor + Bemisia tabaci
Treatment 3. Non-infected donor + Bemisia tabaci
Treatment 4. Infected donor + B. afer
Treatment 5. Non-infected donor + B. afer
Treatment 6. Infected donor - whiteflies

Donor and test plants were grown in pots and placed in the cages made from whitefly-proof mesh. Each cage received a single infected or non-infected plant and three test plants. The plants were observed for symptom development for 3 months.

A vector entomologist was included in the proposed project to investigate other possible vectors. He visited Tanzania to look for eriophyid mites that are known to transmit viruses related to CBSV.

2.1 Screening of local and improved cultivars for resistance to CBSD.

Surveys conducted during the previous project identified several local cultivars that seemed to show some resistance to CBSD. These were collected and screened in field trials at Naliendele and also at Kibaha using screening methods developed in the first phase of the project. Field trials were planted as randomised complete block designs.

2.2. Multiplication and evaluation of CBSD-tolerant cultivars.

Nachinyaya has already been identified as 'tolerant' to the root necrosis symptom of CBSD. A number of other candidate cultivars have been identified. Virus resistance and other characteristics now need to be evaluated and planting material produced from virus-free plants. On-station trials were planted as randomised blocks. For the on-farm trials, sites were considered as replications. CBSD spreads rapidly at Naliendele, so that virus-free stocks must be produced in isolation plots. For larger scale multiplication the sub-station at Nachingwea was used, where CBSD is rarely seen.

3. Socio-economic assessment of cassava in four target villages.

Four villages have been identified in southern Tanzania and a detailed assessment of the socio-economics of cassava production was carried out. Also, farmers in each village have been organised into 'farmer research groups'. We worked with these groups in several ways; to validate control measures [selection of virus-free mother plants and roguing], to disseminate information on virus diseases and their management and as village-based multiplication units for 'improved' planting material. A socio-economist (Mrs Hamza) has been working with the project and agreed to provide socio-economic inputs to the second phase. The NRI socio-economist worked with the project initially, to provide some guidance on methodologies.

4. Detailed survey of cassava virus diseases in at least four target villages.

Including data on present production levels and effect of CBSD as baseline data for impact assessment at the end of the project. Within the target villages at least 300 plants were sampled.

5.1. Distribute virus-free and CBSD-tolerant planting material to farmers.

Five tolerant cultivars were issued to the farmer research groups. This formed the basis of participatory cultivar assessment, and initiated village-based seed multiplication of those cultivars preferred by the participating farmers.

5.2. Evaluate ability of farmers to maintain virus-free status of issued planting material.

The issue of virus-free planting material also provided information on the ability of farmers to maintain the virus-free status of the material in subsequent seasons. This required that they were able to recognise the disease and select planting material from symptomless plants and then rogue any plants which develop CBSD symptoms soon after sprouting. The success of virus-free planting material as a means of control depends on the amount of spread which occurs in a particular area.

6.1 On farm testing of management systems for cassava virus diseases in three altitude/disease incidence zones.

The number of on-farm sites was expanded to have at least two in each altitude zone. Combinations of the four components of the integrated management system were evaluated - host-plant resistance, virus-free planting material, continued selection of planting material from symptomless mother plants and roguing of isolated plants that appear with symptoms soon after sprouting. Farmer groups were selected from the village register with 30 farmers from two villages in each of three altitude zones. The three zones have been designated from work conducted in the previous project: Below 300m, high disease incidence and rapid rate of spread. Between 300 and 500m, variable disease incidence and moderate rate of spread. 500 – 700 m, low disease incidence and little spread. According to the trial design recommended by the Biometrician a minimum of 32 fields are required. Between the two villages 60 fields were planted but only six in each village provided data suitable for analysis.

6.2 Evaluation of adoption of disease management methods.
The detailed assessment of cassava production and virus disease incidence in the target villages provided baseline data to evaluate the extent of adoption of control measures and the impact on disease incidence.

7. Disease survey in Malawi.
Although CBSD is known to occur in Malawi, its distribution and severity was not known. This was established by two surveys. The first survey established the distribution based on foliar symptoms, the second assessed disease severity based on root symptoms. Survey methods were based on those used in previous surveys conducted in Tanzania and Mozambique. 60 – 100 fields were visited at 10 km intervals along the route from northern to southern Malawi. Thirty plants per field were sampled along a diagonal line through the field. Pest and disease incidence was recorded per plant and a mean calculated for the plot.

8. Technology transfer to Mozambique.
The DFID/WVI project in Zambesia Province requested our involvement to assist their programme with disease assessment and selection for resistance to CBSD using methods developed in Tanzania.

9. Produce guide to symptoms of cassava virus diseases.

10. Workshop on management of cassava virus diseases in Tanzania.
A workshop was held at the outset of the project to exchange information on CBSD between researchers from Tanzania, Mozambique (INIA + WVI) and Malawi (NARS + SARRNET). Representatives from SARRNET, Extension Services and Farmers also attended.

OUTPUT 1. Vector of CBSD determined

In both replicates of a cage experiment conducted in Tanzania, one test plant developed symptoms of CBSD. Both infections occurred in cages containing *B. tabaci* which reproduced well on the donor plant. However, the comparison with *B. afer* was not valid as this species did not reproduce well and populations in the cages declined.

At NRI, further vector studies were undertaken for an MSc project. CBSV was successfully transmitted by mechanical means from cassava to *Nicotinana benthamiana* and between cassava plants by grafting. The success of the mechanical transmission was confirmed by PCR-based diagnostics developed at Bristol University [CPP-funded project]. However, we were unable to transmit the virus between cassava plants or from *N. benthaminana* to cassava using either *B. tabaci* or *B. afer*. While it is not possible to prove a negative, the repeated failure to transmit CBSV with whitefly casts some doubt on these insects as possible vectors. [The two single plants that developed CBSD symptoms in the experiments in Tanzania, may have been infected by an unknown vector that was also present in the cages].

Field trials were conducted at Kibaha and Naliendele to determine the rate of spread of CBSD within a field, using infected spreader plants located in the middle of a block of healthy plants. Very little spread occurred in 2001/2002 for the second season in a row. Whitefly numbers were low, but at around 20 per plant [topmost 2 lvs] they were not as low as in 1999/2000 and some spread would have been expected if *Bemisia tabaci* was the vector. At this population density, there were very few *B. afer* which usually represents less than 5% of the total whitefly population.

Whitefly populations on cassava in southern Tanzania normally peak in the wet season between December and April when there is plenty of young leaf tissue. As the weather dries out and the plants mature they appear to become less attractive to whitefly. At this time, leaf damage due to greenmite increases in severity which also seems to make the leaves unattractive to whitefly. Whitefly populations reach their peak around March/April [Fig 1]; the same time that new incidences of CBSD reach a peak. Whitefly populations also vary greatly between seasons. The years when whitefly populations have been high have also been those in which CBSD incidence was highest [Table 1.1]. This does not necessarily show that whitefly is the vector, but points in that direction, or towards another vector with similar population changes.

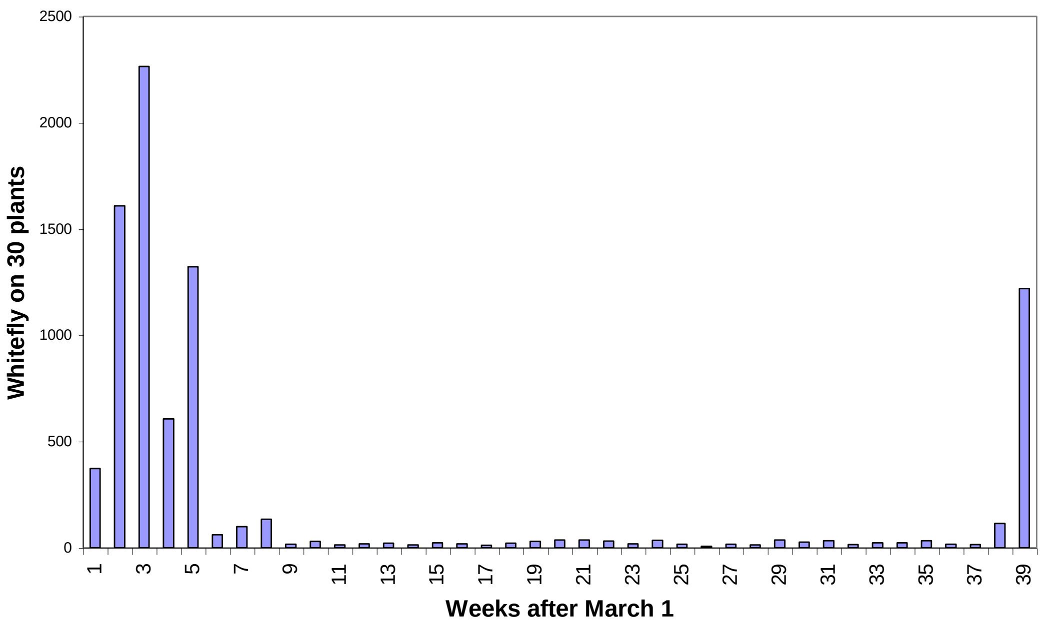
There are technical difficulties in carrying out vector transmission studies when the vector is unknown. However, it is important that this knowledge is obtained as it has a bearing on disease management and on screening methods for disease resistance. In the PMF for the follow-on project it is proposed that further experiments be undertaken in the insectaries at NRI to take advantage of the separate populations of *B. tabaci* and *B. afer* that have been established. However, the search for an alternative vector will continue.

Table 1.1. New incidences of CBSD in April and peak whitefly population at Naliendele 1998 - 2002.

Year	CBSD incidence in April [%]	Whitefly peak population/plant
1998	48	45
1999	7	8
2000	40*	77
2001	0	3
2002	5	21

- No rate of spread trial conducted this year so CBSD incidence estimated from susceptible varieties in variety screening trials.

Fig 1. Total whitefly on two uppermost fully expanded leaves of 30 plants March - December 2000.



OUTPUT 2. Reaction of local cultivars to CBSD evaluated

Local and improved cultivars noted during surveys for their possible resistance to CBSD have been collected and screened at Naliendele. Subsequently virus-free stock of some of these were produced and then they were multiplied at Nachingwea for on-farm testing [See Output 6]. The process of identifying local cvs. with potential resistance to CBSD is intended to be a continuous one and five more local cvs were collected and screened at Naliendele in 1999/2000.

Results - The cvs. Damian and Pembe proved to be susceptible to CBSD but cvs. Kumwembe and Kiroba remained free of the disease until the end of the trial (Table 2.1). None outperformed the standard variety, Kigoma Red in terms of yield.

Table 2.1. Incidence of foliar symptoms of CBSD in local cassava cultivars [Naliendele 1999/2000]

Cutlivar	CBSD incidence (%)		Root yield kg/plant
	At sprouting	Max disease (July)	
Kumwembe	0	0	2.46
Damian	4	24	2.55
Pembe	21	80	2.49
Kiroba	0	0	3.25
Binamuli	0	3	3.10
K/Red	0	3	3.68
F-prob			NS
LSD [0.05,15]			1.02

No analysis was performed on disease incidence due to large number of zero values.

We now have a total of eight cvs. identified as having some resistance to CBSD. This includes six 'local' cvs and two 'improved' [Kigoma Red and Nal 34]. Table 2.2 summarises the characteristics of each of these cvs based on observation and the opinion of the cassava research team at Naliendele.

The nature of the resistance mechanisms is not known. Some of the cvs may show little or no foliar symptoms of CBSD, others such as Nachinyaya, may be highly susceptible to infection, showing marked foliar symptoms but all of them show reduced root necrosis at harvest. In the case of Nachinyaya and Kiroba at least, root necrosis may eventually develop if the plants are left long enough in the field but necrosis develops much more slowly than in the more sensitive cvs., so that these 'tolerant' cvs are able to reach full maturity and therefore realise their yield potential without severe necrosis, despite the presence of foliar symptoms. We still do not know if there are cvs. that show neither foliar symptoms nor root necrosis when exposed to high inoculum pressure.

Table 2.2. Characteristics of CBSD-resistant cultivars [Tanzania]

Character	Cultivars							
	Kiroba	Namikonga	Kitumbua	Kalulu	Kig. Red	Kumwembe	Nachinyaya	Nal 34
CBSD-resistance[1]	5	5	5	5	5	3	4	4
CMD-resistance[1]	5	5	5	5	3	3	4	4
Yield[2]	4	4	3	4	4	3	4	5
No. of roots	8-12	4 - 6	6 - 10	3 - 6	8 - 12	6 - 10	5 - 8	4 - 7
Size of roots[3]	3	4	3	4	3	3	4	5
Maturity[4]	7 - 12	12 - 18	8 - 12	8 - 12	8 - 12	8 - 12	12 - 18	8 - 12
Green mite res.[5]	4	2	3	4	3	3	2	3
Mealy bug res.[5]	2	3	2	4	3	3	3	3
Sweetness[6]	4	4	4	4	4	3	4	4

[1]Disease resistance scale: 5 = most resistant [to root necrosis, not necessarily to infection by the virus and production of foliar symptoms]
[2]Yield: 5 = highest yielding
[3]Size of roots: 5 = largest
[4]Maturity: optimum harvest period in months after planting.
[5]Green mite/mealy bug: 5 = most resistant
[6]Sweetness: 5 = sweetest

In 2001/2002 eight varieties available as virus-free stocks, were tested in two separate trials, one to test their response to CBSD and CMD, the other to test their yield in the absence of disease. However, there was no disease spread in that season and most of the symptomless plants remained so despite the proximity of spreaders. It is interesting that the season was one in which whitefly numbers remained low and this seems to provide further indirect evidence that CBSV is whitefly-transmitted.

The root yield of each of the CBSD-restant cvs. (Table 2.3) shows that in 2001 all performed as well as the standard Variety, Kibaha. In 2002 Kibaha did not perform as well as in the previous season while Nal 34, Kitumbua and Kiroba all gave significantly higher yield. Note that Nachinyaya and Namikonga take more than 12 months to reach full yield potential and this trial was harvested after only 10 months. Nachinyaya [and possibly also Namikonga] are therefore a good food security cultivar as it can be left in the field for 18 months without developing severe root necrosis.

Table 2.3. Root yield from 8 CBSD-resistant culivars at Naliendele.

Cultivar	Yield [fresh root/plant]			
	[2000-2001]		[2001-2002]	
	log X[kg]	Mean [kg]*	log X[g]	Mean [kg]*
Nal 90/34	0.2067	1.61	2.934	0.86
Kibaha	0.2725	1.87	2.638	0.44
Nachinyaya	0.0256	1.06	2.320	0.21
Kigoma Red	0.2112	1.63	2.655	0.45
Namikonga	-0.0186	0.96	2.404	0.25
Kalulu	0.1715	1.48	2.591	0.39
Kitumbua	0.2603	1.82	2.962	0.91
Kiroba	0.2166	1.64	2.848	0.71
F-prob	≤0.05		≤0.001	
LSD[0.05,21]	0.1534		0.116	

* back-transformed means

At Kibaha, Kiroba produced the highest yield and the only cv. to significantly outyield cv. Kibaha, followed by Kigoma Red and then Naliendele 34 [Table 2.4]. Foliar symptoms in Kibaha were derived from cutting infection and there was little spread of CBSD this season. CMD was present in all cultivars, but the incidence at the end of the trial was least in Kiroba and Namikonga and greatest in Naliendele 34. This would suggest that Naliendele 34 may not be suitable for areas with a high incidence of CMD.

Table 2.4. Root yield and disease incidence from 6 CBSD-tolerant cultivars at Kibaha [2001/2002].

Cultivar	Root wt		CBSD incidence		CMD Foliar	
	Log X	Mean*	Leaf symptoms %	Root necrosis No of plants	%*	arcsin
Naliendele	0.7656	5.8	2.5	1	53	46.5
Kibaha	0.4235	2.7	61	8	21	27.6
Kigoma	0.8594	7.2	2.5	2	45	42.1
Namikonga	0.0590	1.1	0	0	12	20.1
Kitumbua	0.6650	4.6	0	1	22	27.6
Kiroba	1.1399	13.8	0	2	8	16.3
F-prob	NS					≤0.01
LSD[0.05.15]	0.5606					19.6

* Back-transformed treatment means

On-farm trials

No CBSD was recorded in any of participatory cultivar evaluation trials in any of the six target villages. As the material included Kigoma Red which will show CBSD foliar symptoms, it must be concluded that no spread occurred into the disease-free planting material. In most of the villages cv. Kitumbua and cv. Naliendele 34 out-yielded the other cvs [Table 2.5] and the mean yield from Nal 34 was significantly different from the other cultivars. CBSD-tolerant varieties were considered by farmers to be nonsignificant F-ratio. Both Kitumbua and Nal-34 were considered by farmers to be sweet and of good cooking quality. Emphasis will be placed on these two cvs in the next phase of the project.

Table 2.5. Summary of yields obtained from four CBSD-tolerant cultivars in five* villages [means of 6 sites per village]

Cultivar	Villages [as reps]						
	Ziwani	Mtiniko	Mtua	Chisegu	Tulieni	log X	mean#
Nal 34	0.80	0.47	4.00	0.71	1.81	+0.057	1.14
Kitumbua	0.68	0.40	2.30	0.61	1.16	-0.068	0.86
Kigoma	0.70	0.27	1.83	0.60	1.15	-0.124	0.75
Namikonga	0.41	0.22	2.34	0.57	1.05	-0.180	0.66
F-prob						0.002	
LSD[0.05,12]						0.1003	

*Planting was delayed in Madaba village and the trials will not be harvested until 2003.
back-transformed mean

Prospects for CBSD-resistant varieties in Mozambique

There are now several cassava improvement projects operating in Mozambique and others are about to start or are being proposed. The budgets are large and the success or otherwise of the projects is closely associated with the availability of suitable varieties of good health status. Herein lies the difficulty as there is only limited information available on the varieties to be released, on their suitability for use by farmers and on their response to pests and diseases.

Project activities have been limited to Nampula and Zambezia Provinces and to occasional visits to the INIA Umbelusi Station, Maputo. The following notes are based on the initial virus data for on-station and on-farm trials set up by World Vision or other NGOs. These trials are yet to be harvested and so there have been no observations on the incidence of the root necrosis symptoms of CBSD which are the main cause of crop loss.

NB: The varieties asterisked were selected for multiplication and distribution in the US AID-funded project. [Decision of the July 2001 workshop, Nampula.] The criteria considered are presented in Appendix

<u>Mulaleia</u> *

Widely grown in Zambezia Province, especially in the coastal areas. Presumably a successful variety that is liked by farmers because it has favourable attributes. There is a generally high incidence of CBSD leaf symptoms but root necrosis does not seem to be a problem. The trials now in progress suggest that Mulaleia is resistant to CMD which may explain the generally low incidence of CMD in Zambezia Province (<10%). There is a need to select and multiply stocks of Mulaleia that are free of both CMD and CBSD. There is also a need to assess the effects of these diseases on growth and yield when they occur alone and in combination.

Questions: Should Mulaleia be grown more widely? If so, a CBSD-free stock should be made available. A limited amount of selected material is available at the WV Murrupula and Muecate sites and should be multiplied as a matter of urgency. Do the current trials confirm that the variety is tolerant of CBSD? What is the cyanogenic potential and what processing is required? Careful recording of roots is required when the current trials are harvested.

<u>Nikwaha</u> *

Grown in Nampula Province and used in WV and other projects. In some stocks there is a high incidence of both CMD and CBSD but root necrosis does not seem to be a problem. The trials now in progress suggest that Nikwaha is susceptible to CMD. This would not be a problem in areas where there is a low incidence of the disease

Questions: Can/should Nikwaha be grown more widely? If so, can a virus-free stock be made available? Do the current trials confirm that Nikwaha is tolerant of CBSD? What processing is required? What is the effect of CMD on the growth and yield of Nikwaha? Will its vulnerability to CMD restrict its suitability and adoption?

Macia 1*

This clone was selected in the south from SARRNET/INIA introductions of seed. It gave promising results in trials at Mocuba (Zambezia) where from initial observations in 1999 it seemed resistant to CBSD, but not to CMD. From the latest on-station and on-farm trials done at Mutange and elsewhere it is apparent that Macia 1 is not very resistant to CBSD or CMD and the inference is that Mocuba gave somewhat misleading results because it is not a site of high CBSD inoculum pressure. Substantial incidences of both CMD and CBSD have been recorded at the Mutange site and in Nampula Province and the roots develop necrotic symptoms. It follows that Macia 1 is not appropriate for use where CBSD and/or CMD are spreading. The latest information should be considered in relation to the outcome of the July workshop in Nampula when Macia 1 was selected for use.

TMS 42025 and TMS 30395

These IITA Ibadan clones have been used widely in on-station trials. They are very susceptible to CBSD and developed severe root necrosis in trial plots. CBSD-free stocks are available at INIA Nampula and should be used in screening and other trials as CBSD-susceptible standards to monitor inoculum pressure.

Nachinyaya *

This variety is used widely in southern Tanzania because it does not develop the root symptoms of CBSD. Stocks were located in Cabo Delgado last year by Ricardo Macia and material is now in on-station and on-farm trials in Nampula and Zambezia Provinces. Almost all the plants express the leaf symptoms of CBSD. A high incidence of CMD has developed in some localities. This suggests vulnerability to the disease and the variety is inappropriate for use in areas where CMD is a problem. Moreover, the CBSD-infected stocks now available should not be used in areas where there is a low incidence of CBSD as they would act as sources of inoculum. [This information should be used to qualify the recommendations of the Nampula workshop.]

Questions: Does Nachinyaya develop root necrosis in Mozambique? Does it meet farmers' requirements? Will it be of value only in areas where CMD is not a problem? Can a CBSD-free stock of Nachinyaya be selected or developed by meristem-tip therapy? Who would do this? What is the cyanogenic potential of Nachinyaya and does it need to be processed?

<u>Mwento Waloya</u>

Also collected last year in Cabo Delgado and said to withstand CBSD. Now in on-station and on-farm trials in Nampula and Zambezia Provinces. Observations show that many of the plants express inconspicuous leaf symptoms of CBSD which suggests that the variety may behave like Nachinyaya in being tolerant rather than resistant. Substantial infection with CMD has occurred at some sites suggesting susceptibility to this disease.

Questions: Will this variety be suitable for use by farmers, at least in areas where CMD is not a problem? Do the current trials show that the variety is tolerant of CBSD in that it does not develop root necrosis? What is the cyanide potential and what processing is required? Can a CBSD-free stock be produced by selection or meristem-tip therapy? Who would do this?

<u>Binte Massuea and Chigoma Mafia</u> *

Two other Cabo Delgado varieties said to withstand CBSD. Now in on-station and on-farm trials in Zambezia and Nampula Provinces (Appendix 6). Both varieties seem to differ from Nachinyaya and Mwento Waloya in that they seldom express leaf symptoms of CBSD and so they seem resistant to infection. Binte Massuea is much more susceptible to CMD than Chigoma Mafia which may limit its suitability for some areas.

Questions: As for Mwento Waloya, as so little is known about these Cabo Delgado varieties. [Additional information could and should be collected on their performance in Cabo Delgado and in the current series of trials in Zambezia and Nampula.]

<u>MZ 89001 and MZ 89186</u>

INIA selections made in the south and later trialled in Zambezia and Nampula Provinces. Early evidence was obtained of resistance to CMD and CBSD and so they were included in the 2000-2001 on-station and on-farm trials. Both selections have expressed a low incidence of CBSD leaf symptoms which are severe and associated with stem necrosis. This may explain some of the high mortality noted in some plots of these selections. There has also been spread of CMD at some sites and so the initial results are not encouraging. Do CBSD-affected plants develop root necrosis?

Recommendation: The available results are equivocal and so the varieties should be carried over into a further series of trials before a decision is made on whether they are to be promoted for use by farmers.

<u>Other Breeding Lines in Mozambique</u>

There have been many other accessions of seed and clones from IITA Ibadan and elsewhere. Some of these are likely to have resistance to CMD and bacterial blight and also to arthropod pests (cassava green mite, cassava mealybug). However, their genetic 'background' may not include resistance to CBSD as there has been no previous exposure to this disease. Moreover, there is no convincing evidence that CBSD occurs at Umbeluzi near Maputo where the introduced progenies are raised and first evaluated.

This is a serious limitation of the breeding approach to date, especially as CBSD-resistant varieties and breeding lines are available from the earlier EAFFRO breeding programme in Tanzania in the 1950s and there has been selection for resistance to CBSD in Malawi, Tanzania and most recently at Mtwapa in coastal Kenya. None of the material known to be resistant to CBSD has been introduced to Mozambique and *introductions merit high priority*. As indicated in previous correspondence with INIA staff, introductions could be made through an 'open quarantine' arrangement or as *in vitro* cultures. There is also scope for introducing seed from crosses with CBSD-resistant parents. This should be done as soon as possible so that selection and evaluation can proceed. However, it is important to appreciate the long time scale of 5-8 years required for suitable material to be identified, tested on-station and on-farm and multiplied in quantity for distribution to farmers. Clearly any such endeavour requires continuity, long-term funding and access to suitable test sites for CBSD, CMD and other biological constraints.

OUTPUT 3. Background information on the role of cassava in food security

A socio-economic evaluation of cassava in four target villages in the Southern Zone [SZ] of Tanzania and two villages in the Coastal Zone [CZ] was conducted. In the SZ the study was conducted by the social scientists based at Naliendele Research Institute, Mr Katanilla and Mrs Hamza. In the CZ the study was conducted by Mrs Mtunda, a social scientist and leader of the zonal root crops programme. The information below is based on extracts from their lengthy reports. [A fuller presentation of the reports is available in Appendix 4].

In the Southern Zone farmers obtained more than 40% of their income from cassava and there was some evidence that the farmers who said they used control methods for CBSD [selection of planting material] had higher incomes Table 3.1. This is probably because better off farmers tend to be the more knowledgeable ones, rather than an effect of CBSD management. In the Eastern zone [Table 3.2] cassava is grown by all farmers and 51% obtain income from selling cassava compared to only 2% for maize.

Table 3.1: CBSD control and income to households [Southern Zone]

Item	**Who Control**	**Do not Control**	**Mean**
Average total income [all sources]	210,336	54,068	150,586
Average income from cassava	103,681	26,333	74,107
Proportion (%) of income from cassava	49	49	49
Sample size (N)	42	26	68

Table 3.2. Farmers growing, consuming and selling crops in Viziwaziwa and Zogowale villages, Kibaha District [Eastern Zone 2001].

	% respondents [N = 85]		
Crop	Growing	Consuming	Selling
Cassava	100	93	51
Maize	42	97	2
Legumes*	84	48	28
Sw. pot.	27	17	13
Coconut	26	26	4
Citrus	39	39	20
Rice	18	47	5
Cashew	66	66	48

* cowpea and pigeonpea

Village profiles

Ziwani: 3552 households with a total population of 18828. 505 of villagers are involved in agriculture, 15% petty traders, 5% sell their labour in nearby salt pans and the rest are engaged in fishing. Food shortage is a major problem with only 1049 tonnes produced in 1999/2000 compared with a requirement of 4745 tonnes. The shortfall is made up by purchases using money derived from selling cashew and off farm activities. All cassava produced in this village is used for local consumption. As land becomes scarce the area under cassava has declined from 3075 acres in 1994/95 to 2160 acres in 1999/2000. One major social problem identified by interviewees was that younger men are selling their land to richer farmers.

Table 3.3. Crops grown and role of men and women

Crop	Extent of male/.female Involvement		Remarks
	MEN	WOMEN	
Cassava	+	+++	
Sorghum	+	+	
Pigeonpea	+	++	No pure stands
Cowpea	+	++	"
Groundnut	+	++	"
Cashew	+++	+	
Coconut	+	+	Mostly hired labour

Table 3.4. Farmers perceptions of constraints to cassava production and possible solutions.

Problem	Solution
1. CBSD	Need resistant varieties More research on how disease is spread.
2. Theft	Use bitter varieties
3. Landlessness	None
4. Poor soils	Need livestock to provide manure.
5. Low yields	Control pests and diseases.

Similar data is available for other villages but some similar patterns emerge. Firstly the importance of cassava for household food security and the role of women in its cultivation [Table 3.3]. Root rot [CBSD] is always mentioned as a priority problem but at Ziwani, theft and poor yields due to declining soil fertility and other pests was also mentioned [Table 3.4]. More land is planted to cassava than any other crop with the exception of Cashew which is the main on-farm source of income in the villages. Some villages come under the 'Kachkumi' scheme in which every household has at least one acre of cashew trees. In most of the villages other than Ziwani, there was surplus cassava for sale. However, our sample is likely to be biased towards those with an interest in cassava growing and may not reflect the situation as a whole.

<u>Conclusions from socio-economic surveys</u>

i. CBSD the major cassava production constraint but few farmers adopt measures to control the disease.
ii. Cassava is an important source of cash income and CBSD must have a considerable impact on livelihoods and food security. This could not be quantified as farmers would not reveal their income in cash terms.
iii. The CBSD control strategies that have been generated by NARI has not effectively reached majority of the targeted farmers. Less than half of the respondents are aware of the technology,
iv. Cassava crop takes a second place in importance after maize in consumption while it takes a first position as a food security crop and staple for the majority of households,

v. Available resources at farm level do have positive impact on the adoption of technology as exemplified by the household farm size,
vi. Farmers' age, experience in cassava production, and education of the farmer have positive relationship to the adoption of the CBSD control technology.

Recommendations from socio-economic survey

i. There is need to strengthen the production and distribution of improved and disease free cassava planting materials in the pilot villages,
ii. Build the farmers' capacity to multiply and distribute improved diseased free planting materials.
iii. Carry out training to improve farmers' ability to diagnose and identify disease symptoms of major cassava diseases.
iv. Provision of leaflets explaining cassava brown streak disease in Kiswahili version as an output of the project.
v. Continue with the introduction of tolerant varieties on farm.
vi. Conduct varietal evaluation on-farm.

Village and Activity Profiles [Southern Zone]

Village	Demography	Infrastructure	Crops in priority	Production trend (kg)	Income sources	Expenditure lines
Ziwani	Total popn: 18828 Males: 8657 Females: 10261	All weather road Primary sch. Dispensary Crop store Division office Water pump Reserved forest Local market	Cassava Sorghum Pigeonpea Cashew Sorghum	96/97 - 1934250 97/98 - 2008500 98/99 - 1620000 99/00 - 1620000	Crop sales Fishing Casual laborer Petty trade	Clothing School fees Food Treatment HH basic needs
Mtiniko	Total popn: 1166 Males: 539 Females: 627	Seasonal road Primary school Dispensary Crop store Mosque Water tank	Cassava Maize Sorghum Rice Cashew		Crop sales Hunting Petty business	Agric activities School fees Clothing Medical treatment HH basic needs

Chisegu	Total popn: Figures not available	All weather road Dispensary Churches Mosque Local open market	Cassava Maize Sorghum Rice Cashew Sesame Pigeon pea bambaranuts		Crop sales Petty business Renting sprayers	Agric. activities House construction Clothing Kitchen utensils

Village	**Demography**	**Infrastructure**	**Crops in priority**	**Production trend (kg)**	**Income sources**	**Expenditure lines**
Tulieni	Total popn: Figures not available	All weather road Primary school Dispensary CCM office	Cassava Maize Sorghum Rice Cashew Sesame Pigeon pea bambaranuts	1994 - 140000 1995 - 280000 1996 - 285000 1997 - 215000	Crop sales Restaurants Petty business	Agric activities School fees Medical treatment House construction Clothing Food HH basic needs

OUTPUT 4. Background information on virus disease incidence in target villages.

At each village between 300 and 500 cassava plants [depending on the abundance of the crop in the sample area chosen] were examined and the presence or absence of CMD and CBSD leaf symptoms was recorded. The variety of each plant was also noted. This provided an update on main varieties grown, their reaction to the two virus diseases and provided baseline data on CBSD incidence for future comparison.

Both CMD and CBSD were found at all the target villages. At all sites except Chisegu, CBSD incidence was greater than CMD incidence, ranging from 31% at Chisegu the highest altitude [approx 400m] to 65% at Tuliene [<100m] (Table 4.1.).

Table 4.1. Virus disease survey in target villages

Village/variety	No. of each var. [% in brackets]	Disease incidence [%] CBSD	CMD
Madaba		**39**	**17**
Nachinyaya	101[23]	51	25
Kigoma Red	135[31]	19	10
Limbanga	90[21]	31	29
Sumu ya Panya	7[2]	86	14
Mbwana Safi	27[6]	50	11
Kigoma Common	10[2]	100	0
Ulenje	5[1]	100	0
Saranga	20[5]	80	15
Others	38[9]	39	8
Tupendane		**35**	**19**
Kalinda	247[53]	42	31
Limbanga	29[6]	28	7
Saranga	108[23]	38	4
Kigoma Common	25[5]	12	0
Mpuya	2[>1]	100	0
Chisegu		**31**	**32**
Mreteta	244[58]	21	41
Isaya	49[11]	51	27
Chimaje	36{8]	83	31
Badi	41[9]	15	10
Sheria	16[3]	19	0
Kigoma Common	10[2]	10	0
Bintisaya	16[3]	44	56
Supa	4[1]	50	0
Mtua		**49**	**8**
Sheria	196[64]	65	4
Kigoma Red	25[8]	8	16

Kigoma Common	23[8]	35	36
Chimaje	14[5]	21	36
Nanjenjeha	28[9]	7	4
Badi	2[>1]	50	0
Others	10[3]	7	0
Tuliene		**65**	**4**
Mreteta	159[46]	76	8
Sheria	141[41]	64	21
Limbanga	19[6]	26	0
Namkatiyau	24[7]	65	4
Ziwani		**40**	**3**
Nachinyaya	90[38]	72	0
Chindu Moto	48[20]	6	0
Kigoma Red	28[12]	11	7
Badi	19[8]		
Kigoma common	6[3]	33	2
Saranga	11[5]	2	3
Mtukane	4[2]	50	0
Nalekuchumba	3[2]	100	0
Albert	20[8]	55	20
Others	11[5]	-	-
Mtininko		**22**	**6**
Kigoma Red	62[32]	0	16
Musa Saidi	28[15]	4	0
Albert	15[8]	20	33
Nachinyaya	49[25]	71	0
Kibaha	9[5]	0	10
Namikonga	17[9]	6	0
Others	13[7]	-	-

Output 5. Sustainability of virus-free planting material evaluated in four villages.

At the beginning of this phase of the project, sufficient virus-free planting material was available only of Kigoma red. This was distributed to 10 farmers in each of six villages in the Southern Zone who were asked to rogue any plants that appeared with CBSD or CMD. In the coastal Zone, farmers were given cuttings of cv. Kiroba but this had not been selected and sprouted with a high incidence of CBSD. Farmers were very unhappy about having to remove so many plants. Cv. Kiroba behaves like Nachinyaya' and although quite susceptible to CBSD' it can be harvested before significant root necrosis develops. The strategy in the coastal zone has been to make this planting material available and assess farmers reaction to it in comparison with their own varieties.

The first stage in the on-farm evaluation of virus-free planting material of the local cvs with some resistance to CBSD, was to obtain virus-free stocks and then multiply them for distribution to farmers. The research sub-station at Nachingwea was chosen for the multiplication sites as the disease pressure for CMD and CBSD is low. Table 5.1 indicates the quantity of planting material multiplied at Nachingwea and Table 5.2 shows the quantity distributed in each of the target villages.

Table 5.1. Varieties and number of plants in multiplication at Nachingwea [July 2001]

Variety	Ratoon [Feb 2000]	New planting [Jan 2001]
Kigoma Red	679	1449
Nachinyaya	1694	1861
Namikonga	307	223
Kitumbua	577	837
Naliendele 34	551	296

Table 5.2. Number of surviving cuttings of CBSD-resistant cvs distributed to farmers [max = 20]

Village/ variety	Stand counts/farm 1	2	3	4	5	6	7	8	9	10
Ziwani										
Naliendele	12	9	15	14	15	0	6	7	7	10
Namikonga	6	4	15	8	14	8	2	6	10	11
Kitumbua	15	17	16	15	15	14	5	9	6	11
Chisegu										
Kigoma	0	16	12	11	8	18	17	20	-	-
Naliendele	15	5	5	16	14	17	18	20	-	-
Namikonga	0	16	11	14	14	20	18	13	-	-
Kitumbua	22	11	9	19	17	18	20	20	-	-
Nachinyaya	16	9	0	17	0	19	16	25	-	-
Mtua										
Kigoma	19	12	7	7	11	15	15	4	-	-
Naliendele	9	16	10	9	15	9	15	3	-	-
Namikonga	15	12	11	6	9	11	16	6	-	-
Kitumbua	18	14	0	9	14	17	16	5	-	-
Nachinyaya	11	10	8	0	0	14	15	1	-	-
Tuliene										
Kigoma	1	0	0	17	11	12	*	*	-	-

Naliendele	0	17	0	12	0	16	*	*	-	-
Namikonga	0	19	13	2	0	17	*	*	-	-
Kitumbua	0	15	0	11	9	11	*	*	-	-
Nachinyaya	0	0	13	16	15	0	*	*	-	-

Mtiniko All but 3 sites too far away to reach

Madaba Planting material not issued this year

*Sites not accessible - these will be replaced next season with more accessible sites.

Some farmers harvested between November 2001 and February 2002, others left the crop in the ground for harvest in August 2002 . In October 2002, planting material was distributed to another set of 10 farmers in each village and this was be evaluated in November 2002. Farmers who harvested, retained some of their planting material and gave some to friends, relatives and neighbours but it was very difficult to quantify this. No CBSD symptoms have been seen in any of the cultivars distributed in any of the villages. However, rates of spread of both CBSD and CMD have been very low during this phase of the project, despite close proximity to the on-farm sites of infected cassava. Such low inoculum potential has made it difficult to evaluate the material for its resistance to infection by CBSD and it was not possible to evaluate the farmers' ability to select planting material from healthy plants.

In Tanzania planting material has been distributed in eight villages to a total of 160 farmers. In addition a large quantity [6000 cuttings] of CBSD-resistant planting material was distributed in drought-prone areas of Liwale District, in response to calls from the Government to provide famine relief assistance. The fate of this material has yet to be assessed.

In Mozambique by the start of the 2002/2003 growing season, CBSD-resistant planting material will have been distributed to 10,000 farmers by the NGOs with which we are collaborating - Save the Children and World Vision.

Output 6. Management systems for virus diseases validated in four villages in southern Tanzania.

It was clear from the on-farm trials conducted in 1999/2000 that roguing is only acceptable to farmers if disease incidence is very low. But at such low incidences the virus diseases are not a production constraint. Selection of disease-free planting material is also difficult because the foliar symptoms are less conspicuous than those of CMD and often do not show in the dry season when planting material is collected. The success of both roguing and planting material selection depends on extensive and effective education and training in symptom recognition. Our conclusion is that resistant or 'tolerant' varieties are the only practical control measure and as a number of 'tolerant' local cvs have been identified more emphasis has been placed on this aspect of control. See Output 5 for distribution of planting material which is being evaluated at the end of 2001 and again at the end of the project in 2002. Farmers have also been asked to pass on to their neighbours planting material of varieties they like.

No formal results were obtained from the 1999/00 on-farm trials for two reasons. In the eastern zone the cultivar used was Kiroba which does not show severe root necrosis but is very susceptible to infection and displays foliar symptoms. Large numbers of plants were rogued out by the farmers and they were very unhappy about losing so many plants. In the southern zone, mainly 'clean' planting material was distributed and with little spread taking place, few plants developed CBSD symptoms. The exception was cv. Nachinyaya which, like Kiroba was mainly infected. This confused the farmers, who could not understand why we were giving them plants with CBSD symptoms. The on-farm trials were simplified for the following season, farmers were not asked to rogue and Nachinyaya was withdrawn.

Because of the lack of disease spread and all our on-farm trials remaining free of CBSD, it has not been possible to evaluate the success of the control measures. Evaluation of the CBSD-resistant varieties will be confined to yield data and farmer preference data which is still being collected. Preliminary findings are that Naliendele 34 is the most popular variety, followed by Kigoma Red and Kitumbua. Mealy bug is becoming an important pest on cassava in the southern zone and both Kigoma Red and Kitumbua seem to be particularly susceptible.
Naliendele 34 looks very promising but is susceptible to CMD and has not been exposed to high inoculum pressure of CBSD.

In response to requests for CBSD-resistant planting material from District Extension Officers in Tanga, cuttings of cv. Kiroba were provided to three villages in Muheza District [Coast Region] to provide the basis for further multiplication and distribution. The funding for this was provided to the roots crops team at Kibaha from the Eastern Zone Client-orientated Research & Extension Project [funded by Irish Aid]. However, it proved difficult to access funds for a follow-up and CPP project funds were used to assess disease incidence in the fields. CMD incidence was very low but CBSD incidence was high especially at Songbalini. However, cv. Kiroba is known to be tolerant to root necrosis [Table 6.1].

Table 6.1. CBSD incidence [foliar] in cv. Kiroba in three villages in Muheza District November 2002.

Village	Total plants	CBSD %	CMD %
Tongwe	586	27	2.5
Magoda	432	17	2.1
Songabatini	684	40	1.8
Mean		28	2.1

Output 7. Distribution and importance of CBSD in Malawi assessed.

The virus disease survey in Malawi was divided into two parts. The first part which took place in June 2001 was to estimate disease incidence based on foliar symptoms. The whole country was covered for this purpose. The follow-up survey was conducted in September 2001 to determine disease severity by examining roots for root necrosis. Only sites where high incidences of CBSD had been recorded were visited again for the root necrosis survey.

Surveys were conducted by root crops specialists from Tanzania and Malawi with logistical support from the SARRNET office in Lilongwe. [We are grateful to Dr Mahungu for his assistance]. The assistance of Mr Raya from Tanzania provided the opportunity to transfer his knowledge of CBSD symptoms and survey methods to the Malawian scientists. Mean CBSD incidence for the survey is not a useful statistic, as incidence varied so much between areas and the disease was absent from the higher altitudes around Chitipa. In the areas close to Lake Malawi at altitudes between 470 and 600m, disease incidence was high. Mean incidence for Karonga was 56 and 42 for Salima. CMD was found at most sites with no obvious pattern of distribution. Generally CMD incidences were high, ranging from 21 between Rumphi and Mzuzu to 91 between Dowa and Salima with an overall mean for the survey of 46 (Table 7.1).

Table 7.1. Summary of disease incidence survey at 54 sites in Malawi [June 2001]

Site No.	Location	Altitude [m]	Disease incidence [%] CMD	CBSD
1	Chitipa	1094	90	0
2		1250	7	0
3		1249	0	0
4		1235	10	0
5		1039	77	0
6		1136	23	0
			35	0
7	Karonga	567	67	43
8		567	70	43
9		492	37	0
10		493	73	87
11		493	50	80
12		492	7	3
13		492	37	83
14		516	73	97
15		473	60	43
16		483	37	80

			44	56
17	Rumphi/Mzuzu	929	53	50
18		1047	3	0
19		1080	20	0
20		1078	10	53
21		813	20	0
			21	21
22	Nkhata Bay	588	40	47
23		560	60	40
24		533	63	0
25		502	50	27
26		532	40	0
27		506	87	13
28		506	63	7
29		588	37	0
			55	17
30	Kasungu/Lilongwe	1237	0	0
31		1170	0	0
32		1166	10	0
33		717	7	0
			4	0
34	Dowa/Salima	599	90	0
35		599	100	7
36		572	83	13
			91	7
37	Salima/N'kota	518	70	0
38		518	87	83
39		518	67	60
40		519	57	53
41		555	100	30
42		539	100	23
			80	42
43	Chiponde	1021	30	0
44		896	10	0
45	Lake Malombe	507	100	0
46		505	90	7
47		489	80	0
48		579	13	0

			54	1
49	Shire Highlands	779	23	0
50		883	43	0
51		814	20	0
52		621	20	0
			27	0
53	Nsanje	699	0	0
54		699	37	0
			19	0
Mean			46	

It is difficult to assess the importance of root necrosis from the second survey because of the variation in age of crop that was examined and some crops were less than 7 months old when they were examined. [Root necrosis becomes more severe with age and it is usually at least 8 months after planting before most cvs show severe necrosis]. Root necrosis severity score was highest in cv. 20:20 but the average age of plants of this cv. that were uprooted was also highest at 14.5 MAP [Table 7.2]. Although the mean severity score for 20:20 was high the incidence of root necrosis was low at only 11%. The largest number of samples came from cv. Manyokola which seems to be rather susceptible with 36% of roots showing necrosis and a mean severity score of 2.8. More detailed studies are required to assess the impact of the disease in Malawi, but this is the first time that root necrosis associated with CBSD has been reported from Malawi. It is clear that CBSD is a threat to food security in the Lakeshore areas where cassava is such an important crop. All the main varieties included in the survey were susceptible to both CBSD and CMD [Table 7.3].

Table 7.2. Summary of root necrosis survey in Malawi for the main cultivars [September 2001]

Cultivar	Mean map[1]	CBSD		
		Above ground Severity [1 - 5]	%	Root necrosis severity [1 - 5]
Gomani [46][2]	11.9	2.9	32	2.1
Korobeka [28]	6.5	2.9	25	2.3
20:20 [38]	14.1	2.7	11	3.3
Manyokola [121]	9.8	2.9	36	2.8

[1]map = months after planting when root samples were taken
[2]Number of plants of each cv. included in the survey.

Table 7.3. Predominant cassava varieties and mean disease incidence [June and September 2001]

Variety	Number of plants		Disease incidence [%]		
	foliar survey	root survey	CMD	CBSD foliar	CBSD root
Thepula	66	5	80	56	40
Gomani	211	46	52	30	32
Manyokola	510	121	56	16	36
Kolobeka	39	28	74	69	25

CBSD survey in Kenya [Additional Output]:

Following the stakeholder workshop in Tanzania in September 2000, the opportunity was taken to travel across the border into Kenya and conduct a short survey there of virus disease incidence. Thirty plants were examined at each of 29 sites on the Kenya coast. The overall incidence of CBSD was 30% and of CMD 58% (Table 7.4). There seemed to be little evidence of spread of either disease and the high incidences of both disease were apparently due to planting infected cuttings. At one or two sites all the plants were infected with CBSV and this result is quite different from the observation by Bock during the 1970s that the incidence of CBSD was very low. At several sites all the plants were infected with one or both virus diseases which has obvious implications for transmission through planting material.

While visiting the KARI research station at Mpwapwa in coastal Kenya, Mike Thresh found that they were maintaining almost a complete collection of the original germplasm from the breeding programme for virus disease resistance conducted at Amani. This material was distributed to Regional Research Centres in the 1950s. As a result of raising awareness among donor agencies and IITA/SARRNET of the importance of this material, A Project funded by the Rockefeller Foundation was initiated in April 2002. This project based at Mikocheni in Tanzania, will focus on breeding cassava varieties with resistance to CBSD for the coastal belt of Kenya, Tanzania and Mozambique. The project will also make the Mpwapwa material available to other National Cassava Breeding Programmes.

Table 7.4. Summary of survey conducted in Kenya [September 2000]

Site	Disease incidence [%]		
	CMD	CBSD	Disease free*
1	87	10	13
2	93	20	3
3	0	100	0
4	0	100	0
5	30	0	70
6	83	0	17
7	13	30	63
8	90	13	3
9	10	17	73
10	17	0	83
11	93	0	7
12	87	27	7
13	90	90	5
14	77	27	6
15	55	13	23
16	43	27	33
17	53	0	47
18	63	10	30
19	87	0	13
20	80	77	7
21	60	40	17
22	97	57	3
23	57	0	43
24	80	0	20
25	7	0	93
26	90	47	0
27	60	30	20
28	30	100	0
29	63	33	37
Mean	58	30	25

* Some plants showed symptoms of both diseases

The number of cassava varieties encountered on Kenya coast was few compared to similar surveys in Tanzania and Mozambique. The predominant variety by far was 'Kibandameno'. Only 'Guzo' looked as if it might have some resistance to CBSD but was susceptible to CMD (Table 7.5.).

Table 7.5. Incidence of CMD and CBSD in cassava varieties in Kenya

Variety	Number of plants	Disease incidence[%]		
		CMD	CBSD	Disease free
Kibandameno	407	74	26	17
Guzo	91	54	1	45
Agriculture	60	13	8	78
Pamba	45	58	6	36
White Kiband.	41	27	14	0
Marewe	41	80	77	7
Kahutele	30	30	0	70

OUTPUT 8. Technology transfer to Mozambique

During the period of this project three visits by NRI staff have been made to Mozambique; the first by Rory Hillocks and subsequent visits by Prof. Thresh. Visits during the previous project were concerned with disease surveys to collect baseline data on disease incidence and severity. Visits in the present project were intended to transfer knowledge gained by CPP projects in Tanzania and Uganda, on cassava mosaic disease (CMD) and cassava brown streak disease (CBSD), to the National Programme and NGOs working in the important cassava-growing provinces of Zambezia and Nampula.

The visits have been arranged in collaboration with the DFID-funded World Vision project (ZADP) in Zambezia which, together with World Vision and other NGOs, covered local costs. Consultancy fees for the March-April visit and international travel were provided by the ASSC allocation for work with NGOs. The July-August visit was part-funded by the CPP CBSD project. Previous visits were funded by CPP, but funds allocated for this activity were insufficient to meet the demand by NGOs involved in distribution of cassava planting material for technical assistance from NRI. Additional funds [£10,000] were therefore sought from ASSC.

During previous visits it was established that CBSD is prevalent in large areas of Nampula and Zambezia Provinces where cassava is the most important staple food crop. The disease causes a severe root necrosis in the many sensitive varieties being grown and undermines food security. It is also a serious constraint on the activities and performance of the various NGO and US AID projects in the two provinces that aim to enhance food production and rural livelihoods. CMD occurs in both provinces and it is prevalent in some varieties and in some districts, but overall it is much less of a problem than CBSD.

Currently there is no effective control for CBSD in Mozambique and the problem was not recognized as a virus disease until the initial NRI visits in 1999. The need for additional studies to address the problem and to develop solutions was recognized by ZADP and a meeting was convened by Mr Tim Russell (team leader) in Mozambique in August 2000 to co-ordinate the activities of the different NGO projects in Nampula and Zambezia Provinces. [It should be noted that the National Research Organization (INIA) has few senior staff working on cassava in Zambezia and the main centre for activity in northern Mozambique is at the INIA station, Nampula (staff: Ricardo Macia, who is now with the SARRNET/US AID project and recently appointed graduate, Constantino Cuambwe). Clones raised from seed at the INIA Umbeluzi station near Maputo in southern Mozambique and introductions from IITA and elsewhere are sent for trials in Zambezia and Nampula by the leader of the INIA Root Crops Programme (Mrs Anabela Zacarias: Maputo). This work is supported by the Southern Africa Root Crops Research Network (SARRNET), which is now co-ordinated by Dr N Mahungu from Lilongwe, Malawi. Dr Andrade has recently been re-appointed as SARRNET representative in Mozambique, she is based in Maputo and administers the US AID disaster relief funds.

The following techniques developed by the project in Tanzania were disseminated to the NGOs in Mozambique;

- ❖ Exploit tolerance to CBSD in local cassava varieties - survey and collect planting material.
- ❖ Evaluate the material for reaction to CMD and CBSD.
- ❖ Multiply the planting material and rogue all plants that show symptoms of CMD.

Rogue plants showing symptoms of CBSD - only if numbers are low, on the assumption that the varieties chosen do not develop severe root necrosis.

The following activities were carried out in Mozambique between January 1999 and September 2001:

- ❖ Advise the NGO consortium and other organisations on methods to control CBSD and on the research required to provide the knowledge to support the control programme.
- ❖ Assist the NGOs to Set-up field trails to screen cultivars for resistance to CBSD and CMD and to investigate aspects of disease epidemiology.
- ❖ Provide the National Programme in Maputo with tissue-cultures and virus indexed plantlets of cv. Kiroba from Tanzania in exchange for cv. Macia sent to Tanzania via the NRI quarantine facility.
- ❖ Monitor the progress of the trials and observations initiated in December 2000 by ZADP and other organizations;
- ❖ Discuss with INIA, NGO and SARRNET staff the scope for CBSD and CMD control and the most appropriate strategy to follow;
- ❖ Discuss with INIA and NGO staff the selection and use of varieties that are suitable for distribution to farmers and of the best available health status;
- ❖ Promote linkages between INIA, NGOs and SARRNET in the work on cassava improvement, with particular reference to virus disease control.
- ❖ Participate and contribute to the cassava workshop convened by ZADP staff and held in Quelimane, 8-9 August. [Proceedings now available from John Steel]

NB. These activities were reported in full in a separate report that has already been submitted to CPP and will be appended to the FTR.

The collaboration with the NGOs in Mozambique has had clear impact in several ways:

1. CBSD was officially reported for the first time.
2. Information given to NGOs involved in cassava distribution of high incidences of CBSD, led to the development of CBSD management strategies in those projects.
3. The methods used in the CBSD management programmes have been adopted under technical supervision from the CPP project.
4. The first of the CBSD-tolerant varieties have been made multiplied on-farm and will be available to 10,000 farmers this season.

IITA and other donors have been alerted to the importance of CBSD.

Output 9. Guide to virus disease symptoms produced.

A comparative guide to diagnosis and control of CMD and CBSD was written by Rory Hillocks and Mike Thresh. Funds were then provided to SARRNET to fund publication of the guide. Versions with colour pictures illustrating disease symptoms were produced in English, Swahili and Portuguese. These were distributed to district Extension offices and to farmers in contact villages in Tanzania and Mozambique. Each of the contact farmers in our six target villages, [total of 180 farmers] received a copy.

Output 10. Workshop on management of cassava virus diseases.

A three day workshop was held at Sugarcane Research Institute, Kibaha, 6 - 8th September, 2000 on '*The Management of Cassava Virus Diseases*'. It was attended by 26 delegates from Tanzania and 12 others from elsewhere in Eastern and Southern Africa.

Overall conclusions from the workshop:

Cassava mosaic disease (CMD) and cassava brown streak disease (CBSD) are major cause of yield loss in Eastern and Southern Africa. CMD is well known and has received much attention. Nevertheless, it continues to cause serious losses and the current pandemic in Uganda and adjacent countries poses a major threat to the region. CBSD has been relatively neglected and yet it is more prevalent than CMD in many areas and undermines food security, especially in the coastal areas of Mozambique and southern Tanzania. There is a need for continuing research on CMD and for increased effort on CBSD.

Although the main discussion focused on virus diseases, it was stressed that post-harvest losses are also major constraints on food security and income generation and that there is a general lack of market opportunities. It was also agreed that there is a need to strengthen collaboration and partnership in the region to ensure more effective flow of information.

Effective management of viral diseases will bring great benefits but will require a sustained programme of basic and applied research, carried out in close collaboration with farmers and extensionists.

Specific recommendations

1. It has been reported that CBSD affects the organoleptic properties of cassava roots and that both CBSD and CMD affect the palatability of leaves. However, there is only limited evidence on these effects and a need for further studies.

2. Farmers perceptions and attitudes towards CBSD and CMD are poorly understood and further research and training are recommended to develop sustainable methods of disease control.

3. In many areas there is uncertainty at the extent to which CBSD and CMD are being spread naturally by vector. Multi-locational trials are required in diverse ecologies to assess inoculum pressure, the need for resistant varieties and the scope for control by phytosanitation.

4. Phytosanitation could have an important role to play in controlling both CBSD and CMD. This involves the use of 'clean' virus free planting material, roguing and crop hygiene. However, only limited attention has been given to this approach, virus free stocks are seldom available and there is a need for additional research to be carried out in close collaboration with farmers and extensionists.

5. Studies are also required on cropping practices (e.g. planting date, spacing, intercropping) in relation to the spread and control of both CMD and CBSD.

6. The widespread occurrence of CBSD and the recognition of different cassava mosaic geminiviruses necessitate a reassessment of quarantine controls of the movement of cassava material between and within countries. There is a need to reconcile the conflicting requirements of ensuring adequate safeguards without impeding the movement of cassava germplasm.

7. The symptoms of CBSD are diverse and can affect leaves, stem, fruits and tuberous roots. The symptoms not well known and there is a need for further studies and training of scientists, extension workers and farmers.

8. The relationship between the leaf and stem symptoms of CBSD is unclear. And there is little information on their effect on the quality and quantity of tuberous roots produced. Symptom observations and yield loss experiments are required on a range of varieties and in different locations.

9. Information is required on possible seed transmission of CBSD or on the possibility of mechanical transmission between plants by leaf contact or by the knives used to prepare cuttings.

10. Current studies indicating that natural spread of CBSD is by the whitefly *Bemisia tabaci* should be extended and the mode of transmission should be determined.

11. The scope for breeding varieties that are in some ways resistant to CBSD has received little attention. There is a need to develop effective screening and scoring methods to identify and utilise sources of resistance and to determine the mode of inheritance.

12. Environmental factors and particularly those associated with altitude are known to have a big influence on the incidence on CBSD and the damage it causes. However, these factors are poorly understood and should be elucidated.

13. Surveys should be undertaken to determine whether CBSD occurs in Angola and to assess the incidence in Zambia and Malawi where the disease is known to occur.

Contribution of outputs to developmental impact

International impact

This project and its predecessor have contributed considerably to the knowledge on CBSD. Disease distribution and importance has been established for the whole region, from Kenya coast to the Zambezi river in Mozambique and also for Malawi. The project was responsible for the first report of the disease in Mozambique. As a direct result of project activities in Mozambique and project publications, the significance of CBSD as a threat to food security has been recognised by IITA/SARRNET and the relevant donor agencies. Six NGO-led projects that include cassava distribution among their activities have adopted CBSD management strategies recommended by the project. USAID have provided a million dollars to SARRNET in Mozambique under 'disaster relief' for a root crops distribution programme that also includes CBSD management. Furthermore, at IITA, resistance to CBSD has been included as a primary criterion in cassava breeding for coastal E. Africa. The Rockerfeller Foundation are supporting a post-doctoral project on breeding for resistance to CBSD. A new project on CBSD funded by IFAD and managed by IITA was initiated in 2002. The methods of disease screening and quantitative assessment of disease severity developed by the project have been adopted by these programmes and by NARS cassava programmes in Tanzania and Mozambique.

Tanzania

The project has promoted control measures in the contact villages and raised awareness of the disease in the project area with villagers and extension workers.

The main approach has been to conduct primary multiplication of CBSD-resistant cultivars on-station but to use farmers groups to evaluate the material and to further propagate and disseminate those cultivars that they consider to be usefull. Project activities in the Southern Zone of Tanzania have led to a general increase in awareness of CBSD as a problem that has a solution. The cultivars that were first identified as resistant to CBSD are now widely grown in Mtwara rural, farmers having adopted them without further intervention from the project. The success of these cultivars in Mtwara rural may be due to the highly susceptible [to CBSD] nature of the main local cultivar [Albert] that was grown when the previous project began.

Mozambique

In the previous project, CBSD was for the first time shown to be widespread in Mozambique and a major threat to food security in the northern Provinces of Zambezia and Nampula. The disease remains a major constraint to cassava improvement programmes sponsored by a number of NGOs and other agencies. In the present project, technical assistance has been given to some of these organisations on research methods to support cassava virus disease management programmes. The project has also provided a link between some of the organisations doing similar work with cassava and has been instrumental in raising awareness of the need to co-ordinate these activities and was instrumental in brining about the workshop that brought many of the cassava distribution projects together. As a direct result of project activities and dissemination, IITA has now greatly increased its activities in Mozambique and has recognised that selection for resistance to CBSD is a priority for cassava varieties intended for the east coast of Africa.

There are many agricultural projects in Mozambique that are concerned with cassava to at least some extent and the total budget is large and increasing and already amounts to millions of US dollars per year. The projects are in a strong position to promote technological innovations and they could make substantial contributions to the declared objectives of reducing poverty and enhancing food security. However, their prospects for doing so are seriously undermined by the limited availability of research support that will lead to superior varieties, improved methods of pest and disease control and other innovations. The overall research effort within Mozambique is limited and fragmented which is a serious constraint and one that impedes progress and inevitably prejudices the success of the various projects. Improved co-ordination of the disparate activities would lead to a more effective use of the funds and expertise available.

As a result of the transfer to Mozambique of technologies developed by the project in Tanzania, standard methods have been adopted for the evaluation of cassava germplasm for CBSD resistance. As a result a number of cvs. and lines have been identified that have some resistance to CBSD. Some of these are already being propagated by NGOs.

Through its linkages with NGO-led cassava distribution programmes in Mozambique, the project outputs have been reached 10,000 farmers and this number will increase as more cassava is distributed. The project has Indirectly reached many more farmers through other donor-funded projects with CBSD management components that have arisen as a result of promoting project outputs in publications and through the internet, that have created awareness of CBSD as a constraint to sustainable cassava production.

Malawi

A nationwide survey of both main cassava virus diseases was conducted for the first time in Malawi and the presence of CBSD root necrosis symptoms was also reported for the first time. As cassava becomes more important as a food security crop in Malawi the high incidences of both CMD and CBSD must have an impact on cassava production and constitutes an important constraint on food security and impact negatively on rural livelihoods. The project has shown that CBSD is a major constraint to food security in the main cassava areas along the shore of Lake Malawi.

Dissemination

Peer-reviewed papers

HILLOCKS, R. J., RAYA, M. D., MTUNDA, K. and KIOZIA, H. (2001) Effects of cassava brown streak virus disease on yield and quality of cassava in Tanzania. *Journal of Phytopathology* **149**, 389 - 394.

HILLOCKS, R. J., THRESH, J. M., TOMAS, J., BOTAO, M., MACIA, R. and ZAVIER, R. (2002) Brown streak disease of cassava in northern Mozambique caused by cassava brown streak virus. *International Journal of Pest Management* **48**, 179 - 182.

Book
HILLOCKS, R.J.,THRESH, J.M. and BELLOTTI, A. [Eds.] (2002) *Cassava: Biology Production & Utilisation*. CABInternational, Wallingford, UK. 332pp.

In preparation:
THRESH J. M. (2003) Cassava virus diseases in coastal Kenya. Roots.

THRESH, J. M. (2003) Udate on cassava virus diseases in Mozambique. Roots

Internal reports

HILLOCKS, R.J. 2000. Report of a visit to Tanzania to initiate follow-on project on management of cassava virus diseases, 19 - 26 February 2000. Project R7563, Natural Resources Institute, Chatham, 2 pp.

HILLOCKS, R.J. 2000. Report of a project management visit to Tanzania, 8 - 20 May 2000. Project R7563, Natural Resources Institute, Chatham, 2 pp.

HILLOCKS, R. J. 2000. Report on a project workshop in Tanzania on management of cassava virus diseases, 6 – 8 September 2000. Project R7563, Natural Resources Institute, Chatham, 5 pp.

THRESH, J. M. 2000. Report of a visit to Mozambique, 11-23 June 2000. Project R7563, Natural Resources Institute, Chatham, 14 pp.

THRESH, J. M. 2000. Report of a visit to Mozambique, 8 - 22 October 2000. Project R7563, Natural Resources Institute, Chatham, 27 pp.

HILLOCKS, R. J. 2001. Report of a project management visit to Tanzania, 13 - 27 January 2001. Project R7563, Natural Resources Institute, Chatham, 2 pp.

HILLOCKS, R. J 2001. Report of a visit to Tanzania to review on-farm trials on cassava brown streak disease control. 24 June - 7 July 2001. Project R7563, Natural Resources Institute, Chatham, 8 pp.

HILLOCKS, R. J. 2002. Report of a project management visit to Tanzania, 2 – 14 March 2002. Project R7563, Natural Resources Institute, Chatham, 3 pp.

THRESH, J. M. 2002. Report on a Visit to Northern Mozambique to Review CBSD Management in NGO Cassava Programmes 8-19 April 2002**.** Project R7563, Natural Resources Institute, Chatham, 16 pp.

Other dissemination of results, training etc

HILLOCKS, R. J. and Thresh, J. M. (2002) Cassava mosaic and brown streak virus diseases in Africa: A comparative guide to symptoms and aetiologies. Roots [Special edition] 7[1], 11 pp.

HILLOCKS, R. J. (2000) Unearthing a solution to cassava root rot. New Agriculturalist [on-line] issue 19 January 2001. http://www.new-agri.co.uk

Siddick, S. [2001] Mechanical transmission of *Cassava brown streak virus* to cassava and other hosts. MSc University of Greenwich, 95 pp. [student from India]

Two workshops were held on diagnosis and management of CBSD. The first, in August 1999 was an international workshop attended by scientists from the Tanzania, Kenya, Malawi and Mozambique. Findings from the first project were presented and activities identified for the present project.

The second workshop was held at Naliendele in March 2002 and was attended by farmers leaders and District Extension Officers to widen awareness of CBSD and the project activities.

Appendix [next page]
Rate of spread trial at Naliendele [2002]

X = new infections with CBSD

0 = spreader block planted with infected cuttings

						x	x								x							x							
							x		x					x						x									
								x							x						x	x	x	x					
				x	x	x		x	x	x	x			x	x					x									
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