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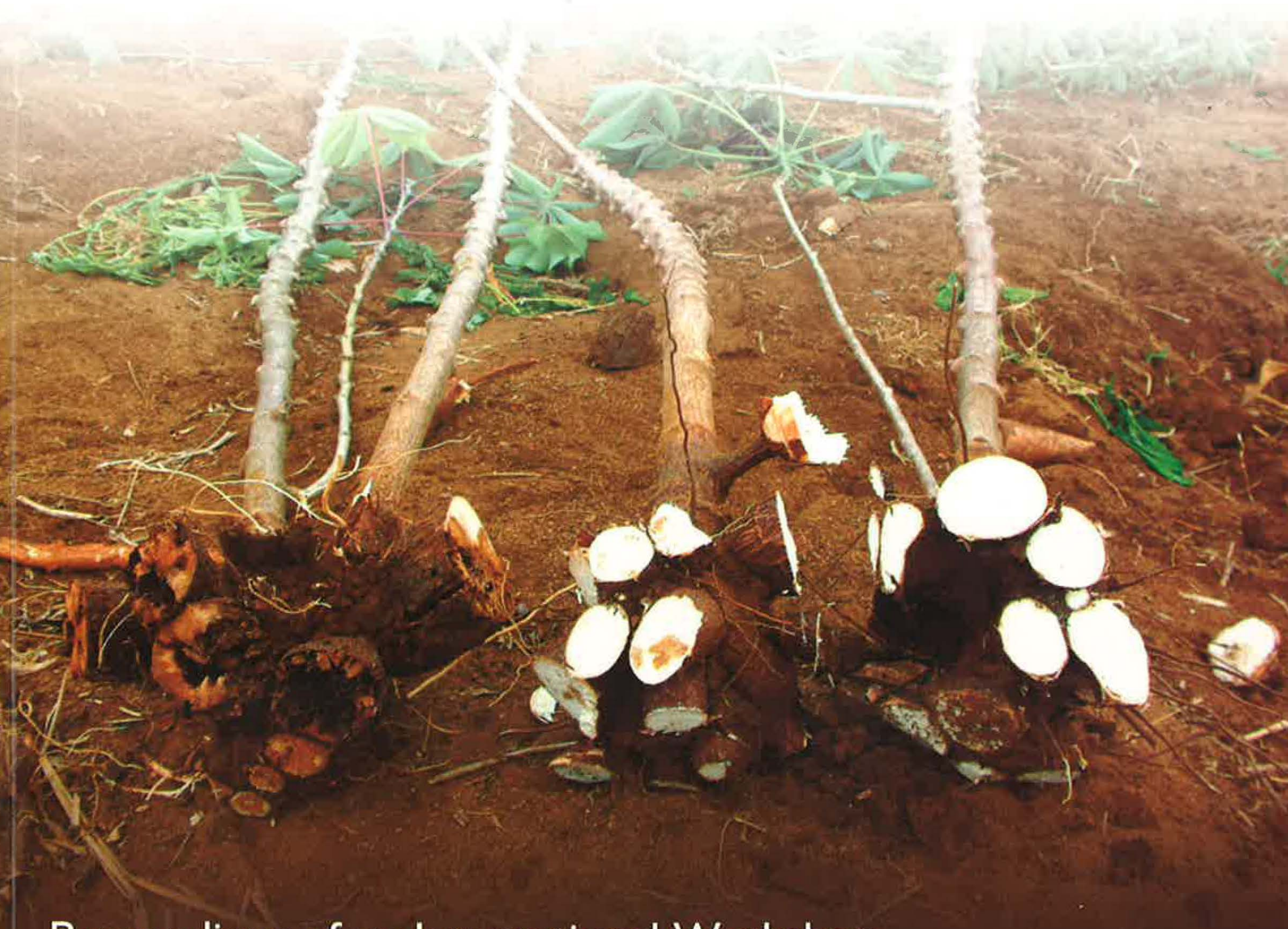
Cassava Brown Streak Virus Disease: Past, Present and Future



Proceedings of an International Workshop
Mombasa, Kenya, 27–30 October 2002

Cassava has been an important success story in Africa's developing agriculture over the past decade. The crop's inherent capacity to cope with marginal growing conditions and unpredictable rainfall, coupled with determined efforts of a number of countries to move away from over-reliance on maize, have helped establish it as the continent's number one crop in terms of total fresh production. The hope provided by these gains is now threatened, however, by the devastating impact of the virus diseases, cassava mosaic and cassava brown streak. Both have been known for many years, but seem to be becoming increasingly damaging, and pose an ever greater threat to the livelihoods of the millions of Africans who depend on cassava as a food staple. Substantial effort has been directed towards understanding and managing cassava mosaic. By contrast, cassava brown streak disease (CBSD), which has a more limited distribution, and causes most severe damage in the coastal lowlands of Eastern and Southern Africa, has received little attention.

In order to address this deficiency, an international workshop was convened at Mombasa, Kenya. This meeting brought together a diverse range of cassava stakeholders with the twin aims of reviewing current research into cassava brown streak and developing a plan to guide future research for development initiatives. The 15 papers presented in these proceedings provide a useful and informative summary of the history and current status of CBSD, recent research initiatives and management options for the worst affected countries – Malawi, Tanzania, Kenya and Mozambique. Outputs of the research and on-farm working group sessions are also included. It is anticipated that this information will serve both as a useful technical resource as well as an essential planning tool for scientists, development workers and others with an interest in the management of CBSD and the development of cassava in Africa.

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Natural Resources International Limited
Park House, Bradbourne Lane, Aylesford, Kent ME20 6SN, UK
Tel: +44 (0) 1732 878686/7 Fax: +44 (0)1732 220497
Website: www.nrinternational.co.uk and www.cpp.uk.com Email: info@nrint.co.uk

Cassava Brown Streak Virus Disease: Past, Present and Future

Proceedings of an International Workshop, Mombasa, Kenya, 27–30 October 2002

Edited by

James P. Legg and Rory J. Hillocks

Workshop organized by
International Institute of Tropical Agriculture
in collaboration with
East Africa Root Crops Research Network
and Southern Africa Root Crops Research Network

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The Communications Coordinator Crop Protection Programme
NR International, Park House, Bradbourne Lane, Aylesford, Kent ME20 6SN
United Kingdom

Tel: +44 (0)1732 878670 (direct line)
Tel: +44 (0)1732 878686/7 (switch board)
Fax: +44 (0)1732 220497
Website: www.cpp.uk.com and www.nrinternational.co.uk
Email: info@nrint.co.uk

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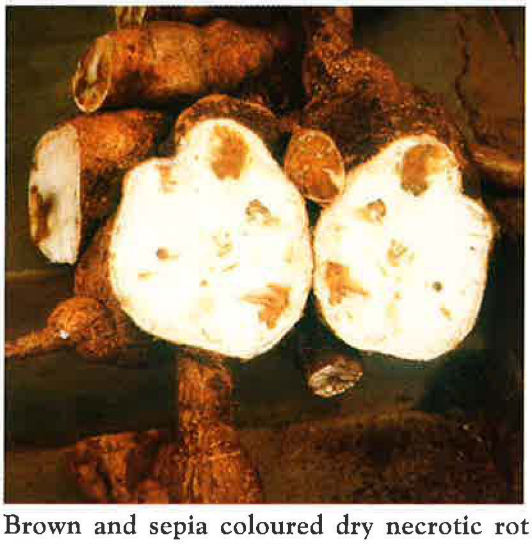

Brown and sepia coloured dry necrotic rot characteristic of severe CBSD infection, Mtwara, Tanzania (J.P. Legg, upper photo; R.J. Hillocks, lower photo)

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Foreword

The key contribution of agricultural research towards poverty elimination is well recognized in international development. Control of the infamous mosaic disease which devastated cassava (*Manihot esculenta* Crantz) production in Uganda during the 1990s is a widely acknowledged research success story. Less well known is the progress achieved in managing cassava brown streak virus disease (CBSD), which contributes to chronic food insecurity in large areas of coastal eastern and southern Africa. It is opportune that the Department for International Development (DFID) Crop Protection Programme (CPP) has collated knowledge from several research projects that are implementing solutions to this problem. The papers published here show how researchers are building on the investments in past research and are using recent innovations to deliver solutions that are urgently needed by poor communities.

Current debate on the impact of agricultural research frequently emphasizes the need for research to be demand led rather than driven by supply. In areas affected by CBSD, for long ravaged by acute poverty caused by civil war, adverse weather conditions, poor soils, social neglect and economic deprivation, many communities have poor understanding of this threat to their food security and are unable to articulate demands for knowledge on this disease to safeguard their food supplies. Fortunately agencies such as DFID have recognized the need to support basic and applied research on CBSD as an essential component of improving livelihoods, and have helped to develop close links between non-governmental organization (NGO)-led rehabilitation programmes and research projects. The papers presented here highlight the unique role and strong impact of 'public good' agricultural research, linked to development programmes, and working together at the front line of poverty elimination.

A broad spectrum of partners participated in this Mombasa workshop including national agricultural research organizations, advanced research institutes, international research centres and international NGOs. The workshop took special care to capture information and knowledge generated from an earlier generation of researchers, including the original descriptions of the disease and foundation breeding work carried out by Nichols and Jennings in the 1940s and 1950s. The outputs provide a challenge for the private sector to invest in improved prospects for production of this crop and to contribute to further research to help realize the potential of cassava for economic growth and social development in Africa.

Frances Kimmins
CPP Programme Manager
June 2003

Acknowledgements

The International Institute of Tropical Agriculture (IITA) and partners from the University of Nairobi (UoN) and the Kenya Agricultural Research Institute (KARI) would like to acknowledge the financial support provided by the UK Department for International Development (DFID) Crop Protection Programme (CPP) for providing the core financial support for the Workshop. Also gratefully acknowledged is the support provided by the International Fund for Agricultural Development (IFAD), The Rockefeller Foundation and the United States Agency for International Development (USAID) funded projects for the participation of a number of the delegates.

KARI-Mtwapa and the UoN are thanked for the local organizational support and for setting up and hosting the field visit. Thanks also go to Ms Flavia Atugonza of IITA-Uganda for administrative support and assistance in the compilation of the proceedings, and to Ms Penny Silverside and Deanna Hash for editing support and preparation of the document that was printed by Pragati Offset Pvt. Ltd.

Editors' Preface

Virus diseases have long been recognized as one of the major limiting factors to cassava (*Manihot esculenta* Crantz) production in Africa, in particular cassava mosaic geminiviruses (CMGs) that cause cassava mosaic disease (CMD). In the past few years another disease appears to have grown in prominence in the Coastal Zone of Kenya, Tanzania and Mozambique and the Lake region of Malawi. Although this disease has been known for a long time it has now been unequivocally shown to be caused by another virus, *Cassava brown streak virus* (CBSV). Today, the disease caused by this virus – cassava brown streak virus disease (CBSD) – is recognized as being responsible for serious losses in these regions. Not only does it cause yield losses but CBSD also gives rise to brown necrotic streaks in the tuberous roots, making them undesirable for cooking and processing. However, very little is known about CBSD and its effects on cassava.

In order to develop sustainable control strategies for a virus disease, various factors must first be understood. These include aspects of virus–vector and virus–host relationships. Resistant cultivars are often viewed as the best long-term solution to virus diseases. However, to ensure that such resistance is sustainable, it has to be supported by other measures to limit the effects of the disease. In the case of a poorly studied disease such as CBSD, sources of genetic resistance first have to be identified and characterized before they can be used in a breeding programme.

Between 1996 and 2000, CBSD was identified as the most devastating disease of cassava in coastal Tanzania and northern Mozambique by researchers from the Natural Resources Institute (NRI), UK, working with local partners. As a result, awareness of the regional scientific community was raised, non-governmental organizations (NGOs) concerned with development in Mozambique began to devote substantial resources to 'stop-gap' emergency measures to tackle the evident food security problem, and the Government of Mozambique and its research and extension systems sought international assistance to address what was seen as a national crisis.

As a consequence of this heightened awareness, a number of research projects were developed and are currently being implemented, with the aim of improving understanding of this virus disease and developing approaches to control. There is a continued focus on the crisis zone in northern Mozambique. These projects are being funded by a range of donors and conducted by researchers from various national agricultural research systems (NARS) and international research institutions. Key donor organizations have included the Crop Protection Programme (CPP) of the UK's Department for International Development (DFID), from 1996 to the present day, The Rockefeller Foundation and the United States Agency for International Development (USAID). However, at this critical stage as new projects get underway, it is essential that researchers and key control practitioners coordinate activities very closely in order to strengthen the overall effort in addressing the problem and avoid wastage of resources through duplication.

In view of this situation, it was clear that there was an urgent need to bring the widest possible range of stakeholders together to share information and to discuss CBSD research for development. With this in mind, a meeting, to be held in coastal Kenya, one of the main CBSD-affected areas, was planned. The twin objectives of the meeting were to review current CBSD research activities that are contributing to development progress and to develop a coordinated plan for future research and development efforts. All aspects of CBSV/CBSD were to be discussed, including existing and planned future research, in addition to the practical management of the disease and the role of the various research and development organizations in implementing control measures. This, it was considered, would allow stakeholders to identify priorities and to determine where their contribution would be most effective and appropriate.

The Workshop was organized jointly by the regional networks: the East Africa Root Crops Research Network (EARRNET) and the Southern Africa Root Crops Research Network (SARRNET), with the executing support of the International Institute of Tropical Agriculture (IITA). Researchers, plant protection/quarantine staff and development practitioners were brought together from all of the CBSD-affected countries, including Kenya, Tanzania, Malawi, Mozambique and Zambia. They were joined by other CBSD and cassava scientists from IITA's Uganda and Benin stations and by experienced CBSD specialists and an NRI scientist from the United Kingdom. The meeting also benefited from the participation of donor representatives from the regional offices of USAID and The Rockefeller Foundation based in Nairobi, and also from DFID-CPP. Local organization was coordinated by University of Nairobi (UoN) and the Kenya Agricultural Research Institute (KARI).

The rich diversity of participants provided an excellent forum to review, discuss and plan for the future. One of the principal outputs of the meeting was to be a record of the technical presentations. In addition, working groups were asked to develop elements of a coordinated plan for future research, and participants were asked to consider the utility of establishing an informal steering or advisory committee that would help with information exchange and coordination of the overall CBSD management effort. Each of these elements is outlined within these proceedings. A selection of scientific papers presented at the meeting and included here covers all aspects of CBSD biology and management, with contributions from each of the major affected countries. The technical coverage ranges from a synopsis of some of the earliest work done on CBSD in the 1930s, 1940s and 1950s in what is now Tanzania, to a resumé of the emergency disease management work currently being implemented by a consortium of NGOs in northern Mozambique.

It is hoped that these proceedings will therefore serve as a useful resource for those interested in learning about the current state of knowledge of CBSD and its management. Additionally, it is hoped that those interested in developing or financing new work on CBSD will find the Working Groups section informative and useful in targeting new research and development interventions as effectively as possible.

James Legg
International Institute of Tropical Agriculture
Eastern and Southern Africa Regional Centre
Kampala, Uganda
and
Natural Resources Institute
University of Greenwich
Chatham, UK

Rory Hillocks
Natural Resources Institute
University of Greenwich
Chatham, UK

Welcome and Opening Remarks

R.W. Muinga

Centre Director, Kenya Agricultural Research Institute, Mtwapa, Kenya

My role this morning is twofold. Firstly, I would like to welcome all of you to Kenya and specifically to coastal Kenya. Please make use of the opportunity to visit the beautiful coastal environment surrounded by the beach. I also encourage you to make plans to come back and visit the countryside with friends or relatives. Secondly, I would like to apologize for the Assistant Director in charge of Food Crops in Kenya Agricultural Research Institute (KARI), Dr. Joseph Ochieng, because he was unable to come and make the opening remarks. He however requested me to stand in for him and on his behalf I would like to commend you for the noble task ahead of you. Thank you for choosing to hold the workshop in Kenya where cassava (*Manihot esculenta* Crantz) is an important food crop.

In coastal Kenya where maize (*Zea mays* L.) forms the main staple diet, cassava is ranked second and in some areas it is the main staple food. This is why in research we have a cassava programme to address constraints to production and processing methods that add value to the crop and contribute to food self sufficiency and poverty reduction. There are recommendations on the use of cassava for livestock feeding but farmers have not adopted them because of the current low production. All the cassava that is produced is used for human consumption and none can be spared for livestock feeding. One of the major constraints to production is disease risk. It is therefore encouraging to note that this workshop will be discussing one of the diseases, the cassava brown streak virus disease (CBSD). The interested parties gathered here will discuss all aspects of CBSD including existing and planned future research, in addition to the practical management of the disease and the role of the various research and development organizations in implementing control measures. This is commendable and I hope that the priorities to be set and research and development efforts to be undertaken will result in effective coordination of future programmes targeting CBSD in order to maximize the utilization of resources and funding.

Finally, on behalf of KARI's Assistant Director in charge of Food Crops, I would like to declare this workshop officially opened.

CBSD PAST AND PRESENT

Brief History of Cassava Brown Streak Virus Disease

J.M. Thresh

Natural Resources Institute, University of Greenwich, Chatham, Kent, UK

This paper presents a brief history of cassava brown streak virus disease (CBSD) as an introduction to more detailed presentations on specific aspects of the disease and the virus responsible.

The first report by Warburg in 1894 was from German East Africa (later Tanganyika and now Tanzania) of a virus disease of cassava (*Manihot esculenta* Crantz) (Warburg, 1894). This was termed *krauselkrankheit*, which is now referred to as cassava mosaic virus disease (CMD).

1935 The first report of CBSD was observed in what is now Tanzania and distinguished from CMD (Storey, 1936). CBSD was shown to be graft-transmissible and in the absence of any visible pathogen assumed to be caused by a virus.

Cassava breeding started at Amani in Tanzania to develop cultivars resistant to both CMD and CBSD (Jennings, 1957).

1939 The whitefly *Bemisia tabaci* was suggested as the vector of CBSD (Storey, 1939).

1945 CBSD observed in Uganda in material introduced from Tanzania in 1934 (Jameson, 1964). Eradication measures adopted in an effort to eliminate the disease.

1950 The first detailed description of the stem, leaf and root symptoms of CBSD and of the occurrence of the diseases in coastal areas of Kenya and Tanganyika and also in Nyasaland (now Malawi). Also observations on the effects of temperature and other environmental factors on symptom expression (Nichols, 1950).

1946 Sap transmission of CBSD from cassava to cassava and also to herbaceous hosts demonstrated in glasshouse studies in Scotland (Lister, 1959).

1964 Elongate virus-like particles detected in CBSD-infected plants by electron microscopy (Kitajima and Costa, 1964).

1976 Overseas Development Administration (ODA) support for a project on CMD, CBSD and other virus diseases of important agricultural crops in Kenya. Sap transmission of CBSD reported, *Nicotiana debneyi* found to be a good indicator host and two virus variants or strains distinguished. Negative results obtained in transmission tests with the whitefly *B. tabaci* and with *Myzus persicae* and other aphid species (Bock, 1994).

1985 Elongate particles 650–690 nm long resembling those of carlaviruses detected in herbaceous plants infected mechanically by sap-inoculation from CBSD-affected cassava. An antiserum was prepared and used in serological tests, which detected the virus in *Nicotiana benthamiana* and erratically in cassava. What was regarded as a separate potyvirus also detected and associated with pinwheel inclusions in *N. benthamiana* (Lennon *et al.*, 1986).

1987 Leaf symptoms of CBSD observed on cassava between Morogoro and Kibaha in Tanzania. A project proposed to investigate the disease (Thresh, J.M., unpublished).

1990 Two separate viruses listed as being associated with CBSD – a carlavirus and a potyvirus (Brunt *et al.*, 1990).

1993 CBSD 're-discovered' in Malawi (Thresh, J.M. and Rossel, H., unpublished). A project funded by ODA/Integrated Pest Management Strategy Area (IPMSA) begins. Activities include an assessment of the effectiveness of the enzyme-linked immunosorbent assay (ELISA) technique for detecting *Cassava brown streak virus* (CBSV).

1993–94 Survey of the incidence of CBSD in Tanzania (Legg and Raya, 1998).

Cassava Brown Streak Virus Disease: Past, Present and Future. Proceedings of an International Workshop, Mombasa, Kenya, 27–30 October 2002. Legg, J.P. and Hillocks, R.J. (Eds) (2003). Natural Resources International Limited, Aylesford, UK. 100 pp.

1994 CBSD 're-discovered' in Uganda at a site near Entebbe (Thresh *et al.*, 1994).

1995 Tolerance to CBSD identified in the local cultivar Nanchinyaya in southern Tanzania (Hillocks, R.J. and Raya, M.D., unpublished).

1996 ODA/Crop Protection Programme (CPP) Work begins at Naliendele in southern Tanzania to collect local cultivars, screen for resistance to CBSD and produce disease-free stocks for distribution to farmers (Hillocks, R.J. and Raya, M.D., unpublished).

1999 CBSD first recorded in Mozambique and shown to be prevalent and causing serious damage in the northern provinces of Nampula and Zambézia (Hillocks *et al.*, 2002).

Farmers in selected villages in southern Tanzania begin evaluating CBSD-resistant cultivars (Hillocks, R.J. and Raya, M.D., unpublished).

2000 CBSD 're-discovered' in Kenya and the incidence of infection assessed in coastal areas north and south of Mombasa (Munga, L.T. and Thresh, J.M., unpublished).

Molecular techniques used to characterize CBSV, which is ascribed to the genus *Ipomovirus* of the family *Potyviridae* (Monger *et al.*, 2001a).

Polymerase chain reaction (PCR) diagnostic test developed at Bristol University in project funded by the Department for International Development (DFID)–Crop Protection Programme (Monger *et al.*, 2001b).

2001 Study in Tanzania on the effects of CBSD on the yield and quality of the tuberous roots produced by four local cultivars (Hillocks *et al.*, 2001).

Root symptoms of CBSD recorded for the first time in Malawi (Raya *et al.*, unpublished).

2000–02 Transmission tests resumed at Kibaha Research Station, Tanzania, and at the Natural Resources Institute (NRI), UK, with the whiteflies *B. tabaci* and *B. afer*. (Mtunda, K., Hillocks, R.J., Colvin, J., and Maruthi, M.N., unpublished).

2002 CBSD workshop held at Mombasa to review research progress and coordinated plan of action for future activities.

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Current Status of Cassava Brown Streak Virus Disease in Tanzania

K.J. Mtunda[1], M. Muhanna[1], M.D. Raya[2] and E.E. Kanju[3]

[1] Sugarcane Research Institute, Agricultural Research Institute – Kibaha, Coast, Tanzania
[2] Agricultural Research Institute – Naliendele, Mtwara, Tanzania
[3] Southern Africa Root Crops Research Network, International Institute of Tropical Agriculture, Agricultural Research Institute – Mikocheni, Dar es Salaam, Tanzania

Introduction

Cassava (*Manihot esculenta* Crantz) is one of the widely grown staple crops in sub-Saharan Africa, and total production, at more than 90 million tonnes (FAO, 2001) is greater than for any other crop in Africa.

The crop is grown in 39 African countries, of which Nigeria, Democratic Republic of Congo, Ghana, Tanzania and Mozambique are among the top 10 producers in the world (FAO, 2001). Cassava is an excellent crop for the smallholder farmer. Its adaptability to relatively marginal soils and erratic rainfall conditions, its high productivity per unit of land and labour, the certainty of obtaining some yield even under the most adverse conditions, and the possibility of maintaining continuity of supply throughout the year make this root crop a basic component of the farming system in many areas of Africa.

In Tanzania, cassava is an important food crop, grown for its leaves and roots as human food. The leaves are normally used as a vegetable while the roots are staple in many parts of the country including the Southern, Eastern and Lake zones. Average yield in Tanzania has been fluctuating over the years (10 t/ha; 1996; 7 t/ha; 2001), which is below the potential of the crop. The low yield is caused by many factors including major pests and diseases prevalent in the country.

The most important diseases affecting cassava production in Tanzania are cassava mosaic virus disease (CMD) and cassava brown streak virus disease (CBSD). CBSD is a viral disease, which has been recorded to be endemic in all East Africa coastal cassava growing areas, but restricted to low and medium altitudes below 1000 m asl (Nichols, 1950).

Symptoms include foliar chlorosis and, sometimes, stem lesions. The disease also affects the tuberous roots which develop a yellow/brown, dry, corky necrosis within the starch bearing tissues, sometimes accompanied by pitting and distortion, that is visible externally (Hillocks, 1997). Root necrosis accounts for the quantitative and qualitative reduction in total yield through the presence of necrotic lesions or discoloration of the root, rendering them unpalatable and non-marketable (Nichols, 1950). Preliminary investigations in Tanzania showed an average yield loss of 34% due to CBSD (SARRNET, 1994). The spread of CBSD is mainly through infected planting materials (Hillocks *et al.*, 1999; Legg and Raya, 1998) but the vector is yet to be positively identified although whitefly (*Bemisia*) species are suspected.

Cassava production in Tanzania

Tanzania is among the top ten largest cassava producers in the world (FAO, 2001) and produces 5,500,000 tonnes annually. More than 84% of the total production is consumed as human food, about 15% as waste and the rest is livestock feed (see Tables 1, 2 and 3).

Table 1. Top 12 cassava-producing countries in the world

Country	Production (t)
Nigeria	33,854,000
Brazil	24,088,000
Thailand	18,283,000
Indonesia	15,800,000
Democratic Republic of Congo	15,436,000
Ghana	8,512,000
India	5,800,000
Tanzania	5,500,000
Mozambique	5,362,000
Uganda	4,966,000
Paraguay	3,854,000
China	3,750,000

Source: FAO, 2001

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Table 2. Countries in Africa producing over 1 million tonnes of cassava roots

Country	Production (t)
Nigeria	33,854,000
Democratic Republic of Congo	15,436,000
Ghana	8,512,000
Tanzania	5,500,000
Mozambique	5,362,000
Uganda	4,966,000
Angola	3,130,000
Benin	2,800,000
Madagascar	2,228,000
Cameroon	1,700,000

Source: FAO, 2001

Major producing areas in Tanzania include: the coastal strip along the Indian Ocean (Tanga, Dar es Salaam, Lindi and Mtwara), around Lake Victoria, Lake Tanganyika and along the shores of Lake Malawi. About 48% of the total production is produced in the coastal area, where CBSD is endemic, 23.7% of cassava produced comes from the Lake Zone, and 13.7% from Lake Nyasa areas. In the areas mentioned above, cassava is regarded as the first or second staple food.

Status of CBSD

Since the early 1990s several surveys have been conducted to assess the status of cassava virus diseases in the country, including CMD and CBSD. A countrywide survey was carried out by Legg and Raya in 1993–94 (Table 4). Hillocks and Raya undertook several detailed surveys between 1996 and 1999 in the Southern coast (Mtwara and Lindi). Brief surveys have also been carried out in Zanzibar (Thresh and Mbwana, 1998), at Kibaha (root/tuber programme) and Muheza, Tanga (Muhanna and Mtunda, 2002).

Table 3. Major cassava-growing areas in Tanzania

Location	Production (%)	Estimated production (tonnes)
Coast/Eastern and Southern	48.8	2,684,000
Lake Zone	23.7	1,303,500
Western Zone	7.9	434,500
Central Zone	5.0	276,100

Source: Ministry of Agriculture and Cooperatives, 2000 (unpublished data)

Highest incidences were recorded in Mtwara and Lindi (36%), followed by Masasi and Nachingwea (25.2%). These two locations are located in the Southern coast between 200 and 400 m asl. In both locations, CMD was found to be less prevalent than CBSD. Around Dar es Salaam, CBSD incidence was recorded at 19.4%. The disease was not recorded around Lake Tanganyika, Zanzibar and in the Lake Zone.

A survey conducted along the Tanzania coastal plain from the Kenya border southwards (Table 5 and see Figure 1) again showed both virus diseases to be present in many cassava fields but the disease incidence varied considerably. Between the Kenyan bor-

Table 4. Cassava virus survey data in Tanzania in 1993–94

Region	Average altitude (m asl)	Number of fields	CMD total (%)	CBSD (%)
Tabora	1190	14	0.7	0.5
Nzega	1170	10	4.0	0
Mwanza	1140	10	10.0	0
Kigoma	880	25	34.9	0
Manda	625	16	7.5	19.6
Tunduru	620	10	4.7	0.7
Mbamba Bay	560	11	3.6	3.0
Newala	455	17	40.0	6.9
Masasi	355	23	15.7	25.2
Morogoro-Segera	350	12	40.8	4.7
Tanga	80	24	64.2	2.3
Dar es Salaam	75	23	21.2	19.4
Mtwara	60	10	21.7	36.0
Zanzibar	20	17	59.4	0
Pemba	20	20	32.2	0
Mean (Total)		(242)	27.5	8.6

Source: Legg and Raya, 1998

Table 5. Incidence of CBSD and CMD in cassava fields on the coastal plain of Tanzania, 1998–2001

Location	CBSD (%)	CMD (%)	Year
Kenya border – Dar es Salaam	32.0	46.0	1998
Dar es Salaam – Rufiji River	23.0	29.0	1998
Rufiji River – Lindi	41.0	13.0	1998
Zanzibar	20.0	71.0	1998
Mtwara (Mikindani/Msijule)	36.8	4.0	1999
Kibaha	24.3	31.0	2001
Mean	29.5	32.3	

der and Dar es Salaam, CMD was observed to be higher than CBSD. Between Dar es Salaam and the Rufiji River the incidences of both CMD and CBSD did not differ much. Higher incidence of CBSD was recorded between the Rufiji River and Lindi. Two cultivars, Kitumbua and Kiroba, found between Dar es Salaam and the Rufiji River were observed to have some resistance to CBSD (Hillocks, 2000).

Major cultivars grown and the effect of CBSD

Six cultivars were examined for CBSD susceptibility or symptom expression. Data in Table 6 represent the typical situation in farmers' fields. Cultivars Sheria, Albert and Nanchinyaya showed higher incidences of CBSD than Saranga, Limbanga and Mreteta based on foliar symptoms. In some fields, for cultivar Sheria, the incidence reached 70%. There is considerable variation in susceptibility to CBSD among local cassava cultivars in Tanzania.

Table 6. Mean incidence of virus diseases (foliar symptoms) for each of the main cultivars in Mtwara (southern coast), Tanzania, 1996

	Disease incidence			
Cultivars	CBSD (%)	Range	CMD (%)	Range
Mreteta	14	0–30	9	0–30
Nanchinyaya	42	17–63	12	3–23
Sheria	48	27–70	14	0–27
Albert	45	23–67	5	0–13
Saranga	5	0–10	36	30–43
Limbanga	8	0–17	30	13–50

Source: Hillocks *et al.*, 1999

Some local cultivars, e.g. Nanchinyaya, have exhibited a form of tolerance to CBSD in which foliar symptoms appeared but the development of root necrosis was delayed allowing the full yield potential to be re-

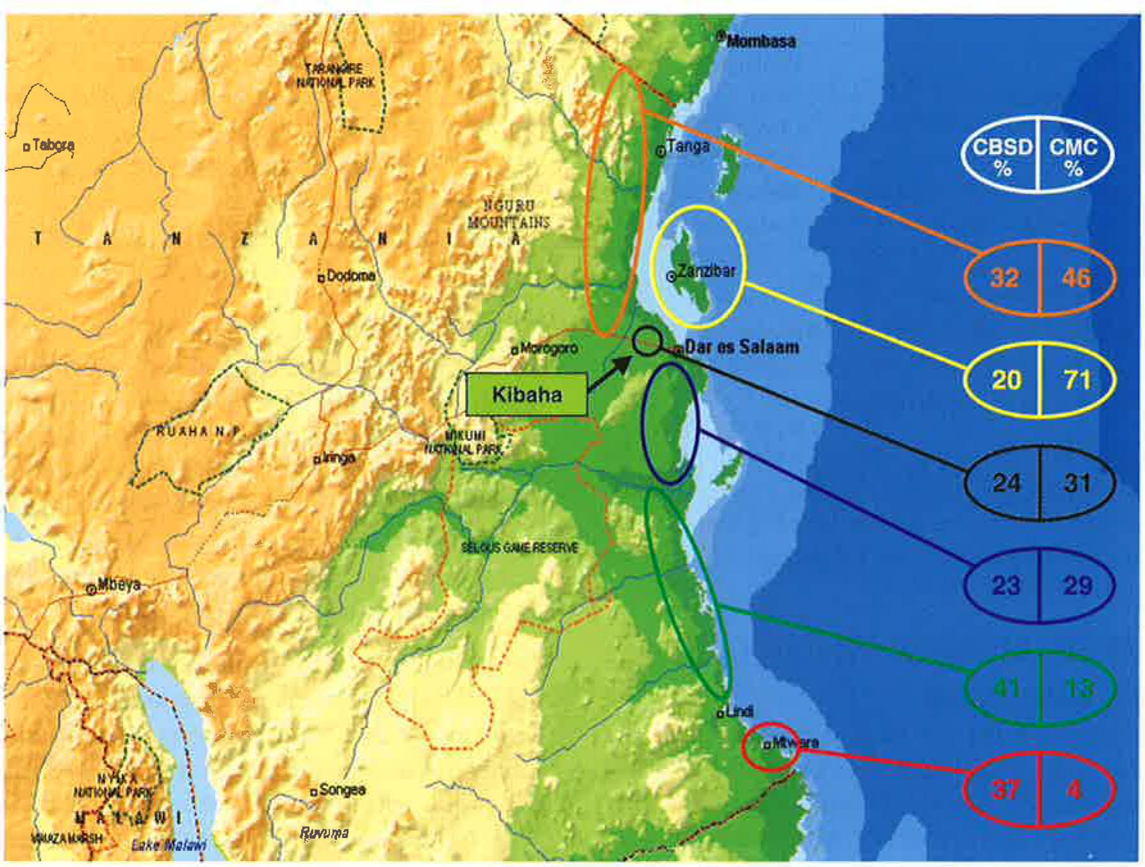

Figure1 Cassava virus disease survey data, along coastal plain of Tanzania 1998–2001

Table 7. Most frequently encountered cassava cultivars (three or more fields) and incidences of CMD and CBSD in Tanzania

Area	Most common cultivars	Number of fields	Mean incidence (%) CMD	Mean incidence (%) CBSD	*B. tabaci*/ plant (number)
Kigoma	Kalulu	6	47.8	0	0.8
Total named cultivars = 4	Kazulabo	4	37.5	0	2.0
	Kilisi	3	21.1	0	3.0
	Naihunde	10	26.0	0	3.4
North-west	Liongo				
	Kwimba	4	8.4	0	1.0
(Mwanza, Nzega and Tabora)	Mganda	3	12.2	0	1.0
Total named cultivars = 10	Kabumba	5	2.7	0	1.3
	Mwasunga	12	1.1	0	0.58
Islands	Agriculture	9	73.0	0	2.1
(Zanzibar and Pemba)	Kiberiti nyeusi	7	11.4	0	2.7
Total named cultivars = 13	Kishindo	3	50.0	0	3.0
	Mjawa	5	64.0	0	6.8
	Mtaimbo	4	34.2	0	2.0
South-east	Albert	3	44.4	11.1	3.7
(Newala, Mtwara and Masasi)	Kigoma cheusi	6	43.4	15.6	7.2
Total named cultivars = 18	Nanjenjeha	3	44.5	1.1	2.7
	Mreteta	12	22.5	24.2	12.8
Tanga	Kibandameno	5	73.3	3.3	7.4
Total named cultivars = 7	Mahiza	7	87.2	2.4	7.6
Central east	Mtabora	3	40.0	0	12.7
(Morogoro-Segera, Dar es Salaam)					
Total named cultivars = 14					
South-west	Beatrice	4	0	0	0.75
(Manda, Mbamba Bay and Tunduru)	Dide	4	5.0	0.8	1.5
Total named cultivars = 13	Gomani	7	2.4	38.1	0.57
	Kifu cha nazi	7	0	0	0.29
	Mwaya	3	7.8	0	0.67
	Songolo	3	21.1	18.9	0.33

Source: Legg and Raya, 1998

alized. (Hillocks *et al.*, 2001). In this case, a plant is susceptible to CBSD, foliar symptoms are expressed but little effect is observed in the root.

For cultivar Mreteta, similar results were obtained by Legg and Raya (1998) who recorded 24% CBSD incidence (Table 7). Other cultivars like Kigoma Cheusi, Gomani and Songolo were also observed to have relatively high CBSD incidences.

CBSD in Muheza District, Tanga (North-east Coast)

A survey was carried out in Muheza district by the root/tuber team from Kibaha in April 2002. It was a response to farmers' demand for action to control what they termed as 'cassava root rot' or *Vidonda* in Swahili, reported by the District Extension Officer. Farmers said the disease had become more serious after El Nino rains of 1997/98. Three villages were surveyed to examine the problem of cassava root rot. Information on varieties/cultivars and crop age was gathered from individual farmers, and a destructive sampling on roots was performed in fields with mature crops of about 12 months. A total of 15 fields were sampled (5 in each village); yield crop loss due to cassava root rot and severity were determined. The root rot described by farmers was found to be CBSD.

Two main cultivars are grown for food and cash most marketable – Mahiza and Kibandameno. Mahiza, the more marketable, was found to be more susceptible to CBSD than Kibandameno. Root necrosis will appear if the crop is left in the field for more than 12 months. A few farmers were harvesting early, between 8–10 months, and managed to escape the problem. Most farmers are not aware of the stem and leaf symptoms.

Table 8. Yield of cassava and proportion of roots affected by CBSD, Muheza, Tanga, Tanzania, 2002

Village	Weight of roots (t/ha)	Weight of unmarketable roots (t/ha)	Crop loss (%)
Tongwe	10.8	5.3	49
Songabatini	22.4	14.2	63
Magoda	12.7	9.4	74
Mean	15.3	9.6	62

Source: Muhanna and Mtunda (unpublished data)

Crop loss as a result of the disease was 62% on average for the three villages (Tables 8).

Discussion

Surveys done between 1993 and 2002 have shown that CBSD was largely confined to the lowland coastal area of the mainland, Zanzibar and the Lake Malawi shores. This was consistent with previous findings (Nichols, 1950) with the exception of Tabora, which is located at 1200 m asl, an altitude above the normal limit for CBSD, although incidence (Table 7) was very low (0.5%).

The distribution of CBSD was much more localized than that of CMD, with local differences in incidence due to altitude, varying sensitivity of cultivars and sources of planting materials. The disease occurred most frequently along the coastal plain, most particularly to the south between the Rufiji River and Mtwara. Increased incidences have been observed in areas around Dar es Salaam and Tanga, where low incidences were previously recorded (1993/94). New infection has been observed in Zanzibar where no incidence was found in 1993/94 (Thresh and Mbwana, 1998; Legg and Raya, 1998).

From data presented here and elsewhere (see Hillocks, pages 23–27), it is clear that cassava virus diseases and CBSD in particular cause substantial losses to cassava production in Tanzania. Tremendous losses are currently being incurred with sensitive cultivars, as demonstrated so clearly from the data for Muheza district in Tanga, where losses of up to 64% were recorded and some farmers reported having to abandon cassava for other crops. This situation demands that urgent attention is given to strengthening the management of CBSD in Tanzania. Only following such interventions will production be enhanced and opportunities provided to farmers for not only meeting their food needs, but also exploiting the numerous opportunities that exist for generating income from the sale of production surpluses.

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Current Status of Cassava Brown Streak Disease in Kenya

R.W. Njeru[1] and T.L. Munga[2]

[1] University of Nairobi, Crop Protection Department, Nairobi, Kenya
[2] Kenya Agricultural Research Institute, Regional Research Centre – Mtwapa, Mtwapa, Kenya

Introduction

Cassava (*Manihot esculenta* Crantz) is widely grown in Kenya and is an important staple food in the western and coastal regions of the country. The roots are a major source of carbohydrates while the leaves are used as a vegetable and are a source of vitamins, minerals and proteins. Nationally, cassava continues to play a big role as a food security crop and is produced mostly through subsistence farming. The crop is mainly grown for human consumption yet there is great potential for use in the feed industry. Cassava production is concentrated in the western and coastal areas of the country (MOA, 1999; Mbwaka, 2000) and the low yields (3–9 t/ha) in farmers' fields are attributed to both abiotic and biotic factors. Cassava mosaic virus disease (CMD) caused by cassava mosaic geminiviruses (CMGs) (Thresh *et al.*, 1998) and cassava brown streak virus disease (CBSD) caused by *Cassava brown streak virus* (CBSV) (Monger *et al.*, 2001) are the major biotic constraints to cassava production in the country.

Prevalence of CMD and CBSD

CMD has been reported in all cassava growing areas. Epidemiological trials in western and coastal regions carried out by Bock (1994) reported incidences of 2–10%. Later surveys revealed incidence levels above 80% in western Kenya (Legg, 1999) and 56% levels in coastal Kenya (Kamau, unpublished). An additional brief survey carried out in coastal areas (Thresh, 2000) reported an overall incidence level of 60%. Generally, there has been a significant increase in CMD incidence throughout the country. Although local yield loss data are scarce, CMD typically causes significant yield losses ranging from 24–75% (Seif, 1982; Lwanga, 2000).

In the coastal areas, cassava is also infected with CBSD. The disease was first reported in Tanzania (Storey, 1936) and in 1950 Nichols reported that CBSD was endemic in all East African coastal cassava growing areas, extending from the north-east border of Kenya to the Tanzanian border. In Kenya CBSD is confined to the coastal areas. Bock (1994) reported that CBSD was present in all coastal districts namely, Kwale, Mombasa, Malindi and Kilifi although the incidence was low. The rate of natural spread was low (6%) and the main spread of the disease was through the use of infected cuttings. Whereas recent work in Tanzania (Hillocks *et al.*, 2001) showed a significant reduction in tuber yield due to CBSD, previous work in Kenya (Bock, 1994) showed insignificant effects on the weight of tuberous roots but root necrosis rendered a large proportion of tubers inedible.

Despite the effect of CBSD on the root quality of both the local and improved cultivars, no attention was given to the disease until 2000 when Thresh carried out a brief survey along the Lunga Lunga-Malindi highway. The survey reported CBSD in 22 of the 29 plantings assessed although the disease incidence was low.

No detailed survey has been carried out throughout the interior of the coastal areas to establish the status of CBSD. However, observations made by the authors on a few farms have revealed that the disease is present, extending from the Kenya-Tanzania border to the north-eastern areas of Malindi. It still remains to be established whether CBSD is common in Taita Taveta district of coastal Kenya, which stands at a higher altitude than the rest of the coastal areas.

Symptoms

Scientists in many disciplines and agricultural extension workers associate CBSD foliar symptoms with nutrient deficiency. To the farmers, the most conspicuous disease symptom is the root necrosis as reported in Tanzania (Hillocks *et al.*, 1996). Farmers associate the root necrosis with long storage in the ground and/or too much water in the soil. Farmers discard tubers manifesting extensive necrosis but cut out affected portions in tubers with slight necrosis. Farmers make no association between shoot and root symptoms although they have reported an increase in tuber necrosis at harvest period. In addition, farmers lack accu-

Cassava Brown Streak Virus Disease: Past, Present and Future. Proceedings of an International Workshop, Mombasa, Kenya, 27–30 October 2002. Legg, J.P. and Hillocks, R.J. (Eds) (2003). Natural Resources International Limited, Aylesford, UK. 100 pp.

rate information on the cause and spread of CBSD. Therefore, there is a need to provide accurate information on diagnosis, cause, spread and management of CBSD.

Disease management

The most commonly grown cultivar (Kibandameno) is highly susceptible to both CMD and CBSD but the hybrid Kaleso is tolerant to CBSD. The response of most landraces to CBSD infection and the effects of the virus on cassava yield need to be established. In addition, there is a need to carry out epidemiological studies in order to provide essential information for the development of disease management strategies so as to increase cassava productivity.

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Cassava Brown Streak Virus Disease Research in Northern Mozambique

S. Mangana

Zambézia Agricultural Development Project – World Vision International, Quelimane, Mozambique

Introduction

In Mozambique cassava (*Manihot esculenta* Crantz) is the second most important staple food after maize (*Zea mays* L.). More than 50% of the population depend on it; principally the poorer communities grow it as a livelihood security food (MOAF, 1994). The four main provinces for cassava production are Nampula, Zambézia, Cabo Delgado and Inhambane.

Yields in the country are consistently low when compared with yield potential. Many factors contribute to this, such as low soil fertility, lack of improved cultivars, poor access and quality of markets, and processing using labour intensive methods. Apart from environment factors, pests and diseases are considered to be the main constraint to cassava production. Cassava mosaic virus disease (CMD) and cassava brown streak virus disease (CBSD) are the important diseases while cassava green mite (CGM) and cassava mealybug (CM) are the main pests.

Since 1997, farmers have been reporting major losses of cassava caused by a root rotting disease, which by 1998 were considerable, and had infected large areas of coastal Nampula province in the northern part of the country. As a result, many farmers started to turn to alternative crops. Farmers in the Zambézia Province, immediately to the south of Nampula were finding the same problem of cassava rot rooting, but were using an avoidance strategy by harvesting roots before the crop had matured so as to reduce the amount of tuber rotting and losses. Two virologists from the Natural Resources Institute (NRI) identified the disease as CBSD in 1999 during a survey carried out in the affected areas of Nampula and Zambézia provinces (Hillocks *et al.*, 2001). From the survey two zones were defined, one with low incidence and the other with high incidence. A consortium of NGOs and Provincial Directorates of Agriculture (DPAs) was formed to investigate and implement possible joint courses of action to alleviate the affected areas in Nampula and Zambézia, especially those suffering from immediate hunger. As a part of this plan, it was decided to set up a number of trials using some promising cultivars in both provinces for testing their tolerance/resistance to CBSD. These trials were established in December 2000.

Cassava Brown Streak Virus Disease: Past, Present and Future. Proceedings of an International Workshop, Mombasa, Kenya, 27–30 October 2002. Legg, J.P. and Hillocks, R.J. (Eds) (2003). Natural Resources International Limited, Aylesford, UK. 100 pp.

Methodology

The trials were carried out at by three research stations at five sites in Nampula and Zambézia provinces and were managed by the following projects: Save the Children (SCF), USA-funded, working in the Nacala coastal area; Nampula Food Security Programme (NFSP), European Union funded/World Vision International (WVI), working in the Mossuril-Angoche coastal region; Instituto Nacional de Investigação Agronómica (INIA) Nampula; and Zambézia Agricultural Development Project (ZADP), Department for International Development (DFID) funded/WVI, working in Gurué, Namacurra and Nicoadala Districts.

Two separate sets of trials were organized for areas of high incidence (NFSP, SCF and ZADP–Namacurra) and of low incidence (INIA–Nampula and ZADP–Gurué). High incidence areas had a full range of cultivars plus a local cultivar. The most common cultivars included: Binte Masude, Muendowaloya, Chigoma Mafia, Nanchinyaya (from Cabo Delgado), Mulaleia, Macia I (from Zambézia), MZ89186 and MZ89001 (from INIA) and Nikwaha (Nampula). In the low incidence area four cultivars were tested: Macia I, MZ89001, MZ89186 and Nikwaha.

Each cultivar plot consisted of a total area 49 m^2 (7 × 7 m). The distance between plants in rows and between rows was 1 m. In addition to the on-station trials, on-farm trials were conducted at the same time in all places. In these trials only one plot of 7 × 7 m or one line per cultivar was established due to the lack of suitable cuttings. The experimental design was a random complete block with four replications. The trials were planted in December 2000 and harvested from October 2001.

During the season, data concerned with phytosanitary problems were taken in the experiments including

CBSD leaf symptoms. At harvest time, the roots were graded into marketable and non-marketable. The marketable roots were those with good size, well shaped and free of defects, and non-marketable ones were the roots with poor quality and/or small size, misshapen or unattractive and with defects. Farmers were invited to evaluate the cultivars and a scoring system was used which ranged from 1 (poor) to 5 (very good).

Analysis of variance (ANOVA) for all the parameters was done using the GenSTAT version 5 computer package.

Results and discussion

Statistical analysis was done for all the parameters measured in all the environments. Significant differences occurred at 5% of probability only at Mutange Station and not at the two other stations.

Gurué Station

In the Gurué trials, yields of the cultivars Nikwaha, MZ89001 and Macia I were relatively high compared to other cultivars although they were not statistically different, with 4.6 t/ha for Nikwaha, 3.8 t/ha for MZ89001 and 3.7 t/ha for Macia I. A low yield of 1.9 t/ha was observed in the local cultivar Kangale (Table 1).

Plant development was poor due to low soil fertility characterized by zinc deficiency. Root knot nematodes were present, particularly on MZ cultivars and there was some mealybug attack, especially on Macia I. Nikwaha, Macia I and the local cultivar were also heavily infected by CMD (Table 2). These factors largely account for the low yields.

Root necrosis was observed in non-marketable roots in three cultivars: Macia I (4.6%), Kangale (7.8%)

Table 1. Yield data[1] for varietal cassava selections at three stations, Mozambique, December 2000 to November 2001

Treatment	Establish-ment (%)	Yield (t/ha)	TNCR	TNNCR	TYCR (t/ha)	TYNCR (t/ha)	CRS (%)	NCRS (%)
Gurué Station, Zambézia Province								
Macia I	68	3.5	18	38	1.9	1.6	0	4.6
MZ89001	83	3.8	23	56	1.7	2.1	0	0
MZ89186	77	3.4	27	48	1.8	1.6	0	0
Nikwaha	96	4.6	19	28	3.1	1.5	0	0.9
Kangale	58	1.9	7	33	0.7	1.3	0	7.8
Average	77	3.4	19	41	1.8	1.6	0	2.7
Mutange Station, Zambézia Province								
Macia I	40	3.3	16	18	2.1	1.1	5.8	17.5
Mulaleia	94	5.8	41	49	3.4	2.4	7.0	11.8
Nanchinyaya	88	4.2	22	23	2.9	1.3	12.0	8.0
Chigoma Mafia	100	3.8	24	16	2.9	0.8	8.8	13.8
Binte Masude	86	2.5	12	21	1.4	1.1	0.8	8.7
Muendowaloya	83	7.2	40	29	5.1	2.1	10.0	13.9
Nikwaha	69	2.7	11	18	1.1	1.6	0	2.0
Local	47	3.6	18	17	1.6	2.0	5.3	27.6
Average	87	4.1	23	24	2.6	1.6	18.0	12.9
Lumbo Station, Nampula Province								
Macia I	84	5.5	64	53	4.5	0.94	2.4	0.13
Mulaleia	79	4.4	45	62	3.2	1.25	5.0	0.16
N'lachi	55	5.0	27	49	3.4	1.62	65.3	31.1
Muendowaloya	67	5.1	71	67	4.0	1.04	11.2	2.6
MZ89001	62	2.9	52	35	2.5	0.43	1.7	0
Binte Masude	85	4.0	52	44	3.3	0.55	2.8	0.34
Nikwaha	92	4.5	66	51	3.8	0.63	2.3	0.15
Chigoma Mafia	89	4.6	78	63	3.9	0.69	2.0	0
Nanchinyaya	87	4.4	74	86	3.3	1.11	4.0	0.79
Average	78	4.5	59	57	3.5	0.92	10.7	3.9

1. TNCR = total number of marketable roots; TNNCR = total number of non-marketable roots
TYCR = total yield of marketable roots; TYNCR = total yield of non-marketable roots
CRS (%) = percentage of marketable roots roots with CBSD symptoms; NCRS (%) = percentage of non-marketable roots roots with CBSD symptoms.

Table 2. Pest and disease incidences[1] in cassava trials at three research stations, Mozambique, June 2001

	Zambézia Gurué			Zambézia Mutange			Nampula Lumbo		
Treatment	CBSD (%)	CMD (%)	CM (%)	CBSD (%)	CMD (%)	CM (%)	CBSD (%)	CMD (%)	CM (%)
Macia I	26	33	67	95	26	28	0	0	36
Mulaleia	–	–	–	100	4	0	51	3	42
MZ89001	3	6	0	17	20	0	0	0	32
MZ89186	9	19	0	22	8	0	10	1	34
Chigoma Mafia	–	–	–	13	6	0	2	0	20
Binte Masude	–	–	–	23	41	4	0.5	2	23
Nanchinyaya	–	–	–	100	56	2	16	3	6
Muendowaloya	–	–	–	21	7	0	26	5	15
Nikwaha	12	23	40	100	85	0	21	3	0.5
Ernesia (local)	–	–	–	100	61	0	–	–	–
Kangale (local)	51	35	57	–	–	–	–	–	–
N'lachi	–	–	–	–	–	–	89	27	17

1. CBSD = cassava brown streak disease; CMD = cassava mosaic virus disease; CM = cassava mealybug. Mean of four replications.

and one other with 0.9%. These results were found also in the on-farm trial in Nipive, Gurué (Table 3).

Mutange Station

Macia I and the local cultivar showed a low establishment rate – 40% for Macia I and 47% for the local cultivar. High percentages of establishment were observed in the cultivars Chigoma Mafia (100%) and Mulaleia (94%) (Table 1). For total yield, the best cultivars were Muendowaloya (7.2 t/ha), Mulaleia (5.8 t/ha) and Nanchinyaya (4.2 t/ha). Binte Masude and Nikwaha were the lowest yielding cultivars with 2.5 t/ha for Binte Masude and 2.7 t/ha for Nikwaha.

Nanchinyaya and Muendowaloya showed a high percentage of necrosis in marketable roots, having 12% (Nanchinyaya) and 10% (Muendowaloya). In non-marketable roots the local cultivar was highly affected with 27.6% infected, followed by Macia I with 17.5% infection. The best cultivar was Nikwaha with 2% of infection in non-marketable roots (Table 1). This result was also confirmed in the on-farm trial in Pidá (results not given here).

During the season a high infestation of mealybug was observed and the cultivars Macia I, Nikwaha and the local cultivar were worst affected (Table 2).

Lumbo station

Macia I (5.5 t/ha), Muendowaloya (5.1 t/ha), Chigoma Mafia (4.6 t/ha) and Nikwaha (4.5 t/ha) were the higher yielding cultivars although they did not differ statistically from others.

Conclusions and recommendations

The results from the cultivar trials can only serve as a basis for subsequent work as firm conclusions cannot be made from only one season's results. The Nikwaha

Table 3. Yield data[1] and CBSD symptoms[2] in on-farm trials at Cassine in Nipive, Gurué, Province of Zambézia, Mozambique, 2001

Cultivar	Establish-ment (%)	Number of roots	PTR (kg)	CRS (%)	CRSS (%)	NCRS (%)	NCRSS (%)	Height of plant (m)
Macia I	80	18	2000	25	60	2.5	13	0.4
MZ89001	80	5	350	0	57	0	43	0.3
MZ89186	80	16	2150	0	88	0	12	0.3
Nikwaha	80	16	3750	0	80	0	20	0.5
Capiye	100	18	5600	29	51	1.8	18	1.2

1. PTR = total weight of roots
2. CRS (%) = percentage of marketable roots with CBSD symptoms; CRSS (%) = percentage of marketable roots without CBSD symptoms; NCRS (%) = percentage of non-marketable roots with CBSD symptoms; NCRSS (%) = percentage of non-marketable roots without CBSD symptoms.

cultivar presented a low percentage of CBSD infection that varied from 0.9% to 2.5%, while Muendowaloya was more heavily infected, from 10.0% to 12.2%. It was observed that there was a low level of root necrosis in Chigoma Mafia in the Lumbo (Nampula) trial and also in some of the other on-farm trials. Both Binte Masude and MZ89001 presented low necrosis in roots in most of the cultivar trials. These types of trials must be continued in different seasons and different ecological areas to get more conclusive information.

There is a need to improve and harmonize the methodology used for CBSD evaluation, e.g. score definition, crop stages in which the evaluation must be done, and the number of evaluations during the crop season

In the high incidence areas of CBSD, the farmers are harvesting the crop before it reaches complete maturity. The research programme must include harvest date trials to recommend to farmers the optimum harvest times.

Summary

Local cassava cultivars were selected from the provinces of Zambézia, Nampula and Cabo Delgado in central and northern Mozambique for their tolerance/ resistance to cassava brown streak virus disease (CBSD). They were tested in different agro-ecological conditions in the Nampula and Zambézia Provinces.

Nine cultivars were tested in areas of high incidence of the disease, and five cultivars in the areas of low incidence. Performance of the tested cultivars was significantly different at Mutange-Namacurra, but not in the trials at Gurué and Lumbo-Ilha de Moçambique.

In Mutange-Namacurra, the best yields were observed in cultivars Muendowaloya, Mulaleia, Nanchinyaya and Chigoma Mafia. The cultivar Binte Masude was lower yielding. Muendowaloya gave a good yield in the trial at Lumbo but this was not significantly different from the other cultivars.

The cultivars Nikwaha and Binte Masude both had a low level of root infection from CBSD, although Nikwaha had a high level of infection in the aerial parts of the plant, at all sites. In palatability tests farmers selected Nikwaha, Chigoma Mafia and Macia I as having the best flavour and plant structure.

Results obtained from these cultivar trials can serve as a basis for subsequent work as firm conclusions cannot be made from only one season's results. More studies are recommended for verification of these results.

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Cassava Brown Streak Virus Disease in Malawi

E.R. Shaba[1], F. Chipungu[1] and E.D.L. Mazuma[2]

[1] Bvumbwe Agricultural Research Station, Limbe, Malawi
[2] Chitedze Agricultural Research station, Lilongwe, Malawi

Introduction

Cassava (*Manihot esculenta* Crantz) crop was introduced into Malawi in the 17th and 19th centuries (Sauti, 1981). It is an important food and cash crop for many Malawians. It is the second most important food crop after maize (*Zea mays* L.) and is a staple food for more than 30% of the Malawian population. It is grown throughout the country as a food security crop and a source of income. Leaves are used as a valuable vegetable. The area under cassava production continues to increase as more and more people grow cassava both for food security and cash generation.

Diseases and pests are the main factors limiting the production of cassava. Important pests of cassava in the country are cassava mealybug (CM), *Phenacoccus manihoti*, and cassava green mite (CGM), *Mononychellus tanajoa*. Important diseases of cassava are cassava mosaic virus disease (CMD), cassava brown streak virus disease (CBSD) and cassava bacterial blight (CBB), *Xanthomonas campestris* pv. *manihotis*.

CBSD was first reported by Storey (1936) in Tanzania, while in Malawi it was first reported in 1950 by Nichols. The disease was reconfirmed in 1990 during collaborative work with the Natural Resources Institute (NRI). It is caused by a single stranded RNA (ssRNA) virus in the family *Potyviridae*; genus *Ipomovirus*. CBSD symptoms include leaf discoloration, chlorosis and brown streaks on the leaf and stem. Most importantly, however, a yellow to brown dry necrotic rot is produced in the roots of severely affected plants that renders them unusable. The disease spreads naturally in the field but a vector has yet to be identified. The symptoms can sometimes be masked by symptoms of CMD making it difficult to identify the disease in the field (Bock and Guthrie, 1976). CBSD alone has been reported to cause up to 70% yield loss in Tanzania (Hillocks *et al.*, 2001) and the combination of the two diseases can cause total loss (Jennings, 1970).

Cassava Brown Streak Virus Disease: Past, Present and Future. Proceedings of an International Workshop, Mombasa, Kenya, 27–30 October 2002. Legg, J.P. and Hillocks, R.J. (Eds) (2003). Natural Resources International Limited, Aylesford, UK. 100 pp.

Unlike CMD, little work has been done on CBSD in Malawi. This paper discusses the status of CBSD in the country. Efforts were made to establish the incidence, severity and distribution of CBSD in Malawi through two surveys conducted in 2001 and a third in 2002.

Distribution of CBSD in Malawi

The first two surveys showed that the disease is widespread in the country. The third survey was done to establish the effects of the disease on the roots of infected plants. The incidence and severity was high in low-lying areas of Lake Malawi: Karonga, part of Rumphi (which is along the lakeshore), Nkhata Bay, Nkhota Kota, Salima and Mangochi. The most severe cases were observed in Nkhota Kota and Nkhata Bay. Typical root necrosis symptoms were observed in all areas mentioned. The third survey was a follow-up survey, which was done in three zones of Karonga, Mzuzu and Salima Agricultural Development Divisions. Root necrosis scores were higher in the Nkhata Bay and Salima areas.

Losses due to CBSD

The majority of farmers experience cassava yield losses of up to a maximum of 60%. Over 20% of the farmers experience a loss of above 40% (Gondwe *et al.*, this volume, pp. 000). CBSD reduced yield by reducing the size of roots and by causing pitting and constriction, which rendered the roots unusable. The average loss due to CBSD damage along the lakeshore in 2001 was from 137,000 t to 172,000 t.

Efforts to control CBSD

As previously highlighted, not much is known about the status and impact of CBSD in Malawi. Some research was carried out for four years both on-station and on-farm to evaluate cultivars for resistance to major pests and disease problems including CBSD. Two cultivars, CH92/112 and CH92/077, showed some level of resistance to CBSD. These cultivars are due for release.

Over 100 families of cassava were planted at a seedling nursery at Chitala Research Station in Salima District where CBSD is prevalent. Clones which show

CBSD symptoms are normally marked red for eradication.

Future plans for CBSD work in Malawi

Since the disease is already present in all areas of the country, quarantine is of no use. The first step in tackling CBSD is to identify resistant cultivars that are high yielding and have characteristics desired by the people and the commercial industry. The cultivars should also be resistant to other major diseases (CMD and CBB) and pests (CM, CGM and termites). Once resistant cultivars have been identified, they should be multiplied and distributed to farmers.

There is a need to organize campaigns and to train farmers as well as extension staff in field disease identification and application of control measures. It should also be noted that very little work has been done on CBSD, and Malawi could benefit from sharing research experience with counterparts who have had a longer working experience on the disease. There is a need to intensify efforts to control the disease both through research and dissemination of information as the disease seems to be becoming more prevalent and severe than in previous years.

Areas which need further research include the field assessment of yield losses due to CBSD in Malawi, the effect of altitude on the severity of CBSD and the identification of alternative hosts for CBSD (if they exist) to improve management and aid in the development of an integrated pest management (IPM) approach to CBSD control. Training is necessary for scientists in order to acquire the required knowledge in carrying out this type of research and for extension people and farmers to equip them with knowledge in management of the disease.

Summary

CBSD is one of the major constraints to cassava production in Malawi. Currently, very little work has been done on the disease in the country. Three surveys to assess the distribution and severity, economic losses and farmers' knowledge of the disease showed that it is widely distributed and severity is high in the low lying areas of Malawi, particularly along the shore of Lake Malawi in the areas of Nkhata Bay, Nkhota Kota and Salima. According to farmers, economic losses can be as high as 60%. Yield losses due to CBSD along the lakeshore ranged from 137,000 t to 172,000 t in 2001. Current efforts to manage the disease involve the evaluation of cassava cultivars for resistance to CBSD and other important pests and diseases. Two cultivars were identified that showed some levels of resistance to CBSD, CH92/077 and CH92/112. These will be multiplied and distributed to farmers. There is a need for campaigns and training for extension staff and farmers in the identification and management of the disease.

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CURRENT CBSD RESEARCH

Cassava Brown Streak Virus Disease: Summary of Present Knowledge on Distribution, Spread, Effect on Yield and Methods of Control

R.J. Hillocks

Natural Resources Institute, University of Greenwich, Chatham, UK

Introduction

Cassava brown streak virus disease (CBSD) was first described by Storey (1936) from symptoms observed near the coast in northern Tanzania. The disease was later reported to be widespread on the East African coast and Malawi up to an altitude of 1000 m asl (Storey, 1939; Nichols, 1950). Disease incidence data were not presented. CBSD was considered sufficiently important for resistance breeding to be included in the cassava (*Manihot esculenta* Crantz) improvement programme supported by the British Government during the 1940s and 1950s under the auspices of the East African Agriculture and Forestry Research Organisation (EAAFRO). A number of selections derived from crosses made at that time were distributed to research stations across East Africa in the late 1950s and some of this material has recently been retrieved for use in current CBSD breeding programmes. During the 1970s and 1980s some work was conducted in Kenya on the aetiology of CBSD supported by the UK Government, but little was done on the management of CBSD. The research focus was on the other main virus disease affecting cassava in Africa, cassava mosaic virus disease (CMD). Then, during the late 1980s, CBSD was observed at unexpectedly high incidences between Dar es Salaam and Morogoro, in Tanzania. This led to a project funded by the UK Department for International Development Crop Protection Programme (DFID-CPP). The project was managed by the Natural Resources Institute (NRI) and built upon the previous work of EAAFRO. This project has extended our knowledge of the distribution and spread of CBSD, its symptomatology and has promoted the use of local cassava cultivars that show tolerance to the root necrosis symptom of CBSD as an interim approach to control in areas severely affected by the disease.

Cassava Brown Streak Virus Disease: Past, Present and Future. Proceedings of an International Workshop, Mombasa, Kenya, 27–30 October 2002. Legg, J.P. and Hillocks, R.J. (Eds) (2003). Natural Resources International Limited, Aylesford, UK. 100 pp.

Distribution

A number of surveys have been conducted by projects funded by DFID-CPP that confirmed the presence of CBSD at high incidences in the coastal areas of Kenya, Tanzania, northern Mozambique and areas close to the shore of Lake Malawi in both Tanzania and Malawi (Legg and Raya, 1998; Hillocks *et al.*, 1996; Thresh and Mbwana, 1998; Munga and Thresh, 2002; Gondwe *et al.*, 2002). Surveys conducted in 1999 reported CBSD from Mozambique for the first time and found the disease to be present at alarmingly high incidences in some of the coastal districts of Nampula and Zambézia provinces (Hillocks *et al.*, 2002). As noted by Nichols (1950) the distribution of CBSD is delimited by altitude. The disease is rarely found above 1000 m asl, although symptoms can be expressed at altitudes above this if infected cuttings are taken from the coast. This pattern of distribution has been confirmed in Tanzania (Table 1), Mozambique and Malawi, with highest average incidences occurring below 300 m, moderate incidences between 300 m and 600 m and low incidences above 600 m (Hillocks *et al.*, 1999; Hillocks *et al.*, 2002; Gondwe *et al.*, 2002). The explanation for such a restricted pattern of distribution is unknown at present but is likely to be due to either, or both, the distribution of the vector and the distribution of alternative hosts in the natural vegetation.

Table 1. Effect of altitude on disease and pest incidence[1] in cassava in Mtwara Region of south Tanzania

Altitude (m asl)		CMD	CBSD	Whitefly/field (number) Bt	Ba
High	400–700	17.3	10.3	19.0	2.5
Mid 1	300–400	16.8	23.2	23.0	1.2
Mid 2	200–300	14.3	26.8	92.6	8.5
Low	0–200	8.8	51.4	119.5	9.9

1. Bt = *Bemisia tabaci*; Ba = *Bemisia afer.*

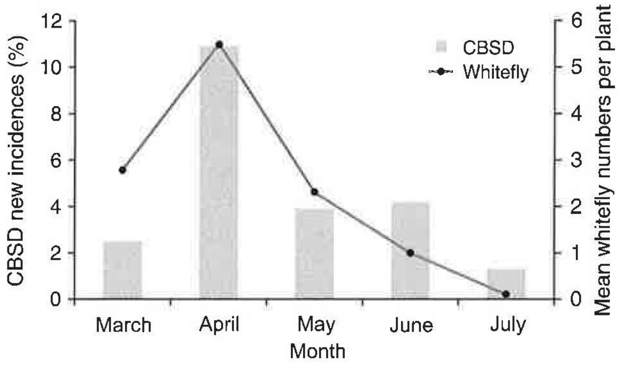

Figure 1 New incidences of CBSD and mean monthly whitefly population at Kibaha, Tanzania, in 1998

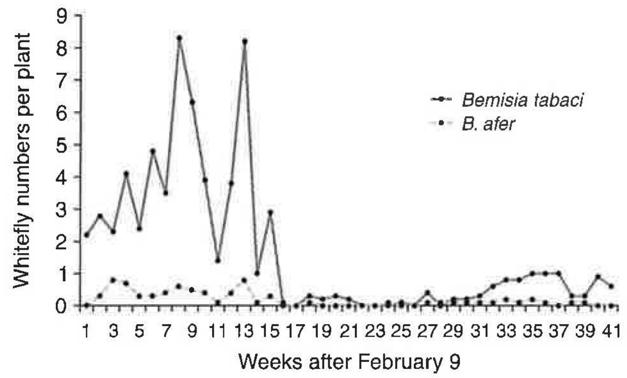

Figure 2 Weekly changes in whitefly populations on cassava at Kibaha, Tanzania, in 1998

Aetiology

It was reported that two different flexuous filamentous particles occur in CBSD-affected plants (Lennon *et al.*, 1986), and sap transmission to herbaceous hosts induced 'pin-wheel' inclusions, similar to those associated with the *Potyviridae* (Harrison *et al.*, 1995). This suggested that CBSD-affected cassava was infected either with a novel type of virus or with a complex of two dissimilar viruses. Brunt *et al.* (1990) describe two brown streak viruses, a 'carlavirus' and a 'potyvirus'. They also stated that the carlavirus was transmitted by *Bemisia tabaci* although this was speculation and had not been demonstrated experimentally. The role of the two types of particle associated with CBSD symptoms had not been determined and the aetiology of the disease remained uncertain until the report of Monger *et al.* (2001), which supported the view that CBSD is caused by a virus in the genus *Ipomovirus* of the family *Potyviridae* (see Legg, pages 41–45).

Disease spread

Field experiments in Tanzania have shown that CBSD spreads between plants within a field of cassava plants planted from virus-free stocks. However, the vector remains unknown. Transmission experiments have been conducted with aphids (Lennon *et al.*, 1986) without success and with whitefly (Hillocks *et al.*, unpublished). Results from cage experiments in Tanzania seemed to result in two transmissions with the whitefly, *B. tabaci* (Mtunda and Kiozia, unpublished). However, repeated attempts at NRI to transmit CBSV from cassava to cassava and from *Nicotiana benthamiana* to cassava using both *B. tabaci* and *B. afer* have failed. Further work is required on this important aspect of the epidemiology of CBSD. Results from field experiments on disease spread show that the main period for spread in Tanzania is April and May in crops planted in January and February (Figure 1) Further spread ceases with the onset of the dry season. This may be because the plants are no longer attractive to the vector or the vector disappears in the dry season. This coincides with the peaks in whitefly population (Figure 2). In one year, 1999, there was a very close association between new incidences of CBSD and fluctuations in whitefly population (Figure 3). However, there is no evidence that this is more than just a coincidence. Whitefly populations on cassava decline almost to zero in the dry season. Also by May, cassava green mite (CGM) damage to the upper leaves of the cassava crop in Tanzania has usually increased to the point where they become unattractive to whitefly. While further work on disease spread may help to indicate a possible vector, or eliminate whiteflies from the search, once the vector is known, it will be easier to conduct experiments on the dynamics of disease spread.

Effect of CBSD on yield

Previous results from experiments on the effect of CBSD on root yield have indicated that there is little effect on root weight but that root necrosis greatly decreases root quality. Work conducted in Tanzania has shown that loss of root weight is associated with

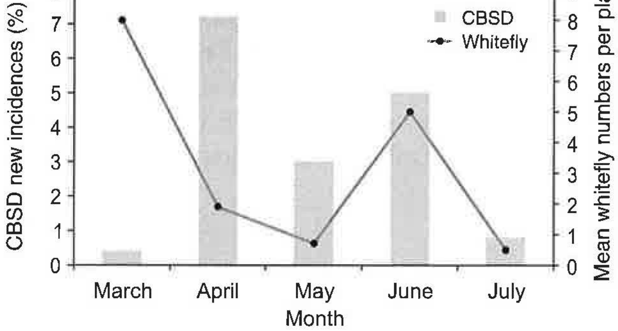

Figure 3 New incidences of CBSD and mean monthly whitefly populations at Naliendele, Tanzania, in 1999

Table 2. Incidence and severity of foliar and root symptoms of CBSD and yield from four cassava cultivars at Kibaha, Tanzania, planted March 1995, harvested March 1996

Cultivar	Source of cuttings	CBSD foliar symptoms maximum incidence (%)	Root necrosis severity (0–4)	Root yield (g/plant)	Loss (%) (H–D)[1]
Mreteta	H	26	1.4	1523	52
	D	63	2.5	724	
Kigoma	H	15	1.4	867	16
	D	68	2.3	724	
Albert	H	47	1.8	1511	55
	D	72	2.7	683	
Kibaha	H	5	1.2	878	29
	D	20	2.0	625	
LSD[2]			1.0	599	

1. H = healthy i.e. symptomless mother plants; D = diseased i.e. mother plants showing CBSD symptoms.
2. LSD = least significant difference.

CBSD and that it can be as much as 50% (Table 2) in the most susceptible cultivars.[1] The time of infection does not have much effect on the severity of root necrosis, which appears to be related more to the physiological age of the crop (Tables 3 and 4). Sequential harvesting experiments show that root fill is retarded in the more susceptible cultivars such as Albert as they become severely affected by necrosis, compared to the 'tolerant' cultivars, such as Nanchinyaya, that continue to bulk and in which root necrosis begins to appear much later in crop development (Table 5). However, the main cause of loss is when necrotic areas of the root have to be removed and discarded when the roots are peeled and chopped before drying. If the roots were intended for market however, then the loss is total as roots with CBSD root necrosis are unmarketable. Secondary losses occur as a consequence of early harvesting, which farmers use as a strategy to avoid root necrosis but the crop is harvested before reaching the roots are fully expanded. Such early harvesting or preference for early-maturing cultivars decreases the food security value of cassava, which has the benefit of being storeable in the field for harvest at the end of the dry season, when other sources of food are scarce.

Control

Management of CBSD depends on phytosanitary measures and/or the use of less-susceptible cultivars. Phytosanitation relies on the ability of the farmer to select planting material only from symptomless mother plants, and then to rogue out any plants that show symptoms soon after sprouting. In areas where no spread is occurring, this in itself would provide adequate control. The drawbacks to this approach are:

- Farmers often find it difficult to recognize CBSD symptoms because of their variability and they are poorly expressed on leaves that develop after dry season defoliation.
- Planting material is taken at different times.
- Planting material is often in short supply, decreasing the choice of plants from which to take it.
- Farmers are reluctant to rogue.

1. The necrosis scale of 0–4 in Tables 2 and 5 has been superceded by the IITA method using 1–5 [see Standardization of CBSD Evaluation (symptoms) in On-farm Working Group Report, p. 81].

Table 3. Root necrosis and root yield in relation to date when symptoms of CBSD were first observed in the rate of spread trial at Naliendele, Tanzania, 1999

Month of first symptoms	Roots/ plant (number)	Roots with CBSD necrosis (%)	Necrosis score (1–5)	Root yield (kg)
March (3)[1]	13	18	2	2.1
April (65)	7	44	2.3	0.96
May (27)	8	25	2.1	1.24
June (48)	6	28	2.1	1.00
July (6)	9	17	2.2	1.42
Symptomless (30)	11	0	1.0	3.03

1. Figures in parentheses are the total number of plants showing first symptoms at each date and from which all other records were derived.

Table 4. Yield from plants that developed CBSD foliar symptoms at different times and yield loss compared to symptomless plants at Naliendele, Tanzania, 1999

	Total root yield		Marketable yield	
Month of first score	Root wt (kg)	Loss[1] (%)	Market wt (kg)	Additional loss (%)
Symptomless	3.03	–	3.03	–
March	2.10	31	2.10	0
April	0.96	68	0.80	17
May	1.24	59	1.15	7
June	1.10	67	0.93	7
July	1.42	53	1.32	7

1. Compared to symptomless plants

- The crop will become re-infected if the incidence of CBSD in the surrounding fields is high and the vector is present.

The most realistic approach to control is the deployment of less-susceptible cultivars. There is no conclusive evidence that immunity to CBSD exists or that some cultivars can resist transmitted infection, although they might be fully sensitive to the disease once infected.

A number of local cultivars have been identified by the DFID-CPP project in both Tanzania and Malawi that show tolerance to root necrosis. That is to say they are fully susceptible to infection by the virus and display typical leaf symptoms, but the onset of root necrosis is delayed. The cultivar Nanchinyaya (see Table 5) was the first of these tolerant types to be identified and it is now widely grown in the Mtwara Region of southern Tanzania. Root necrosis may begin to show after 5–6 months in the more sensitive cultivars but is delayed until 12–18 months in Nanchinyaya. In the case of the cultivar Kiroba, it is simply early maturing and can be harvested at 6–9 months before severe necrosis occurs.

CBSD management in the DFID-CPP project is based on the multiplication and distribution of these tolerant local cultivars. This approach has also been adopted by several NGO programmes in northern Mozambique and by the Southern Africa Root Crops Research Network (SARRNET) disaster relief programme in Mozambique that is supported by the United States Agency for International Development (USAID).

A detailed review of present knowledge and research needs has recently been published to raise awareness amongst policy makers and to promote control measures and 'best bet' technologies (Hillocks and Jennings, 2003).

Table 5. Effect of harvest interval on CBSD root necrosis and root yield in three cassava cultivars in Naliendele, Tanzania, 1999

Harvest interval (months)	Cultivar	Necrosis score (0–4)	Root yield (kg)
6	Nanchinyaya	0	1.03
	Albert	1.23	1.07
	Mreteta	0.87	1.10
8	Nanchinyaya	0	1.27
	Albert	1.53	0.90
	Mreteta	1.73	1.33
10	Nanchinyaya	0	1.13
	Albert	2.20	0.57
	Mreteta	2.57	0.63
12	Nanchinyaya	1.00	1.10
	Albert	4.00	0.37
	Mreteta	3.67	1.43
18	Nanchinyaya	1.30	2.74
	Albert	4.00	0.50
	Mreteta	3.33	1.00

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Economic Losses Experienced by Small-scale Farmers in Malawi due to Cassava Brown Streak Virus Disease

F.M.T. Gondwe[1], N.M. Mahungu[1], R.J. Hillocks[2], M.D. Raya[3], C.C. Moyo[4], M.M. Soko[5], F.P. Chipungu[5] and I.R.M. Benesi [6]

[1] International Institute of Tropical Agriculture/Southern Africa Root Crops Research Network, Lilongwe, Malawi
[2] Natural Resources Institute, University of Greenwich, Chatham, Kent, UK
[3] Agricultural Research Institute – Naliendele, Tanzania
[4] Lunyangwa Research Station, Mzuzu, Malawi
[5] Bvumbwe Research Station, Limbe, Malawi
[6] Chitedze Research Station, Lilongwe, Malawi

Introduction

Cassava (*Manihot esculenta* Crantz) is an important root crop in Malawi. It is the second most important food crop after maize (*Zea mays* L.). It is grown throughout the country as a food security crop, snack/ cash crop, and as a staple food crop along the shore of Lake Malawi. It is a staple for over 30% of the country's population.

Cassava has the potential to sustain food security and alleviate poverty among the rural communities because it is adapted to many agro-ecological zones in Malawi. Promotion of cassava as a food crop to traditionally non-cassava staple areas has intensified with the drought problems experienced in the early 1980s and 1990s. The area under cassava has grown from 70,000 hectares in 1990 to 200,000 hectares in 2000 (Famine Early Warning System Project data). Cassava is now becoming a more important crop for both food and for cash income to the rural areas. Recently cassava has become the second staple food to some of the non-cassava staple areas. It has also become an important fresh market commodity in the urban areas throughout the country. Table 1 shows that the area under cassava in major growing areas where it is a staple, such as Karonga, Mzuzu, Salima and Machinga, has increased by about 50%, while in non-traditional cassava eating areas near urban centres such as Lilongwe and Kasungu, it has increased by more than 400%.

The average yield for smallholder cassava farmers in Malawi is about 15 t/ha. At the present yields, cassava is providing more than five times as much staple food (per unit area) as maize in Malawi. On the other hand, when cassava is offered for sale on the fresh market, it generates more cash income than the traditional high value cash crops such as tobacco (*Nicotiana tabacum* L.). Compared to 5.2 for cassava in the peri-urban fresh market, the benefit/cost ratios for tobacco are 1.08, for maize 0.90, for soyabeans (*Glycine max* (L.) Merr.) 1.05, and 1.74 for groundnuts (*Arachis hypogaea* L.) (Akoroda and Mwabumba, 2000). When cassava is processed its benefit-cost ratio is still higher at the traditional market than most other crops. A survey in 2001 by the Southern Africa Root Crops Research Network (SARRNET) revealed that the benefit/cost ratio for production of fermented chips was 2.9 and for fermented flour was 3.7. Farmers can therefore grow cassava more efficiently and exploit the market opportunities and combat poverty and food insecurity.

Farmers are not benefiting as much as they might from cassava because they are faced with a number of constraints. These include: (i) inherent low yielding and late maturing local cultivars, (ii) pests and diseases prevalent in the country and (iii) low promotion of good cultural practices. The major pests and diseases of cassava in Malawi are, cassava mosaic virus disease (CMD), cassava bacterial blight (CBB), cassava brown streak virus disease (CBSD), cassava green mite (CGM), cassava mealybug (CM) and termites.

CBSD was first reported in East Africa in the 1930s (Storey, 1936). Nichols (1950) reported that the disease was endemic in all East African coastal cassava-growing areas up to 1000 m asl from Kenya to southern Tanzania and also at lower elevations in Malawi. CBSD has been reported to seriously affect cassava production in the coastal areas of East Africa. A virus belonging to the family *Potyviridae*, genus *Ipomovirus*, causes the disease (Monger *et al.*, 2001). The vector for the transmission of this disease is not yet known. Symptoms of the disease include brown streaks on stems, leaf chlorosis and root necrosis. Stem

Cassava Brown Streak Virus Disease: Past, Present and Future. Proceedings of an International Workshop, Mombasa, Kenya, 27–30 October 2002. Legg, J.P. and Hillocks, R.J. (Eds) (2003). Natural Resources International Limited, Aylesford, UK. 100 pp.

Table 1. Cassava production estimates for 1995/96 and 2000/01 in Malawi

Agriculture Development Division	1995/96 Area (ha)	1995/96 Production (tonnes)[1]	2000/01 Area (ha)	2000/01 Production (tonnes)[1]
Karonga	8,979	141,767	14,183	284,466
Mzuzu	26,588	680,390	38,693	936,098
Kasungu	4,882	46,390	16,636	232,010
Salima	16,564	322,513	26,940	359,295
Lilongwe	5,851	72,947	20,223	276,259
Machinga	21,925	253,513	43,167	567,869
Blantyre	30,136	243,353	40,367	519,442
Shire Valley	1,598	20,957	1,494	22,611
National total	116,523	1,781,830	201,703	3,201,051

1. Famine Early Warning System Network (FEWSNET) 2001 crop estimates (2nd round); production is tonnes of fresh weight.

necrosis develops as brown elongated necrotic lesions on young tissues from which the name 'brown streak' was derived.

The disease impacts on the farmer in two major ways: low yield and poor root quality due mainly to root necrosis. The disease causes low yield because it leads to production of fewer roots, roots of smaller size, and distorted roots due to pitting and constriction. The effects of CBSD on growth and yield of a cassava crop are not fully documented. SARRNET reported an average of 34% loss due to CBSD in Tanzania (SARRNET, 1996). Field experiments to determine the effect of the disease on yield and quality of the roots showed that CBSD can decrease root weight in the most sensitive cultivars by up to 70% in Tanzania (Hillocks *et al.*, 2001). In addition to loss in root yield the disease has an important effect on root quality caused by patches of root necrosis that make the roots unsuitable for home consumption or the market (Bock, 1994; Hillocks *et al.*, 2001). The length of time between the appearance of foliar symptoms and the development of root necrosis is a varietal characteristic. In the most susceptible cultivars, root necrosis may appear within six months of planting cuttings derived from symptomatic mother plants. There are cultivars that exhibit a form of 'tolerance' to CBSD in which foliar symptoms appear but with a delayed development of root necrosis, allowing the full yield potential to be realized (Hillocks *et al.*, 2001). Photographs of CBSD symptoms and root necrosis loss can be seen in the Annex at the end of this paper.

The objective of this study was to determine the economic impact of CBSD on the farmers in Malawi where the disease is prevalent.

Methodology

The study was conducted in three surveys: the CBSD incidence survey (May 2001), the CBSD severity survey (September 2001) and the follow-up survey (February 2002).

The incidence study was a nationwide exploratory survey carried out along the major roads from the northern tip (Chitipa) to southern tip (Nsanje) covering the full length of the country. It covered the road along the shore of Lake Malawi and the mainland roads. Fields were sampled to check for the incidence of the CBSD from area to area. In major cassava growing areas, sampling was done at regular intervals of about 10 km apart while in places where cassava is not commonly grown, sampling depended on the presence of the crop. Sampling was mainly done on a crop that was old enough to start losing old leaves. Three observers traversed a field at regular distances and each counted the number of CBSD-affected plants at regular intervals in the field. Close to 100 fields were visited from all over the country. Data were collected in all locations on the presence of the disease in the field and farmers' knowledge where the disease was present.

A follow up to the incidence survey was conducted to assess the severity of the disease in terms of root necrosis. The survey was carried out in an unstructured form along the shore of Lake Malawi in areas where CBSD was prevalent based on the incidence survey. It was conducted in all four Agriculture Development Divisions (ADDs) where CBSD is prevalent. A sample of 10 fields with foliar CBSD symptoms was studied per zone and 10 diseased plants per field were sampled. A second follow-up survey was conducted in February 2002, at a time when cassava plants, planted by February 2001, were believed to be over 12 months old. ADDs in three zones, Karonga, Mzuzu and Salima, were selected. A sample of 7 fields was used from each zone and a total of 22 fields were surveyed. At each field, a sample of two plants per cultivar was used, one plant with and one without symptoms of CBSD. In such fields where more than five cultivars were planted, a maximum of four common cultivars was sampled. In the two follow up surveys a total of 418 diseased plants were sampled.

The sampled plants were uprooted to check for root necrosis and constrictions. CBSD data collected included scoring for symptoms on leaf chlorosis and root necrosis (Hillocks *et al.*, 1996), variety of cassava and age of plants. Yield comparisons were made between infected plants and plants without symptoms in the same field. Economic losses were arrived at by assessing the impact of the disease on the uses of leaves, stems and roots. Impact on root use was computed by an approximate percent yield loss using number of roots and size of roots, and further assessing percent necrosis on all the tuberous roots on each plant. This was then computed into a total root loss. Analysis was done using frequencies, averages, and percentages and cross tabulations using the social sciences analysis software SPSS.

Results and Discussion

Presence of CBSD in Malawi

CBSD symptoms vary with cultivar of cassava, environmental factors and age of the plant (Hillocks *et al.*, 1999). The disease is more prominent along the shores of Lake Malawi at low altitudes between 400–1000 m asl. It is present in Karonga, Rumphi, Nkhata Bay, Nkhota Kota, Salima, Dedza, Machinga and Mangochi (Figure 1). Over 40% of the crop in low altitude areas along the shore of Lake Malawi was infected by CBSD with an average severity assessment of class 3 from shoot symptoms.

It was also found that farmers who were using cassava cuttings from research and NGOs had clean fields in the high-pressure areas of the most important diseases. However, in infected fields, neither farmers nor extension workers were aware of this disease. The farmers thought that the symptoms were mainly due to heavy rainfall or water logging. In a few cases farmers thought it was due to old age. It was found that all the most common cultivars, Manyokola, 20:20, Korobeka, Thepula, Beatrice and Gomani, had some CBSD symptoms and 31 of the sampled cultivars had CBSD.

Age of the plants

Most plants in the field during the severity study were less than 12 months old. Table 2 shows by cumulative percent that about 70% of the sample was less than 10 months old. It also shows that relatively severe symptoms (class 3, 4 or 5) are more common in plants that are above 8 months old, demonstrating that CBSD becomes more severe as the plant gets older. The age distribution shows that Nkhota Kota, Mangochi and Karonga had relatively younger crops than Nkhata Bay and Salima. The following list of Rural Development Projects (RDPs) shows the mean crop age in parentheses: Karonga (10.8), Nkhata Bay (12.3), Nkhota Kota (7.7), Salima (15.6) and Mangochi (10.2).

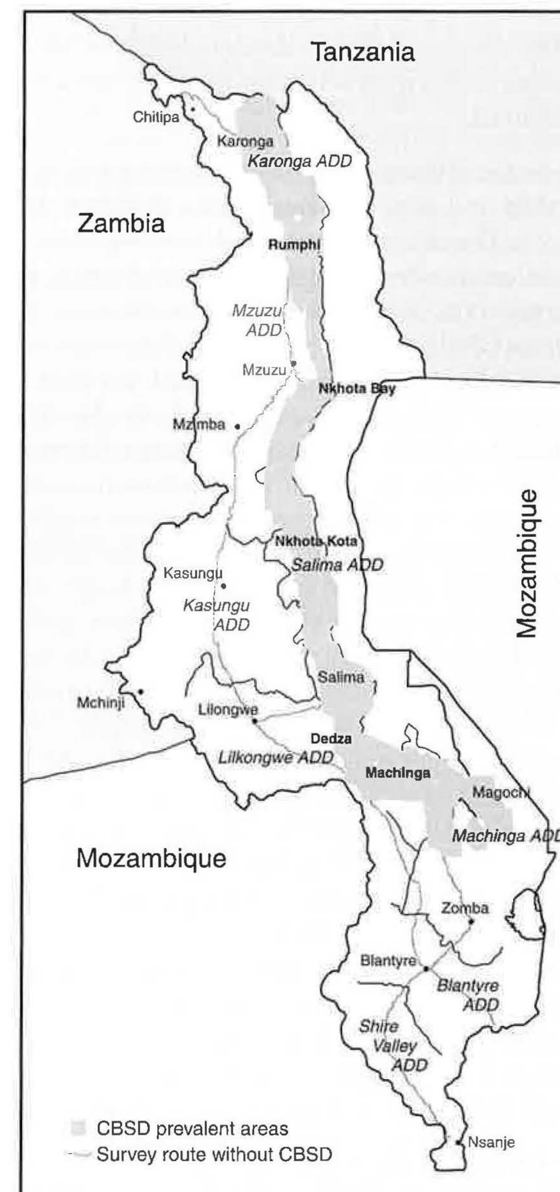

Figure 1 Cassava brown streak prevalent areas of Malawi (also showing areas covered by survey not affected by CBSD)

Table 2. CBSD leaf score of plants in Malawi

Age of plants in months	CBSD leaf score (severity) 2	3	4	5	Total plants in class	Total plants (%)	Cumulative percentage
2	3	1	–	–	4	1.0	1.0
5	1	5	4	–	10	2.4	3.3
6	–	6	1	–	7	1.7	5.0
7	5	5	–	–	10	2.4	7.4
8	37	23	3	1	64	15.3	22.7
9	33	42	2	–	77	18.4	41.1
10	35	62	18	1	116	27.8	68.9
11	3	12	1	1	17	4.1	73.0
12	–	2	2	–	4	1.0	73.9
13	1	–	–	–	1	0.2	74.2
14	2	7	1	–	10	2.4	76.6
17	1	1	1	7	10	2.4	78.9
19	5	38	8	3	54	12.9	91.9
21	9	10	5	–	24	5.7	97.6
30	–	5	4	1	10	2.4	100.0
Total	135	219	50	14	418	100.0	

CBSD leaf severity symptoms

In the CBSD-prevalent areas, it was found that CBSD is more widespread in Karonga than the rest of the survey areas while it was least widespread in Nkhota Kota. About 70% of the crop has CBSD in Karonga against a mean of 45% (Table 3). The mean of the leaf scores was 2.9 showing that CBSD severity is moderate. More severe leaf symptoms were found in Karonga, Nkhata Bay and Nkhota Kota RDPs than in Salima and Mangochi.

CBSD root severity symptoms

The results in Table 4 show that about 34% of the plants had root necrosis and that there was higher necrosis in Nkhata Bay and Salima, which had older crops than the other locations. Where low root necrosis was observed, i.e. in Karonga and Mangochi, less than 25% of the plants with leaf symptoms had root necrosis. Further analysis was done to assess the association between leaf score and root necrosis. Cross-tabulations of leaf score by root score show that more plants that had lower leaf symptoms expression of class 2 had no apparent root symptoms. These may have been plants that had just started showing leaf symptoms, i.e. due to young crop age and early stage of infection. Plants with a score of 3, 4 or 5 for leaf symptoms had more serious root necrosis (Table 5).

Table 3. CBSD leaf score for sites in Malawi

CBSD leaf score	Survey sites: Karonga	Nkhata Bay	Nkhota Kota	Salima	Mangochi	Total
1 No apparent symptoms	0	0	0	0	0	0
2 Slight foliar mosaic, no stem lesions	33	32	4	29	37	135
3 Foliar mosaic, mild stem lesions, no dieback	68	50	13	34	54	219
4 Foliar mosaic and pronounced stem lesions, no dieback	16	12	4	9	9	50
5 Defoliation with stem lesions and pronounced dieback	1	11	–	2	–	14
Total	118	105	21	74	100	418
Average incidence (%)	70	55	15	50	40	46
Mean leaf score	2.87	3.02	3.00	2.78	2.72	2.86

Table 4. CBSD root necrosis (%) at survey sites in Malawi

CBSD root necrosis score	Survey sites: Karonga	Nkhata Bay	Nkhota Kota	Salima	Mangochi	Total
Not apparent	79.7	55.2	61.9	51.4	75.0	66.5
Less than 5% of root necrotic	10.2	28.6	33.3	29.7	20.0	21.8
5–10% root necrotic	6.8	2.9	4.8	10.8	4.0	5.7
10–25% of root necrotic, mild root constriction	1.7	2.9	–	1.4	–	1.4
25% of the root necrotic and severe root constriction	1.7	10.5	–	6.8	1.0	4.5
Total	100	100	100	100	100	100
Sample size (N)	118	105	21	74	100	418
Mean	1.36	1.85	1.43	1.82	1.32	1.56

Economic loss due to CBSD

Farmers were asked about the effect of disease on plant uses such as roots or leaves. The impact of CBSD on yield was also assessed by comparing yield from plants with symptoms to those without symptoms.

Leaves: Farmers normally use young leaves as a green vegetable. However, it was found that most farmers did not separate healthy from infected plants. They used leaves of plants with CBSD as well as those without it because they did not recognize the disease. They were not aware that CBSD had any effect like early leaf defoliation, or change of taste of the leaves. Farmers therefore said that CBSD had no effect on leaf use.

Stems: Most farmers only use the stems for planting (cuttings) and a few for fuel wood. Just like the leaves, farmers said they were not experiencing any loss in amount of stems because even the infected stems were being used for planting since they did not recognize the disease. In the main cassava-growing areas it was found that stems do not have much monetary value since farmers mostly share them for free and the seed market is not well developed. Some farmers who sold some planting material also used infected cuttings in their own fields. Thus, the loss in planting material is transferred to yield since farmers do not select planting material. It was noted in some fields however, that the crop was stunted and sometimes had such very pronounced dieback due to CBSD that the stems were not fit for planting. Such farmers had heavy yield losses. It was also found that planting material was a constraint only in terms of availability and not cleanliness. For cleanliness, farmers select through stem symptoms and in most cases just against mealybug but not other pests or diseases.

Roots: The most important impact of CBSD to the farmers is on roots. Losses were well expressed by necrosis and constriction of the roots. However, most plants showed necrosis on only a few roots. It was found that necrosis was present more on old plants than on younger plants. It was also observed that fewer roots were produced by affected plants. Also, some affected plants had smaller roots than plants without

Table 5. CBSD leaf score by CBSD root necrosis score

CBSD leaf score	CBSD root necrosis score (%): 1	2	3	4	5	Total (%)
2 Slight foliar mosaic, no stem lesions	43.9	14.3	–	–	–	32.3
3 Foliar mosaic, mild stem lesions, no dieback	50.4	70.3	37.5	33.3	21.1	52.4
4 Foliar mosaic and pronounced stem lesions, no dieback	5.4	15.4	62.5	33.3	21.1	12.0
5 Defoliation with stem lesions and pronounced dieback	0.4	–	–	33.3	57.9	3.3
Total	100	100	100	100	100	100

Table 6. Impact of CBSD on root harvest in Malawi

Loss from CBSD plants compared to clean plants (%)	Survey site (plants surveyed) Karonga	Nkhata Bay	Nkhota Kota	Salima	Mangochi	Total plants
0	36	32	6	32	60	166
5	11	6	4	3	8	32
10	17	7	3	2	6	35
15	10	11	2	2	1	26
20	10	7	1	3	2	23
30	9	13	4	9	4	39
40	4	8	–	7	8	27
45	–	–	–	1	–	1
50	6	2	–	3	6	17
60	2	2	1	3	1	9
75	5	7	–	3	3	18
80	3	2	–	2	–	7
90	3	6	–	1	–	10
95	1	–	–	–	–	1
100	1	2	–	3	1	7
Total	118	105	21	74	100	418
Mean loss	21.2	26.3	13.3	24.7	12.8	20.7

CBSD symptoms. In some cases yield loss was mainly due to constriction and pitting such that some roots were totally useless. Comparison of infected and uninfected plants in various survey locations showed that Karonga, Nkhata Bay and Salima had higher losses than Nkhota Kota and Mangochi. Root loss was about 20% over the three locations (Table 6).

When farmers were asked to estimate yield losses due to necrosis from CBSD after being shown the symptoms, they estimated yield losses from 0% to 60%. It was noted that the number of farmers that estimated high yield loss was quite significant; 20% of the farmers said they lose over 40% of their yield, and the average loss reported was 24.3%. Farmers based their losses on recall of the proportion of necrotic roots that are found at harvest. Women were more aware of the symptoms than men since they are involved in the peeling and the subsequent processing. They could easily make an estimate of the proportion of necrotic roots on a basket full of cassava harvest. High root loss was reported by farmers in Karonga, Nkhata Bay and Salima, which matched the field observations (Table 7).

The farmers said that they sometimes eat some necrotic roots if necrosis is light but throw them away if necrosis is heavy. They said that extensively damaged roots have a bad taste whether processed or unprocessed and hence are thrown away. For flour

Table 7. Yield loss (%) due to CBSD as estimated by farmers at the various survey sites in Malawi

Reported yield loss (%)	Survey site Karonga	Nkhata Bay	Nkhota Kota	Salima	Mangochi	Total (%)
0	–	1	–	1	–	3.4
5	–	1	–	3	2	10.3
10	3	1	2	2	2	17.2
15	1	–	–	1	2	6.9
20	2	1	–	1	1	8.6
25	4	3	–	–	1	13.8
30	6	3	–	–	1	17.2
40	3	1	1	–	–	8.6
50	2	2	–	1	1	10.3
60	1	–	–	1	–	3.4
Mean loss	29.3	26.2	20.0	18.0	18.5	24.3

the lightly affected parts are in most cases used but the extensively damaged roots may be cut off or otherwise thrown away entirely. Under the fermentation process, the affected parts do not soften but remain as brown, hard, corky particles and hence can easily be separated for subsequent flour-making processes. Flour from heavily necrotic roots is discolored and has a bitter taste that makes it unpalatable.

As seen in Tables 6 and 7, the mean loss in production ranges from 20–25% depending on the method of estimation. This range of loss at a 40% average incidence translates to 137,000–172,000 t in cassava per year due to CBSD (Table 8). This loss in monetary terms, using the cassava price for the year 2001 (MK 3.00/kg), ranges from MK 400 million to MK 500 million, which is about US$ 6 million to US$ 7 million each year. When farmers run out of food, they buy maize grain or cassava flour from other farmers at more than 10 times the farm value of cassava, i.e. a further degradation of the farmers' resources.

Farmers' practices that influence trends in CBSD

Where CBSD is severe, such as in Karonga, farmers complained that it was sometimes necessary to harvest early to avoid root necrosis. During the survey it was observed that most farmers had started to harvest young crops and very few had crops that were more than 12 months old. Farmers said that they get fewer necrotic roots in young plants. Another reason for early harvesting in these areas was the lack of food. Since farmers have little knowledge about the disease, they keep on recycling the infected planting material. When asked about the symptoms present in most fields, farmers attributed them to loss of soil fertility, heavy rains and waterlogging. It was also noted that apart from early harvesting some farmers practice selective harvesting, in which they harvest plants that seem to have larger roots, hence they remove healthy plants first. Such farmers postpone harvesting diseased plants to a later date in order to get well filled roots. Harvesting healthier plants first means leaving diseased plants in the field and these then become the pool for next season's planting material. This puts the farmer in a cycle of decreasing yield as the disease builds up. The above two systems of harvesting have different effects on susceptible and tolerant cultivars, i.e. farmers who plant susceptible cultivars may be harvesting a young crop in subsequent harvests while those growing a tolerant cultivar may be selectively harvesting healthy plants while building up the disease in the remaining crop.

Conclusion

Since farmers and extension workers do not recognize CBSD, the disease continues to spread as farmers continue to share and use infected cuttings for planting in their fields. The intensity of the disease is also increasing because farmers are adopting practices that exacerbate the situation as yields begin to be adversely affected by the disease.

Yield losses by farmers were quite high, at an average loss of 24%. Since yield loss depends on the severity of the disease, higher losses will be reported as the disease continues to spread and its average severity increases. Since some plants give 100% yield loss, especially at 12 months or more after planting, farmers stand to lose a significant proportion of their food reserve through ground storage. This disease has serious food security implications for the population along

Table 8. Value of CBSD yield losses in areas along the shore of Lake Malawi

Location	Production 2001 (tonnes)[1]	18.9% loss (tonnes)	25% loss (tonnes)
Karonga RDP[2]	234,832	18,787	23,483
Nkhata Bay RDP	743,055	59,444	74,306
Nkhota Kota RDP	342,078	27,366	34,208
Salima RDP	96,022	7,682	9,602
Namwera RDP	63,112	5,049	6,311
Kawinga RDP	133,023	10,642	13,302
Balaka RDP	23,015	1,841	2,302
Mangochi RDP	76,106	6,088	7,611
Total (tonnes)	1,711,243	136,899	171,125
Total value in MK		410,697,000	514,375,000
Total value in US$		5,475,960	6,845,000

1. Famine Early Warning System Network (FEWSNET) data

2. RDP = Rural Develpment Project

the shore of Lake Malawi and urgent attention is required, as a significant proportion of this population (20%) has reported high yield losses (>40%).

Recommendations

1. The cassava research organizations should mount urgent awareness campaigns of the disease and its management for both extension agents and farmers.

2. The cassava research organizations should establish effective collaboration with the extension system on matters of proper cassava husbandry to effectively and efficiently control the disease.

3. The cassava research organizations should carry out local collection exercises for cultivars that show CBSD disease resistance in the high disease pressure areas

4. There is an urgent need for cassava research and extension organizations to multiply cultivars (e.g. Beatrice in Nkhota Kota) and promising clones (e.g. CH92/077 and CH92/112) that have shown multiple disease resistance and that are widely accepted by farmers for distribution in the heavily affected areas.

5. The cassava research and extension organizations in collaboration with entrepreneurs need to develop and strengthen sustainable seed multiplication and distribution systems as a way of assuring the provision of clean planting material.

Summary

Cassava is an important root crop in Malawi. It is a staple food for about 30% of the population. Production of cassava has increased in the past 10 years from about 0.6 million tonnes in 1992 to 3.2 million tonnes in 2001. However, diseases and pests affect cassava production in Malawi with the major ones being CBSD, CMD, CBB, CGM, CM and termites.

CBSD has been reported to seriously affect cassava production in the coastal areas of eastern Africa (Kenya, Tanzania and Mozambique) and the areas along the shore of Lake Malawi. The symptoms of the disease are brown streaks on stems, leaf chlorosis, root necrosis and root pitting or constriction. The symptoms vary with cultivars, age of the plant and the environment. The major economic impact of the disease to the farmers is low root yield, as the number and size of roots is reduced and root quality is decreased due to necrosis.

Surveys were conducted in 2001/02 in Malawi and data were collected on cultivar of cassava, age of plant, CBSD leaf chlorosis, CBSD root necrosis, proportion of necrotic roots on total yield, yields of diseased plant versus apparently healthy plants in the same field, and the effects of CBSD on uses of leaves, stems and roots.

CBSD is widespread in the low altitude areas along the shore of Lake Malawi and about 40% of the crop in these areas is affected. It is more prevalent in the northern areas along the shore of Lake Malawi from Nkhata Bay to Karonga than those areas south of Nkhata Bay. CBSD, however, is not well known to either farmers or extension workers. They ascribe symptoms of the disease to heavy rainfall and water logging. It was found that the disease is spreading in farmers' fields through harvesting practices. Farmers select plants with filled roots for harvest and thus remove the healthier plants first. The more affected plants may remain in the field until the rainy season and they become the seed stock.

The disease is causing from 18% to 25% yield loss where it is prevalent. This loss translates to about MK 400 million to MK 500 million or US$ 5 million to US$ 7 million annually based on farm-gate prices.

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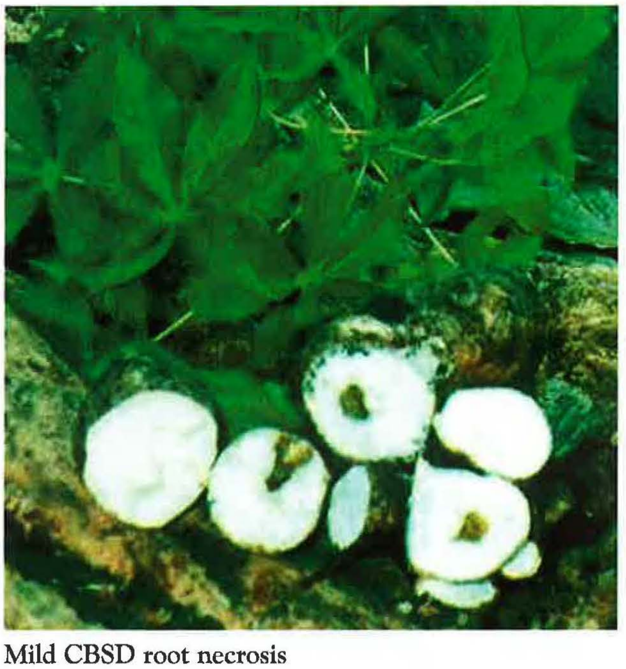
CBSD Symptoms and Root Necrosis Loss

Brown streaks on the cassava stems

Early CBSD leaf symptoms of serious attack on a young plant



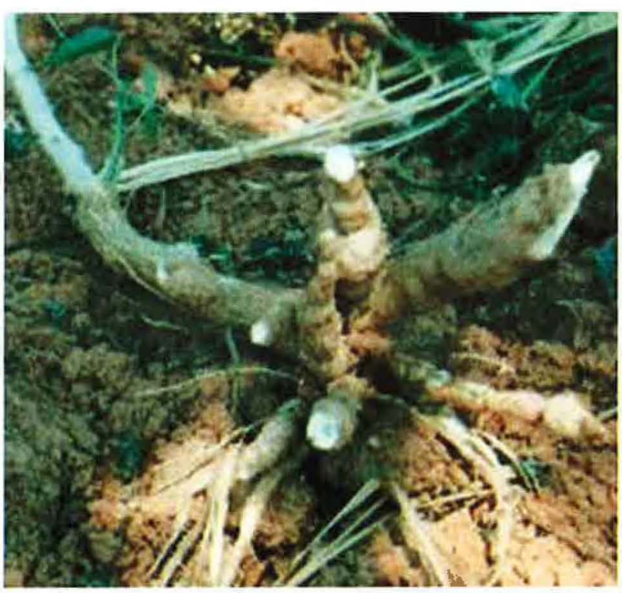
Mild CBSD root necrosis

Severe CBSD root necrosis

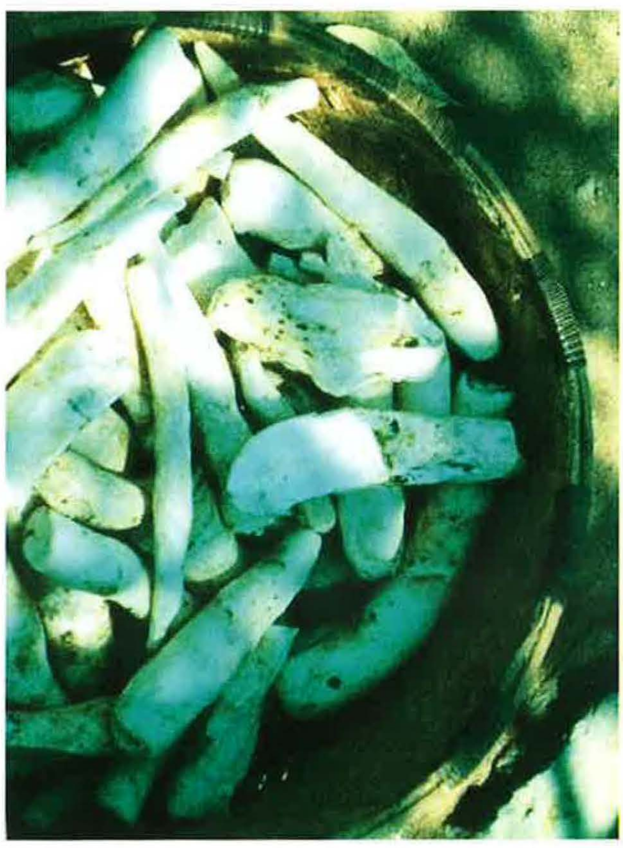
Comparing stuntedness and root yield of CBSD plant (left) with a healthy plant of the same cultivar and age (Photo Mr Chirambo, Timbiri, Nkhata Bay)

100% loss from CBSD necrosis

Heavily necrotic roots that did not soften during fermentation but remained corky



Heavy yield loss due to CBSD root constriction



Slightly necrotic roots still left for flour processing

Cassava Brown Streak Virus Disease Transmission Studies in Tanzania

M. Muhanna and K.J. Mtunda

Root and Tuber Research Programme, Kibaha Sugarcane Research Institute, Coast, Tanzania

Introduction

Cassava brown streak virus disease (CBSD) is the most important cassava (*Manihot esculenta* Crantz) disease affecting production in the coastal areas of Tanzania. CBSD was first described by Storey (1936) who recorded the disease on the foothills of the Usambara Mountains in Tanzania. Nichols (1950) later reported that the disease was endemic in all East African coastal cassava growing areas, from the north-east border of Kenya to Mozambique, and was widespread at lower altitudes in what is now Malawi. Since CBSD was first described, the causal agent was assumed to be a virus. This was later confirmed by Lister (1959) and in later experiments of Bock and Guthrie (1976). The disease was sap transmitted to a range of herbaceous indicator hosts; virus particles were detected by electron microscopy in leaf samples showing typical CBSD symptoms. Recent work at Bristol University in the UK has now shown the virus to be an *Ipomovirus*. Storey (1936) demonstrated that the causal agent of CBSD was graft transmissible and that the cuttings from CBSD-infected plants give rise to plants showing characteristic foliar symptoms of CBSD. The disease is therefore introduced to newly planted areas through the use of infected planting materials.

Transmission experiments carried out in Tanzania using mixed populations of *Bemisia tabaci* and *B. afer* have so far been unsuccessful. In Kenya, Bock (1994) was also unable to transmit *Cassava brown streak virus* (CBSV) with *B. tabaci*. However in one experiment conducted in 2000 at Kibaha, Tanzania, there was an indication that *B. tabaci* might be the vector of CBSV. Test plants used in transmission experiments were derived from seeds of the susceptible cultivar Albert. In 2001/02 tissue culture plants of cultivar Albert were also used in an attempt to determine the vector of CBSD and whether transmission actually occurs in the field.

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Materials and methods

Test plants (virus-free materials)

Tissue culture plantlets of the CBSD-susceptible cultivar Albert and plants derived from seeds of the same cultivar were used.

Experiment 1. Twenty-one tissue-cultured plantlets were planted in the field between rows of the most CBSD-susceptible cultivar, Cheupe. Plot size was 42 m^2 and plants were spaced 1 m apart within rows and between rows. Tissue culture plants were observed weekly for CBSD symptom expression. The objective of this experiment was to find out whether transmission actually occurs.

Experiment 2. This experiment was done within cages in the screenhouse. Two CBSD-infected cuttings and one non-infected cutting were planted in small pots and, before sprouting, each cutting was placed in a cage (1.8 × 0.9 × 0.9 m) – with each cutting in a single cage. Three established tissue culture plantlets were then placed in a circle around a single cutting in each cage. Twenty whitefly nymphs collected from CBSD-infected cassava plants were introduced into two of the three cages, one containing an infected (T1) and one an uninfected (healthy) cutting (T3), after the plants in the pots had formed the first few leaves. In one of the cages containing an infected cutting, no whiteflies were introduced and the treatment served as a control (T2). The treatments are summarized below:

T 1 – Infected plant + Whiteflies + Test plant

T 2 – Infected plant – without Whiteflies + Test plant

T 3 – Healthy plant + Whiteflies + Test plant

The experiment was not replicated because of the limited number of tissue culture plants. The plants were observed weekly for CBSD symptom expression.

Experiment 3. This experiment was conducted on the floor of the screenhouse. Seeds of cultivar Albert were planted in pots (3 seeds/pot). When they had sprouted a plastic tube was placed around one shoot and was fixed in place with a stick. Whiteflies collected from CBSD infected plants in the field were placed inside the plastic tubes and the ends were closed with cotton wool. Whiteflies were allowed to feed for five days before the tubes were removed. The design was a randomized complete block replicated five times. Treatments were different whitefly numbers (0, 1, 5, 10, 15 and 20) and plants were observed weekly for CBSD symptom expression.

Results and conclusion

In all experiments no CBSD symptoms have so far been observed on the tissue culture plants both in the field and in cages within the screenhouse. Similarly there were no symptoms of CBSD in plants derived from seeds of the cultivar Albert in the screenhouse. The current results give no evidence of transmission of CBSD by whiteflies. However since the plants are still growing, symptoms may appear during the later stages of growth.

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Cassava Brown Streak Virus Characterization and Diagnostics

J.P. Legg

International Institute of Tropical Agriculture, Eastern and Southern Africa Regional Centre, Kampala, Uganda
and
Natural Resources Institute, University of Greenwich, Chatham, UK

Introduction

Seventeen viruses have been reported to infect cassava (*Manihot esculenta* Crantz) worldwide, of which roughly half are known to occur in Africa (Calvert and Thresh, 2002). Of this number, only two groups are considered to be of any economic importance: the cassava mosaic geminiviruses (CMGs) (Family: *Geminiviridae*, Genus: *Begomovirus*) and *Cassava brown streak virus* (CBSV) (Family: *Potyviridae*, Genus: *Ipomovirus*). The CMG group currently comprises eight species, six of which occur in Africa (Fauquet and Stanley, 2003). The two most widespread and prevalent species are *African cassava mosaic virus* (ACMV) and *East African cassava mosaic virus* (EACMV). Only one form of CBSV is currently recognized. Both of these principal viruses of cassava cause major economic losses through their effects on the growth and tuberous root production of cassava. CMG infection produces a chorotic mosaic on leaves, leaf distortion, reduction in size of leaves, stems and overall plant size, and through these effects on the above ground plant parts has variable but often substantial effects on the production of tuberous roots. Cassava mosaic virus disease (CMD), caused by CMGs, occurs throughout the cassava-growing areas of sub-Saharan Africa, and has been estimated to cause losses of between 12 and 25% of the total African crop, equivalent to US$ 12–23 million (Thresh *et al.*, 1997). Cassava brown streak virus disease (CBSD) is most important in the coastal East African countries of Kenya, Tanzania and Mozambique, but also occurs widely in Malawi (Calvert and Thresh, 2002). CBSD produces variable symptoms on leaves and stem, but most importantly gives rise to a dry brown necrotic rot in the tuberous roots that renders them unusable (Nichols, 1950; Hillocks *et al.*, 1996). Although there are no overall estimates of yield loss, Hillocks (see pages 23–27) has quantified the effects of production in Tanzania and noted that whilst the effect on overall root weight is minimal, major losses can occur through the dry root rot symptoms that characterize severe CBSD infection.

Early studies on virus aetiology

CBSD was first reported from Tanzania (Storey, 1936). Early studies on the possible causal agent revealed that it was graft transmissible, and as there was no visible sign of a pathogen on affected plants, it was assumed to be a virus. The first detailed description of the symptoms and effects of the disease were made by Nichols (1950), again working in Tanzania. Lister (1959) demonstrated that CBSV could be transmitted mechanically to indicator plants, and was also able to return the isolate from an indicator plant to cassava and reproduce the symptoms of CBSD. The first study to use electron microscopy to look for virus particles was that of Kitajima and Costa (1964), in which it was shown that rod-shaped particles occurred in infected plants. Numerous additional studies were conducted within the framework of the Kenya-based Plant Virology project of the UK's Overseas Development Administration (ODA) during the 1970s and 1980s. Bock (1994) and colleagues were able to demonstrate the sap transmission of CBSD isolates to numerous indicator plants, of which the best was *Nicotiana debneyi*, which was useful as a diagnostic test plant. Two distinct isolates were identified that produced distinct symptoms when transferred to *N. debneyi*. Filamentous particles were again shown to be associated with CBSD infection, and these were typically around 650 nm in length. It was noted that these were similar in morphology to carlaviruses. The concentration of virus particles was very low both in infected cassava and in indicator plants; in many preparations no particles were seen at all, and none were detected in symptomless leaves of infected plants.

Further efforts to characterize CBSV at the Scottish Crop Research Institute in Dundee met with limited success. Pin-wheel inclusions were noted in association with the filamentous particles assumed to be

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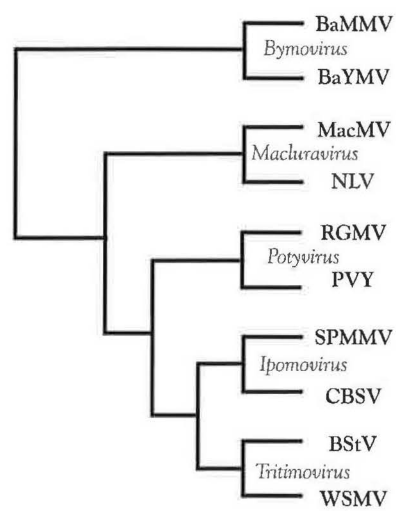
CBSV (Lennon *et al.*, 1986), and it was assumed from this that potyviruses were present, since at that time pin-wheel inclusions had only been observed in association with potyvirus infection. A confusing result that arose at this time, however, was the occurrence of a weak serological reaction between extracts from CBSD- infected material and antibodies to the carlavirus, *Cowpea mild mottle virus* (Lennon *et al.*, 1986). An enzyme-linked immunosorbent assay (ELISA)-based diagnostics technique was developed and used to test infected material in Malawi (Sweetmore, unpublished data). This approach was useful in detecting CBSV in leaf, stem and root tissues with clear symptoms of CBSV, but was not very sensitive and did not pick up CBSV in symptomless parts of infected plants.

Molecular characterization of CBSD

In view of the incomplete understanding of the nature of CBSV, set against its obvious importance as a pathogen of cassava in Africa, a Department for International Development's Crop Protection Programme (DFID–CPP) project was initiated by the University of Bristol to provide a detailed characterization of the virus causing CBSD. CBSD-infected material was collected from Tanzania and grown in glasshouses at the University (Monger *et al.*, 2001a). Leaf material from plants showing clear symptoms was macerated and used to infect *Nicotiana benthamiana*. Following symptom development in these plants, partial virus purifications were made using standard techniques. A series of universal primers for candidate virus genera were used in reverse-transcription polymerase chain reaction (RT-PCR) experiments, to see if any would amplify products. Primers for carlaviruses and the *Bymovirus* and *Macluravirus* potyvirus genera all failed to give PCR products. As a result, cDNA was prepared from the partial virus purifications from CBSD infected material, cloned and sequenced. The longest sequence generated was 1114 bp, and specific primers designed from this sequence were then used in RT-PCR with RNA from infected material, producing a 300 bp product. Comparisons of the deduced amino acid sequence of this product were made with related viruses that showed closest identity in a computer search using the Genbank database.

During initial searches (Monger *et al.*, 2001a), the closest match (43.2%) obtained was with *Sweet potato mild mottle virus* (SPMMV) (Family: *Potyviridae*; Genus: *Ipomovirus*). Relationships with other potyvirus species and genera were presented in a phylogenetic tree, presented diagrammatically in Figure. 1. Subsequent Genbank searches, however (G. Foster, unpublished data), have revealed an even closer homology (76.3% in the deduced amino acid sequence) with *Cucumber vein yellowing virus* (CVYV), another newly described member of the *Ipomovirus* genus (Lecoq *et al.*, 2000). Monger *et al.* (2001a) further developed a series of sets of specific primers that produced products in RT-PCR for infected cassava samples but failed to produce a product for uninfected cassava. Protein analysis was done by taking partially purified CBSV, running on an SDS-PAGE gel and staining with coomassie blue. A single protein was strongly stained that was approximately 45 kDa in size. This is also similar to the size (larger than usual for *Potyviridae* – 33/34 kDa) of the protein subunits of SPMMV and CVYV and provides further evidence for the location of CBSV in the *Ipomovirus* genus. Similarities in both size and sequence of the coat protein of CBSV and that of CVYV provide strong circumstantial evidence for *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) as vector, since CVYV is known to be transmitted by this species, albeit with low efficiency (Mansour and Almusa, 1993).



BaMMV	*Barley mild mosaic virus*
BaYMV	*Barley yellow mosaic virus*
MacMV	*Maclura mosaic virus*
NLV	*Narcissus latent virus*
RGMV	*Rice golden mosaic virus*
PVY	*Potato virus Y*
SPMMV	*Sweet potato mild mottle virus*
CBSV	*Cassava brown streak virus*
BStV	*Brome streak virus*
WSMV	*Wheat streak mosaic virus*

Figure 1 Phylogenetic tree illustrating relationships between CBSV and related viruses in the *Potyviridae* (modified from Monger *et al.*, 2001a)

Symptom and sequence variability

CBSD-diseased material collected from three cultivars sampled at Kibaha, Tanzania, was used to infect indicator plants (Monger *et al.*, 2001b). Each of the three isolates produced different symptom responses in *N. benthamiana*. Using RT-PCR and specific primers, portions of the CBSV genome were amplified for each of these isolates and sequence comparisons made. For all comparisons, there was greater than 92% homology at the nucleotide level. Similarly, comparisons were made between CBSV isolates from samples collected from Zambézia and Nampula provinces in Mozambique, and again there was a high degree (>92%) of homology for all nucleotide-level comparisons between isolates (G. Foster, unpublished data). These results, whilst limited in scope, appear to suggest that a single virus is associated with CBSD in the geographical areas in which it is most important.

Development of a diagnostic protocol

It has been known for many years that symptoms of CBSD are highly variable both from one season to the next and between cultivars. In addition, early work on the characterization of the virus noted that virus particles were present in very low concentrations. Serological diagnostic tests (Lennon *et al.*, 1986) were able to detect CBSV in test plants but weakly and inconsistently in cassava plants. There was therefore a vital need to develop an effective diagnostic technique that worked with infected cassava plants and that was sufficiently sensitive to be able to detect CBSV in parts of infected plants not expressing symptoms, such as the newly-emerging young leaves where symptoms are least apparent. Following the characterization of CBSV, Monger *et al.* (2001b) proceeded to develop such a sensitive diagnostic protocol based on RT-PCR. A range of options for RNA extraction, RT-PCR primers, RT-PCR reaction conditions and thermal cycling machines were tested, with the aim of developing the most efficient and robust approach possible. This optimizing was successful, and a protocol was developed that worked with a range of CBSV isolates from some of the main affected areas in Tanzania and Mozambique, and that could reasonably be carried out in a moderately well equipped laboratory in Africa. This protocol is summarized in Boxes 1a and 1b.

Conclusions

The identity of the causal agent of CBSD has been confirmed as *Cassava brown streak virus* (Family: *Potyviridae*: Genus: *Ipomovirus*) although full Koch's postulates have yet to be demonstrated. The closest

Box 1a Summary of CBSV diagnostic protocol. Step 1 – RNA extraction

Step 1 – RNA Extraction

CTAB RNA extraction method

(based on a modification by R. Mumford of a protocol described by Lodhi *et al.* (1994). *Plant Molecular Biology Reporter* **12**: 6–13)

1. Grind 0.1–0.3 g CBSD-diseased leaf sample in liquid nitrogen.
2. Before thawing occurs, add 10 volumes of grinding buffer* and vortex thoroughly.
3. Take 800 μl of the ground sap into a microfuge tube and incubate at 65°C for 10–15 mins.
4. After incubation, add 600 μl of chloroform: IAA (24:1) and mix to emulsion by inverting the tube.
5. Centrifuge at 13,000 rpm in a microfuge for 10 min at room temperature.
6. Remove upper aqueous layer and transfer to a fresh tube. Repeat extraction with the chloroform.
7. Remove upper aqueous layer, taking extra care not to disturb the interphase (about 300 μl) and mix with 0.5 volumes of 5M NaCl and two volumes of ice-cold ethanol. Mix well and incubate at -20°C for 20–30 min.
8. Centrifuge at 6,500 rpm for 10 min to pellet the nucleic acid. Remove ethanol and resuspend the pellet in 2M LiCl. Incubate at 4°C overnight.
9. Centrifuge for 30 mins at 13,000 rpm at 4°C if possible to pellet the RNA.
10. Decant off LiCl and wash pellet by adding 500 μl 70% ethanol.
11. Decant off the ethanol and dry the pellet to remove residual ethanol. NB. Do not dry completely as the pellet will become difficult to resuspend.
12. Resuspend pellet in 50–100 μl of DEPC-treated distilled water.

From step 7 onwards, care must be taken not to contaminate with RNase.

**Grinding buffer (make up to 100 ml with distilled water)*

2% C TAB	2 g
2% PVP-40	2 g
100mM Tris-HCl, pH 8.0	10 ml of 1M stock
20mM EDTA	4 ml of 0.5M stock
1.4M NaCl	8.1 g

Mix and autoclave

Box 1b Summary of CBSV diagnostic protocol. Steps 2 and 3 – cDNA generation and PCR

Step 2 – cDNA generation (Monger *et al.*, 2001b)

- Generate cDNA from extracted RNA using a commercial cDNA generation kit such as the 'First Strand RT-PCR kit' of Stratagene Ltd., Cambridge, UK.
- Follow manufacturer's instructions, using 7 μg of total RNA and the primer oligo dT since the virus has a polyA tail.

Step 3 – The PCR Test (Monger *et al.*, 2001b)

- PCR primers: CBSV 10 (F) 5' – ATC AGA ATA GTG TGA CTG CTG G – 3'
  CBSV 11 (R) 5' – CCA CAT TAT TAT CGT CAC CAG G – 3'
- Primers generate a 231 bp product from within the coding region of the virus coat protein.

PCR reaction mix (total of 20 μl)		11 × PCR buffer	Total 676 μl
Primer 1 (CBSV 10)	80 ng	2M Tris-Cl (pH 8.8)	165.0 μl
Primer 2 (CBSV 11)	80 ng	1M ammonium sulphate	85.0 μl
11 × PCR buffer**	1.8 μl	1M magnesium chloride	33.5 μl
cDNA (sample)	1 μl	2-mercaptoethanol	3.6 μl
Taq polymerase	0.5 units	10mM EDTA	3.4 μl
		Each dNTP (100mM stock)	75.0 μl × 4
		10 mg/ml BSA	85.0 μl

1. 11 × PCR should be filter sterilized and stored in smaller aliquots at -20°C.
2. Prepare the PCR reaction mix for cDNA samples.
3. Reaction mix can be overlayed with 20 μl mineral oil depending on thermal cycler used.
4. PCR programme: 94°C for 1 min, 50°C for 1 min, 72°C for 1 min repeated for 30 cycles.
5. Make a 1% agarose gel in TAE buffer (0.4M Tris-HCl, 0.2M acetic acid, 0.01M EDTA) containing 10 mg/ml ethidium bromide.
6. Load and run reaction products from PCR in the agarose gel for 45 min at 80 V using a horizontal gel apparatus filled with TAE buffer.
7. Visualize DNA bands by transilluminating with UV light and record results with a Polaroid camera or an alternative gel-recording system.
8. Infected samples produce a 231 bp product that is apparent on UV transillumination. Absence of a DNA band indicates a negative reaction. This can be assumed to indicate the absence of CBSV in the sample if a positive control provides a positive reaction, although for indexing work, confirmation of a negative result should be made through repeat testing.

currently described relative is CVYV. Since this is vectored by the whitefly *Bemisia tabaci*, it seems likely that CBSV may also be transmitted by a *Bemisia* species, of which there are two (*B. tabaci* and *B. afer*) that occur commonly on cassava in sub-Saharan Africa. Based on the characterization studies conducted by the team at the University of Bristol, a robust diagnostic protocol has been developed. This has the potential to play a vital future role in further studies on the aetiology and epidemiology of CBSD and in supporting CBSD management efforts. Some of the most important aspects of this include the identification, enhancement and deployment of mechanisms of host- plant resistance and the phytosanitary control of the inter-regional and inter-continental spread of CBSV.

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Social Impact of Cassava Brown Streak Virus Disease on Rural Livelihoods in Southern Tanzania

N.A. Katinila, H. Hamza and M.D. Raya

Agricultural Research Institute – Naliendele, Mtwara, Tanzania

Introduction

Cassava (*Manihot esculenta* Crantz) is one of the most important tropical root crops in developing countries. The wide adoption of cassava in Africa has been due to its suitability and adaptability to traditional farming and food systems and the socio-circumstances of farming communities. Cassava can be grown on poor marginal soils; it can be produced at lower cost than cereals while producing higher yields (Bainbridge *et al.*, 1997).

In the Southern Zone, cassava is an important food staple for the majority of the population. It is mainly grown throughout the zone as a food security or cash crop, particularly during the hunger stress period. In many districts it ranks first in importance while in the districts of Nachingwea, Ruangwa and Tunduru it ranks second after maize (*Zea mays* L.)/paddy rice (*Oryza sativa* L.). Most farmers in the zone perceive cassava as the food for lower-income groups or as a famine crop in years of drought.

Previous studies in the Southern Zone have also shown that there are higher incidences of cassava brown streak virus disease (CBSD) than cassava mosaic virus disease (CMD); CBSD incidence can reach 70% in some fields. CBSD is prominent at low altitudes, is caused by *Cassava brown streak virus* (CBSV) and spreads through planting of infected stems. The virus is also believed to be spread by insects (MOAFS, 2002). Between 20% and 80% of the root is rendered unsuitable for consumption depending on the cultivar and time of infection. Socio-economic surveys conducted under the Department for International Development (DFID) projects (CPP R6765 and R7563) have shown that root rot is the main cassava production problem faced by farmers.

Control strategies have been developed to reduce the negative effect of the disease, including roguing, use of resistant cultivars, early planting and early harvesting. A number of local cultivars have been identified that appear to have some resistance/tolerance to CBSD. The introduction of suitable disease control management strategies has been shown to reduce the disease pressure on farmers. However, previous studies (Katinila and Kwikwega, 2001) have shown that the acceptance of disease control strategies is slow, as only 58% practise one or more of these strategies leaving the remaining 42% not controlling the disease.

Inadequate postharvest technologies at the farm level and low producer prices are factors that act as a 'disincentive' to farmers, hampering wider adoption of CBSD control strategies. In this context, farmers generally consider that any increase in production due to management practices will be lost during storage. The *Plant Pests Field Handbook* (MOAFS, 2002) outlines the following control strategies:

- Planting disease-free stems/cuttings
- Destroying infected plants
- Early harvesting
- Growing tolerant/resistant cultivars.

In order to improve the effect and impact of CBSD control strategies on farmers, it was necessary to undertake a study to investigate socio-economic factors that influence them. Therefore, this study was an attempt "to investigate socio-economic factors affecting control strategies of CBSD in the Southern Zone of Tanzania." The study concentrated on participating farmers in the contact villages and was implemented from May 2001 to September 2002. This research was organized and implemented by the Socio-Economic Unit of the Naliendele Agricultural Research Institute (NARI) by utilizing funds from the Crop Protection Programme (CPP)-funded project and executed by the Natural Resources Institute (NRI) of the United Kingdom.

Description of the study area

Location

The study was conducted in five villages: Mtiniko and Ziwani in Mtwara Rural District, Tulieni in Lindi Rural District, Chisegu in Masasi District and Tupendane in Newala District. These villages have been participating in cassava on-farm research trials through farmer research groups (FRGs). FRGs were established

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to facilitate research trials on control of CBSD and multiplication of disease-free planting materials.

Climate and soils

Climatic conditions in the Southern Zone are influenced by two major airstreams, the southeast trade winds in mid-year and the northeast trade winds during the turn of the year. Temperatures vary very little, the mean temperature being 24.3°C in the coolest months of June/July and 27.5°C in December/January, the hottest months. The mean maximum temperature is 30.5°C and the mean minimum temperature is 21.7°C. The rainfall pattern is unimodal but often has seasonal interruptions. Approximately 85% of the precipitation falls between December and April. The average annual precipitation varies between 810 mm and 1090 mm.

The dominant soils are the reddish sands and loamy sands that have developed on sediments, granites and acid gneiss. These soils are well-drained, moderately deep, red to yellowish in colour, have poor structure and profile development with low natural fertility. Other soil types are reddish sandy clays with moderate organic matter content and high subsoil acidity.

Demography

The zone has a total area of 103,478 km^2 divided between 17,750 km^2 for Mtwara Region and 66,950 km^2 for Lindi Region, with the remaining 18,778 km^2 for Tunduru District. Based on projections[1] from the 1988 Population Census, the population for Mtwara Region is estimated at 1.2 million with an average population density of 63 persons/km^2. Likewise the population for Lindi Region is estimated at 0.9 million with an average population density of 12 persons/km^2.

Cassava cropping systems

In the Southern Zone, most of the cassava crop is mix-cropped with other crops like maize, legumes and cashew (*Anacardium occidentale* L.) (when cashew is young). Most people plant the bitter types mainly for sale in dry (*makopa*) form while the sweet ones are planted mainly for selling when fresh or for snack preparation. The cropping duration ranges from 12–24 months depending on the type and cultivar. Planting and harvesting is carried out simultaneously before the rains between August and November. Drying of the crop is normally carried out in the field and it is transported home for storage when dry. Selling of the dry cassava becomes most profitable between November and February particularly in January when the hunger stress is at its peak.

1. Regional population growth rate is 1.4% for Mtwara and 1.7% for Lindi regions.

Cassava production trend

Table 1 shows the positive cassava production trend in Lindi and Mtwara from 1992 to 2000. Cassava production increased substantially during 1998/99 and 1999/2000 compared to other staples like maize, sorghum and rice. During the 1992/93 season, production was high and constituted about 67% of the total food production. Increased cassava production can partly be explained by an increased area under cassava.

Table 1. Cassava production trend in Mtwara and Lindi regions, southern Tanzania, 1992–2000

Year	Area under cassava (ha)	Production of cassava (t)	Cassava productivity (t/ha)
1992/93	183,227	446,153	2.4
1993/94	212,113	252,576	1.2
1994/95	260,194	215,792	0.8
1995/96	208,775	369,666	1.8
1996/97	274,509	337,329	1.2
1997/98	331,184	410,550	1.2
1998/99	254,988	480,905	1.8
1999/00	286,959	516,377	1.8
2000/01	292,000	570,332	1.9

Source: RADO-Lindi (2000); RADO-Mtwara (2000)

Methodology

Village selection

The study was conducted in five villages in Lindi and Mtwara regions that were selected for the Cassava On-Farm Research trials in the zone. In these villages, CBSD trials had been conducted and the villages were selected because their cassava was severely affected by CBSD. Accessibility to the village was also considered in the selection of these villages. Table 2 indicates the location of villages selected.

Table 2. Participating villages and their respondents, southern Tanzania

District	Village	No. of respondents
Mtwara	Ziwani	12
	Mtiniko	13
Lindi	Tulieni	11
Masasi	Chisegu	12
Newala	Tupendane	16
Total		64

Data collection and analysis

Data collection was made through the use of checklists and questionnaires. Village surveys were made in contact villages and both FRG members and non-FRG members were involved. A sample of 64 farmers was interviewed using the questionnaire while key informants were interviewed using the checklist. Extension officers assisted in conducting interviews for information collection. Some group discussions were conducted. Some data were also collected from district and village extension offices. Literature searches were made to complement the collected information.

Consultations were made with village leaders and FRG functionaries in the villages visited. These leaders facilitated the appointment and location of interviewees (respondents). The interviewer administered informal and formal surveys. Questionnaires were used in the formal survey while checklists were used in the informal survey. The informal survey was used to collect information on the village profile and associated information.

The collected data were post coded and computed using a spreadsheet (Excel 97). Data were analysed using descriptive statistics and the social sciences analysis package, SPSS. Analysed information has been presented in the form of charts, graphs and tables and in some cases in SPSS output format, from which interpretations have been made.

Results and discussion

Social characteristics

Household size. In decision making for the adoption of technological recommendations, household size and income play important roles. The bigger the household, the more the farmer becomes risk averse and thus cannot easily take risks in trying out new technologies. Distribution of household size is shown in Figure 1. Those households with one to three and four to six members represent 78% of the total. Subsequent analysis showed that the bigger the household, the more the adoption of control strategies. This is mainly due to greater labour availability.

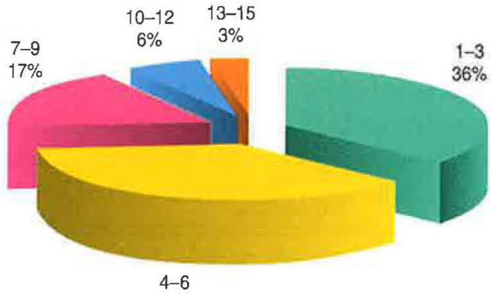


Figure 1 Household size

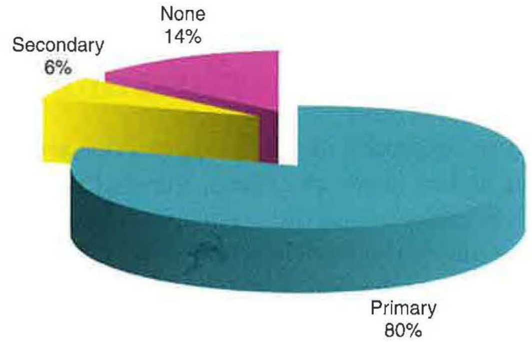


Figure 2 Education of respondents

Education

The rate of illiteracy was very low for respondents in the study area (Figure 2). Only 14% reported that they had not attended any formal schooling, although some had attended 'Adult Education Programmes'. The majority of the respondents had had primary school education while very few had obtained secondary school education.

Factors affecting acceptance of CBSD control strategies

Overview of the technology

Adoption of technology in most cases depends on a number of factors that influence the acceptance process. These factors are vested in the technology, the individual person or the medium channel. In general four levels of awareness are recognized in respondents:

- not aware of the technology
- aware of the technology
- aware but are not adopting the technology
- aware and have adopted the technology.

There are several factors that affect farmers in adoption of technologies. Available resources (land, labour, capital), age of the farmer, experience in cassava cultivation and the importance of the commodity in the household. Figures 3 and 4 show proportions accepting control measures and control measures used. Many farmers were aware of CBSD control measures, and it is encouraging that only 7% were unaware. Some respondents (31%) had gone beyond awareness and were practising the CBSD control methods whilst others (16%) were aware but not practising them. Data indicated that roguing was practised by many farmers (46%) and hence could be a good entry point in the move for consolidation of disease control strategies (Figure 4). The sizeable proportion reported to

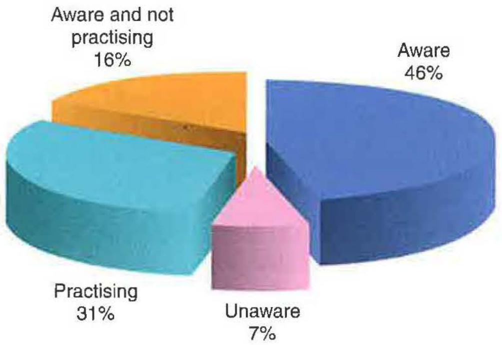


Figure 3 Acceptance of CBSD control measures

"do nothing" in respect to CBSD control is alarming and calls for a more integrated approach in technology dissemination. This can be achieved by involving the extension service and the use of participatory methodologies in dissemination. Furthermore, the current dissemination strategy seems to be inefficient as it reaches only a small proportion each season, e.g. FRGs. Therefore, this calls for the need to devise appropriate dissemination strategies for a wider and enhanced adoption. On the other hand, the most important and practical method of controlling CBSD is by the use of disease-free planting material and tolerant cultivars. However, as shown in Figure 4, only 3% used disease-free planting material and 5% used tolerant cultivars. This trend may be due to shortage or unavailability of tolerant cultivars in the farmers' vicinity. Therefore this should be promoted to enhance availability and accessibility at the farm level through demand-driven multiplication of those cultivars.

Farmers' perceptions

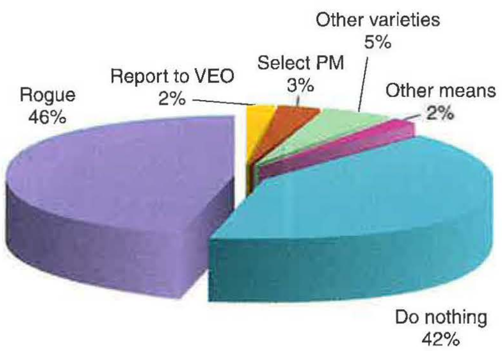
From discussions with respondents it was noted that cassava is perceived as a rescue crop particularly in bad (drought) years and for poor farm families. Studies by Katinila (1997) indicated that crop preferences for food were: rice, maize, cassava and sorghum (*Sorghum bicolour* (L.) Moench) (in that order). This could be an obstacle for increased cassava production and thus a disincentive to the adoption of CBSD control strategies.

Available resources at household level

A farmer with adequate resources may adopt technologies easily, assuming that he has an interest and willingness to try the innovation. For convenience the farm area has been taken to represent the available resources at the farmers' level. Other resources like labour and capital are difficult to assess and thus lead to complexities. There was a distinct relationship between the resource (farm size) and the adoption of CBSD control strategies (Figure 5). The most important and easily measured resource is the household farm, and the relationship discussed here refers to that. The fact that the crop becomes 'very important' during bad years gives room for speculation to traders that are risk takers. This also explains why the bigger the farm size the greater the adoption, as wealthy farmers are willing to take risk if a 'good profit' is expected. Some people have benefited considerably in these years as they managed to sell the crop at a good profit during times of hunger stress. The larger the size of the farm the greater the proportion that adopt the technology. This is possibly due to the fact that a big farm is less risky compared to a small farm and, with more land, the farmer can adopt the technology on a portion of the land.

Education category of the respondents

The more educated a person is the more he/she becomes exposed to innovations. This is an indication that awareness and training of farmers in aspects of



VEO - Village Extension Officer; PM = planting material

Figure 4 CBSD control measures used by respondents

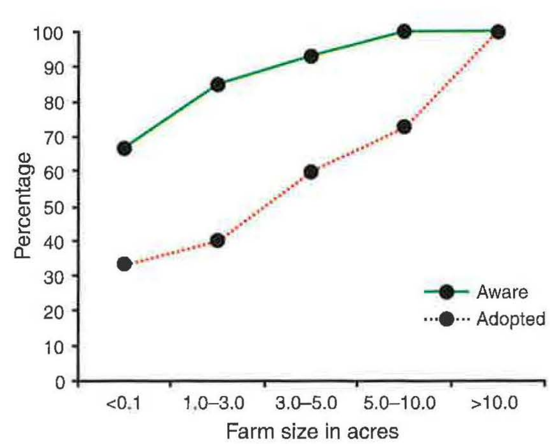


Figure 5 Farm size and acceptance of technology (1 acre = 0.405 hectares)

CBSD control can make it more likely that the rate of adoption will be increased. This is possibly due to the fact that the most educated people at the village level are from wealthy backgrounds and hence consumption of cassava is perceived as lowly. For such a person there is less interest in cassava production and consumption; thus there is no need to look for the technologies. The relationship between education and technology awareness and adoption appears to be conflicting as shown by Figure 6. Increase in education from a lower to a higher level was equalled by an upward trend in the awareness and this is a normal trend. Surprisingly, however, the upward shift in education category led to a decrease in adoption of the technology.

Practice of CBSD control measures

The extension and research institution in the zone have over time exerted considerable effort in sensitizing farmers on the advantages of utilizing CBSD control measures. The five villages in the study area revealed some promising results suggesting that they are heading towards adopting these control measures.

About 42% of the respondents do not use CBSD control strategies whilst 58% of the respondents were reported to practise CBSD control measures (Table 3). The adoption of CBSD control strategies varied across villages.

Importance of the crop

There are a number of important factors affecting production of cassava: prevalence of diseases and pests (particularly CBSD), perishability of the crop, lack of attractive market to producers and the resources allocated to the production of the crop. All these factors when combined contribute to the importance of the crop. The importance of the crop is reflected in the allocation of resources, particularly land, to the crop (Figure 7). On average, farm sizes ranged from 0.4 to to 1.6 hectares. More land was allocated to cassava crop than the other crops; on average 47% of the total cropping area of the respondents was used for cassava production. Those according most importance to cassava were ready to accept CBSD control measures.

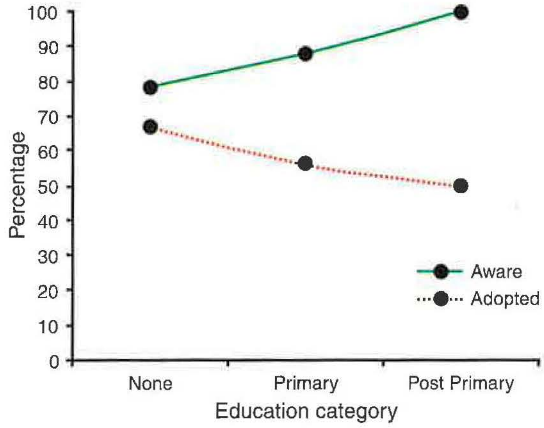


Figure 6 Education levels and technology

Table 3. CBSD control strategies across villages in southern Tanzania

Village	Respondents	Strategies	Percentage practising
Mtiniko	13	Do nothing	15
		Rogue	62
		Tolerant PM[1]	23
Ziwani	12	Do nothing	50
		Rogue	42
		Others	8
Chisegu	12	Do nothing	58
		Rogue	42
Tupendane	16	Do nothing	38
		Rogue	50
		Select PM	12
Tulieni	11	Do nothing	55
		Rogue	36
		Select PM	9

1. PM = planting material

Household expenditure

Regarding household expenditure, respondents listed the main items that their income is used for, which ranged from agriculture to kitchen utensils. Education, clothing and basic household needs appeared to be the main items, as shown in Figure 8. These findings imply that respondents are not investing heavily in agriculture. However, while agriculture actually consumes relatively more resources, this is not reflected in the figures since labour and land were not effectively taken into consideration.

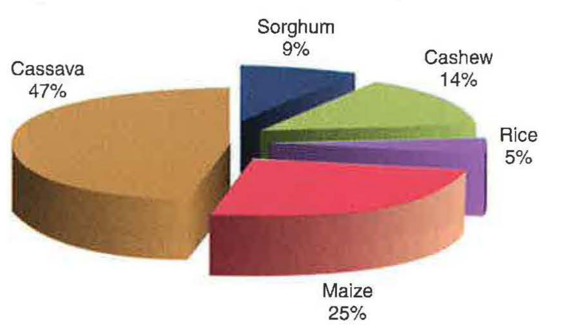


Figure 7 Allocation of land to crops

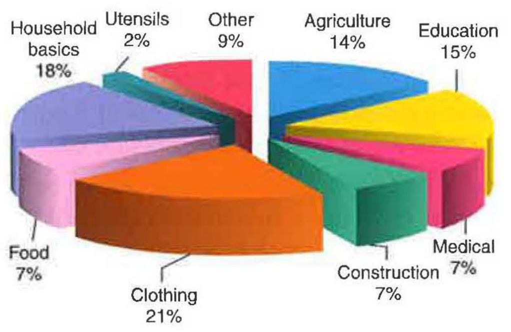


Figure 8 Household expenditure on priorities

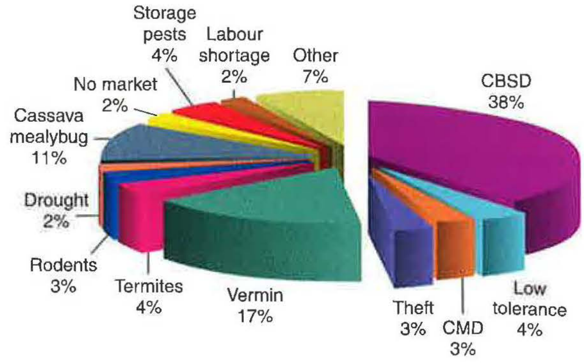


Figure 9 Cassava production constraints

Cassava production constraints

In the study area there are various production constraints that hinder production of the cassava crop (Table 4). The constraints are ranked according to three priorities – those in the first rank are of greatest importance and demand solutions at the earliest opportunity.

Many production constraints were mentioned by respondents (Figure 9) with CBSD being the most important production constraint in the area. The next most important constraint was prevalence of vermin attacking their crops, mainly wild pigs, rodents and monkeys. The third most important constraint was the prevalence of cassava mealybug on cassava, a problem for many years now. Other minor problems amounting to 7% included low soil fertility, shortage of capital, weed infestation, shortage of improved planting materials and shortage of extension services.

Conclusions

Table 4. Cassava production constraints of 64 respondents (%)

Constraints	Priority I	Priority II	Priority III
Occurrence of CBSD	44	13	6
Low resistant to pests and disease	3	3	2
Occurrence of CMD	0	6	0
Theft incidences	3	2	0
Vermin attack	17	9	2
Occurrence of termites	2	5	3
Occurrence of rodents	0	3	6
Cassava mealybug	11	5	5
Drought in some years	3	0	0
Unfavourable market	3	0	0
Prevalence of storage pests	3	3	2
Weed infestations	0	0	3
Shortage of labour	0	2	5
Other constraints	5	3	3

Bearing in mind the importance of cassava in the Southern Zone, this study was undertaken in order to provide a broad overview of the socio-economic considerations that affect CBSD control strategies in the two regions of Lindi and Mtwara. The study made the following important findings:

1. The CBSD control strategies that have been generated by NARI have not reached the majority of the targeted farmers. Less than half of the respondents are aware of the technology.
2. The cassava crop takes second place in importance after maize in consumption while it takes first position as a food security crop and staple for the majority of households.
3. Cassava production over time has increased, mainly due to an increase in the area cultivated. This is most likely due to the emphasis put by the Government on the crop.
4. There is low investment in agriculture as revealed by respondents' expenditure patterns which give priority to clothing, basic household needs and education, in that order.
5. Available resources at farm level do have a positive impact on the adoption of technology as exemplified by the household farm size.
6. Farmers' age and experience in cassava production have a positive relationship with the adoption of the CBSD control technology, but curiously, level of education appeared to correlate negatively with adoption.

Recommendations

Based on the findings of this study and bearing in mind the objectives set out for this study, the following recommendations are suggested:

1. Establish an integrative relationship between research and the extension service to facilitate technology development between research and farmers.

2. Conduct further studies on marketing of cassava and its products followed by interventions focused towards cassava product promotion.
3. Train farmers on appropriate storage practices and postharvest processes using participatory approaches that build on the current farmer practice.
4. Strengthen the production and distribution of improved and disease-free cassava planting materials in the pilot villages.
5. Build farmers' capacity to multiply and distribute improved diseased-free planting materials.
6. Carry out training to improve farmers' ability to diagnose and identify the symptoms and effects of the major cassava diseases.

Acknowledgement

The authors wish to appreciate the assistance given by the UK Department for International Development's Crop Protection Programme, through the Natural Resources Institute, for its continued financial support, and the Naliendele Agricultural Research Institute for its logistic and technical support. The staff of Naliendele and the organizers of this workshop and participants are gratefully acknowledged.

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CBSD MANAGEMENT

Historical Perspective on Breeding for Resistance to Cassava Brown Streak Virus Disease

D.L. Jennings

'Clifton', Honey Lane, Otham, Maidstone, Kent, UK

Introduction

Most workers involved with cassava (*Manihot esculenta* Crantz) research will have heard of Amani in Tanzania. It is situated some 300 feet asl in the Eastern Usambara mountains of Tanzania, rising steeply from the coastal plain near the port of Tanga. Research began at Amani when Tanganyika, as it was then called, belonged to Germany and the German, Zimmermann (1906), reported the first studies of a cassava disease in 1906. After World War 1, it came under British colonial management and was reopened as a research institute in 1927. Storey and Nichols joined in the early 1930s and began their classical studies of cassava mosaic virus disease (CMD) and cassava brown streak virus disease (CBSD). A worldwide collection of cassava cultivars revealed only moderate degrees of resistance to CMD, and so in 1937 they began the lengthy process of transferring genes for resistance to both CMD and CBSD from related species. Worthwhile resistance to CBSD was found later in the Brazilian cultivars Aipin Valenca and Macaxeira Aipin (*aipin* is Portuguese for cassava).

Methods used to evaluate resistance to CBSD

A brief description of the methods used at Amani to evaluate resistance to CBSD and discussion of some observations on the expression of this resistance (Nichols, 1947; Jennings, 1957, 1960) is provided.

Early trials

All cassava breeding material was raised and maintained at Amani, where few virus vectors occur and very little virus spread is seen. The material was therefore always healthy when planted in resistance trials. In trials on the coastal plain from 1941 to 1953, the test material was planted in the short rains (October/November) adjacent to diseased plants and harvested in the following August. Each trial always contained the same three susceptible control cultivars, which became infected with CBSD.

Cassava Brown Streak Virus Disease: Past, Present and Future. Proceedings of an International Workshop, Mombasa, Kenya, 27–30 October 2002. Legg, J.P. and Hillocks, R.J. (Eds) (2003). Natural Resources International Limited, Aylesford, UK. 100 pp.

In evaluating resistance to CBSD, leaf symptoms were ignored because leaf fall was advanced, particularly in respect of mature symptom-bearing leaves. The procedure at harvest time was as follows. One member of the team cut away the swollen leaf bases to reveal stem symptoms, whose intensi ty was scored from 0 to 3 by a following member. Other members then lifted the roots and sliced them to reveal root symptoms, which were also scored from 0 to 3 for intensity. With 12 plants per genotype in a trial, and each one scored from 0 to 3 for stem and 0 to 3 for root symptoms, each entry received a total score of from 0 to 36 for each symptom.

The data were used to calculate percent resistance, the number of symptom-bearing plants and their mean symptom intensities. The large variation that occurred in symptoms of CBSD from 1941 to 1953 in the susceptible control cultivars was highly correlated with variations in the resistance that they showed to CMD. These variations were attributed to soil fertility differences, a high nitrogen/low potash combination leading to severe symptom expression in both diseases. CBSD symptoms in these two cultivars are illustrated in Nichol's 1950 paper, which shows extremely severe symptoms in hybrid 4026/15. Hence, even an extremely susceptible cultivar can show wide variation in symptoms.

In cultivars with some resistance to CBSD, symptoms became less or disappeared following active symptom-free stem or root growth, which compressed or occluded the necrotic tissues. This often occurred following growth between 9 and 15 months from planting, while symptoms became severe after 18 months, apparently because stem and root growth was minimal at this stage.

For CBSD, genotypes that had a low incidence of symptom-bearing plants also had a low intensity of symptoms in the plants which showed the disease, but derivates of *Manihot melanobasis* were exceptional. They were highly resistant and rarely became diseased but, when present, the symptoms were severe. This was attributed to a low capacity to recover from symptoms; their long 'sausage-like' roots showed minimal increases in girth and hence had a minimal opportunity to reduce symptoms with new symptom-free growth.

Sixty percent of the cultivars with intermediate or high resistance had root symptoms but no stem symptoms. This may have been due to an ability to localize virus in the base of the plant as postulated for resistance to CMD (Jennings, 1957). Those with high resistance either remained symptom-free or had only mild symptoms

Breeding for resistance using inter-specific hybrids

Storey and Nichols made crosses with four tree-like species and two shrub-like species: only the results for M. *glaziovii* of the former and M. *melanobasis* of the latter will be discussed here. The problem was to retain the resistances of these species while eliminating their non-cassava characteristics using a process of backcrossing. For M. *glaziovii*, the first cross was made in 1937 and the first, second and third backcrosses were made in 1940, 1943 and 1946/47, taking three years to raise and evaluate each generation. It should be noted that the work continued in wartime, when Amani was isolated from London and largely engaged in wartime activities. Acceptable cassavas were not obtained until the third backcross, when the genetic make up of the progenies had been restored to 15/16th of the cassava germplasm with only 1/16th of the donor germplasm remaining. The first cross with the shrub-like M. *melanobasis* was not made until 1950. Allem (2002) considers that M. *melanobasis* is a synonym of M. *esculenta* subspecies *flabellifolia*, which is common in Brazil.

The programme was struck by tragedy in 1951 when Nichols was killed in an accident. This meant that Jennings who had arrived in East Africa in 1950 to breed maize was transferred to Amani in 1952 to continue the cassava work.

At this time, favourable reports were being received of the good quality of the third backcross M. *glaziovii* material, though resistance to CMD – but not to CBSD – had failed at a few sites. Resistance to CMD was considered to be multigenic and recessive, and it was thought that inter-crosses among the resistant selections would bring together different resistant genes that had been dispersed during the backcrossing process, and also allow the expression of resistant genes. Hence the inter-crossed material raised in 1953 proved much superior for CMD resistance than that of the third backcross material, which by this time was rated as only 80% resistant. Resistance to CBSD was satisfactory in the backcrosses and was maintained in the inter-crosses. Crosses were made between M. *glaziovii* and M. *melanobasis* derivatives, partly to strengthen CBSD resistance and partly to retain other good features of the latter species. Hence not all the M. *melanobasis* parents used had resistance to CBSD.

Impact of resistant cassava in East Africa

In 1953, a profitable collaboration was initiated with A.H.B. Childs, the Agricultural Officer for Tanga District. The object was to identify the best hybrids and use them to eliminate cassava virus diseases in the area. Childs (1957) realized that he first needed to win the confidence of the farmers by demonstrating the merits of the material. He also realized that the benefits of resistance were directly related to the amount of stress that affected plant growth. Cassava growing on the fertile red soils suffered less stress than cassava growing on the sandy soils, and in both instances the stress was reduced by growing on ridges. His results for 46106/27, the most successful hybrid studied, with very high resistance to CBSD, relate to 12 sites, subdivided for flat and ridge cultivation. Ten of the sites contained the popular local cultivar Gide as control – Gide, of course, was infected with both CMD and CBSD. His data have been simplified by expressing the results as a percentage improvement over the control:

Improvement from use of resistant cultivar (%)

	Red laterite soils		Sandy soils	
	Ridged	Flat	Ridged	Flat
Establishment (%)	144	188	232	300
Yield of established plants	126	153	178	275

The results clearly show the dramatic superiority of 46106/27 and the major importance of stress factors. Childs observed no CBSD in 46106/27 and very little CMD, though the incidence of CMD increased later (Childs, 1958). He described his ambitious plans as: "in 1957 – 99 acres will be planted with 46106/27 to supply cuttings in one concentration on the sandy soil, so that in 2–3 years the area will be free of local cultivars and cleaner of disease." Childs left the area in 1956 without knowing whether or not he was successful.

Advancing 30 years to 1987, Abubaker *et al.* (1989) reported results of a cultivar evaluation at Msabaha, Kenya, from 1984 to 1987. They were clearly not aware of Child's 1957 publication and recommended the multiplication and wide distribution of four cultivars, which they had chosen for high yield and popularity with the farmers.

The cultivars were:

- Guzo – a local cultivar
- Kibandameno– a local cultivar reputed to be related to the highly susceptible Mpezaze
- 5543/156 – ex Amani
- 46106/27 – now named Kalenso (or Kaleso) by Kenya farmers (in Tanzania it is sometimes known as *Bwana mrefu* – the tall *bwana* and Nichol's nickname).

It was very satisfactory that 46106/27 had increased in popularity over this long period. This is clearly a starting point for the present discussions. Cultivar 5543/156 is from a cross made in 1955 between a first backcross M. *melanobasis* derivative and a fourth backcross M. *glaziovii* derivative. M. *melanobasis* contributed to the improvement of several characteristics, and so the parents chosen may not have been resistant to CBSD. Surviving records do not show the resistance status of the parents of 5543/156, but two of the four grandparents used in the previous generation were resistant and the other two were susceptible. Thus it is likely that 5543/156 also has resistance to CBSD, but a resistance trial is needed to confirm this. Possibly the records of pedigrees could be useful to assess the potential of other cultivars in the collection.

International impact of resistant cassava germplasm from Amani

In 1954 there were rumours that cassava breeding at Amani would be discontinued in 1958, when the evaluation of existing material would be completed (Jennings was moved to other projects in 1956). There was concern that the valuable germplasm would not survive and be utilized, and therefore open-pollinated seed was distributed from the most CMD-resistant material to many centres in Africa (fears of spreading CBSD precluded the distribution of cuttings). Much of the seed fell on stony ground and did not survive, but good use of it was made at Moor Plantation in Nigeria. Beck (1982) describes how selections from this material became the starting material of the International Institute for Tropical Agriculture (IITA) programme in the 1970s. An important selection was 58308, which came from the seed of 5318/34, one of the most CMD-resistant selections from the intercrosses made in 1953. Other selections were also used but 58308 was the most important. Unfortunately, like its parent 5318/34, it was only moderate for yield. The IITA breeders upgraded the material by crossing with high yielding parents from Nigeria and also from South America. They selected for resistance to CMD, but could not select for resistance to CBSD. It is still possible that genes for this resistance remain in the IITA germplasm, but such genes will clearly have been diluted by many generations of crossing with other material.

Outlook for the future

The present problems with CBSD can only be solved by the use of resistant cultivars, but the present material must be multiplied and distributed in bulk to maintain an adequate health status in respect of both CMD and CBSD. The proposals of Childs (1957) are therefore recommended. The cultivar 46106/27 (Kalenso) provides a starting point, because its resistances, yield and popularity have been proved over some 30–50 years. Other selections in the cultivar collection probably have potential too, which should be assessed in resistance trials. Future breeding should aim to upgrade the best of the present material in respect to yield and other qualities, and should operate on a larger scale than the relatively small scale used in the Amani programme. Consideration of IITA's experience using directly sown seed and polycross pollination techniques could be useful.

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Role of the Kenya Plant Health Inspection Service in Germplasm Diversification and Exchange with Respect to *Cassava Brown Streak Virus*

R. Onamu, E. Kimani, W. Songa and C.J. Kedera

Kenya Plant Health Inspectorate Service, Nairobi, Kenya

Introduction

The Kenya Plant Health Inspectorate Service (KEPHIS) is charged with the responsibility of ensuring quality agricultural inputs and produce; including vegetatively propagated planting materials (potatoes, cassava etc.).

The Plant Quarantine Station (PQS) was established to implement safeguarding activities and facilitate the safe movement of plant materials, categorized as high risk due to their ability to carry quarantine diseases including latent infections, especially viruses. Quarantine pests are those not reported in the importing country or if reported, those that are under official control due to their economic importance.

Cassava (*Manihot esculenta* Crantz) is categorized under high-risk plant materials due to the fact that a number of injurious pests are reported to affect the crop. Currently, cassava mosaic virus disease (CMD) and cassava brown streak virus disease (CBSD) are threatening cassava production in Kenya. As a result, scientists have initiated extensive research to come up with more tolerant cultivars. In this regard, KEPHIS has had to facilitate the introduction of germplasm from several sources (most notably Nigeria and Uganda) to diversify the germplasm. Due to the limited space at the PQS, an open quarantine procedure has been adopted to facilitate the plant introductions. Although tissue culture has been recommended for the safe movement of cassava germplasm, vegetative cuttings were used due to the emergency situation that the cassava crop was experiencing in Kenya. However, plans are under way to utilize tissue culture on a routine basis. This is especially important for *Cassava brown streak virus* (CBSV), the cause of CBSD, which has a limited geographical distribution (see other reports in this volume).

Cassava Brown Streak Virus Disease: Past, Present and Future. Proceedings of an International Workshop, Mombasa, Kenya, 27–30 October 2002. Legg, J.P. and Hillocks, R.J. (Eds) (2003). Natural Resources International Limited, Aylesford, UK.100 pp.

Role of Plant Quarantine Station

The PQS, Muguga, Kenya, will collect (source), hold germplasm as long-term *in vitro* storage and, whenever the materials are requested, organize the exchange of clean materials. In cases where cuttings are introduced, open quarantine procedures can be adopted accordingly (see Mohamed, pages 63–65). In addition, testing for the virus diseases and clean up using meristem tip culture and thermotherapy will be done.

Some of the tests used include mechanical inoculation to indicator plants, serological tests using enzyme-linked immunosorbent assay (ELISA) and symptomatology. Some viruses are better identified using modern methods such as polymerase chain reaction (PCR), particularly CBSV, for which a reverse-transcription polymerase chain reaction (RT-PCR) technique is required (see Legg, pages 41–45). However KEPHIS does not have the PCR equipment and there is a need for staff to be trained in modern virus testing methods due to the large numbers of plant materials processed through the PQS.

The PQS aims to:

1. Promote efficient collection and safe *in vitro* storage of cassava germplasm
2. Ensure safe movement and exchange of clean cassava germplasm
3. Virus index plant material to be maintained or exported.

PQS activities

To ensure safe movement of plant materials, the following activities form part of the quarantine procedures.

Export/Import documents

Import documents. Anyone wishing to import plant materials into Kenya **must** obtain a plant import permit (PIP) from Kenya **prior** to shipment of such plants. The permit specifies the requirements for plant health indicating prohibitions, **restricted quarantine** importations and additional declaration with regard to preshipment treatments. The original plant import permit must therefore reach the plant health authorities in the country of origin for strict adherence to Kenyan permit requirements.

Any plant consignment arriving in Kenya should therefore be accompanied by a copy of the Kenya permit and additional health certificate (Phytosanitary Certificate, International model or its equivalent) from the exporting country.

It is advised that all visitors arriving in Kenya must, therefore, declare all plant materials in their possession on arrival at the points of entry. It is illegal to import plants into Kenya without a proper authority from KEPHIS.

Export documents. A phytosanitary certificate is issued following inspection of domestic plants and plant products offered for export provided that such materials are apparently free from injurious diseases and pests and that the consignment is believed to conform to the current phytosanitary regulations of the importing country.

Export/Import regulation

The requirements imposed by the above mentioned documents constitute the phytosanitary regulations. Based on the import permit requirements, plant materials are categorized as:

1. **Prohibited** – The plants are totally banned from entering the country except for research purposes and only on the approval by the Kenya Standing Technical Committee on Imports and Exports (KSTCIE).
2. **Quarantine** – Significant and destructive diseases may be borne in or on the seed and/or plant materials. Laboratory tests are inadequate to render the material to be classified as posing a high risk and the only safe approach is to reduce the risk by:
   a) limiting the quantity of materials which may be imported
   b) applying chemical treatment
   c) growing the imported plant materials in isolation post-entry quarantine such as Open Quarantine (OQ)
   d) more efficient introductions through tissue culture.

   To import materials under quarantine regulations, approval must be sought from KSTCIE.
3. **Permit** – The plants enter the country and are released to the consignee on issuing of an import permit. The risks involved in importing the plants in question are relatively low.
4. **Endangered and/or rare species** – Imported only on the approval by the government of the exporting country and in accordance with the Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora.

Cassava – categorized as a quarantine crop

The cassava crop is prone to several diseases and pests, some of which are latent, making them difficult to detect on simple observation. In this regard, it is safest to exchange cassava germplasm as tissue-cultured materials where facilities allow, or under open quarantine procedures where tissue culture facilities are not available and/or an emergency situation prevails while the disease is already reported in the area. When untested vegetative stem cuttings are moved they must be treated with the appropriate pesticides in the country of origin. These materials are to be further processed at the intermediate or post-entry quarantine facilities before they can be released. (For details on safe movement of cassava germplasm, see Annex at the end of this paper)

Cassava brown streak virus disease (CBSD)

Distribution

CBSD was reported to be widespread in Kenya (Bock, 1994; Nichols, 1950). It has also been reported to be present in Uganda, Tanzania, Malawi, Mozambique, Zanzibar and Zambia.

Phytosanitary significance

No known risk from the movement of seed has been recorded but vegetative propagules are a serious hazard. It is important to control the disease between and within regions in a country. This is particularly necessary through preventing the spread of the disease from affected to unaffected areas where CBSD has not yet been reported.

Symptoms

Symptoms are observed on mature leaves as described elsewhere in this volume. Root symptoms comprise dry necrotic rotten patches ranging from sepia to dark brown in colour. In severe cases, these render the roots unusable.

Diagnosis

Symptoms are rather variable, depending on the environment and cultivar. ELISA and indicator plants do not provide reliable diagnoses. However, a recent RT-PCR based diagnostic method, developed by Monger *et al.* (2001), and summarized here (see Legg, pages 41–45) has been shown to detect CBSV even in symptomless newly emerging leaves of otherwise CBSD-diseased plants.

Control

1. Phytosanitation
    - Containment of the disease within a limited area of distribution in East and parts of Southern Africa by observing strict quarantine regulations
    - Meristem tip therapy – to meet quarantine requirements
    - Management of foundation seed stock through inspection and rigorous roguing during active growth and at harvest, if found free, to be used for multiplication and distribution to farmers
    - Simple procedures introduced to farmers for selecting clean planting materials e.g when to select
2. Host-plant resistance
3. Integrated pest management, combining 1 and 2 and including prevention by exclusion through the development of an efficient plant quarantine system in the region.

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Annex
Safe Movement of Cassava Germplasm

FAO–IPGRI[1] Recommendations

Material should be collected, processed and shipped with the necessary precautions to avoid accidental movement of pests.

Under no circumstances should germplasm be moved as rooted plant materials except for *in vitro* plantlets.

Cassava germplasm can be moved as seed, pathogen-tested *in vitro* material, or cuttings from re-established pathogen-tested *in vitro* materials that have been grown under containment. Each of these three categories should be treated as described in the Technical Recommendations.

Only under special circumstances should the movement of untested, vegetative material be considered.

All germplasm should be collected from healthy-looking plants and when possible from areas where quarantine pests are not present. Germplasm from areas where pests of quarantine concern are known to occur should go through intermediate or post-entry quarantine.

The transfer of germplasm should be carefully planned in consultation with quarantine authorities and should be in amounts that allow adequate handling and examination. The material should be accompanied with the necessary documentation.

Technical Recommendations

1. Seed

- Seed production should be carried out in areas which are free from diseases of quarantine significance whenever possible.
- Fruits should be harvested from healthy looking plants.
- Seeds of normal size should be selected from healthy looking fruits.
- Seeds should be treated according to the following recommendations, either in the country of origin or in the country of destination:
  - Immerse the seeds in water and discard any floating seeds.
  - Treat the seeds immersed in water in a microwave oven at full power until the water temperature reaches 73°C and pour off the water immediately after the treatment.
  - If a microwave oven is not available, treat the seeds with dry heat for 2 weeks at 60°C.
  - Dry the seeds and treat them with thiram dust.
  - Pack the seeds in a paper bag.
- After arrival in the country of destination, the seeds should be inspected for the presence of insect pests. If found to be infected, they should be fumigated or destroyed (if fumigation is not possible).
- Seeds should be sown under containment or in isolation and kept under observation until the plants are well established and normal healthy leaves are produced.

2. Pathogen tested *in vitro* cultures

- Stem cuttings should be collected from healthy looking plants, whenever possible.
- Stem cuttings should be grown in pots and on sprouting, be subjected to thermotherapy in a growth room with temperatures of 40°C by day and 35°C by night.
- Meristem-tips of less than 0.4 mm should be cultured and each meristem-tip derived plantlet should be given an accession number and multiplied.
- For each meristem-tip derived accession, one plantlet should be grown out under containment and indexed for diseases. (It is not necessary to index for bacterial and fungal pathogens, as these will reveal their presence in the culture medium.)
- When the indexing procedures reveal that the plants are free of concern, *in vitro* plantlets derived from the same meristem-tip can be transferred.
- For the movement of *in vitro* plantlets, neither antibiotics nor charcoal should be added to the culture medium.
- In the recipient country, *in vitro* plantlets, should be examined for contamination and if found free, grown out and maintained with regular inspection.

3. Cuttings for pathogen-tested *in vitro* cultures

- This method is recommended only where recipient countries are unable to handle *in vitro* materials.

[1] Food and Agriculture Organization of the United Nations–International Plant Genetic Resources Institute

- Pathogen-tested plantlets produced according to the procedures described above should be grown out and multiplied in an insect-free facility with adequate measures to prevent re-infection by pathogens.
- Stem cuttings from these plants should be washed, surface sterilized with sodium hypochlorite and treated with appropriate insecticides, acaricides and fungicides before despatch.
- In the recipient country, the cuttings should be grown under containment and subjected to regular inspection.

Note: Permission for the importation of biological control agents (BCA) and living modified organisms (LMO) is facilitated by KEPHIS after approval by KSTCIE.

Role of Open Quarantine in Regional Germplasm Exchange

R.A. Mohamed

Ministry of Agriculture and Food Security, Plant Health Services, Dar es Salaam, Tanzania

Introduction

One of the major challenges facing developing countries is to achieve national food security and at the same time reduce environmental degradation and the depletion of natural resources. Most governments have invested significant resources into strengthening agricultural capacities. In addition, countries have received assistance from bilateral and multilateral development agencies to attain food security. Despite these efforts, agricultural production still lags behind the national food demand.

Quality seed (germplasm) is one of the primary requirements for improving agricultural production and food security to farmers. Farmers' access to quality seed can only be achieved if there is a viable seed supply system to multiply and distribute the seeds that have been produced or preserved, and if mechanisms to assist farmers in emergency situations have been established.

Seed imports help to introduce new cultivars to the farming community. However, such importations are associated with risks of introducing dangerous exotic pests (viruses, bacteria, fungi, nematodes, weeds and insects) that threaten agriculture and biodiversity. Due to the threat posed by pest introduction, phytosanitary restrictions limit the importation of some important germplasm and agricultural commodities. Many of these restrictions admittedly constitute trade barriers that can be challenged. Limiting seed importation prevents farmers from reaping the benefits of better cultivars marketed by neighbouring countries.

Impacts of introduced crop pests

The economic impacts of introduced pests can be complex and go beyond the immediate impact on the directly affected agricultural producers. Introduced pests leave their natural enemies behind and can multiply to very high population densities, and therefore cause substantial crop loss. The production costs increase due to efforts to contain the pest. Similarly, price of the commodity also increases because supply cannot meet demand for the product. Such pests also have major implications for farmers who produce crops for export. Countries that are free from key pests will tend to protect their local agriculture by excluding importation of products from countries affected by those pests. For example in 1986 Tanzania failed to export maize to Zambia and Zimbabwe due to larger grain borer (LGB) infestation in Tanzania.

Experience of introduced crop pests in Tanzania

Introduction of quarantine pests normally involves human intervention, either through importation of agricultural products or accidental or deliberate smuggling into the country. Most of these introductions are undetectable and, although most are harmless, without improved detection methods for pests with cryptic life stages, exclusion efforts will not be successful. This problem is chronic for the control of seed-borne pathogens including viruses, bacteria and fungi.

Larger grain borer

LGB (*Prostephanus truncatus*) was accidentally introduced to Tanzania in 1980 through food aid. The Government was spending substantial sums annually to contain the pest, but once the pest was established, eradication was not possible. Since then the pest has spread to Kenya, Zambia, Burundi, Rwanda and Malawi. Prior to LGB introduction losses of stored maize ranged between 5% and 9%, which thereafter rose sharply to over 30% after three months of storage. To a small-scale producer, a loss of 30% is a substantial amount.

Cassava mealybug and cassava green mite

Cassava mealybug (CM) (*Phenococcus manihoti*) and cassava green mite (CGM) (*Mononychellus tanajoa*) were also accidentally introduced into Africa from Latin America in the 1970s through cassava cuttings. Both pests established and spread in the cassava-growing regions of Africa (Markham *et al.*, 1992). In Tanzania, CM was first reported in 1987 around Lake Malawi then spread to all cassava-growing regions.

Cassava Brown Streak Virus Disease: Past, Present and Future. Proceedings of an International Workshop, Mombasa, Kenya, 27–30 October 2002. Legg, J.P. and Hillocks, R.J. (Eds) (2003). Natural Resources International Limited, Aylesford, UK. 100 pp.

The pest caused significant yield losses ranging from 50% to100%. The Government was forced to provide food relief in Mara Region because cassava is a key food security crop there and it was devastated by this pest.

Cassava mosaic virus disease

Cassava mosaic virus disease (CMD) is an important disease in all cassava-growing regions of Africa. Recently a pandemic of an unusually severe form of CMD spread within and beyond the borders of Uganda into Kenya, Tanzania, Democratic Republic of Congo, Congo Brazzaville and Sudan. The pandemic is caused by a new strain of the virus known as Ugandan variant of *East African cassava mosaic virus* (EACMV-Ug), which was first reported in Uganda in late 1980s (Deng *et al.*, 1997; Zhou *et al.*, 1997; Legg, 1999). EACMV-Ug is a recombinant hybrid derived from the two principal cassava mosaic geminivirus species known to occur in Africa, *African cassava mosaic virus* (ACMV) and *East African cassava mosaic virus* (EACMV) (Zhou *et al.*, 1997). In Tanzania, severe and rapidly spreading CMD was first recorded in September 1998 in Missenye and Kiziba divisions of Bukoba District, in the Lake Zone (Jeremiah and Mukandala, 1998) causing significant losses. Subsequent diagnostic tests confirmed the association of severe CMD with the presence of EACMV-Ug (Legg and Okao-Okuja, 1999). Since then the disease has spread rapidly, covering Bukoba, Karagwe, Muleba and Biharamulo districts in Kagera Region and Geita (2000) and Sengerema (2002) districts in Mwanza Region; Kibondo District in Kigoma Region and Bukombe District in Shinyanga (2002) (Jeremiah and Ndyetabula, 2002).

Measures to prevent introduction of quarantine pests

Quarantine

Quarantine means confinement of a consignment under conditions of strict containment under official supervision. Quarantine is the first line of defence against introduced plant pests. It is a legislative or regulatory control, which aims to exclude pests from hosts or from a certain geographic area. Legislation by itself does not control pests, but it establishes the statutory authority for government agencies to engage in limiting pest dispersal or in treating localized infestation of pests.

The risk of pest introduction varies with the type of plant material and types of pests, and hence requires different levels of containment. Vegetatively propagated germplasm is a potential pathway for the introduction of plant pests such as viruses, viroids, nematodes, phloem and xylem – limited bacteria and immature stages of arthropods. Some plants appear clean but may have latent infection, which is not easy to detect even with molecular diagnostic techniques. Therefore, importation of such materials has been responsible for introduction of and spread of many important pests in the world such as CM and CGM accidentally introduced from South America.

Micro-propagation

The availability of micro-propagation techniques such as tissue culture and pollen culture provides a solution to minimize the introduction of pests that may be present in vegetatively propagated germplasm. The unavailability of virus indexing or other related equipment may limit the use of this technique.

Open quarantine

This is the quarantine of plants without using such physical confinement structures as glasshouses or screen-houses. This can be used to reduce or eliminate the risk of spread of pests by adhering to a quarantine protocol. The technique has been used successfully in East and Central Africa to exchange germplasm resistant to EACMV-Ug. Open quarantine has facilitated safe introduction of large quantities of cassava germplasm, which would not have been possible through other means. The method was cheaper than micro-propagation and plant mortality was also low. This method can be used in germplasm exchange programmes where the climate and pest species are more or less similar.

Protocol used in cassava germplasm exchange in East Africa

Location of the open quarantine field

1. The field should be located in a government-owned institution such as a research institute.
2. Isolation distance should be 200–400 m away from any other cassava field.

Source of materials

1. Cultivars should be obtained from a reputable source where the history of the cultivars in relation to pests and diseases is well documented.
2. Plant quarantine officers and plant breeders of both importing and exporting countries should be involved in the selection of the materials.
3. Background information (passport data) of the materials to be introduced should be provided to the importing country.
4. The importing country should provide a plant import permit.

Field establishment

1. Site selection should be done by the institution where the field will be located and approved by the plant quarantine officers.
2. The field should be fenced and should have only one outlet. A disinfectant trough should be located at the entry point for use by persons and equipment entering the facility.
3. Prior to introduction the materials should be treated with both fungicide and insecticide.

Field maintenance

1. Thorough inspection of the plants should be done daily by authorized staff.
2. Roguing and burning of any plants that sprout with symptoms of diseases such as cassava bacterial blight (CBB), cassava anthracnose, viral diseases and scale insects.
3. No planting materials should be allowed out of the quarantine field until they are certified to be free of quarantine pests and diseases.
4. Quarantine officers bear the responsibility of the field until the materials are certified to be clean for distribution.

Duration of the quarantine field

1. Introduced materials should be under strict observation of plant quarantine officers for one crop cycle or a minimum of one year.
2. Ratooning of the first planting materials can proceed one year after introduction.
3. Materials may then be distributed for multiplication or for further research.

Conclusion

Open quarantine facilitated germplasm exchange within the East African region with minimum risk of introducing quarantine pests. It was used successfully after the outbreak of the severe form of CMD in the region. Transportation requirements are not as critical as for *in vitro* propagated materials. Unless the materials are present in the laboratory, it takes time from virus indexing until they are ready for exportation and again requires additional time and nurturing before they are ready to be planted in the field.

Open quarantine may, however, present a risk of introducing quarantine pests through germplasm exchange for materials imported from other regions or continents unless strict quarantine measures are adhered to.

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Management of Cassava Brown Streak Virus Disease in Tanzania

E.E. Kanju[1], K.J. Mtunda[2], M. Muhanna[2], M.D. Raya[3] and N.M. Mahungu[4]

[1] International Institute of Tropical Agriculture, c/o Agricultural Research Institute – Mikocheni, Dar es Salaam, Tanzania
[2] Agricultural Research Institute – Kibaha, Kibaha, Tanzania
[3] Agricultural Research Institute – Naliendele, Mtwara, Tanzania
[4] Southern Africa Root Crops Research Network, Lilongwe, Malawi

Introduction

Cassava (*Manihot esculenta* Crantz) is an important food crop in Tanzania. It is grown for its roots and leaves mainly for human consumption. The main production zones are: Eastern (Coast, Tanga and Morogoro regions), Lake (Mwanza, Shinyanga, Mara and Kagera regions) and Southern (Mtwara and Lindi regions). In terms of production, Tanzania is ranked eighth after Brazil, Nigeria, Thailand, Indonesia, Congo (Democratic Republic), Ghana and India. Annual root production is estimated at 5,500,000 t from 761,100 hectares. This corresponds to average yields of 7.4 t/ha, which are far below the world's average estimated at 10.5 t/ha (FAO, 2001). Many factors contribute to the low yields, among which are: pests and diseases; poor agronomic practices; poor soil fertility and use of planting material of inferior genetic potential mainly due to limited access to improved cultivars.

The major pests are cassava green mite (CGM) (*Mononychellus tanajoa*) and termites. However, cassava mealybug (CM) (*Phenaccocus manihoti*), which has been successfully controlled by biological means, is still a sporadic menace in some pockets of the country. In some areas of the country outbreaks of the variegated grasshopper (*Zonocerus variegatus*) and white scales (*Aonidomytilus albus*) can cause significant damage to the cassava crop.

The major diseases are cassava mosaic virus disease (CMD), cassava brown streak virus disease (CBSD) and cassava bacterial blight (CBB). CMD is caused by cassava mosaic geminiviruses, two species of which are prevalent in Africa: *African cassava mosaic virus* (ACMV) and *East African cassava mosaic virus* (EACMV) (Legg, 1999). A very virulent virus variant (which appears to be the recombinant hybrid of EACMV and ACMV) referred to as the Uganda variant of EACMV (EACMV-Ug) has spread rapidly from Uganda into Kagera Region on the western shores of Lake Victoria, causing epidemics of severe CMD with great losses (Legg, 1999).

CBSD was first reported in the 1930s (Nichols, 1950) and is now considered to be one of the major biotic constraints to cassava production especially in the coastal lowlands (Mahungu *et al.*, 1999). An Ipomovirus of the family *Potyviridae* (Hillocks and Thresh, 1998) whose vector is yet to be positively identified causes CBSD. CBSD is a serious threat to food security because, not only does it reduce total yields, it also renders the roots useless for human consumption due to the necrosis it causes to the starch storage tissues (Hillocks *et al.*, 2001).

CBB is caused by the bacterium *Xanthomonas axonopodis* pv *manihotis*. It has in recent years assumed economic importance status in Kagera (Bukoba District), Mwanza (Ukerewe District) and Mara (Tarime District) regions. Farmers in these areas are now demanding resistant cultivars. The main cropping zones for cassava and other crops are shown in Figure 1.

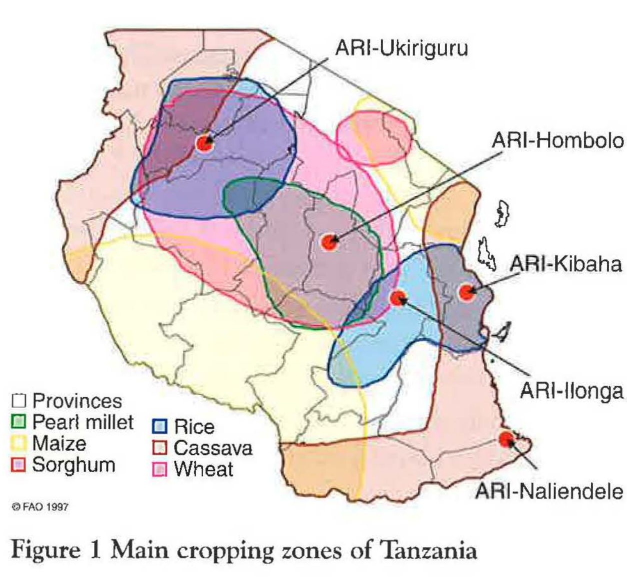

Figure 1 Main cropping zones of Tanzania

Cassava Brown Streak Virus Disease: Past, Present and Future. Proceedings of an International Workshop, Mombasa, Kenya, 27–30 October 2002. Legg, J.P. and Hillocks, R.J. (Eds) (2003). Natural Resources International Limited, Aylesford, UK. 100 pp.

Management of CBSD

Resistant/tolerant cultivars

Early workers in East Africa appreciated the use of resistant cultivars for the control of both CMD and CBSD. Their efforts led to the development of resistant cultivars popularly known as the Amani hybrids. Some of the so-called 'local cultivars' could have been distributed from Amani (Mahungu *et al.*, 1999). Many of the Internacional Institute of Tropical Agriculture (IITA's) most popular cultivars (including TMS 30572, TMS 4(2)1425) were developed with a CMD-resistant clone (58308) as one of their parents. This clone was a selection from third backcross derivatives of the interspecific cross between cassava and ceara rubber (*Manihot glaziovii*) from Nichol's work at Amani, Tanzania, in the 1940s (Asiedu *et al.*, 1994; see Jennings, pages 55–57).

During their annual research coordinating committee meeting in 1980, root crops researchers at the Agricultural Research Institute (ARI) at Naliendele, Mtwara, reported that CBSD was becoming a more economically important disease in Mtwara Region than previously assumed. They called for concerted efforts to control the disease (NRTCP, 1980). Since that time, selection for resistance to the disease was incorporated as one of the major criteria in developing improved cultivars by the small breeding sub-programme at the station. Breeding activities carried out at the station included: germplasm collection, introduction, evaluation and maintenance, and establishment of seedling nurseries using true seeds from both controlled hand crossing and open pollination (OP). Highly promising seedlings selected from the seedling nursery were cloned for further evaluation following the breeding scheme developed by IITA, i.e. from clonal evaluation trials through preliminary and advanced yield trials to uniform yield and on-farm trials. Breeding lines selected by farmers were then multiplied on station (breeder's seed) for distribution to farmers and other stakeholders for secondary multiplication.

Two local cultivars were identified to have tolerance/resistance to CBSD at Naliendele: Kigoma Red (Kigoma Mafia or Kigoma cha Kilwa) and Nanchinyaya (Nyachinyaya). The former was highly recommended because it rarely showed foliar symptoms, and when it did, they were very mild. Root symptoms were very rarely observed (small flecks). Nanchinyaya, on the other hand, showed severe leaf symptoms – and at high incidences – such that finding 'clean' planting materials of this cultivar was a major problem. However, it also showed very mild root symptoms.

In 1989 the Regional Commissioner of Mtwara Region directed the Regional Agricultural Officer to solve the serious problem of cassava root rot reported in Masasi District (about 200 km southwest of the coastal town of Mtwara). Researchers from Naliendele identified the problem to be CBSD and advised the farmers to plant the tolerant/resistant cultivar Kigoma Red (Kanju, 1989). The disease was mostly confined to Lukuledi division and was of epidemic proportions. Farmers in this ward had planted a single cultivar, called Mbwani Safi, on a large scale and almost in monoculture. This cultivar was very susceptible to the disease and yield losses from severely diseased roots were estimated at more than 60%.

From 1980 onwards, ARI Naliendele was the only research station in the country that was actively involved with CBSD research until 1994 when the Sugarcane Research Station at Kibaha started doing so when the Southern Africa Root Crops Research Network (SARRNET) regional breeder was based there. However, the root and tuber crops sub-programme at Naliendele was seriously understaffed.

Serious shortage of senior staff (BSc and above) at Naliendele and frequent discontinuity due to study leave adversely affected the output from the sub-programme. By 1995 only one breeding line (NDL 90/34) that had reached advanced stages of testing (multi-locational trials) was highly preferred by farmers and was undergoing multiplication on station. Since then, this clone has undergone on-farm testing in the Southern and Eastern Zones and is now earmarked for official release probably by the end of 2002. It is highly resistant/tolerant to CBSD, high yielding, sweet and has high dry matter content. However, it succumbs to CMD especially in the Eastern Zone where the disease pressure seems to be higher than in the Southern Zone.

Other cultivars that have shown high resistance/tolerance to CBSD at Naliendele are TMS 60142, TMS 4(2)1425 (from IITA) and Kitumbua and Namikonga (local cultivars collected in 1995 and evaluated after 1996). Kitumbua and Namikonga have been earmarked for official release.

At Kibaha the following cultivars evaluated from 1994 onwards have proved to have good tolerance/resistance to CBSD: Msitu Zanzibar, Mzungu, Nanchinyaya and Kiroba (local); KBH 95/0587, KBH 95/0047, KBH 95/0068, KBH 95/0732, KBH 95/0332 and UKG 93/041 (breeding lines); and TMS 300440 and TMS 82/0061 (from IITA) (Mahungu *et al.*, 1999). Among the breeding lines, only UKG 92/041 has reached the on-farm evaluation stage. However, it was not recommended for official release due to its poor sprouting ability. Among the local cultivars only Kiroba has been earmarked for official release.

Selection of clean planting materials

A basic approach to control virus diseases of vegetatively propagated crops is to use virus-free cuttings for all new plantings. Potential benefits of adopting this approach include better plant establishment and rapid growth, which will greatly enhance productivity (Thresh, 1987). Furthermore, this will decrease the extent of infection in the locality and the opportunity for further spread by vectors (Thresh, 1987; Thresh *et al.*, 1998). Researchers have recommended this strategy for adoption since the outbreak of the CBSD epidemic in Masasi District in 1989.

Roguing

Roguing is the removal of diseased plants from within crop stands. It is a well-known means of disease control of wide applicability and has been recommended repeatedly as a means of controlling CMD (Thresh *et al.*, 1998). Roguing has been adopted as an essential feature of official cassava planting material multiplication for distribution to farmers and other stakeholders. This applies for the control of both CMD and CBSD. Weekly inspections are usually recommended for the first two to three months of growth. Thereafter, frequency will depend on rate of spread of the disease into or within plantings. This will depend on the susceptibility of the cultivar and the inoculum pressure prevailing at the propagation site (Thresh *et al.*, 1998).

Current status on adoption of CBSD management strategies

As indicated above, researchers have recommended these three management strategies for adoption for more than 10 years now. But have farmers adopted them? A recent survey conducted in five villages in the Southern Zone where CBSD is endemic has revealed that many farmers (93%) were aware of the control measures but only 31% were practising them (Katinila and Hamza, 2001). Roguing was the most widely practised method (46%) whereas selection of clean planting materials was practised by 5% of farmers and use of tolerant cultivars was practised by 3% of the farmers (see Katinila, pages 46–52). Shortage or unavailability of tolerant cultivars was cited as the major constraint to adopting the use of tolerant/resistant cultivars. Farmers not practising roguing said that it lowers plant population and consequently leads to low yields.

A very recent survey was conducted in the Eastern Zone (Muheza District, Tanga Region) very close to where CBSD was first reported and where the major breeding work was done by early researchers. The survey was done as a result of the district officials requesting research intervention at the outbreak of a cassava root rot disease. The researchers diagnosed the disease as CBSD. However, the survey revealed that the majority of the farmers (77%) did not know the cause of the root rot nor of its foliar diagnostic symptoms. The rest attributed it to wrong causes, e.g. mealybugs, soil, other pests, prolonged drought and incoming planting materials (Muhanna and Mtunda, unpublished data). As expected, the majority did not practise any control measures. However, a few farmers reported to have abandoned the cultivation of very susceptible cultivars (Mahiza) for tolerant ones (Kiroba and Mamosi). Yield losses (determined from actual plot cuts as the difference between affected and non-affected roots) reported from the three surveyed villages ranged from 49–74% (Muhanna and Mtunda, 2002).

Suggestions to improve future adoption of the management strategies

- Training of farmers and extension workers on cause, diagnosis and control of CBSD
- Production and wide dissemination of extension materials to create awareness
- Community-based multiplication of resistant/tolerant cultivars
- Additional research to assess the effectiveness and advantages of adopting phytosanitation measures.

Summary

Cassava is a major food crop in Tanzania. Annual production is estimated at 5,500,00 tonnes, making Tanzania the eighth largest producer in the world. However, yields are lower than the world's average, estimated at 10.5 t/ha. The major causes for the low yields are: pests and diseases, poor agronomic practices, poor soil fertility and use of cultivars with poor genetic potential. The major pests are cassava green mite (CGM) and termites. However, mealybugs, variegated grasshopper and white scales can sometimes cause serious damage in some parts of the country. The major diseases are cassava mosaic virus disease (CMD), cassava brown streak virus disease (CBSD) and cassava bacterial blight (CBB). CBSD, first reported from Amani, Tanzania, in 1936, is now a serious threat to food security in the coastal lowlands where yield losses ranging from 49–74% have recently been reported in some areas. Management strategies

that have been advocated to control the disease include: use of resistant/tolerant cultivars, selection of clean planting materials and roguing. Early workers at Amani, Tanga, Tanzania, in the 1940s started breeding for resistance to the disease. Resistant cultivars developed by them have now assumed local names. The National Root and Tuber Crops Research Programme (NRTCP) started to select for resistance to CBSD in the 1980s. Resistant/tolerant cultivars identified and recommended for official release are: Kiroba, Namikonga, Kitumbua and NDL 90/034. However, recent surveys have revealed that in some areas the majority of farmers are not aware of the cause of the disease, its symptoms, nor its control measures. For those farmers who are aware of the disease and its control strategies, unavailability of planting material of tolerant cultivars has been cited as one of the major constraints in the adoption of this control strategy. Furthermore, some farmers were not willing to rogue diseased plants because the practice lowers plant population, and therefore yield. Suggestions to improve future adoption of control strategies are briefly mentioned.

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Cassava Brown Streak Virus Disease Management in Mozambique: the NGOs' Perspective

J.A.C. Steel

World Vision International – Mozambique, Zambézia Agricultural Development Project II, Quelimane, Mozambique

Introduction

This paper gives a synopsis of non-governmental organization (NGO) activities related to cassava brown streak virus disease (CBSD) in northern Mozambique and how the NGOs formed a loose consortium to tackle the various issues relating to this disease.

By 1998, Zambézia Agricultural Development Project – Phase II (ZADP II) and other NGOs had documented the problem of cassava root necrosis in some coastal areas, so the project initiated the process of obtaining assistance from the Natural Resources Institute (NRI), UK, to help identify the disease. As discussed elsewhere in this volume, two NRI virologists (Dr Rory Hillocks and Prof Mike Thresh) conducted two field visits in 1999 with ZADP in the two provinces of Nampula and Zambézia (see Figure 1 on page 73) and identified the disease as CBSD (Hillocks *et al.*, 2001) and began work to identify the main areas of infection. Technical support by NRI was provided by funding the Department for International Development (DFID) Crop Protection Programme (CPP) and an Advisory Services Support Contract.

At this time, no other CBSD work was being conducted in the country, so efforts were made to link with other NGOs based in the Nampula and Zambézia provinces, and Instituto Nacional de Investigação Agronómica (INIA) in Nampula to form a consortium with technical assistance from NRI. The objective of the consortium's work was to have a common strategy to focus on possible short-term remedies that could help alleviate the problem for those families most at risk. Longer-term strategies would be dependent upon longer-term research. The developed strategy was to identify and select cultivars that might be resistant/tolerant to CBSD, multiply the most suitable cultivars and distribute in the affected areas to farmers.

Cassava Brown Streak Virus Disease: Past, Present and Future. Proceedings of an International Workshop, Mombasa, Kenya, 27–30 October 2002. Legg, J.P. and Hillocks, R.J. (Eds) (2003). Natural Resources International Limited, Aylesford, UK. 100 pp.

Importance of cassava and the effect of CBSD

Cassava is the principle staple food for the 5 million inhabitants of the Nampula and Zambézia Provinces. Particularly the poorer communities in the region grow and depend upon it as a livelihood security food crop. Furthermore, they intercrop with maize, beans and vegetables. Other staple crops such as rice and maize are often preferred, but are more susceptible to drought and floods as has been shown in the past two years. CBSD invaded different areas in various ways. Farmers had been reporting major losses of cassava since 1997, by an unidentified root rotting disease. By 1998, this disease was causing considerable loss, and had affected large areas of coastal Nampula and Zambézia Provinces. Inland and higher areas were less or not infected by CBSD, but do tend to have high levels of cassava mosaic virus disease (CMD). For example, CMD is so prevalent in Gurué District (Zambézia Province) that it is regarded as the norm rather than as a disease. Furthermore, the CMD-infected leaves make a better-flavoured vegetable.

In Zambézia, where many cultivars showed signs of root necrosis, farmers were harvesting at approximately eight months or less to avoid large losses due to rotting, but obviously yields were reduced and more labour was required for more frequent land preparation. Initially, there did not appear to be any awareness that the disease was, principally, being spread by propagating infected planting material.

In Nampula, many cultivars showed more dramatic symptoms. For example, farmers in Mogincual District growing the cultivar Calamidade simply had no tubers – just a mass of rotting tissue. When farmers immediately replanted, the result was the same, as most planting material was diseased. The net result was that people were rapidly turning to other crops. Other cultivars were less affected, but the disease was still causing a large reduction in useable roots. Furthermore, some farmers were making efforts to obtain planting material from areas where root rot was not a problem or to obtain it from farmers who had cultivars that were apparently clean of infection.

Position of NGOs

In mid-2000, there was a fairly clear idea as to the importance of CBSD and it was decided to form a working group with Save the Children-Nacala (SCF) and the Nampula Food Security Programme (NFSP) of World Vision-Nampula. Some other projects joined later [e.g. Nampula Integrated Food Security Project (AusAID-NIFSP), United States Agency for International Development (USAID)-funded project in Zambézia (OVATA)]. Furthermore, it was important to involve INIA at Nampula because of the severity of the disease, and with the hope that it would ultimately be the driving force for finding a long-term solution to CBSD. Additionally, most agriculture projects were already collaborating with INIA by carrying out cassava screening trials for INIA.

When Prof Thresh visited in August 2000, a meeting was held at INIA-Nampula where the problem was debated and a plan of action drawn up. However, it is worth considering the status of the NGOs when the CBSD work first started. Points to note were:

- ZADP and other NGOs were all generally managing donor funded projects that had a short time span (two to five years) with short-term objectives to complete specific pieces of work (see Annex at the end of this paper).
- NGOs were running projects with different objectives and expected outcomes. However, most were broadly complementing the activities of the various provincial and district departments of agriculture.
- NGOs had to make and fit in identified CBSD activities within existing planned project work.
- Resources were limited as no allocation had been made specifically for CBSD work, but this was clearly an issue that could not be ignored. A joint application was therefore made to NRI to tap particular funds allocated to support NGO operations.
- ZADP examined its crop research and extension work and made CBSD one of its priority activities, and so accordingly was able to make some resources available. This included finding funds for a suitable research person to manage the project's own CBSD work, and coordinate and liase between the others in the consortium so that results and experiences could be better shared.
- Other NGOs in the consortium were not so fortunate. Some were 'in-between' projects, so funds were scarce. However, it did give them the opportunity to re-examine the planned activities in the future project and accordingly relocate funds where possible when they became available.

Planned and actual strategy

There was a need to have a common strategy so that CBSD work could be made more effective. Actions were to:

- Evaluate present status of known information such as main areas of infection, cultivars that appeared to be tolerant/resistant to the disease and others that were very susceptible.
- Plan what was needed to establish common on-station and on-farm trials at different sites in Nampula and Zambézia provinces where the incidence of CBSD was high (e.g. Nacala and Mossuril) or low (e.g. Gurué). In the high incidence sites, nine cultivars were to be tested that were believed to be tolerant/resistant to CBSD. In low incidence sites, four cultivars that were free of CBSD were to be tested. The first trials started in December 2000 and were repeated in 2001 (see Mangana, pages 14–17).
- Plan for a meeting after one year to discuss results and evaluate progress. This actually resulted in the Cassava Workshop in Quelimane of August 2001.
- Develop a clear policy that any likely infected material must not be transported to areas of low CBSD incidence.
- Build upon initial information gained by Ricardo Marcia (INIA Nampula) and collect more resistant/tolerant material from Cabo Delgado. The Nampula NGOs were to go and collect the material needed. It was known that a lot of promising CBSD tolerant/resistant material had 'leaked' across the boarder from Tanzania where it was more readily available.
- With NRI support, we had hoped to have assistance from Tanzania to select suitable cultivars in Cabo Delgado, but due to time constraints, this was not possible.
- Insufficient planting material was obtained from Cabo Delgado due to lack of resources and time, and there had to be a rethink on the design of trials so that all sites had some material to evaluate, select and possibly multiply. In the first year, all trials were laid out using a single row for each cultivar on a random design, replicated four times.
- Trials were established in all participating NGO areas and continued to have the support of NRI to monitor and evaluate their progress. Prof Thresh provided this support except for the final visit where Dr Hillocks joined him. Furthermore, Serafina Mangana accompanied them to evaluate the CBSD work. She had joined the ZADP team in 2001 to manage and liase these activities.

- Initial multiplication work was similarly done in blocks, but in the second year, due to a number of factors (lack of material, poor growing season, etc.), multiplication was switched to rapid multiplication beds producing planting material. This method produces more readily available clean planting material.

Results and issues

Cultivars

The results of the NGO trials have been presented elsewhere in this volume by S. Mangana (see pages 14–17). In brief, Muendowaloya, Mulaleia, Nanchinyaya and Chigoma Mafia give the best yields in the high-incidence areas of CBSD. The most palatable cultivars are Nikwaha followed by Chigoma Mafia and Macia I, which also have plant structure desired by farmers.

These results are from the work of just two seasons, which showed considerable variation in climate and apparent levels of CBSD. In addition, since the consortium first started in August 2002, INIA, the Southern Africa Root Crops Research Network (SARRNET) and the International Institute of Tropical Agriculture (IITA) have started work relating to CBSD. Furthermore, it is clear more research is still required as part of a longer process.

Multiplication

These trials have led to the multiplication of selected cultivars, enabling farmers to have access to improved material. In the case of Zambézia Province, the ZADP initiated work is being continued by a sister-project, OVATA. Both NFSP and ZADP have been carrying out rapid multiplication to give greater access for farmers to better planting material. NFSP has concentrated on multiplying Nanchinyaya and Chigoma Mafia by this means. SCF is multiplying Nikwaha using traditional techniques.

Sweet or bitter cultivars

Almost all of the cultivars selected from the trials are regarded as sweet, but is this what the farmers want in all areas? NFSP has discovered that bitter cultivars reduce theft by monkeys and other animals. Furthermore, bitter cultivars generally need some processing – they cannot be eaten uncooked – so are less susceptible to theft by humans. In addition, bitter cultivars are reputed to produce higher yields than sweeter ones.

Clearly, these are areas for future investigation and development if the needs of the rural communities are to be met. Particularly, the level of cyanide (associated with bitter cultivars) is important, as traditionally the northern Mozambican cultivars have low cyanide contents.

Reducing risk – changing to other crops?

In Zambézia, CBSD has not affected local cultivars as much as it has in many parts of Nampula Province. Most cassava is intercropped with maize, beans, vegetables, etc. and, additionally, coconut also is widely grown in the same area and is an important part of the diet, particularly in the coastal region. Generally Zambézia farmers appear to be growing a greater diversity of crops than those in Nampula Province. The net result of these factors is that the effects of CBSD have been less potent in Zambézia.

In Nampula Province, some local cultivars have been particularly susceptible to CBSD with the result that whole areas in the Coastal Zone are devoid of cassava. This has put greater pressure on the effort to find at least an intermediate solution by growing known tolerant cultivars and/or growing other crops such as maize, sweet potato, sorghum and millet. However, most alternative crops also have their own risks and problems. Maize growing has been particularly vulnerable, as much of it has failed because of lack of rain at the right time. Similarly, sweet potato production is dependent upon having some humidity available throughout the year in order to preserve the vines; for example, people are able to conserve them from one season to the next only where there are humid valleys. Sorghum and millet appear to be vulnerable to bird attack. Cassava continues to remain the crop of choice in Nampula Province. Cassava prices have been higher than maize in Nacala and Nampula in sharp contrast to Zambézia (Mocuba and Quelimane) where maize has been fetching a higher price.

Annex
History of ZADP II

Introduction

The Zambézia Agricultural Development Programme – Phase II (ZADP II) started in June 1998 with the goal of improving food security, increasing farm production, income sources and securing access to land for rural families. It plans to have reached 130,000 people with particular emphasis on reaching the poorer households by the end of the project in April 2003. This goal is being achieved by giving greater support to institutional development and helping farmers move away from subsistence agriculture and enabling them to have better food security, improved incomes and generally improved household wealth (DFID, 1998).

This project is funded by the Department for International Development, UK (DFID) and managed by World Vision International (WVI) and is one of a number of projects that the NGO manages in Zambézia Province and in other areas of the country for donors as well as implementing those projects funded by private donations. Other projects include agricultural, health, roads and child-support programmes.

ZADP II works in 3 of the 16 districts of the Province – Namacurra, Nicoadala and Gurué (see Figure 1). It builds upon ZADP I which chiefly consisted of emergency and short-term stabilization activities initiated immediately after the 1994 elections. The key elements of ZADP II are (i) land security and tenure, (ii) credit and (iii) community agricultural development. Operations for land security and tenure work with a local NGO (ORAM) to inform people of their land rights and improve the information systems for land use and land titles. The credit component targets off-farm activities that can enhance family income in rural areas by setting up solidarity (small group) saving schemes. The agricultural activities focus upon providing low-cost means of supplying rural families with information and technologies to give greater economic stability and independence from subsistence agriculture. Some of the main activities include developing farmer seed multiplication units, organizing awareness meetings and improving marketing through the creation of marketing associations/groups. The programme also provides support to livestock (as the poorest of families keep poultry), tree crops and honey production. In addition, it helps improve access to communities by building bridges and improving tertiary roads. Finally, ZADP has had a lot of experience managing research and other activities with many partners. For example, it has collaborated on many research activities, some started in ZADP I, with other institutions [e.g. Instituto Nacional de Investigação Agronómica (INIA) and the International Institute of Tropical Agriculture (IITA)] as well as adaptive investigations using (i) farmer field schools and (ii) seed multiplication groups.

Agricultural production in Zambézia

As in all the neighbouring countries, the agricultural sector is the primary economic provider (70%) in the province (Ellenbroek, 1999). This comprises both small family farms and large-scale farming companies. The Province has a humid tropical climate except where it is moderated by altitude such as around Gurué. The average temperature along the coast is about 27°C, falling to 21°C or less in the hills around Gurué. Annual rainfall varies between 1400 and 2000 mm.

The farming companies are involved in the rehabilitation of plantation crops of tea and coconut. Cattle-ranching is also being restarted in parts of the province. The large-scale enterprises for cashew nut production have not been rehabilitated since their decline in the 1980s. Almost all of these large-scale enterprises require new investments for new machinery and/or livestock, which is beginning to occur, and also for the re-clearing/reclaiming of land. For example, many of the tea estates are heavily pruning the tea bushes to the usual height of 0.8–1.5 m as no prun-

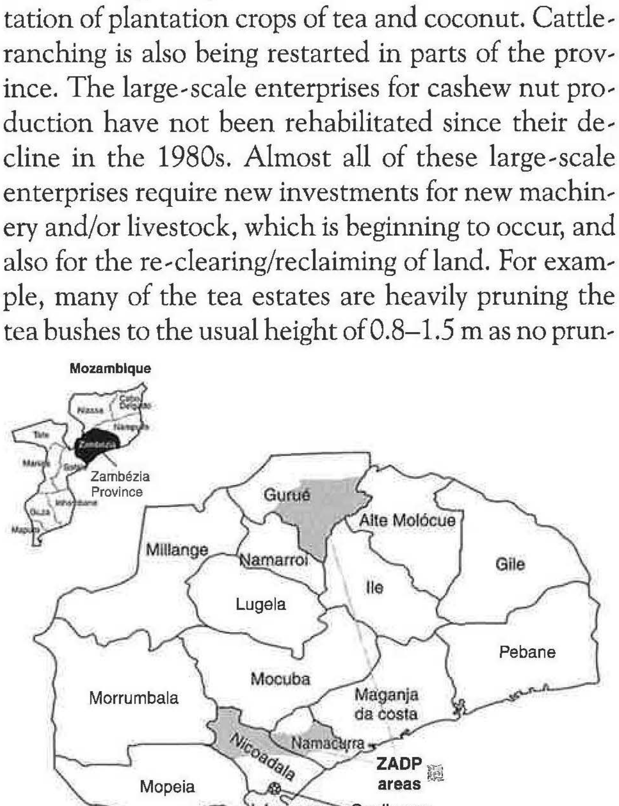

Figure 1 Areas where ZADP II works in Zambézia Province of Mozambique

ing had been done for almost two decades. Many tea bushes had reverted to their natural height of approximately 6–8 m.

Much of the following information is based upon some recent surveys in the province (ARDP, 1995; ZADP II, 1997; 1998). The small family farms vary in size according to their location and cropping arrangements. Smallholder farming in the province can be divided into lowland and upland type farming. In almost all small farming areas of the province, cassava is usually the principal crop grown, as it provides food throughout the year and produces at least something regardless of flooding or drought. However, other crops vary according to the location. Very simplified, the Namacurra and Nicoadala districts (the coastal region of lower Zambézia) – have more intensive cropping systems where rice is the dominant cereal and have access to some irrigation. Typical farming systems are rice–cassava, rice–coconut, and cassava–cashew nut systems (Ellenbroek, 1999). In Gurué (higher Zambézia, at 400–1200 m asl), cropping methods are more extensive rainfed systems, growing maize–cassava–sorghum, sorghum–cassava, and maize–cassava–Irish potato–beans–vegetables. In all areas, livestock is usually limited to poultry, while some people keep pigs in the Gurué area.

The average farm size in the project areas of Namacurra and Nicoadala is about 0.8 ha, while in Gurué average farm size is larger, about 1.2 ha. The purchase and use of farm inputs is very limited, so the use of inorganic fertilizer is practically non-existent. However, people do use organic fertilizer (compost) in the Namacurra (42%) and Nicoadala (30%) areas. Similarly, there is little use of insecticides or herbicides. Furthermore, practically all cultivation is done by hand, with almost no use of draught animals or tractors.

Sales of crops from small farms are limited. In a survey of farm sales, the percentages of households selling crops were 16% for maize, 6% for rice and 6% for cassava. However, these percentages are very variable. After the 2001 flooding in Zambézia, only cassava was generally available for sale, as there was almost no maize production in the province. Most sales generally take place after harvest when there is an urgency to service other financial needs. Besides various agronomic factors and lack of labour, many have attributed the lack of increased off-farm sales to the difficulties in reaching markets and traders (poor road infrastructure). Historically within the country, Zambézia Province has suffered from the lowest rate of investment in infrastructure development. However, roads are slowly being improved which should provide better market opportunities. The main road going through Zambézia linking Sofala and Nampula Provinces will start to be rehabilitated in 2003. The cross-border trade to Malawi has been very active in recent years (Whiteside, 1998) and continues to be very active this year particularly for maize, beans and rice. ZADP II is active in promoting trading associations as well as encouraging Malawian traders to visit and buy. However, although Malawi has proposed a free/reduced tariff trade agreement with Mozambique, there are a number of restrictions on this trade at present. Similar agreements are already in operation between Zimbabwe and Mozambique.

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WORKING GROUP REPORTS

Research Working Group Report

The 'Research' working group discussed a series of CBSD-related research issues, including those relating to the virus, vector, epidemiology, plant breeding, yield loss studies, control and training. Within the framework of these discussions, particular attention was given to the following aspects:

- Existing research plans and work likely to start next year – indicated in parentheses
- Identification of gaps in knowledge – indicated in text as (GAP)
- Linkages and coordination – is there a need to have a mechanism for sharing?
- Training – scientists and postgraduates
- Methodologies
  - Standardization
  - Training courses once methodologies have been developed and standardized.

Notes are provided below on the outcome of these discussions:

1. Virus studies

1.1 Molecular diagnostics methods

- Application of techniques developed by DFID-CPP Project R7796 (to be implemented by the IITA-IFAD Cassava IPM Project)
- Use of existing laboratories
  - Tanzania – clean up material from Kagera by passing through tissue culture, virus index, and distribute
  - Kenya – PQS on production and exchange of 'clean' germplasm; UoN complements work by PQS
  - Mozambique laboratory to be equipped at INIA or university (USAID, Rockefeller Foundation support?)
- Concern over need to have laboratory in areas where virus is present – where a problem exists, RNA can be isolated on site and shipped for diagnosis in laboratories, although protocols need to be carefully reviewed, as RNA is considerably less stable than DNA.
- Virus detection methods need to be used to relate virus content to symptom expression. Also need to answer the question of whether symptomless plants or plant parts contain virus, and if so, whether they can act as a source of inoculum.

1.2 Strain variation. Does it affect resistance in different environments? (GAP) More information should become available after which a university group could perhaps develop a proposal for this issue as diagnostic information becomes available.

1.3 Host range of CBSV. Does CBSV occur in other host plants, such as *Manihot* spp., euphorbs, herbaceous hosts? CBSV is an African virus on a South American host. Assume therefore that CBSV came from other hosts; distribution could be related to other hosts? (GAP) Universities might be in a position to conduct studies to investigate this, including developing vegetation maps and using GIS techniques.

1.4 Interactions with other pathogens. What are they? Are there interactions with the viruses causing CMD? (GAP)

1.5 Environmental effects. Are there effects of the environment on symptom expression (soil fertility and climate)? (GAP)

1.6 Distribution of CBSV within the plant. (GAP)

1.7 Geographic distribution of CBSV. New reports from outside areas of known distribution (the IITA-IFAD Project will follow this up in collaboration with laboratories in Tanzania and elsewhere).

2. Vector

2.1 Vector identity – Is it *Bemisia tabaci*, *Bemisia afer*, eriophyiid mites or some other organism? Does *B. afer* transmit geminivirus? Possible soil-borne transmission will be investigated in the follow-on NRI-CPP project (NRI-CPP)

2.2 Vector–virus interactions – need to look at how the whiteflies are acquiring the virus and whether they are transmitting it; use PCR to detect virus in the vectors. (GAP)

2.3 Other methods of transmission
- o Seed transmission
- o Mechanical transmission on cutting knife and/or while collecting leaves. (GAP)

3. Epidemiology

3.1 Points of concern raised
- Clean stock needs to be evaluated under different agro-ecologies to determine rate of spread.
- What are the varietal effects, particularly with symptom expression?
- Estimates of rates of spread are needed for all the affected countries.
- Use of standard susceptible and resistant cultivars in epidemiology trials
  - o TMS 42025 should be distributed to all groups as a susceptible check for epidemiology trials. These could help in locating hot spots and perhaps identifying low pressure areas where phytosanitation might be effective. (Rory Hillocks responsible for determining the availability and distribution of this clone)
  - o TMS 30001 could be used as a less susceptible standard check. Widely spread and all countries have it. Can we get tissue culture materials from IITA? (IITA group to follow up)
  - o Kaleso could be used as a resistant check (farmer cultivar) but should be cleaned-up of CMD. This could be done with the support of PQS, Kenya.
  - o Put all three cultivars in all trials to see how they respond before final recommendations on their use as standards in epidemiology trials and breeding.
- Planting date – how does it affect rate of spread? Make monthly recordings of leaf and stem symptoms, and use a standardized approach to recording root symptoms.
- Isolation (fields and plants) – what is the safe isolation distance? Very little information is currently available. NRI (Rory Hillocks) showed some data on spread within a field. Some information will be available from the work in Mozambique. There is information available on CMD and the approach used for CMD could be tried for CBSD.
- Health status of planting material is crucial.
- IFAD Project may play a role in coordinating the epidemiology as this is related to the implementation of diagnostics.
- Records of whitefly abundance should be taken on a weekly (or minimum biweekly) basis; it is possible to distinguish the species at the adult stage (*B. tabaci* and *B. afer*); counts should preferably be made on the standard cultivars.
- CPP has offered to provide some funds to put all the methodologies on a CD-rom for distribution to all users. (Rory Hillocks to follow up with CPP management)

3.2 Where should this work be carried out, and who should do it?

3.3 Prospective sites
- Mozambique – 3 trials in each of Zambezia and Nampula provinces
- Malawi – 3 sites on the lake shore
- Kenya – Mtwapa and Msabaha, Kikoneni, Chonyi, Kalango
- Tanzania – northern, central and southern locations in the Coastal Zone.

4. Control

4.1 Phytosanitation

- Distribution of clean planting material – ability to select clean planting material (key feature is the presence of necrosis at harvest; use material without symptoms which may or may not be infected).
- Farmer selection.
- Roguing – clean plants tagged (difficult); how early do symptoms occur? This affects when roguing could be done.
- Crop residues – what is the effect of older material next to new material?
- Removal of alternative hosts (when identified).
- Means of enhancing the phytosanitation approach and developing a realistic approach that can be readily adopted by farmers need to be investigated.
- Phytosanitation may not work so well as at the research level, but may be acceptable to farmers with lots of training.
- Identify conditions under which phytosanitation might work and then look at cultivars of different susceptibilities and contrasting disease spread conditions. (Rose Njeru could test this in an MSc project in Kenya) Isolation is an option. (Rose Njeru also to follow this up)
- It was recommended that the epidemiology, yield loss, and selection trials should be done using the same cultivars.
- It was noted that it is difficult to follow-up what farmers are doing after being given clean material. Spread may have taken place by the time roguing is done.

4.2 Who will be working on phytosanitation?

- Kenya – Rose Njeru (UoN) with proposed support from The Rockefeller Foundation
- Malawi – through SARRNET activities
- Tanzania – through the regional Rockefeller Foundation cassava germplasm project (Edward Kanju)
- Mozambique – through The Rockefeller Foundation grant to INIA.

5. Plant breeding

5.1 Issues discussed

- Need to standardize methodologies. (Edward Kanju and Bill Khizzah to coordinate)
- Existing clones in the breeding programme need to be ranked in terms of their response to CBSD as a stop-gap measure. This should facilitate the release of the materials presently in the final stages of the breeding cycle.
- Breeders need to follow two sets of activities: 1) provision of clean planting material for distribution, and 2) assessment of diseased materials at the end of the maturity period to look at the necrosis to see how they respond.
- Techniques of breeding and selection should be spelt out.
- Progress can be made quickly by exploiting what is already available and identified.
- Problem – farmers may not accept the resistant/tolerant cultivars over traditional cultivars; advantage of breeding with local materials is that they are known to be acceptable to farmers. Here lies the advantage of 'cut and paste' transformation approaches.
- Resistance is thought to be multigenic and recessive resistance so it could be incorporated into breeding programme. (IITA-Rockefeller Foundation regional project to pursue, Edward Kanju)
- What are the effects of CBSD on organoleptic properties?

5.2 Who will be involved?

- Kenya – evaluate selection and roguing. MSc proposals (Rockefeller Foundation)
- IITA-Rockefeller Foundation regional project – germplasm collection because of the potential loss of this germplasm. Material will be maintained by the countries affected.
- EARRNET and SARRNET to coordinate regional trials.
- Statistical support and joint collaboration. (IITA-ESARC, UoN)

5.3 Biotechnology (GAP)

- No major gene for brown streak resistance identified to date, but transformation should be possible with the coat protein.
- No artificial inoculation techniques are currently available.
- Since there are no very good existing sources of resistance to CBSV, transgenics may be an important option. (James Legg will take up this issue with the IITA biotech lab; Mike Thresh will contact Claude Fauquet; Rose Njeru interested in developing this aspect)

6. Yield loss trials

6.1 Points raised

- Each of the main cultivars should be tested in each country.

6.2 Who will be carrying out the trials?

- Mozambique – through the IITA-IFAD cassava IPM project?
- Malawi – SARRNET
- Tanzania – Kibaha and Naliendele research institutes (with support from NRI)
- Kenya – The Rockefeller Foundation student project pending

It was agreed that a small committee meet later during the meeting to discuss yield loss methodology. This comprised: Rose Njeru, James Legg, Evance Shaba, Anabella Zacharias, and Mike Thresh.

7. Training

7.1 Training courses to practise methodologies

7.2 Postgraduates, technicians

Research group participants

Maria Andrade
Felistus Chipungu
Nurbibi Cossa
Rory Hillocks
Derek Jennings
George Kaitisha
Edward Kanju
Charles Kariuki
Bill Khizzah
James Legg
Serafina Mangana
Rose Mohamed
Ana Maria Mondjana
Teresia Munga
Rose Njeru
Sila Nzioki
Rose Onamu
Jose Ricardo
Goretti Ssemakula
Evance Shaba
Mike Thresh
James Whyte
Anabela Zacarias

On-farm Working Group Report

Standardization of CBSD evaluation (symptoms)

1. Discussion

a) Standard scale/methodology for describing disease incidence in roots

IITA Scale of 1–5. Primarily, this is for data entry purposes, as in most computer software a '0' indicates no data. Need to explain to invigilators, etc. why 0 is **not** used to report 'nothing' – and why 1 is to be used instead. Main criterion of scale is that there are five categories.

1 No symptoms
2 Less than 2%
3 2–10%
4 10–30% (NRI 10–40%)
5 More than 30% (NRI 50% plus – total destruction?)

Resolution 1: ***Use scale of 1 to 5, not 0 to 4.***

b) Where do we take the samples from the field?

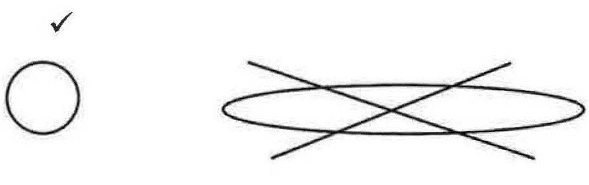
Different sampling techniques were described by working group members. It is not easy to design a standard sampling method for root necrosis as it will depend to some extent on the purpose of the survey.

Resolution 2: No agreed approach was determined during the discussion at the meeting, but it is proposed that the following steps can act as a guide in order to standardize procedures.

- The full sampling technique must be explained to the farmer and permission must be obtained before proceeding.
- Disease incidence should be recorded on 30 plants in a diagonal transect.
- To assess disease symptoms in the roots, only plants with above ground symptoms should be uprooted. A random sample may throw up too many symptomless plants.
- 20 plants per field should be sufficient although researchers must ask farmers before doing this as many may object even to this number!
- The figure that is recorded for CBSD root necrosis severity should be the mean of the individual scores for each root.
- An estimate of crop loss can be made by multiplying disease incidence by disease severity after converting the mean score for root necrosis to % tissue loss.
- When screening for disease resistance the maximum score must be recorded since this represents the potential of a particular genotype to develop necrosis.

c) Where do we take the samples from the plant?

Resolution 3: Take the worst root cross section and measure level of infection within the root.



d) 'Best-Bet' cultivar selection criteria, hence identification (where are they and how do we get them?)

The process of selection was described by working group members and the following resolution was agreed:

Resolution 4: Document the following criteria to identify the best cultivars according to the various agro- and socio-ecological conditions as each location may have its own 'best-bets'.

- Document the whole process where on-farm trials took place and what results were achieved
- Selection of cultivars by researcher or by farmer researcher
- Cyanide content needed for specific areas
- Disease/pest susceptibility
- Disease free/disease status.

It was noted that for cross-border movement of plant materials, cultivars have to be under open-quarantine before on-farm testing.

2. Assessment of technology (impact) – appropriateness and acceptance

- Start with baseline survey – indicators
- Survey to estimate 'change' or monitoring
- Post-project evaluation
- Assess those involved and not involved in the project
- Establish if the surrounding area/s is/are adopting technologies – use surveys, questionnaires, etc.
- Increase in yield/quality
- Price (relative) comparison indicator of maize-cassava
- Livelihood analysis.

Resolution 5: Projects must have baseline data to perform meaningful impact assessments. Impact should be measured with an array of tools combining economic and livelihood studies.

3. Standard methodology for on-farm trials

- The standard plot size used by IITA/SARRNET was given – plot size 4 × 10 m (4 lines – 1 cultivar). In addition the number of test cultivars was discussed and a maximum of six was suggested.
- Degree/level of research involvement was discussed in trial design and the three levels were discussed.
  - Researcher-Managed Researcher-Implemented
  - Researcher-Managed Farmer-Implemented
  - Farmer-Managed Farmer-Implemented.

  In addition augmented trials should involve farmers testing different cultivars or where a few cultivars were involved, all farmers can be given an opportunity to test them.
- The 'Mother and Baby' trial design was discussed (Snapp, 1999[1]). The design comprises 'mother' trials which test a number of different cultivars/technologies, and 'baby' trials which test a subset of three (or fewer) cultivars/technologies, plus one control. The design makes it possible to collect quantitative data from 'mother trials' managed by researchers, and to systematically cross-check them with 'baby trials' on a similar theme that are managed by farmers. The design is very flexible – Snapp (1999) reports mother trials located on-farm at central locations in villages, but they could as easily (depending on need and logistics) be located at nearby research stations. Farmer participation in baby trial design and implementation can vary from consultative to collaborative.
- Whichever design is selected it was proposed that the trial duration of two years should be the minimum, especially for non-indigenous cultivars.

4. Raising awareness of donors, farmers, policy makers and others

Resolutions were also relating to communication initiatives. The following were agreed:

1. Snapp, S.S. (1999) Mother and baby trials: A novel trial design being tried out in Malawi. *Target Newsletter of the Southern Africa Soil Fertility Network* **17**: 8.

Resolution 6: Development agencies and researchers should use a wide range of communication channels, including:

- Presentation to donors and policy makers – use all methods possible
- Radio and TV programmes (notices, education messages, discussion, dramas, etc.)
- Posters, fliers
- Meetings, field days, exchange visits, farmer-to-farmer meetings, farmer field days, etc.
- Researchers meeting and discussing with extension providers.

5. **Identify strategies sustainable for multiplication and dissemination of tolerant/resistant materials**
   - Start with primary nurseries (on-station), then secondary, tertiary, etc. nurseries on-farm.
   - Use communal farmer nurseries, entrepreneurs, institutions, etc. from secondary nursery level onwards – actual mechanism depends upon local opportunities, culture, etc.
   - Clean (tolerant) materials must be multiplied on-farm followed by handover to people/farmers.
   - Measurements of the amount of planting material needed/produced/distributed was discussed:
     - Malawi – in metres – approx 4 cuttings/m
     - Tanzania – cuttings 20–25 cm
     - Mozambique – cuttings 25–30 cm
     - Bundles of 50 sticks of 1 m (Malawi).
   - Rapid multiplication method described by STC Mozambique – use 2–3 node cuttings with plastic bag.
   - Need to take approx 1 ha of nursery material to plant 10 ha – a guide only!

Resolution 7: Aim to standardize on reporting as to how many hectares are planted with distributed planting material – impact oriented measurement.

On-farm group participants

Constantino Cuambe
Nick Dexter
France Gondwe
Nathaniel Katinila
Frances Kimmins
Ricardo Macia
Eric Mazuma
Steve McSween
Kiddo Mtunda
Matthew Raya
Chande Ossufo
Alves Sandramo
John Steel

CBSD Research for Development Steering Committee

The workshop participants discussed the formation of a CBSD Steering Committee (SC) and consensus was reached on which positions should be included and who would be the best current representatives for each. It was envisaged that the SC would serve both in accessing, providing and disseminating information on CBSD research for development, and as a body that could play an advisory and non-executive coordinating role for the CBSD research/development effort. Initially, it was suggested that the CBSD SC would function through e-mail communication, although in future, opportunities to meet might be sought. The details of the terms of reference for the group were to be developed at a later date. The positions and current members are as follows:

Position	Member
Country: Mozambique	Nurbibi Cossa
Country: Tanzania	Kiddo Mtunda
Country: Kenya	Charles Kariuki
Country: Malawi	Felistus Chipungu
NGOs	Chande Ossufo
NRI-CPP Project	Rory Hillocks
IITA-Rockefeller	Edward Kanju
IITA-USAID	Maria Andrade
IITA-IFAD	Rachid Hanna
INIA-Rockefeller	Anabela Zacarias
KARI-Rockefeller	Teresia Munga
IITA	James Legg
Senior Advisory – 1	Mike Thresh
Senior Advisory – 2	Derek Jennings
Universities	Rose Njeru
Plant Quarantine – 1	Rose Mohamed
Plant Quarantine – 2	Rose Onamu

Participants and Contact Information

KENYA

Joe de Vries
The Rockefeller Foundation
International House
Mama Ngina Street, Nairobi
Kenya
Tel: +254 2 228061
Mobile: +254 733 727047
Email: jdevries@rockfound.or.ke

Charles W. Kariuki
Kenya Agricultural Research Institute
NARS – Muguga
Crop Protection Programme
PO Box 30148, Nairobi
Kenya
Tel: +254 2 32883/32348
Fax: +254 2 32348
Email: ckariuki@nbnet.co.ke

Hudson Masambu
USAID-REDSO-ESA
ICIPE Campus, Thika Road
Duduville
PO Box 30261, Nairobi
Kenya
Tel: +254 2 862400/02
Mobile: +254 722 277965
Email: hmasambu@usaid.gov

Rahab W. Muinga
Director
Kenya Agricultural Research Institute
RRC – Mtwapa
PO Box 16, Mtwapa
Kenya
Tel: +254 11 5485842
Email: karimtw@africaonline.co.ke

Rose W. Njeru
University of Nairobi
CAVS, Crop Protection Department
PO Box 30197, Nairobi
Kenya
Email: rwnjeru@kenyaweb.com

Sila S. Nzioki
Kenya Agricultural Research Institute
NDFRC – Katumani
PO Box 340, Machakos
Kenya
Tel: +254 145 20330/21746
Mobile: +254 733 926243
Email: nzioki@hotmail.com

Rose Onamu
KEPHIS-PQS – Muguga
PO Box 49421, Nairobi
Kenya
Tel: +254 154 32715
Email: pqs@nbnet.co.ke

Teresia L. Munga
Kenya Agricultural Research Institute
RRC – Mtwapa
PO Box 16, Mtwapa
Kenya
Tel: +254 11 5486207
Email: karimtw@africaonline.co.ke

MALAWI

Felistus Chipungu
Bvumbwe Agricultural Research Station
PO Box 5748, Limbe
Malawi
Tel: +265 1 471292
Email: horticulture.mw@malawi.net

France M. Gondwe
IITA-SARRNET
PO Box 30258, Lilongwe 3
Malawi
Tel: +265 1 707004/707014
Email: sarrnet@malawi.net

Eric Mazuma
Chitedze Agricultural Research Station
PO Box 158, Lilongwe
Malawi
Tel: +265 1 707222
Email: ericmazuma@hotmail.com

Evance R. Shaba
Bvumbwe Agricultural Research Station
PO Box 5748, Limbe
Malawi
Tel: +265 1 471292
Email: pesticideboard@malawi.net

MOZAMBIQUE

Maria Andrade
USAID-SAD-IITA-CIP-SARRNET
c/o INIA, FPLM Mavalane
CP 2100, Maputo
Mozambique
Tel: +258 1 460097/99
Fax: +258 1 460074
Email: sarrnetmoz@teledata.mz

Nurbibi Cossa
INIA – Maputo
CP 3658, Maputo
Mozambique
Fax: +258 1 460074
Email: bibicossa@hotmail.com

Constantino Cuambe
USAID-SAD-IITA-CIP-SARRNET
c/o INIA, FPLM Mavalane
CP 2100, Maputo
Mozambique
Tel: +258 1 460097/99
Fax: +258 1 460074
Email: sarrnetmoz@teledata.mz

Nick Dexter
WV R. Daniel Nopstemice
CP 146, Nampula
Mozambique
Email: nick_dexter@evi.org

Ricardo Macia
USAID-SAD-IITA-CIP-SARRNET
c/o INIA, FPLM Mavalane
CP 2100, Maputo
Mozambique
Tel: +258 1 460097/99
Fax: +258 1 460074
Email: sarrnetmoz@teledata.mz

Serafina Mangana
ZADP – World Vision International
CP 517, Quelimane
Mozambique
Tel: +258 4 214460/213807
Email: serafina_mangana@mail.com

Steve McSween
Save the Children-USA – Nacala
CP 164, Nampula
Mozambique
Tel: +258 82 610263
Email: csmcsween@yahoo.com

Ana Maria Mondjana
Universidade Eduardo Mondlane
Faculdade da Agronomia
Florestal
CP 257, Maputo
Mozambique
Email: amondjan@agronomia.uem.mz

Chande Ossufo
Save the Childeren – Nacala
CP 164, Nampula
Mozambique
Tel: +258 82 610263
Email: scnacala@teledata.mz

Jose Ricardo
USAID-SAD-IITA-CIP-SARRNET
c/o INIA, FPLM Mavalane
CP 2100, Maputo
Mozambique
Tel: +258 1 460097/99
Fax: +258 1 460074
Email: sarrnetmoz@teledata.mz

Alves Sandrano
USAID-SAD-IITA-CIP-SARRNET
c/o INIA, FPLM Mavalane
CP 2100, Maputo
Mozambique
Tel: +258 1 460097/99
Fax: +258 1 460074
Email: sarrnetmoz@teledata.mz

John A.C. Steel
ZADP – World Vision International
CP 517, Quelimane
Mozambique
Tel: +258 4 214460/213807
Email: jacsteel@cwcom.net

Anabela M. Zacarias
INIA – Maputo
CP 3658, Maputo
Mozambique
Email: anabelazacarias@hotmail.com

TANZANIA

Edward E. Kanju
IITA-SARRNET
Mikocheni Agricultural Research Institute
PO Box 6226, Dar es Salaam
Tanzania
Tel: +255 22 2700092
Mobile: +255 744 289107
Email: ekanju@cgiar.org

Nathiel A. Katinila
Naliendele Agricultural Research Institute
PO Box 465, Mtwara
Tanzania
Tel: +255 23 2333836/2334023
Mobile: +255 744 379679
Email: katinila2002@yahoo.com

Rose A. Mohamed
Plant Health Services
Ministry of Agriculture Food and Security
PO Box 9071, Dar es Salaam
Tanzania
Tel: +255 22 2865642/3
Email: rose_mohamed@yahoo.com

Kiddo J. Mtunda
Sugarcane Research Institute
Kibaha Agricultural Research Institute
PO Box 30031, Coast
Tanzania
Tel: +255 23 2402017
Mobile: +255 744 466201
Email: sri@africaonline.co.tz

Matthew Raya
Naliendele Agricultural Research Institute
PO Box 465, Mtwara
Tanzania
Tel: +255 23 2333836
Email: utafiti@makondenet.com

UNITED KINGDOM

Rory J. Hillocks
Natural Resources Institute
University of Greenwich
Chatham, Kent ME4 4TB
UK
Tel: +44 1634 883303
Email: r.j.hillocks@gre.ac.uk

Derek Jennings
'Clifton', Honey Lane
Otham, Maidstone
Chatham, Kent M15 8RJ
UK
Email: joanderjen@otham31.fsnet.co.uk

Frances Kimmins
NR International
Park House, Aylesford
Kent ME 20 6SN
UK
Tel: +44 1732 878677
Fax: +44 1732 220498/9
Email: f.kimmins@nrint.co.uk

Mike Thresh
Natural Resources Institute
University of Greenwich
Chatham, Kent ME4 4TB
UK
Tel: +44 1634 883284
Email: kathie.clark@blueyonder.co.uk

UGANDA

Bill W. Khizzah
IITA-ESARC
PO Box 7878, Kampala
Uganda
Fax: +256 41 223494
Email: khizzah@iitaesarc.co.ug

James P. Legg
IITA-ESARC
PO Box 7878, Kampala
Uganda
Tel: +256 41 223445
Mobile: +256 77 221204
Email: jlegg@iitaesarc.co.ug

Goretti Ssemakula
NARO – Uganda
PO Box 7084, Kampala
Uganda
Tel: +256 77 481888
Email: nankingag@yahoo.com

James B.A. Whyte
IITA-ESARC
PO Box 7878, Kampala
Uganda
Tel: +256 41 223445
Mobile: +256 75 787804
Email: j.whyte@iitaesarc.co.ug

ZAMBIA

George C. Kaitisha
Ministry of Agriculture and Cooperatives
Mt. Makulu Research Station
Private Bag 7, Chilanga
Zambia
Email: genetics@zamnet.zm

Acronyms and Abbreviations

ACMV	*African cassava mosaic virus*
ADD	Agriculture Development Division, Malawi
ANOVA	analysis of variance
ARI	Agricultural Research Institute, Tanzania
asl	above sea level
BCA	biological control agents
BSA	bovine serum albumin
CBB	cassava bacterial blight
CBSD	cassava brown streak virus disease
CBSV	*Cassava brown streak virus*
CGM	cassava green mite
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
CM	cassava mealybug
CMD	cassava mosaic virus disease
CMGs	cassava mosaic geminiviruses
CPP	Crop Protection Programme
CTAB	hexadecyltrimethyl-ammonium bromide
CVYV	*Cucumber vein yellowing virus*
DEPC	diethylpyrocarbonate
DFID	Department for International Development, UK
DPAs	Directorates Provincial do Agricultura, Mozambique
DTT	dithiothreitol
EAAFRO	East African Agriculture and Forestry Research Organisation
EACMV	*East African cassava mosaic virus*
EARRNET	East Africa Root Crops Research Network
ELISA	enzyme-linked immunosorbent assay
FEWSNET	Famine Early Warning System Network
FRG	farmer research group
IAA	isoamylalcohol
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
INIA	Instituto Nacional de Investigação Agronómica, Mozambique
IPM	integrated pest management
IPMSA	Integrated Pest Management Strategy Area
KARI	Kenya Agricultural Research Institute
KEPHIS	Kenya Plant Health Inspectorate Service
KSTCIE	Kenya Standing Technical Committee on Imports and Exports
LGB	larger grain borer
LMO	living modified organisms
NARI	Naliendele Agricultural Research Institute
NARS	national agricultural research systems
NFSP	Nampula Food Security Programme
NGO	non-governmental organization
NIFSP	Nampula Integrated Food Security Project, AusAID
NRI	Natural Resources Institute
ODA	Overseas Development Administration, forerunners of DFID
OP	open pollination
OQ	open quarantine
OVATA	USAID-funded project in Zambézia
PCR	polymerase chain reaction
PIP	plant import permit

PQS	Plant Quarantine Station, Kenya
RDP	rural development project
RT-PCR	reverse-transcriptase polymerase chain reaction
SACMV	*South African cassava mosaic virus*
SARRNET	Southern Africa Root Crops Research Network
SCF	Save the Children
SDS-PAGE	sodium dodecyl sulphate polyacrylamide gel electrophoresis
SPMMV	*Sweet potato mild mottle virus*
SPSS	statistical package for social scientists
ssRNA	single-stranded RNA
TAE	tris-acetate EDTA
UoN	University of Nairobi
USAID	United States Agency for International Development
WVI	World Vision International
ZADP	Zambézia Agricultural Development Project, Mozambique
ZCMV	*Zanzibar cassava mosaic virus*