MOZAMBIQUE

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Abstract

The second phase of the Cassava Diagnostics Project (CDP) was implemented in Mozambique from 2013 to 2017. The project addressed three aims: (a) understanding the threat from evolving viruses and vectors, (b) reaching farmers directly and through partners and (c) building sustainable regional capacity. Cassava mosaic disease (CMD), cassava brown streak disease (CBSD) and whitefly abundance were monitored in smallholder cassava fields in seven major cassava growing provinces in the country. The CMD incidence was highest in Gaza province (53.1 %) and Inhambane (51.5%) and lowest in Cabo Delgado (12.1%). There was no significant change in CMD severity among years and provinces. The CBSD incidence was highest in Zambezia (64.5%), followed by Nampula (36.6%) and Cabo Delgado (34.3%) provinces and lowest (<2.0%) in the southern provinces of Inhambane, Gaza and Maputo. Mean CBSD severity score ranged within 2.3–2.6 but with no significant differences among provinces. Generally, adult whitefly abundance was higher in the 2013 and 2015 than the 2017 surveys. Mean whitefly populations were highest in Inhambane (20.26 per plant) and Gaza (18.62) provinces and lowest in Cabo Delgado (3.49) and Nampula (1.34). Molecular characterization showed the presence of two cassava mosaic begomoviruses, namely *African cassava mosaic virus* and *East African cassava mosaic virus*, and two *Cassava brown streak viruses* (CBSVs), CBSV and *Uganda cassava brown streak virus*. The dominant whitefly (*Bemisia tabaci*) population in Mozambique was identified as SSA1-SG3.

Training was conducted for farmers, extension staff and several stakeholders in outreach activities in on-farm demonstration plots in Boane and Inharrime. The outreach activities were conducted on awareness of cassava viral diseases (CMD and CBSD) and their transmission by whitefly vectors and infected planting materials, production and management strategies. In addition, awareness was created the benefits of using virus-free cassava planting materials.

Infrastructure and human capacities to conduct virus diagnostics was greatly improved at Instituto de Investigação Agrária de Moçambique (IIAM), Maputo. The infrastructure included acquisition of diagnostic laboratory equipment, refurbishment of one greenhouse for contained trials, installation of a new water tank and pump to provide steady water supply to the CDP molecular laboratory and other laboratories, and one project vehicle to facilitate transport for field activities. This has not only

enhanced the capacity of IIAM's scientists to do molecular diagnostics, but also other scientists at IIAM, and other institutions in Mozambique. One MSc student and one PhD student were trained.

Acronyms and abbreviations

5CP	New Cassava Varieties and Clean Seed to Combat CBSD and CMD Project
ACMV	*African cassava mosaic virus*
CBSD	Cassava brown streak disease
CBSV	*Cassava brown streak virus*
CDP	Cassava Diagnostics Project
CMB	Cassava mosaic begomovirus
CMD	Cassava mosaic disease
CTL	Country Team Leader
EACMV	*East African cassava mosaic virus*
IIAM	Instituto de Investigação Agrária de Moçambique (Institute of Agricultural Research of Mozambique)
TARI	Tanzania Agricultural Research Institute
UCBSV	*Uganda cassava brown streak virus*
ZARI	Zambia Agricultural Research Institute

Results summary: Mozambique

Aim I: Understand the threat from evolving viruses and vectors

Objective 1: Disease epidemiology

Disease and whitefly prevalence surveys conducted	• Three surveys conducted in 2013, 2015 and 2017, covering 1023 fields in seven regions. • Survey data for 2013 and 2015 were cleaned and validated by the TARI–Mikocheni team and Cambridge modeling team during a data entry and assembly workshop held from 27 November to 3 December 2016 in Dar es Salaam, Tanzania. • A new SOP for countywide survey developed and used to collect 2017 data. • Cassava leaf samples with cassava mosaic disease (CMD)- and cassava brown streak disease (CBSD)-like symptoms were collected for laboratory analysis.
Alternative hosts for CBSVs and CMBs and associated insect vectors identified	• Carried out as part of Mr Jamisse Amisse's PhD research. • One manuscript on *Cassava brown streak virus* (CBSV) diversity is currently in press.

Objective 2: Characterization of emerging viruses

Cassava virus isolates in the project countries sequenced and analyzed	• Seven new whole CBSV genomes from total RNA isolated from CBSD-symptomatic cassava leaves collected from Nampula and Zambezia in Mozambique. • One manuscript by Amisse et al. (2018) 'In press'. Genetic diversity of Cassava brown streak viruses in Mozambique using whole genome sequences, *Plant Pathology.* • Ms Marta Solemanegy characterized the cassava mosaic begomovirus (CMB) isolates from the May 2016 survey in southern provinces of Mozambique using diagnostic PCR species-specific primers. Results revealed the presence of *East African cassava mosaic virus* (EACMV), EACMV-UG2 and *African cassava mosaic virus* (ACMV) in Maputo province. Mixed infections of ACMV and EACMV occurred in all three provinces of the south, except that ACMV was not found in Maputo. *South African cassava mosaic virus* was confirmed to also occur in Mozambique.
Cassava virus distribution maps generated (incidence, severity, whitefly, viruses, sat)	• Disease distribution maps were produced and distributed to the stakeholders.

Objective 3: Characterization of disease vectors

Potential insect vectors of CBSVs identified	• Carried out as part of Mr Jamisse Amisse's PhD research.

Objective 4: Diagnostic tools

Lab-based diagnostic tools developed	• Diagnostic primers were developed by Mr Jamisse Amisse and Ms Martha Solemanegy for detection of CBSVs and CMBs, respectively.

Aim II: Support clean seed systems for farmers	
Objective 6: Conventional breeding support	
Breeders' material monitored for disease and indexed for virus (CMBs and CBSVs) load at 3, 6, 9 and 12 MAP	• Twenty-five varieties were indexed for CMBs and CBSVs. • EACMV was detected in 6.98% of the materials assessed. • CBSV was detected in 67% of the materials assessed.
Objective 9: Reaching farmers directly and through partners	
Farmers trained on CMD and CBSD disease symptom recognition and management strategies	• Seventy-two farmers (22 male and 50 female) were trained at the demonstration sites in 2013 and 2015.
Demonstration plots for benefits of using virus-indexed planting materials established on-farm	• Two demonstration plots were set up to show farmers the benefits of clean planting materials.
Information materials developed and disseminated	• One article was published 1 April 2015 in Canal de Mozambique on cassava viral diseases and their management. • One pamphlet on identification and management of cassava viral diseases.
Aim III: Build sustainable regional capacity	
Objective 10: Strengthening stakeholder linkages	
Team leader meeting to develop country-specific milestones	• One Country Team Leader (CTL) and one assistant participated in the development of country-specific milestones.
Project inception and consultative meeting with stakeholders conducted	• One CTL and one assistant participated in project inception and consultative meetings.
Awareness on availability of diagnostic capacities created through training and different media	• One radio broadcast aired on different topics on cassava virus diseases and management. • One article published in Agritech News. • One brochure developed (>1500 copies issued).
Exchange visits between scientists in the project countries conducted	• The Instituto de Investigação Agrária de Moçambique (IIAM) Cassava Diagnostics Project (CDP) team leader, Ms Nurbibi Coosa and her assistant participated in the first exchange visit to Zambia Agricultural Research Institute during 15–21 May 2016. • The team visited the CDP research activities in Zambia, including the new screenhouse and laboratories, and farmers' fields to assess the disease situation.

Objective 11: Strengthening human capacity and infrastructure	
Human capacity	
Project staff recruited	• Seven staff: one driver, one MSc and one PhD student, two research assistants, one assistant CTL and one CTL.
PhD and MSc students trained on various aspects of cassava virus diseases	• One PhD and one MSc student trained.
Advanced specialized training and visits for project scientists (1-2 months) conducted	• The CTL, Ms Nurbibi Cossa, visited the Agricultural Research Organisation of Israel during 2–8 February 2014 with TARI–Mikocheni project management and all six CTLs. • Ms Nurbibi Cossa visited Rutgers University, USA, to learn analysis of begomoviruses in Mozambique in June 2015 with instruction from Prof Siobain Duffy.
Extension workers, crop inspectors and other stakeholders (1 week) training	• One workshop conducted for extension officers.
Project staff trained on IP, biosafety issues and communication strategies	• Ms Nurbibi Cossa attended training in intellectual property and communication strategies for 17 project scientists during 27–31 October 2014 at ICRAF, Nairobi, Kenya.
Project results and information disseminated	• Two journal articles accepted in Physiological and Molecular Plant Pathology (Non-cassava host plants with CBSVs) and Plant Pathology (CBSVs diversity).
Institute Directors trained in Leadership and management	• Director of IIAM, Mozambique, attended the 'Leadership Skills for Institutional Directors' conducted in July 2014 in Entebbe, Uganda, and Kigali, Rwanda.
Infrastructure strengthening	
Greenhouses constructed/renovated	• One greenhouse renovated and in use. • One water tank to supply the molecular laboratory.
Vehicles, laboratory equipment and consumables procured	• One project vehicle procured and in use. • Various equipment procured and in use.
Project management	
Project management	• One IIAM Accountant participated in the workshop on accounting package TALLY, during 14–17 May 2013 in Dar es Salaam, Tanzania. • The CDP CTL, Ms Nurbibi Cossa, participated in the financial management training workshop in Kigali, Rwanda, in 2015. • The CTL and students attended the AgShare.Today training and scientific report writing skills in January 2016 in San Diego, USA.

Background

Cassava (*Manihot esculenta* Crantz.) was introduced to Mozambique by the Portuguese in the 17th century (Thresh and Hillocks, 2003). Cassava is one of the most important food crops in the country. It ranks fourth as a food staple after maize with 5.3 million tonnes produced annually (FAO, 2014). Estimates from FAO for Mozambique indicate that over 80% of cassava is consumed as food. In terms of regional distribution of consumption, cassava is a major food staple in central and northern Mozambique and is mainly consumed roasted and in the form of flour mixed with water to make nutritious porridge. Fried or boiled fresh cassava roots constitute almost 12% of the total cassava consumed in the southern region of the country (IITA, 2008; Dias, 2012).

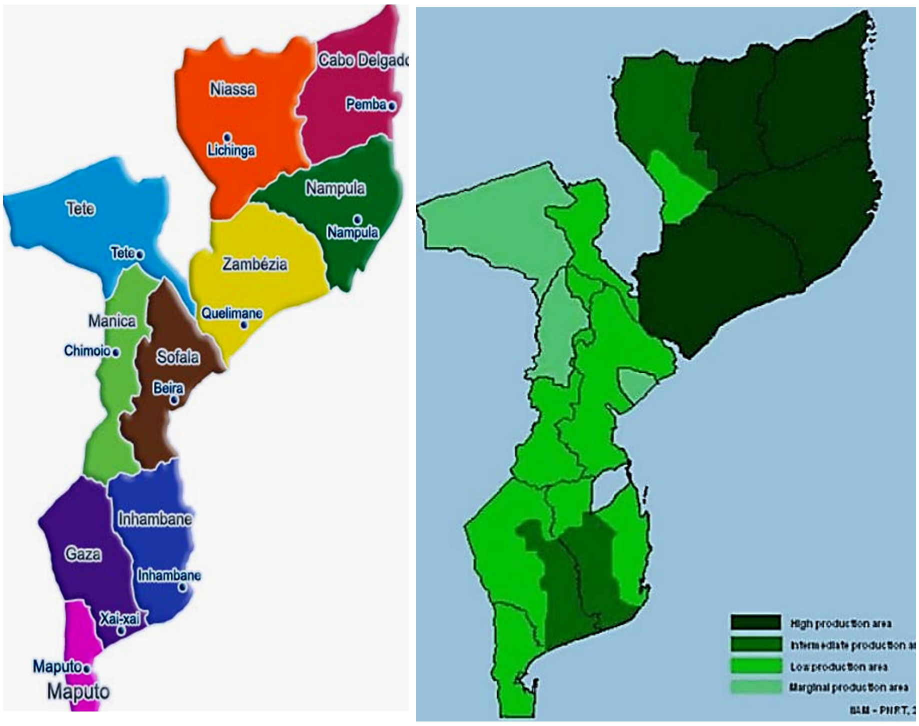

Figure 1 Cassava production areas in Mozambique; Source: IIAM/PNRT (2007)

Cassava is produced countrywide, although the highest production area is in the northern provinces of Nampula, Niassa and Cabo Delgado, in the central province of Zambezia and the southern provinces of Inhambane, Gaza and Maputo (Figure 1). Production is mainly by small-scale farmers, where roughly 61% are engaged in production of the crop on marginal and sub-marginal lands (IITA, 2008; Dias, 2012). Production reached a maximum of 10.09 million tonnes in 2011 compared to 5.3 million tonnes in 2014. Yields followed the same pattern and reached a maximum of 78.02 hg/ha in 2011 compared to 60.9 hg/ha in 2014, which is however still below the average of most African countries (9.3 t/ha). Under ideal growing conditions, disease-free cassava can yield more than 30 t/ha. However, despite attributes such as drought tolerance and low input requirements, yield is poor with only 4 t/ha. This low yield can be due to both abiotic and biotic stresses. The most important of the biotic factors are thought to be pests and diseases. Poor agronomic practices, lack of clean planting materials, low yielding varieties and long maturity periods are additional major problems (IITA, 2008; Dias, 2012). Of the diseases that affect cassava production, cassava mosaic disease (CMD) and cassava brown streak disease (CBSD) contribute the most to yield loss (Cossa, 2005). Because of these two diseases, many farmers have turned to alternative crops such as maize and sweet potato to ensure food security in their households. The CBSD is reported to occur mainly in the coastal regions of northern Mozambique (Hillocks et al., 2002). In contrast, CMD occurs all over the country where cassava is grown. At least five cassava mosaic begomovirus (CMB) species were reported to cause CMD in Mozambique: *African cassava mosaic virus* (ACMV), *East African cassava mosaic virus* (EACMV), *East African cassava mosaic Malawi virus*, *East African cassava mosaic Cameroon virus* and *South African cassava mosaic virus* (Cossa, 2005).

SECTION ONE: Understanding the threat from evolving viruses and vectors

Disease epidemiology

Sampling framework and data collection

Countrywide cassava virus disease monitoring surveys were carried out in 2013, 2015 and 2017 in seven provinces: Cabo Delgado, Gaza, Inhambane, Niassa, Maputo, Nampula and Zambezia. The main aim of the countrywide surveys was to understand the threat from the evolving virus and vectors in Mozambique, with specific focus on determining the status of CMD and CBSD and characterizing the associated insect vectors and mapping the geographical occurrence of these two major diseases in Mozambique.

During surveys, cassava fields were sampled along major roads (Figure 2) and representative samples collected according to Sseruwagi et al. (2004) and the modified Cassava Diagnostics Project (CDP) harmonized standard operating procedure protocol (CMD/CBSD survey manual on the CDP intranet on the AgShare.Today platform; Sseruwagi et al., 2017).

Figure 2 (left) Scientists assessing cassava viral diseases and insect vectors with smallholder farmer and (right) scientists assembling leaf samples for safe transportation and storage until laboratory analysis

Results from the countrywide survey showed CMD occurred in all provinces. Incidence was generally moderate, and the trend showed that CMD incidence decreased from 2013 to 2017 (Table 1); however, disease severity increased. Across provinces, the most affected province was Gaza with mean CMD incidence of 53% followed by Inhambane with 51% and the least was Cabo Delgado with 14%.

The CMD symptom severity varied between years with the trend showing no significant change between years. The highest CMD severity score was in 2017 (3.04) and the lowest was in 2015 at (2.16). Among the seven provinces, Maputo had a slightly elevated severity score (Table 1, Figure 3 and Figure 4).

Table 1 Incidence (Inc.) and mean symptom severity (sev.) of CMD in major cassava growing provinces in Mozambique (2013–2017). '–' indicates that the district was not surveyed during those years

Province	2013		2015		2017			
	Inc. (%)	Mean sev.	Inc. (%)	Mean sev.	Inc. (%)	Mean sev.	Overall mean inc. (%)	Overall mean sev.
Cabo Delgado	20.8	2.5	5.3	2.1	10.2	2.88	**12.1**	**2.5**
Inhambane	81	3	37.02	2.28	36.37	3.06	**51.5**	**2.8**
Gaza	75	2.9	33.3	2.1	51.01	3.31	**53.1**	**2.8**
Maputo	38.1	2.9	20.27	2.2	35.56	3.08	**31.3**	**2.7**
Nampula	17	2.4	1.5	2.04	8.47	2.88	**9.00**	**2.4**
Niassa	29	2.6	–	–	–	–	–	–
Zambezia	36	2.5	18.7	2.22	20.73	3.0	**25.1**	**2.6**
Mean	**42.41**	**2.69**	**19.35**	**2.16**	**27.06**	**3.04**	**30.35**	**2.63**

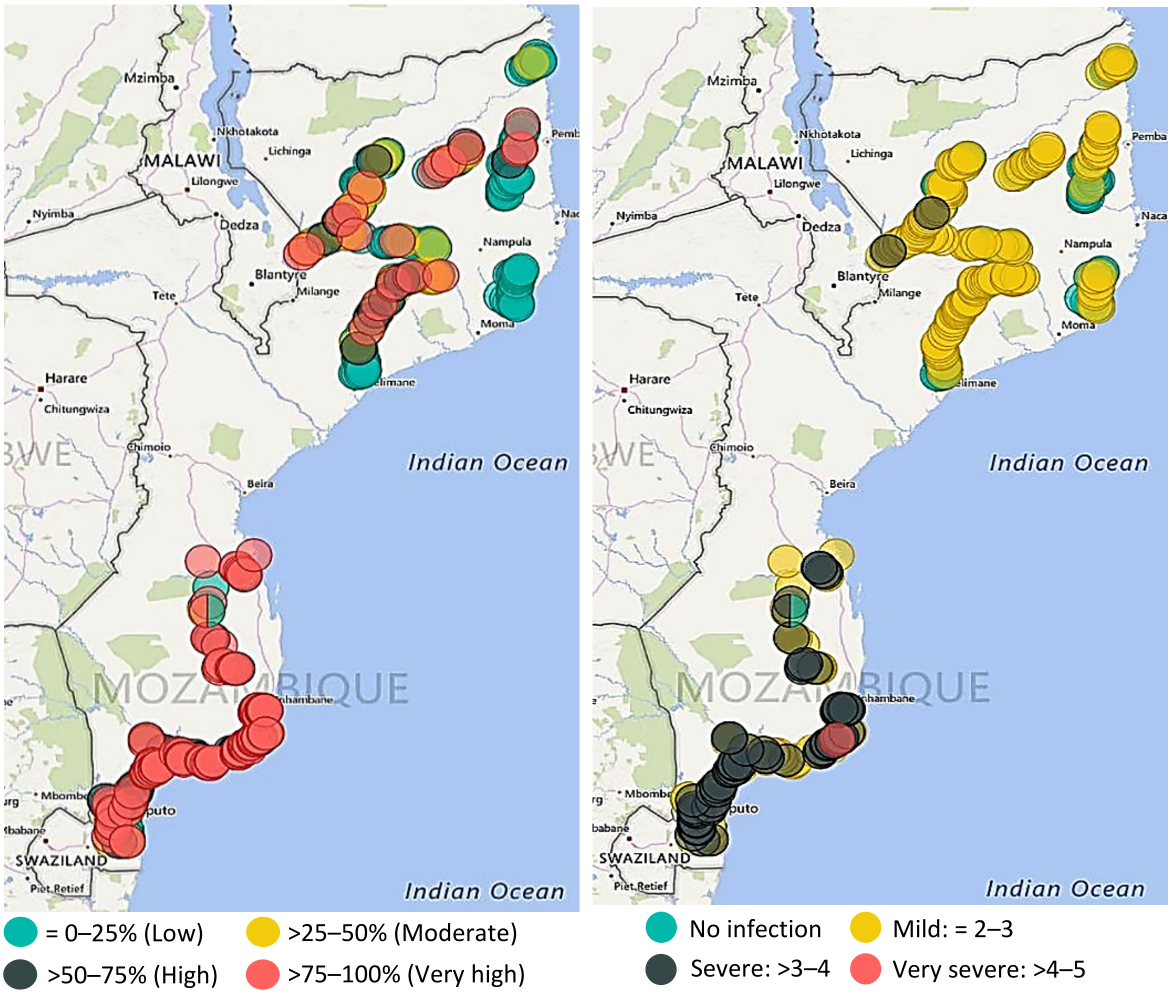

Figure 3 Distribution and severity of CMD – 2013 survey: (left) incidence and (right) severity

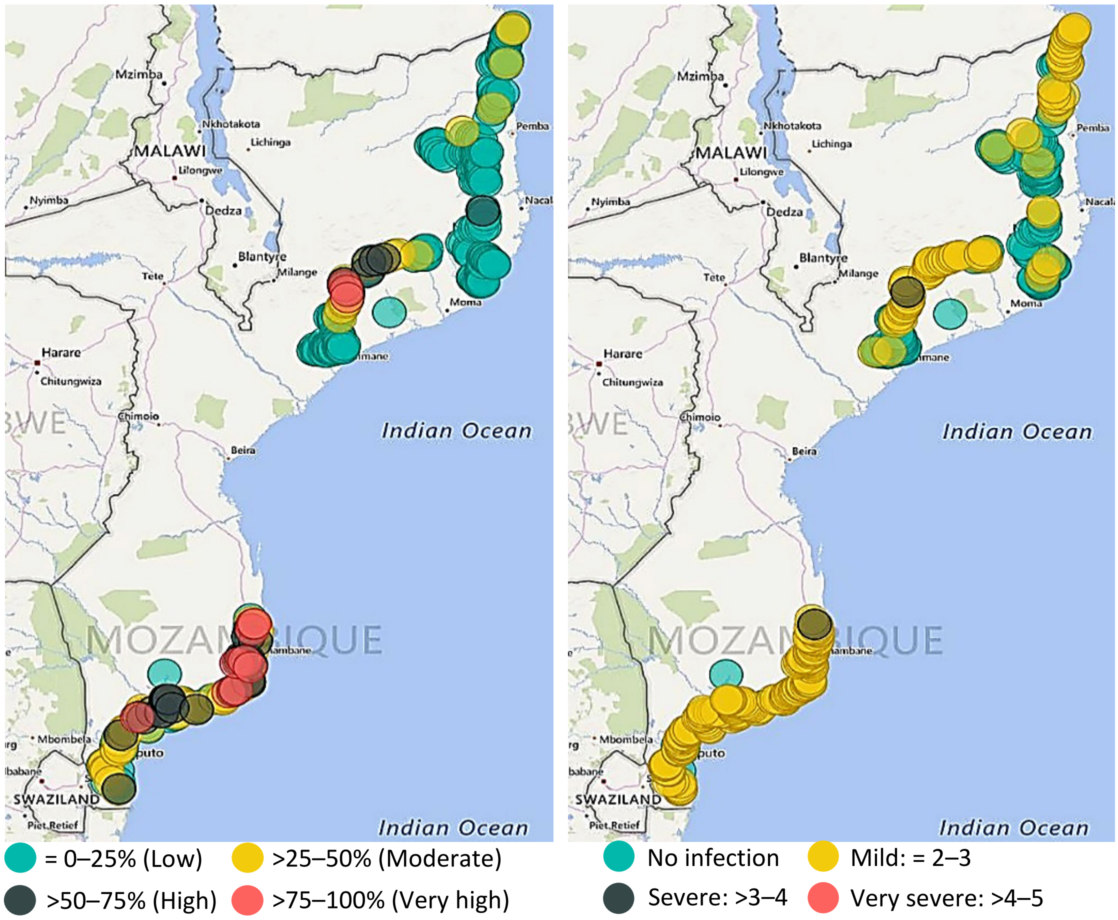

Figure 4 Distribution and severity of CMD – 2015 survey: (left) incidence and (right) severity

Incidence and severity of CBSD

An increasing trend of CBSD incidence was observed during 2013–2017. The most infected province was Zambezia during those years (Table 2). Unlike CMD, CBSD was recorded in few provinces; three provinces – Gaza, Inhambane and Maputo – had incidences of CBSD <5% in 2013. No CBSD was noted in these provinces for 2015 and 2017 surveys (Table 2, and Figure 5 and Figure 6).

Table 2 Mean incidence (Inc.) and mean symptom severity (sev.) of CBSD in major cassava growing provinces in Mozambique (2013–2017). '–' indicates that the district was not surveyed during those years

Province	2013		2015		2017			
	Inc. (%)	Mean sev.	Inc. (%)	Mean sev.	Inc. (%)	Mean sev.	Overall mean inc. (%)	Overall mean sev.
Cabo Delgado	14.5	2.7	17.5	2.6	70.78	2.66	**34.3**	**2.65**
Inhambane	0.46	2.1	0	0	0	0	**0.2**	**2.10**
Gaza	0.46	2.1	0	0	0	0	**0.2**	**2.10**
Maputo	4.35	2.2	0	0	0	0	**1.5**	**2.20**
Nampula	20.73	2.9	13.47	2.1	75.7	2.54	**36.6**	**2.51**
Niassa	1.9	2.7	–	–	–	–	–	–
Zambezia	67.9	2.7	60.79	2.2	64.69	2.65	**64.5**	**2.52**
Mean	**15.76**	**2.49**	**15.29**	**2.3**	**35.20**	**2.61**	**22.9**	**2.35**

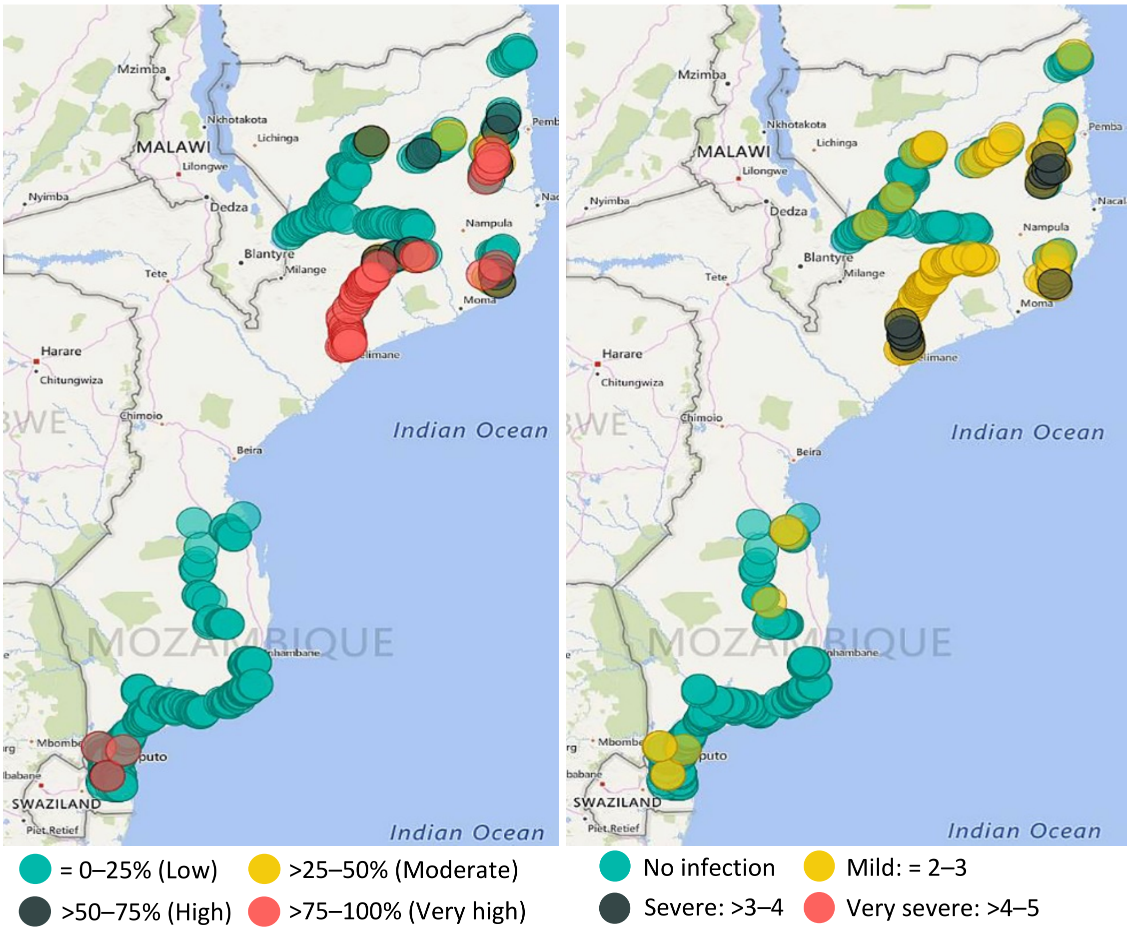

Figure 5 Distribution and severity of CBSD – 2013 survey: (left) incidence and (right) severity

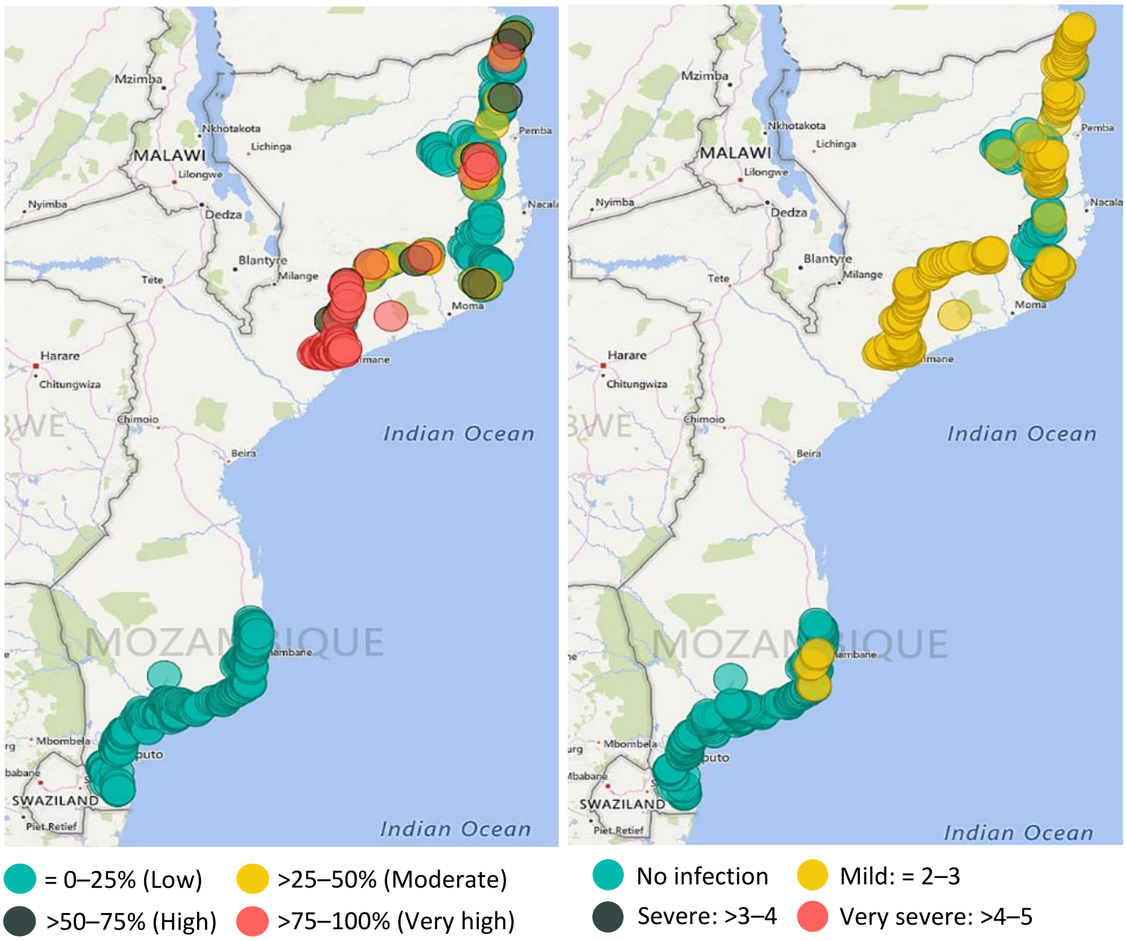

Figure 6 Distribution and severity of CBSD – 2015 survey: (left) incidence and (right) severity

The CBSD symptom severity was moderate across years and regions. Mean severity score ranged within 2.3–2.6, although there was no difference in CBSD severity between regions.

Adult whitefly abundance

Whitefly numbers were low to moderate in all surveys, with Inhambane showing slightly higher whitefly counts per plant (20.26) in the three surveys (Table 3), and the least was Maputo (1.34). Across surveys, the highest mean whitefly count was 12.02 per plant in 2013 compared to 2017 with 3.45 per plant (Table 3).

Table 3 Mean whitefly counts per plant in major cassava producing provinces in Mozambique (2013–2017). '–' indicates that the province was not surveyed during those years

Province	2013	2015	2017	Mean
Cabo Delgado	2.4	3.71	4.56	**3.49**
Inhambane	33.02	22.98	4.8	**20.26**
Gaza	29.8	18.18	7.88	**18.62**
Maputo	0.59	9.8	1.01	**3.8**
Nampula	0.8	1.4	0.98	**1.34**
Niassa	–	–	–	
Zambezia	5.52	10.57	1.48	**6.36**
Mean	**12.02**	**11.11**	**3.45**	

Alternative hosts for CBSVs and associated insect vectors

This work was addressed by Mr Jamisse Amisse as part of his PhD research. It aimed to determine the alternative hosts for *Cassava brown streak viruses* (CBSVs). Using transmission studies, all insects found on CBSD-infected plants in cassava fields were collected, sequenced characterized and used for transmission studies to see if they played a role in transmitting CBSVs.

Characterization of emerging viruses

CMD- and CBSD-symptomatic leaf samples were collected in Inhambane, Gaza and provinces in the 2015 countrywide survey. The samples were analyzed using PCR. The results showed the presence of two CMBs (ACMV and EACMV) and two CBSVs (CBSV and *Uganda cassava brown streak virus* – UCBSV).

Characterization of disease vectors

A total of 1800 whitefly samples were collected from six provinces in Mozambique during the 2013, 2015 and 2017 surveys (Table 4). DNA was extracted from all samples and sequence-characterized using mtCO1 markers in order to determine the identity of whitefly species prevalent in Mozambique that may vector CMD and CBSD.

DNA was extracted from 508 samples of which 98 were successfully amplified by the *mtCO1* primer pair. A total of 45 DNAs of the 202 samples were submitted for sequencing at Fasteris SA, Switzerland, and the sequences sent to TARI–Mikocheni for analysis by Dr Peter Sseruwagi to be included in a regional manuscript on *B. tabaci*. The dominant *B. tabaci* species in Mozambique was identified as SSA1-SG3.

Table 4 Whiteflies amplified and sequenced from various regions of Mozambique

Survey	No. of samples collected	Samples amplified	No. of samples sequenced
2013	415	21	0
2015	683	98	45
2017	702	83	0
Total	**1800**	**202**	**45**

SECTION TWO: Integrated pest management

Conventional breeding support

Breeders’ material monitored for disease and indexed for viruses (CMBs and CBSVs)

To ensure effective breeding for durable resistant cassava varieties in Mozambique, the CDP team supported breeding of resistant cassava materials through virus indexing and breeder trial joint monitoring and virus load evaluation on promising materials and potential parents. In 2013, five variety trials were assessed for cassava viruses (three in Nampula and two in Umbeluzi) (Table 5); and in 2015, one multiplication plot of 25 varieties for the New Cassava Varieties and Clean Seed to Combat CBSD and CMD Project (5CP) was monitored for virus response at Umbeluzi, and 10 in Nampula and 46 representative samples evaluated for virus presence (Table 6).

Table 5 Detection of CMBs in samples from breeders of Mozambique in 2013

Region	No. of samples tested	EACMV	ACMV	EACMV + ACMV
Mongicual	43	6.98 %	0	0
5CP Boane	10	0	0	0
Total	**53**	6.98 %	**0**	**0**

Table 6 Detection of CBSVs in samples from breeders of Mozambique in 2015

Region	No. of samples tested	UCBSV	CBSV	CBSV + UCBSV
Mongicual	43	0	0	0
5CP Boane	29	0	0	0
5CP Nampula	18	0	16.67 %	0
Total	**90**	**0**	**16.67%**	**0**

Reaching farmers directly and through partners

Farmers trained on CMD and CBSD disease symptom recognition and management strategies

This activity aimed at creating awareness of CMD and CBSD among cassava farmers in Coast, Western, Eastern and Nyanza regions. All farmers that were visited during the survey were ‘trained’ on identification (symptom recognition) and management of the diseases and the benefits of using virus-free materials. On-farm demonstration plots and virus-free cassava multiplication plots were established in two regions: Boane and Inharrime.

Two trainings for farmers and extension workers were conducted respectively at Umbeluzi and Nhacoongo. A total of 72 farmers (22 men and 50 women) were trained in the two regions.

Theoretical background on the concepts of what diseases are, what causes them, etiology and symptomatology of CMD and CBSD were introduced. Groups were formed to discuss control strategies for the diseases. The training also included field practicals, to teach trainees how to recognize and identify CMD and CBSD in the field, and how to identify the whitefly vector.

Two demonstration plots were established at Boane and Nhacoongo districts (Figure 7), to create awareness among farmers on CMD and CBSD, and to show the benefit of using clean plant materials. During surveys, farmers were also taught about the diseases and about roguing infected plants.

Demonstration plots for benefits of using virus-indexed planting materials established on-farm

Demonstration plots were established at Boane and Nhacoongo districts (Figure 7 and Figure 8), to create awareness among farmers on CMD and CBSD, and to show the benefit of using clean plant materials. During surveys, farmers were also taught about the diseases and about roguing infected plants.

Figure 7 Two demonstration plots established at Boane and Nhacoongo districts, to create awareness among farmers on CMD and CBSD diseases and the benefit of using clean planting materials

Figure 8 (A) Demonstration plot establishment in Nhacoongo in 2017, (B) demonstration plot established in Boane district in 2015, (C) demonstration plot in Nhacoongo in 2015, (D) distribution of clean planting material to farmers in Boane district in 2017

Information materials developed and disseminated

A pamphlet (Figure 9) concerning identification and management of CMD and CBSD was distributed to farmers, extension workers and inspectors.

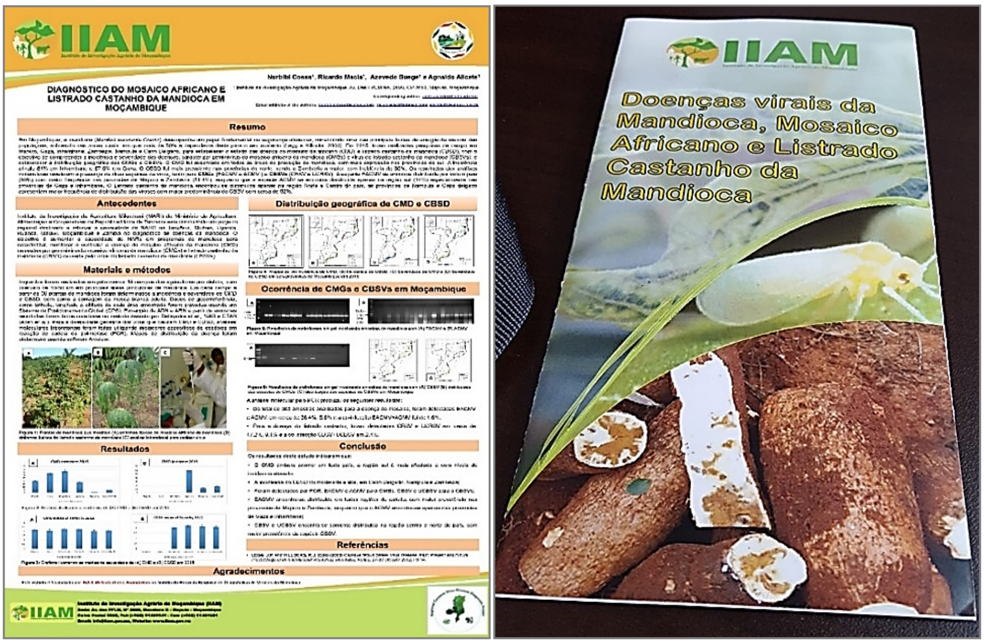

Figure 9 Pamphlet on identification and management of CMD and CBSD

A journal article was published in Canal de Mozambique Journal (Figure 10) about the issue of cassava viral diseases in Mozambique, and the steps taken to minimize the impacts of CMD and CBSD.

Canal moz

1 April 2015 ·

Doenças virais ameaçam cultura da mandioca no país (#canalmoz)

Maputo (Canalmoz) – Doenças provocadas por vírus, nomeadamente, a mosaico africano da mandioca e a podridão radicular, estão a comprometer os níveis de produção da mandioca no país.

Segundo Nurbibi Cossa, do Instituto Nacional de Investigação Agrária de Moçambique, as doenças, registadas pela primeira em 1999 na zona norte país, estão neste momento a propagar-se para a zona sul.

Segundo Nurbibi Cossa, a mosaico africano da mandioca e podridão radicular são doenças que, quando atacam, as plantas da mandiocaficam com as folhas amareladas e atrofiadas, e por causa disso a sua raiz não se desenvolve, razão pela qual são consideradas principais limitantes da produção da mandioca.

Com a propagação em quase todo o território nacional, os níveis de produção deste produto agrícola mais consumido no país depois do milho, baixaram drasticamente, chegando a atingir 70% de redução na produção global em Moçambique.

Estação Agrária do Umbelúzi ensaia mandioca resistente a doenças virais

Por se tratar de doenças sem tratamento, uma vez que ainda não foram descobertos insecticidas, o IIAM, está neste momento a fazer ensaios de variedades de mandioca melhorada, na Estação Agrária do Umbelúzi, com vista a testar a resistências às referidas doenças.

Este trabalho está a ser desenvolvido em quase todas as províncias com elevado potencial de produção de mandioca, como é o caso de Inhambane e de Nampula.

Caso sejam aprovadas, as referidas variedades serão multiplicadas e distribuídas pelos produtores, para que possam recuperar os níveis de produção e de produtividade da mandioca.

Paralelamente aos trabalhos de ensaios de novas variedades da mandioca resistentes a doenças que limitam a produção da mandioca no país, o IIAM lançou na terça-feira, na Estação Agrária do Umbelúzi, no distrito de Boane, província de Maputo, um programa nacional de formação de produtores de mandioca do sector familiar em matéria de identificação e vigilância das referidas epidemias. (Raimundo Moiane

TRANSLATED FROM PORTUGUESE

1 April 2015

Viral diseases threaten the country's cassava crop.

Maputo (Canalmoz) - Diseases caused by viruses, namely the African cassava mosaic and root rot, are jeopardizing the levels of cassava production in the country.

According to Nurbibi Cossa, of the National Mozambique Agricultural Research Institute, the diseases were detected for the first time in 1999 in the north of the country and are now spreading to the south.

According to Nurbibi Cossa, the African cassava mosaic and root rot are diseases that attack cassava plants resulting in yellowish and atrophied leaves. Because of this their roots do not develop and this is the main factor limiting cassava production.

With spread to almost all the nation, the production levels of the country's most consumed agricultural product after maize have fallen drastically by 70%.

The Umbeluizi Agricultural Research Station researches cassava resistant to viral diseases.

Due to the fact that these diseases are not treated and no effective insecticide has been discovered, the IIAM is carrying out trials of improved cassava varieties at the Umbeluizi Agricultural Research Station to test the resistance to these diseases.

This work is being carried out in almost all provinces with high potential for cassava production, such as Inhabane and Nampula.

If approved, these varieties will be multiplied and distributed by producers so that they can recover the production and productivity levels of cassava.

In parallel with the testing of new disease-resistant cassava varieties to increase cassava production in the country, IIAM launched a national training program for cassava producers in the country at the Umbeluizi Agricultural Research Station in the Boane district of Maputo on Tuesday – the aim of the program is the identification and surveillance of these epidemics (Raimundo Moiane).

Figure 10 Canal Moz article on cassava viral diseases and their management

Awareness

A radio broadcast was aired on different topics related to cassava virus diseases and management. Additionally, one article was published in Agritech News, and one brochure was produced and over 1500 copies were distributed.

Strengthening stakeholder linkages

As a way of building sustainable national capacity in disease diagnostics, Instituto de Investigação Agrária de Moçambique (IIAM) strengthened its linkages with stakeholders by enhancing the accessibility of information and technologies to farmers through stakeholders. Thus, for the past four years, IIAM has worked with several stakeholders (Table 7) to enhance accessibility of information to farmers.

Table 7 Stakeholders collaborating with IIAM

Institution	Location	Partnership/ Type of stakeholder	Respondent(s)	Role	Contact person(s)
Institute of Agricultural Research of Mozambique (IIAM)	Maputo	NARS (Project partners)	Ms Nurbibi Cossa (Team Leader), Mr Azevedo Suege (Research Assistant), Mr Agnaldo Alicete (Research Technician)	Hosting the project, breeding for resistance to CMD and CBSD and disease diagnostics	Ms Nurbibi Cossa Mr Azevedo Suege
IIAM	Maputo	Project Students	Mr Jamisse Amisse, Miss Martha Solemanegy	Research and cassava virus diagnostics	Mr Jamisse Amisse
IIAM	Maputo	NARS (Plant protection, biotechnology and seed certification)	Ms Serafina Ernesto Mangana (Head of Plant Protection Department), Mr Frederico Pedro Madabula (Biotechnologist), Mr Elsa Timana (Head of Department, Seed Certification)	Plant health, biotechnology research and seed certification	Ms Serafina Mangana Mr Frederico Madabula Mr Elsa Timana
Ministry of Agriculture, National Directorate of Rural extension	Maputo	Government	Mr Leitao Pedro Isabel (Program Officer/Extensionist)	Training farmers, distribution of planting materials	Mr Leitao Pedro Isabel

Institution	Location	Partnership/ Type of stakeholder	Respondent(s)	Role	Contact person(s)
Service of Economic Activities in Boane district	Boane	Government	Ms Carolina Sitoe (Extensionist)	Training of farmers and distributing clean planting materials	Ms Carolina Sitoe
Farmers	Saldanha, Boane district	Farmer	Ms Amelia Sitoe, Mr Elias Matola, Mr Francisco Matola and Mr Eugenio Freira	Cassava production	Mr Francisco Matola
Eduardo Mondlane University	Maputo	University	Mr Amandio Miguel Muthambe (Plant Pathologist and Course Dean)	Training and supervision of students	Mr Amandio Miguel Muthambe

Exchange visits between scientists in the project countries

The CTL, Ms Nurbibi Cossa, and her assistant participated in the first exchange visit to the Zambia Agricultural Research Institute (ZARI) during 15–21 May 2016. They visited the CDP research activities in Zambia including the new screenhouse and laboratories, and farmers' fields to assess the disease situation.

Strengthening human capacity and infrastructure

During the project duration, several staff provided the project with a range of skills (Table 8).

Table 8 Project staff

S/No.	Name	Position
1	Nurbibi Cossa	CTL
2	Ricardo Macia	Assistant CTL
3	Azevedo Suege	Research Assistant
4	Agnaldo Alicete	Project Technician
5	Artur Olisses	Project Driver
6	Jamisse Amisse	PhD student (Makerere University)
7	Marta Solemanigy	MSc student (Makerere University)

Figure 11 Project staff trained in field disease assessment and laboratory analysis by Dr Peter Sseruwagi and Ms Catherine Gwandu from TARI–Mikocheni, Tanzania, June 2013

Table 9 Summary of short-term training conducted for capacity building to TARI–Mikocheni staff for the period of 2009–2017

Professional training	Year	Venue
Virus diagnostics and laboratory practices	2009/2013	TARI–Mikocheni Biotech Lab-DSM, Tanzania
Scientific writing skills	2010/ 2016	Mombasa, Kenya; San Diego, USA and Lusaka, Zambia
Training in IP	2014	Icipe, Nairobi, Kenya
Cassava disease diagnostics and survey methodologies	2014	Dar es Salaam, Tanzania
Advanced specialized training and visits for project scientists (1–2 months) conducted	2015	Department of Ecology and Evolution and Natural Resources, Rutgers University, USA
Development and training in use of a TARI–Mikocheni CDP SharePoint system	2015	Dar es Salaam
Workshop on bioinformatics	2016	TARI–Mikocheni, Dar es Salaam
PAG 2016	2016	San Diego, USA
Women in Science Leadership	2016	San Diego
Data sharing	2016	Dar es Salaam
Exchange visits between scientists in the project countries	2016	ZARI, Lusaka, Zambia

Infrastructure strengthening

From 2013 until 2016 the infrastructure of IIAM was significantly enhanced through acquisition of new basic equipment for virus diagnostics. The procured infrastructure and status are listed in Table 10.

Table 10 Equipment procured under CDP

Asset-description	Serial no.	Date of purchase	Current location	Condition
Toyota Hilux 4WD Double cabin	ADF-108-MP	2013	IIAM	Good
Generator BUNDU POWER	BP20S3, 20KVA	2013	IIAM	Good

Asset-description	Serial no.	Date of purchase	Current location	Condition
Greenhouse rehabilitation		2013–2017	IIAM	Good
Weighing balance	419641/14	2014	IIAM	Good
Microwave oven	DEFY-DMO349	2013	IIAM	Good
ELISA reader	PR4100	2014	IIAM	Good
BioDoc-It imaging system	UVP trans illuminator	2014	IIAM	Good
PCR machine x TECHNE	53897-2	June 2016	IIAM	Good
Freezer ultra –85°C	Chest, 130 L	June 2016	IIAM	Good
Freezer –20°C and 4°C	Samsung	2016	IIAM	Good
Desktop HP	Intel(R)Pentium® CPU-G3250@3.20GHz 4.00 GB RAM	2016	IIAM	Good
Printer HP	HP LaserJet P1102	2016	IIAM	Good
Gilson pipettes	P200, P20 and P10	June, 2016	IIAM	Good
Stabilizer	6313A01284	2014	IIAM	Good
Tablet	Samsung Galaxy Tab A6	2017	IIAM	Good

SECTION THREE: Impacts, success stories and learning outcomes

Impacts

This information was not available at the time of writing.

Success stories

This information was not available at the time of writing.

Learning outcomes

We learned more about team spirit within the region to solve common issues in the agriculture sector, especially cassava viral diseases and networking among regional and international research institutions.

We have been able to exchange information on cassava varieties tolerant to both CMD and CBSD and that are available in the region.

List of manuscripts

Amisse, J.G., Ndunguru, J., Tairo, F., Ateka, E., Boykin, L.M., Kehoe, M.A., Cossa, N., Rey, C.M. and Sseruwagi, P. (2018) Analyses of seven new whole genome sequences of cassava brown streak viruses in Mozambique reveals two distinct clades: evidence for new species. In Press. *Plant Pathology*.

Amisse, J.G., Ndunguru, J., Tairo, F., Boykin, L.M., Kehoe, M.A., Cossa, N., Ateka, E., Rey, C.M. and Sseruwagi, P. (2018) First report of Cassava brown streak viruses on alternative hosts in Mozambique. *Physiological and Molecular Plant Pathology,* https://doi.org/10.1016/j.pmpp.2018.10.005

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References

Cossa, N. (2005) Epidemiology of Cassava Mosaic Disease in Mozambique. Thesis for Master Degree at School of Molecular and Cell biology at Witwatersrand University, Johannesburg, South Africa, 30pp.

Dias, P. (2012) Analysis of incentives and disincentives for cassava in Mozambique. Technical notes series MAFAP, FAO, Rome.

FAOSTAT (2014) http://www.fao.org/faostat/en/#search/Cassava%20production (accessed on March 27, 2017).

Hillocks, R.J., Thresh, J.M., Tomas, J., Botao, M., Macia, R. and Zavier, R. (2002) Cassava brown streak in northern Mozambique. *International Journal of Pest Management*, 48:179–182.

IIAM/PNRT (2007) Cassava production areas in Mozambique.

IITA (2008) Distribution of cassava mosaic disease and cassava green mites in farmers' fields in twelve major cassava producing districts of Zambia, December 2007 and January 2008. In: Cassava Transformation in Southern Africa (CATISA) Project Zambia Report 2007. IITA/SARRNET.

Sseruwagi, P., Sserubombwe, W.S., Legg, J.P., Ndunguru, J. and Thresh, J.M. (2004) Methods of surveying the incidence and severity of cassava mosaic disease and whitefly vector populations on cassava in Africa: a review. *Virus Research*, 100:129–142.

Sseruwagi, P., Tairo, F., Stutt, R., Szyniszewska, A. and Godding, D. (2017) Cassava virus and whitefly surveillance: standard operating procedure, January 2017. https://docs.google.com/document/d/19YtZcI7_k-FvTrdsJvz5yTqOlXMhqb83YYRLuV 7tzDY/ edit?usp=sharing.

Thresh, J.M. and Hillocks, R.J. (2003) Cassava mosaic and cassava brown streak diseases in Nampula and Zambézia provinces of Mozambique. Roots 9 (Forthcoming).