FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS

INTERNATIONAL BOARD FOR
PLANT GENETIC RESOURCES

FAO/IBPGR TECHNICAL GUIDELINES

FOR THE

SAFE MOVEMENT OF CASSAVA GERMPLASM

Edited by
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In collaboration with

Centro Internacional de Agricultura Tropical

INTRODUCTION

Collecting, conservation and utilization of plant genetic resources and their global distribution are essential components of international crop improvement programmes.

Inevitably, the movement of germplasm involves a risk of accidentally introducing plant quarantine pests* along with the host plant material; in particular, pathogens that are often symptomless, such as viruses, pose a special risk. In order to minimize this risk, effective testing (indexing) procedures are required to ensure that distributed material is free of pests that are of quarantine concern.

The ever-increasing volume of germplasm exchanged internationally, coupled with recent rapid advances in biotechnology, has created a pressing need for crop-specific overviews of the existing knowledge in all disciplines relating to the phytosanitary safety of germplasm transfer. This has prompted FAO and IBPGR to launch a collaborative programme for the safe and expeditious movement of germplasm, reflecting the complementarity of their mandates with regard to the safe movement of germplasm. FAO has a long-standing mandate to assist its member governments to strengthen their Plant Quarantine Services, while IBPGR's mandate - *inter alia*- is to further the collecting, conservation and use of the genetic diversity of useful plants for the benefit of people throughout the world.

The aim of the joint FAO/IBPGR programme is to generate a series of crop-specific technical guidelines that provide relevant information on disease indexing and other procedures that will help to ensure phytosanitary safety when germplasm is moved internationally.

The technical guidelines are produced by meetings of panels of experts on the crop concerned, who have been selected in consultation with the relevant specialized institutions and research centres. The experts contribute to the elaboration of the guidelines in their private capacity and do not represent the organizations to which they belong. FAO, IBPGR and the contributing experts cannot be held responsible for any failures resulting from the application of the present guidelines. By their nature, they reflect the consensus of the crop specialists who attended the meeting, based on the best scientific knowledge available at the time of the meeting.

The technical guidelines are written in a short, direct, sometimes 'telegraphic'

* The word 'pest' is used in this document as it is defined in the revised edition of the International Plant Protection Convention. It encompasses all harmful biotic agents ranging from viroids to weeds.

style, in order to keep the volume of the document to a minimum and to facilitate updating. The guidelines are divided into two parts: The first part makes recommendations on how best to move germplasm of the crop concerned and is divided into general and technical recommendations. Institutions recovering and maintaining healthy cassava germplasm as well as those that can act as intermediate quarantine stations, and selected references on therapy procedures are listed at the end of this first part. The second part gives descriptions of the most important pests and diseases that could be of quarantine concern.

The information given on a particular pest or disease does not pretend to be exhaustive but concentrates on those aspects that are most relevant to quarantine. At the end of each description a few key references are given, referring mainly to geographical distribution, transmission and methods of indexing.

The present guidelines were developed at a meeting held in Cali, Colombia, from 8 to 10 May 1990. The meeting was hosted by the Centro International de Agricultura Tropical (CIAT), and organized in collaboration with CIAT and the International Institute of Tropical Agriculture (IITA).

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GENERAL 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 material except for *in vitro* plantlets.

- Cassava germplasm can be moved as seed, pathogen-tested *in vitro* material, or as cuttings from re-established pathogen-tested in vitro material that has been grown under containment. Each of these 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 of 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 6O°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 infested, 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, after 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 the diseases present in the area of origin of the material, and/or in areas where the material has been field-grown prior to deriving meristems, according to the procedures recommended in the present guidelines. (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 the pathogens 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 under containment with regular inspection.

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

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

- 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 reinfection 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.

4. Untested vegetative material

- Untested material, either as *in vitro* cultures or as stem cuttings, should only be moved to intermediate or post-entry quarantine facilities where they will be subjected to the therapy and indexing procedures described above, before being released. When stem cuttings are moved they must be treated with the appropriate pesticides in the country of origin.

INSTITUTIONS HOLDING AND/OR PRODUCING PATHOGEN-TESTED *IN VITRO* GERMPLASM OF CASSAVA

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Colombia

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Selected references on therapy procedures

Adejare, G.O. & Coutts, R.H.A. 1981. Eradication of cassava mosaic disease from Nigerian cassava clones by meristern-tip culture. *Plant Cell Tissue Organ Culture* **1**:25-32.

Frison, E.A. 1981. Recommendations for transplanting and handling tissue culture material. IITA Manual Series No. 6. International Institute of Tropical Agriculture, Ibadan.

Frison, E.A. 1981. Tissue Culture : A tool for improvement and international exchange of tropical root and tuber crops. *IITA Research Briefs* **2** (1): l-4.

Kaiser, W.J. & Teemba, L.R. 1979. Use of tissue culture and thermotherapy to free East-African cassava cultivars of African cassava mosaic and cassava brown streak diseases. *Plant Dis. Reptr* **63**:780-784.

Kartha, K.K. & Gamborg, O.L. 1975. Elimination of cassava mosaic disease by meristem culture. *Phytopathology* **65**:826-828.

Lozano, J.C., Laberry, R. & Bermudez, A. 1986. Microwave treatment to eradicate seed-borne pathogens in cassava true seed. *J. Phytopathol.* **117**:1-8.

Roca, W.M., Szabados, L., Mafla, G., Roa, J. & Nolt, B. 1988. Virus elimination and clonal propagation of cassava *(Manihot esculenta* Crantz). In: Proceedings of the International Congress on Plant Tissue Culture: Tropical Species. Bogota, Colombia.

DESCRIPTIONS OF PESTS

Viral diseases

1. African cassava mosaic virus (ACMV) and Indian cassava mosaic virus (ICMV)

Symptoms

Depending on variety, cassava plants may show mild to severe mosaic, yellowing, distorted leaves, and stunted growth. Disease symptoms may be expressed irregularly throughout the plant, particularly in more resistant varieties commonly grown in Africa. In some varieties, the majority of plants do not show any symptoms, especially in later stages of growth. Erratic disease expression is a result of restricted infection within the plant (Rossel *et al.*, 1989).

Geographical distribution

ACMV isolates have been found in cassava throughout tropical Africa (Storey &

Fig. 1. African cassava mosaic virus in local variety in Nigeria. (Ir H.W. Rossel, IITA, Ibadan)

Fig. 2. African cassava mosaic virus isolates in *Nicotiana benthamiana* (healthy control in centre). (Ir H.W. Rossel, IITA, Ibadan)

Nichols, 1938) and in its adjacent islands, including Cape Verde, Sao Tome and Principe, Malagasy, and Seychelles (Bock & Harrison, 1985). In India and Sri Lanka a similar disease, called Indian cassava mosaic disease, is caused by Indian cassava mosaic virus (Aiton *et al.*, 1988; Malathi *et al.*, 1988).

Transmission

ACMV is transmitted by vegetative propagation and by the whitefly *Bemisia tabaci* in a persistent manner (Chant, 1958). Sap transmission of ACMV from cassava to cassava has been reported (Bock & Guthrie, 1978), but this has not been confirmed. Mechanical inoculation of ACMV to *N. benthamiana* is possible, but success varies between isolates. Transmission from *Nicotiana* spp. to cassava is difficult (Bock & Woods, 1983; Rossel *et al.*, 1988). ACMV has not been shown to be transmitted by seed. ICMV is transmitted by *Bemisia tabaci* from cassava to cassava and by mechanical inoculation from cassava to *N. benthamiana.*

Particle morphology

The particles typically are bisegmented, approximately 30 x 20 nm.

Therapy

Thermotherapy followed by meristem-tip culture.

Indexing

The use of serological techniques (preferably ELISA, using monoclonal antibodies) is recommended (Thomas *et al.*, 1986; Aiton & Harrison, 1989). As there are serological differences between isolates of ACMV from East and West Africa and between ACMV and ICMV (Harrison *et al.*, 1987), it is important to use monoclonal antibodies that detect the virus isolates occurring in the country of origin. Serological detection should be done in conjunction with inoculation to *N. benthamiana.*

References

Aiton, M.M. & Harrison, B.D. 1989. Monoclonal antibodies to Indian cassava mosaic geminivirus. p. 175. In: *Annual Report 1988.* Scottish Crop Research Institute, Dundee.

Aiton, M.M., McGrath, P.F., Robinson, D.J., Roberts, I.M. & Harrison, B.D. 1988. Variation in Indian cassava mosaic geminivirus. p. 191. In: *Annual Report 1987.* Scottish Crop Research Institute, Dundee.

Bock, K.R. & Guthrie, E.J. 1978. Transmission of African cassava mosaic virus by mechanical inoculation. *Plant Dis. Reptr* **62**:580-581.

Bock, K.R. & Harrison, B.D. 1985. African cassava mosaic virus. AAB Descriptions of Plant Viruses No. 297. Association of Applied Biologists, Wellesbourne.

Bock, K.R. & Woods, R.D. 1983. Etiology of African cassava mosaic disease. *Plant Dis.* **67** :994-995.

Chant, S.R. 1958. Studies on the transmission of cassava mosaic virus by *Bemisia* spp. (Aleurodidae). *Ann. appl. Biol.* **46**:210-215.

Harrison, B.D., Lennon, A.M., Massalski, P.R., Robinson, D.J. & Thomas, J.E. 1987. Geographical variation in geminivirus isolates associated with cassava mosaic disease. p. 179-180. In: *Annual Report 1986.* Scottish Crop Research Institute, Dundee.

Malathi, V.G., Thankappan, M., Nair, N.G., Nambisan, B. & Ghosh, S.P. 1988. Cassava mosaic disease in India. pp.l89-198. In: *Proceedings of the international seminar on African cassava mosaic disease and its control.* Yamoussoukro, 4-8 May 1987. CTA, Ede.

Rossel, H.W., Thottappilly, G., van Lent, J.W.M. & Huttinga, H. 1988. The etiology of cassava mosaic in Nigeria. pp. *43-56.* In: *Proceedings of the international seminar on African cassava mosaic disease and its control,* Yamoussoukro, 4-8 May 1987. CTA, Ede.

Storey, H.H. & Nichols, R.F.W. 1938. Studies on the mosaic disease of cassava. *Ann. appl. Biol.* **25**:790-806.

Thomas, J.E., Massalski, P.R. & Harrison, B.D. 1986. Production of monoclonal antibodies to African cassava mosaic virus and differences in their reactivities with other whitefly-transmitted geminiviruses. *J. gen. Virol.* **67**:2739-2748.

2. Cassava brown streak virus (CBSV)

Symptoms
Yellow blotches and mottling develop on mature leaves, but not on young leaves. Small thin lesions may develop on young stems and later coalesce to form blotchy patches. Lesions extend into the cortex and are not easily seen once bark has formed. Unripe fruit may have black necrotic spots which extend to the fleshy tissues beneath. Roots show longitudinal fissures surrounded by discoloured tissues and internal lesions also develop. In young plants, stem symptoms are often observed before leaf symptoms.

Geographical distribution
Cassava growing regions in East Africa: Kenya, Malawi, Tanzania and Uganda (Lennon *et al.*, 1986; Nichols, 1950).

Transmission
CBSV is transmitted by vegetative propagation and is experimentally transmitted by mechanical inoculation to test plants, but not back to cassava (Lister, 1959). Possibly whitefly transmitted *(Bemisia* spp.).

Particle morphology
It is not clear whether 1 or 2 viruses with filamentous particles are involved. In pure virus preparations two particle lengths are sometimes observed: 650-700 nm (carlavirus-like) and a longer, more fragile flexuous (potyvirus-like) particle. (Distant serological

Fig. 3. Cassava brown streak virus on cassava. (Scottish Crop Research Institute, Dundee)

relationships to both a carlavirus and potyviruses have been observed.) Infected test plants contain pinwheel inclusions.

Therapy
Thermotherapy followed by meristem-tip culture.

Indexing
The virus can only be detected in plants showing symptoms. Mechanical inoculation with sap from older, lower leaves will produce local lesions in *Chenopodium quinoa* and vein yellowing, mottling and distortion in *Nicotiana benthamiana*. The virus can be detected in symptom-bearing cassava leaves by ELISA using polyclonal antiserum. Symptom development in cassava takes several months.

References
Lennon, A.M., Aiton, M.M. & Harrison, B.D. 1986. Cassava viruses from Africa. p. 168. In: *Annual Report* 1985. Scottish Crop Research Institute, Dundee.

Lister, R.M. 1959. Mechanical transmission of cassava brown streak virus. *Nature* **183**:1588-1589.

Nichols, R.F.W. 1950. The brown streak disease of cassava. Distribution, climatic effects and diagnostic symptoms. *East Afric. Agric. For. J.* **15**:154-160.

3. Cassava common mosaic virus (CCMV)

(Potexvirus group)

Symptoms
Mosaic symptoms and chlorotic areas that are often limited by the veins.

Geographical distribution
CCMV occurs thoughout tropical America from Mexico to Paraguay (Costa & Kitajima, 1972).

Transmission
The virus is readily transmitted by mechanical means or through vegetative propagation. The virus is mechanically transmitted to *N. benthamiana* (systemic host) and *Chenopodium amaranticolor* (local lesion host). No known vector.

Particle morphology
Semiflexuous rod, approximately 495 x 15 nm.

Therapy
Thermotherapy followed by meristem-tip culture.

Fig. 4. Cassava common mosaic virus on cassava. (Dr L.A. Calvert, CIAT, Cali)

Indexing

The virus is readily detected by serological methods including ELISA and ISEM. Mechanical inoculation of *N. benthamiana.*

Reference

Costa, A.S. & Kitajima, E.W. 1972. Cassava common mosaic virus. CMI/ABB Descriptions of Plant Viruses No. 90. Commonwealth Agricultural Bureaux, Slough.

4. Cassava green mottle virus (CGMV)

(Tentative member of the nepovirus group)

Symptoms

Faint or distinct mottling and mosaic, often on puckered leaves with distorted margins. Plants often recover to give slightly stunted but otherwise symptomless plants. Occasionally, plants are severely stunted.

Geographical distribution

CGMV has been reported only from Choiseul, Solomon Islands (Lennon & Aiton, 1987; Lennon *et al.*, 1987).

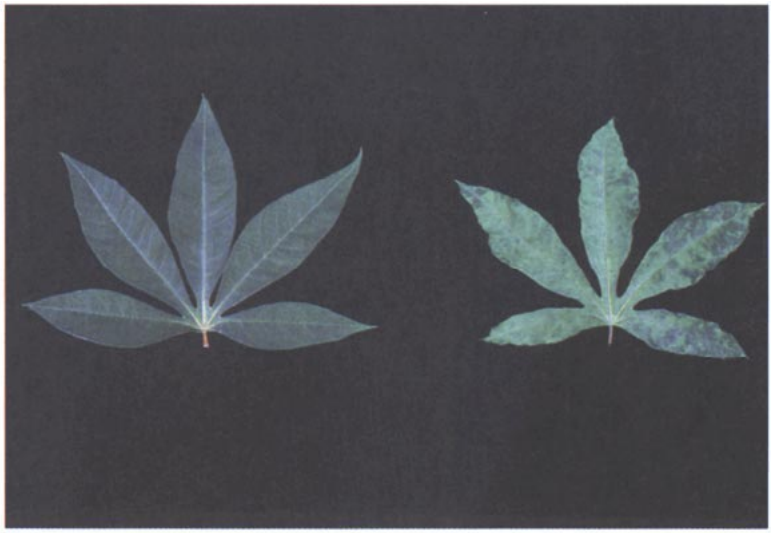

Fig. 5. Cassava green mottle virus on cassava (left = healthy). (Scottish Crop Research Institute, Dundee)

Transmission

CGMV is transmitted by vegetative propagation. Experimentally transmitted by mechanical inoculation to cassava, *N. clevelandii and Chenopodium quinoa.* In cassava symptoms develop in 2-5 months. The virus has been shown to be transmitted through seeds of *N. clevelandii,* but seed transmission in cassava has not been tested. Affinities to the nepovirus group imply possible transmission by nematodes.

Fig. 6. Cassava green mottle virus on cassava. (Dr G.V.H. Jackson, SIT, Fiji)

Particle morphology
Isometric, approximately 26 nm in diameter.

Therapy
No information available.

Indexing
By ELISA using a polyclonal antiserum. In mechanically inoculated plants, the virus can be detected only after symptoms develop, but can still be detected after the symptoms disappear.

References
Lennon, A.M. & Aiton, M.M. 1987. A new virus infects cassava in the Solomon Islands. *Cassava Newsletter* **11**:6-7.

Lennon, A.M., Aiton, M.M. & Harrison, B.D. 1987. Purification and properties of cassava green mottle, a previously undescribed virus from the Solomon Islands. *Ann. appl. Biol.* **110**:545-555.

5. Casava vein mosaic virus (CVMV)

(Caulimovirus group)

Symptoms
Symptoms include a chlorosis of the veins which can either appear as a chevron pattern or coalesce to form a ringspot pattern. Some leaves show a mosaic pattern over the entire leaf. There is often leaf distortion and sometimes the young leaves show epinasty. Expression of symptoms is variable and symptoms may fade with age or not be expressed during certain times of the year.

Geographical distribution
The virus has been reported from many states in Brazil and is prevalent in the northeastern states.

Particle morphology
Isometric, approximately 50 nm in diameter (Kitajima & Costa, 1980).

Transmission
The virus is transmitted by vegetative propagation. There is no conclusive evidence about vectors of this virus.

Therapy
Thermotherapy followed by meristem-tip culture.

Indexing

The virus can be detected by standard serological methods (Lin & Kitajima, 1980).

References

Kitajima, E.W. & Costa, A.S. 1980. Particulas esferoidais associados ao virus do mosaico das nervuras da mandioca. *Bragantia* **25**:211-221

Lin, M.T. & Kitajima, E.W. 1980. Purificacao e serologia do virus do mosaico das nervuras da mandioca. *Fitopatol. Bras.* **5**:419.

Viruses not known to cause disease

1. Casava American latent virus (CALV)

(Tentative member of the nepovirus group)

Symptoms

No symptoms on cassava.

Geographical distribution

The virus was isolated from cassava collected in Brazil and Guyana; it is not known if it occurs elsewhere (Walter *et al.*, 1989).

Fig. 7. Cassava vein mosaic virus causing vein mosaic and leaf curling on cassava. (Dr L.A. Calvert, CIAT, Cali)

Transmission
The virus can be mechanically transmitted to cassava and *N. benthamiana* (systemic hosts), as well as to *Chenopodium quinoa* and *C. amaranticolor* (local lesion hosts).

Particle morphology
Isometric, approximately 28 nm in diameter.

Therapy
No information available.

Indexing
The virus can be detected by serological methods including ELISA.

Reference
Walter, B., Ladeveze, I., Etienne, L. & Fuchs, M. 1989. Some properties of a previously undescribed virus from cassava: cassava American latent virus. *Ann. appl. Biol.* **115**:279-289.

2. Cassava Colombian symptomless virus (CCSV)

(Tentative member of the potexvirus group)

Symptoms
No known symptoms.

Geographical distribution
The virus was isolated from cassava collected in Colombia, however it is not known if it occurs elsewhere (Aiton & Harrison, 1988).

Transmission
CCSV is transmitted by vegetative propagation. Experimentally transmitted by mechanical inoculation to *Chenopodium quinoa* (local lesion host), but not back to cassava. No vectors of CCSV are reported.

Particle morphology
Semiflexuous rod, approximately 495 x 15 nm.

Therapy
No information available.

Indexing
The virus is readily detected using ELISA or ISEM.

Reference

Aiton, M.M. & Harrison, B.D. 1988. Cassava Colombian symptomless virus (CCSV). p. 192. In: *Annual Report 1987*. Scottish Crop Research Institute, Dundee.

3. Cassava Ivorian bacillifom virus (CIBV)

(Tentative member of the alfalfa mosaic virus group)

Symptoms

No known symptoms.

Geographical distribution

The virus was isolated from cassava collected in Côte d'Ivoire, however, it is not known if it occurs elsewhere (Fargette & Harrison, 1990; Fargette *et a1*., 1989).

Transmission

Vector unknown. Experimentally transmitted by mechanical inoculation to *Chenopodium murale* (local lesion host) and *C. quinoa* (systemic host), but not back to cassava.

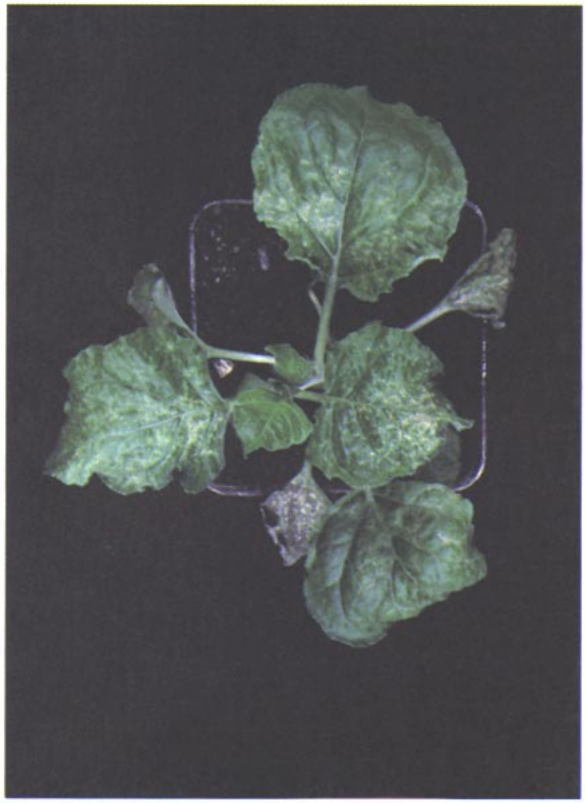

Fig. 8. Cassava Ivorian bacilliform virus - systemic tip necrosis symptoms in mechanically inoculated *Chenopodium quinoa.* (Scottish Crop Research Institute, Dundee)

Particle morphology
Bacilliform particles of three predominant lengths: 42, 48 and 75 nm.

Therapy
No information available.

Indexing
Mechanical inoculation to *Chernopodium quinoa* (tip necrosis). The virus can be detected in test plants using ELISA with polyclonal antiserum, but this has not been applied to cassava.

References
Fargette, D., & Harrison, B.D. 1990. Properties of cassava Ivorian bacilliform virus. p. 87. In: *Annual Report 1989.* Scottish Crop Research Institute, Dundee.
Fargette, D., Roberts, I.M. & Harrison, B.D. 1989. Cassava Ivorian bacilliform virus. p. 179. In: *Annual Report 1988.* Scottish Crop Research Institute, Dundee.

4. Casava X virus (CsXV)

(Tentative member of the potexvirus group)

Symptoms
No symptoms on cassava.

Geographical distribution
CsXV is found in the north coast of Colombia, however, it is not known if it occurs elsewhere (Lennon *et al.,* 1986).

Transmission
CsXV is transmitted through vegetative propagation. Experimentally transmitted by mechanical inoculation to cassava (systemic infection), *Nicotiana benthamiana* (systemic infection) or to *Chenopodium quinoa* and *C. amaranticolor* (local lesion hosts). Vector unknown, but an aerial vector is suspected. Not transmitted through seed.

Particle morphology
Semiflexuous rod, approximately 15 x 495 nm.

Therapy
Thermotherapy followed by meristem-tip culture.

Indexing
The virus is readily detected by ELISA or ISEM.

Reference

Lennon, A.M., Aiton, M.M. & Harrison, B.D. 1986. Cassava viruses from South America. p. 167. In: *Annual Report 1985.* Scottish Crop Research Institute, Dundee.

Fig. 9. Cassava X virus - systemic necrosis symptoms in mechanically inoculated *Nicotiana benthamiana.* (Scottish Crop Research Institute, Dundee)

5. Unnamed Virus

(Laboratory code name: cassava C virus)

Symptoms

It is not known if the virus causes symptoms in cassava because it was isolated from plants infected with ACMV.

Geographical distribution

The virus was first isolated from cassava in Côte d'Ivoire and Malawi; however it also occurs in Cameroun (Aiton *et al.,* 1988; Swanson, unpublished results).

Transmission
Experimentally transmitted by mechanical inoculation to *Nicotiana benthamiana, Chenopodium amaranticolor* and *C. quinoa.* Vector unknown.

Particle morphology
Small, slightly elongated particles of about 26 x 16 nm.

Therapy
No information available.

Indexing
The virus can be readily detected by ELISA with polyclonal antiserum (Swanson, unpublished results).

References
Aiton, M.M., Lennon, A.M., Roberts, I.M. & Harrison, B.D. 1988. Two new cassava viruses from Africa. p. 43. In: Abstracts 5th International Congress of Plant Pathology, Kyoto.
Swanson, M.M. Unpublished results.

Fig. 10. Unnamed virus (cassava C virus) - mild systemic necrosis symptoms in mechanically inoculated *Nicotiana benthamiana.* (Scottish Crop Research Institute, Dundee)

Virus-like disease

1. Frogskin disease (FSD)

Cause

The causal agent of frogskin and a similar disorder called 'Caribbean mosaic disease' (CMD) is not known, but a virus is suspected because the disease is graft-transmitted.

Symptoms

For FSD, most cassava genotypes do not show symptoms on the stems or leaves, but the roots are stunted and do not fill with starch. The lower stem may become enlarged. The root periderm and corky layer enlarge and form raised lip-shaped fissures. When the root symptoms are mild, the fissures often form a constricted ring around the root. A few cassava clones such as Secundina develop mosaic symptoms and the plants are stunted.

For CMD, root symptoms are much less pronounced than in the case of FSD, but this may be an effect of temperature since CMD is endemic in areas were the air and soil temperatures are frequently above 30°C. Some cultivars are stunted and show mosaic svmptoms on the leaves and yields are reduced.

Fig. 11. Frogskin disease - root fissures typical of mild symptoms (Dr L.A. Calvert, CIAT, Cali)

Geographical distribution

FSD is found in the Andean regions of central and southern Colombia. It is also endemic in the Amazon regions of Colombia. CMD is found in the northern areas of Colombia near the Caribbean (Anonymous, 1990; Lozano & Nolt, 1989).

Transmission

The disease spreads rapidly. The whitefly *Bemisia tuberculata* is suspected to be the vector of both FSD and CMD.

Therapy

Thermotherapy followed by meristem-tip culture.

Fig. 12. Frogskin disease - severe mottling and leaf distortion on indicator clone Secundina grafted on infected stake (leaves from buds on rootstock show no symptoms (Dr L.A. Calvert, CIAT, Cali)

Indexing

Plants can be indexed for FSD and CMD by grafting cuttings of an indicator clone of cassava (Secundina) onto them. The buds should be removed from the plant to be tested and the grafted plants should be maintained below 30°C. Plants which index positively show a severe mosaic on the new leaves, approximately one month after grafting.

Reference

Anonymous. 1990. Cassava virology. pp. 31-39. In: *Annual Report: Virology Research Unit.* Centro International de Agricultura Tropical, Cali.

Lozano, J.C. & Nolt, B.L. 1989. Pests and pathogens of cassava. pp. 174-175. In: *Plant Protection and Quarantine* Vol. II. Ed. R.P. Kahn. CRC Press, Boca Raton.

Fig. 13. Frogskin disease - cassava roots with severe symptoms (Dr L.A. Calvert, CIAT, Cali)

Procaryotic diseases

1. Cassava antholysis

Cause
Mycoplasma-like organisms.

Symptoms
Symptoms are first observed as virescence of the normally pinkish-cream tepals, followed by hypertrophy and phyllody to produce a syndrome known as antholysis. Elongation of the floral axis is common in these flowers. Deformed flowers are sterile and abort prematurely. Sometimes, the malformed flowers become necrotic and remain attached to the plant for prolonged periods of time. A similar situation occurs in male flowers. Affected plants never produce normal flowers (Jayasinghe *et al.*, 1984).

Geographical distribution
Brazil (especially in the Northeast region), the Caribbean, Central America, Colombia and Venezuela.

Transmission
Transmitted by vegetative propagation.

Fig. 14. Cassava antholysis - tepals of flowers show virescence and phyllody (leaf-like structures). (Dr J.C. Lozano, CIAT, Cali)

Alternative hosts
None known.

Therapy
Thermotherapy followed by meristem-tip culture.

Indexing
No procedures known.

Reference
Jayasinghe, U., Pineda, B. & Lozano, J.C. 1984. Antholysis in cassava *(Manihot esculenta* Crantz) possibly caused by mycoplasma-like organisms. *Phytopathol. Z.* **109**:295-300.

2. Cassava witches' broom

Cause
Mycoplasma-like organisms

Fig. 15. Cassava witches' broom - excessive proliferation of branches is one of the most typical symptoms. (Dr J.C. Lozano, CIAT, Cali)

Symptoms
Three different types of symptoms have been reported: a) stunting and excessive proliferation of branches; shoots have small leaves and shortened internodes, without distortion or chlorosis; b) proliferation of shoots from the cutting with generally weak growth; c) a few weak, stunted shoots germinate from the cutting which never reach normal size (Kitajima & Costa, 1979). Moderate temperatures (between 13 and 20°C) favour the disease, and at higher temperatures the symptoms disappear.

Geographical distribution
Locally important in Brazil (States of Ceara, Pernambuco and Sao Paula) and southern Mexico (Costa & Kitajima, 1972).

Transmission
Transmitted by vegetative propagation. Mechanical transmission has also been reported, but insect transmission is unknown.

Alternate hosts
None known.

Therapy
Thermotherapy followed by meristem-tip culture.

Indexing
No procedures known.

Fig. 16. Cassava bacterial blight - leaf wilting and dieback of immature shoots from infected cutting. (Dr J.C. Lozano, CIAT, Cali)

References

Costa, A.S. & Kitajima, E.W. 1972. Studies on virus and mycoplasma diseases of the cassava plant in Brazil. In: Proceedings IDRC/IITA Cassava Mosaic Workshop. International Institute of Tropical Agriculture, Ibadan.

Kitajima, E.W. & Costa, A.S. 1979. Microorganismos do tipo micoplasma associados a molestias do tipo amarelo en algunas plantas cultivadas e ornamentais no Estado de Sao Paulo e no Distrito Federal. *Fitopatol. Bras.* **4**:317-327.

3. Cassava bacterial blight (CBB)

Cause

Xanthomonas campestris pv. *manihotis*

Symptoms

Initially, angular, water-soaked leaf spots, more clearly seen on the undersurface, sometimes with yellow halos above, rapidly expanding, and turning brown. Leaves wilt, desiccate, roll and fall off. Petioles are also attacked, leading to vascular infection on young shoots, stem rot and dieback. Regrowth is similarly and rapidly affected, as well as shoots developing from infected cuttings. Yellowish exudate often collects in droplets on leaf spots or is exuded from cracks that develop on young infected stems and petioles. Lesions may occur on fruits and seeds may be deformed with necrotic spots on the cotyledons and endosperm. Roots are rarely affected, although rots around dead vascular tissues occasionally occur on susceptible cultivars (Lozano, 1986).

Fig. 17. Cassava bacterial blight - angular leaf spots. (Dr G.V.H. Jackson, SPC, Fiji)

Geographical distribution

CBB has been reported in almost all countries of Africa, Asia and Latin America. It is present in the Federated States of Micronesia, Guam, Indonesia and the Philippines (Anonymous, 1977; Elango & Lozano, 1980; Persley, 1976). However, many areas are still disease free, including the South Pacific.

Biology

The bacterium is spread to new areas in infected, symptomless stem cuttings and seed (Persley, 1979). Within the crop, spread is mostly by rain splash. Infection requires 12 hours at 90-100% relative humidity with temperatures of 22-26°C. The bacterium remains viable for many months in stems and gum, renewing activity in wet periods. Entry occurs through stomata or wounds and via the vascular tissues to other parts of the plant, including seeds (Lozano, 1986). In addition to rainfall, wide fluctuations between night/day temperature, in the range 15-30°C, affect disease severity.

Quarantine measures

To prevent movement of CBB, cuttings or seeds should only be taken from plantations that are free of the disease. Seeds should be treated as described in the 'Technical Recommendations'. The bacteria grow readily on culture media and the plantlets show symptoms during *in vitro* culture.

References

Anonymous. 1977. *Xanthomonas manihotis* (Arthaud-Berthet & Bondar) Starr. CMI distribution maps of plant diseases. No 521. Commonwealth Agricultural Bureaux, Slough.

Bradbury, J.F. 1977. *Xanthomonas manihotis.* CMI Description of Pathogenic Fungi and Bacteria. No 559. Commonwealth Agricultural Bureaux, Slough.

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Lozano, J.C. 1986. Cassava bacterial blight: A manageable disease. *Plant Dis.* 70:1089-1093.

Moffet, M.L. & Croft, B.J. 1983. *Xanthomonas.* pp. 180-228. In: *Plant Bacterial Diseases: A Diagnostic Guide.* Eds. P.C. Fahy & G.J. Persley. Academic Press, Sydney.

Persley, G.J. 1979. Studies on the survival and transmission of *Xanthomonas manihotis* on cassava seed. *Ann. appl. Biol.* **93**:159-166.

Fungal diseases

1. Cassava anthracnose

Cause

Glomerella cingulata

Syn: *Colletotrichum gloeosporioides*
C. gloeosporioides f.sp. *manihotis*
C. graminicola

Symptoms

Initial infection is characterized by leaf spots and distortion of young leaves. Later the pathogen invades petioles and green stems, inducing partial or total necrosis. On the stems, it produces cankers and dieback. In the central part of these lesions, pinkish areas, formed by the fructifications of the fungus, can be found. Fruits show blackish lesions and may become mummified. Seeds from affected fruits may show light discolourations and deformation, but generally infected seeds are symptomless (Lozano *et al.*, 1981).

Geographical distribution

Anthracnose occurs in most cassava growing areas where annual rainfall is higher than 900 mm.

Fig. 18. Cassava anthracnone - blackish areas on fruits which become mummified; seeds of severely affected fruits are discoloured and deformed. (Dr J.C. Lozano, CIAT, Cali)

Biology
Spores formed on the lesions are spread in wind-driven rain and dew. The pathogen penetrates the host through wounds, but invasion occurs in green tissues during periods of high relative humidity.

Alternative hosts
Several crop and weedy species.

Quarantine measures
Meristem-tip culture eliminates the disease. Seeds should be treated as described in the 'Technical Recommendations'.

References
Lozano, J.C. & Nolt, B.L. 1989. Pests and pathogens of cassava. pp. 169-179. In: *Plant Protection and Quarantine* Vol. II. Ed. R.P. Kahn. CRC Press, Boca Raton.
Lozano, J.C., Bellotti, A., Reyes, J.A., Howeler, R., Leihner, D. & Doll, J. 1981. (2nd ed.) *Field Problems in Cassava.* Centro International de Agricultura Tropical, Cali.

2. Dry root and stem rot

Cause
Diplodia manihotis

Symptoms
The root system becomes blackish and deteriorates. The stems become systemically invaded by the fungus through wounds or via the roots and the vascular system becomes necrotic, the epidermis ruptures and exudes gum. Stem and root rots lead to partial or total wilting and dieback. Pycnidia are present on affected stems.

Geographical distribution
Cassava growing regions in Asia and tropical America.

Biology
The pathogen is disseminated over long distances by infected stem cuttings, and within the crop the spread is by wind or rain splash. The pathogen is not transmitted by seed.

Alternative hosts
Several crop and weedy species.

Quarantine measures
Meristem-tip culture eliminates the disease.

References

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3. Phomopsis blight

Cause

Phomopsis manihotis

Perfect stage: *Diaporthe manihotis*

Other related species causing similar symptoms are *Phoma manihot* (syn. *Phyllosticta manihot, P. manihobae* and *Phomopsis* (*Phyllosticta*) *manihot*) and *Phyllosticta manihoticola.* The taxonomy of these fungi is still debated (Gonzalez & Pons, 1986; Punithalingam, 1982).

Fig. 19. Phomopsis blight - brown spots with concentric rings of pycnidia on the upper surface of the leaf. (Dr J.C. Lozano, CIAT, Cali)

Symptoms
Large, watersoaked spots on young leaves, often at the tips and margins. They are pale green at first, rapidly enlarging and turning brown. Spore- containing pycnidia are formed in concentric rings on the upper leaf surface or on stems. Severe attack leads to defoliation, stem girdling and dieback (Lozano & Booth, 1976; Punithalingam, 1982).

Geographical distribution
Widespread throughout the cooler cassava growing areas at high altitudes, or in the lowlands during the rainy season.

Biology
Conidia formed on the leaves and stems are dispersed by water-splash, with maximum germination between 20 and 25°C. Survival between crops is not understood, but probably occurs as pycnidia or perithecia in leaf and stem debris.

Alternative hosts
Tests have shown that *Solanum melongena* is susceptible to *P. manihotis.*

Quarantine measures
Meristem-tip culture eliminates the disease.

Reference

Gonzalez, M.S. & Pons, N. 1986. Revision taxonomica de las especies de *Phyllosticta sobre Manihot. Ernstia* **37**:30-40.

Lozano, J.C., & Booth, R.H. 1976. *Diseases of Cassava*. Series DE-5. Centro International de Agricultura Tropical, Cali.

Punithalingam, E. 1982. *Diaporthe manihotis.* CMI Description of Pathogenic Fungi and Bacteria. No 559. Commonwealth Agricultural Bureaux, Slough.

4. Superelongation disease

Cause
Sphaceloma manihoticola
Perfect state: *Elsinoë brasiliensis*

Symptoms
White, irregular spots on the leaf blades, but more commonly along midribs and veins, and on petioles, often joining together to form cankers several centimetres long. Infection occurs when leaves are still young. Damage to veins prevents normal leaf expansion and consequently leaves are small, twisted, curled, have torn edges and

sometimes become necrotic, resulting in considerable defoliation. Young stems have elongated internodes and are thin and weak. Yields of heavily infected plants are severely reduced (Lozano & Booth, 1976).

Geographical distribution

Brazil, the Caribbean, Central America, Colombia and Venezuela. *Sphaceloma manihoticola* has also been recorded from Cook Islands associated with scab-like lesions and leaf distortion, but without stem elongation.

Biology

The disease is worse during the rainy season and volunteer plants and infected cuttings are the main sources of infection. Temperatures of 20 to 23°C and relative humidites of 90 to 100% increase the disease incidence. Minute spores, produced in the scabby lesions and spread by rain-splash and wind, germinate in free moisture and penetrate leaf surfaces directly.

Alternative hosts

Manihot spp., *Euphorbia brasiliensis, Jatropha curcas* and *J. aconitifolia* var. *papaya* (Ziegler *et al.*, 1984).

Quarantine measures

Meristem-tip culture eliminates the disease. Seeds should be treated as described in the 'Technical Recommendations'.

Fig. 20. Superelongation disease - white, irregular spots on the leaf lobes inducing curling and torn edges. (Dr J.C. Lozano, CIAT, Cali)

References

Dingley, J.M., Fullerton, R.A. & Mckenzie, E.H.C. 1981. Records of fungi, bacteria, algae and angiosperms pathogenic on plants in Cook Islands, Fiji, Kiribati, Niue, Tonga, Tuvalu and Western Samoa. New Zealand Department of Scientific and Industrial Research. Plant Diseases Division. Technical Report No. 2.

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Zeigler, R.S. & Lozano, J.C. 1983. The relationship of some *Elsinoë* and *Sphaceloma* species pathogenic on cassava and other members of the Euphorbiaceae in Central and South America. *Phytopathology* **73**:293-300.

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Fig. 21. *Amblypelta* (coreid bug). (Dr G.V.H. Jackson, SPC, Fiji)

Arthropod pests

1. Coreid bugs

Amblypelta spp.

Damage

Initially a wilt of the terminal shoot which, if it survives, develops cankerous swelling and cracks. Alternatively, shoots die and laterals develop. Continued attack of regrowth results in stunted, flat-topped plants. Cracks also occur in petioles with characteristic drooping of the leaf. Levels of damage are high relative to *Amblypelta* numbers, hence the assumption that toxins are injected during feeding (Brown, 1958b).

Geographical distribution

Northern Australia, Indonesia (Java and Timor), New Caledonia, Papua New Guinea, Solomon Islands and Vanuatu (Brown, 1958a).

Biology

There are 18 species and subspecies. For *A. coccophaga,* eggs are laid singly on leaves or stems, they hatch after 8 days and there are five nymphal instars. Development from egg to adult takes about 35 days. Adults are 20-30 mm long, pale reddish brown with yellowish legs. Both sexes have an unpleasant smell when handled.

Alternative hosts

Amblypelta spp. are polyphagous. *A. cocophaga,* for example, has been recorded from 35 species in 23 families, with many members of the Euphoribiaceae as hosts (Brown, 1958b).

References

Bigger, M. 1988. The insect pests of forest plantation trees in the Solomon Island. Solomon Islands' Forest Record No. 4. Overseas Development Natural Resources Institute, Chatham and Solomon Islands Ministry of Agriculture, Honiara.

Brown, E.S. 1958a. Revision of the genus *Amblypelta* Stal, (Hemiptera, Coreidae). *Bull. Entomol. Res.* **49**: 509-541.

Brown, E.S. 1958b. Injury to cocoa by *Amblypelta* Stal. (Hemiptera, Coreidae) with a summary of food plants of species of this genus. *Bull. Entomol. Res.* **49**:543-554.

2. Mealybugs

Phenacoccus manihoti
Phenacoccus herreni

Damage

Damage symptoms due to *P. manihoti* and *P. herreni* are very similar and are characterized by leaf yellowing, curling, and deformation resulting in a tight cabbage-like appearance of the apical buds. Large numbers of mealybugs cause extensive leaf necrosis, defoliation, stem distortion and dieback.

Geographical distribution

P. manihoti is found throughout most of the cassava growing regions of Africa, while in the Americas it is confined to Bolivia, southwestern Brazil and Paraguay. *P. herreni* is reported from northeastern Brazil, Colombia, the Guyanas and Venezuela. Neither species is present in Asia.

Biology

Eggs, placed in ovisacs where several hundreds may be present, hatch in 5 to 8 days at 25-30°C. First instar nymphs are highly mobile and disperse throughout the plant. *P. manihoti* is parthenogenetic and no males have been found; *P. herreni* has both males and females. Mealybugs can be disseminated by wind, or carried by animals or on vegetative planting material.

Fig. 22. *Phennacocus herreni* mealybug feeding around the bud of a cutting. (Dr A.C. Bellotti, CIAT, Cali)

Alternative hosts

Both *P. manihoti* and *P. herreni* feed primarily on cassava.

References

Bellotti, A.C. & van Schoonhoven, A. 1978. Mite and insect pests of cassava. *Ann. Rev. En tomol.* **23**:39-67.

Bellotti, A.C., Reyes, J.A., Guerrero, J.M. & Varela, A.M. 1985. The mealybug and green spider mite complex in the Americas: Problems and potential for biological control. In: *Cassava Research, Production and Utilization.* Eds. J.H. Cock, & J.A. Reyes. Centro International de Agricultura Tropical, Cali.

3. Mites

Mononychellus tanajoa
Mononychellus progresivus
Tetranychus urticae and other species

Damage

The *Mononychellus* mite is usually found around the growing points of the plant, on buds, young leaves and stems. Newly emerged leaves are marked with yellow spots or appear mottled, bronzed and deformed. Damage by *Tetranychus* mite appears initially on the lower leaves of the plant forming yellow dots along the main leaf vein, eventually spreading over the whole leaf which later dries and drops.

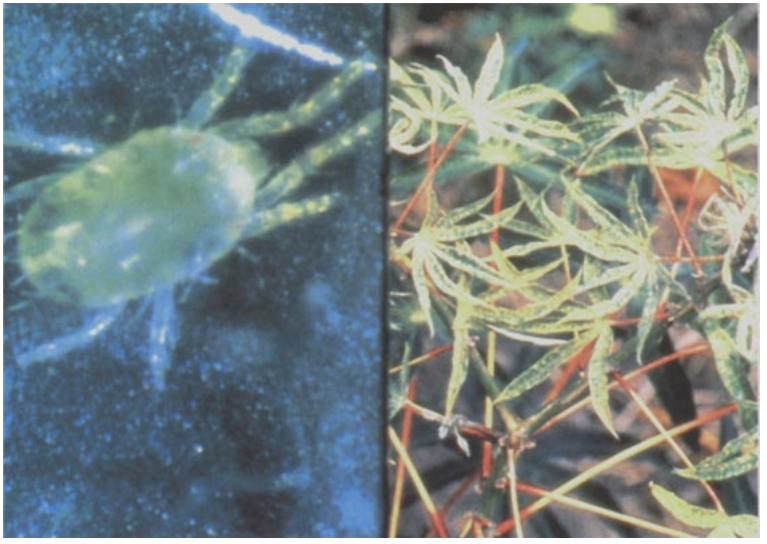

Fig. 23. Adult female of the cassava green mite, *Mononychellus tanajoa* and corresponding damage to cassava foliage. (Dr A.C. Bellotti, CIAT, Cali)

Geographical distribution

Mononychellus mites are found throughout Africa, the Americas, India and the Marianas Islands. They have not been reported in other Asian countries. Many *Tetranychus* species are found infesting cassava, for instance *T. kanzawai* in the Philippines (Villacarlos, 1985), Japan and Taiwan (Byrne *et al.*, 1983), and the *T. cinnabarinus* complex in India, Indonesia and Malaysia. *T. urticae* has been reported in nearly all casssava growing regions.

Biology

Mites are primarily dry season pests and all stages are easily washed off by rain (Bellotti & van Shoonhoven, 1978; Villacarlos, 1985). They have very short life cycles (7-13 days) and populations build up rapidly (Bellotti & van Schoonhoven, 1978). Eggs are laid singly on undersurfaces of leaves. They hatch in 3-5 days and in another 4-8 days the mites are mature. Mites are wind-dispersed on silken threads. Webs are formed by *Tetranychus*, but not by *Mononychellus*.

Alternative hosts

Not known for *Mononychellus*, but over 100 plant species are hosts for *Tetranychus*.

References

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Byrne, D.H., Bellotti, A.C. & Guerrero, J.M. 1983. The cassava mites. *Trop. Pest Mgmt* **29**:378-394.

Villacarlos, L.T. 1985. Cassava Red Spider Mite. Plant Pest Clinic Advisory Bulletin. Pest Management Series. Department of Plant Protection, VISCA, Leyte, Philppines.

4. Scale insects

Aonidomytilus albus (Cassava stem mussel scale)
Saissetia spp.
Pseudaulacaspis pentagona (White peach scale)

Damage

High scale populations may cover the stems and lateral buds. Leaves yellow prematurely, wilt and fall. Severe infestations retard plant growth. Cuttings from infested stems do not sprout well, initial growth is slow and shoots may dessicate and die.

Geographical distribution

Scales have been reported attacking cassava stems in many cassava-growing regions

of Africa, the Americas and Asia (Vargas, 1978). *Pseudaulacaspis pentagona*, probably native to China and Japan, has been reported on various fruit trees and ornamental plants in Africa, the Americas, Asia, Australia, the Caribbean, Mediteranean Europe and the Pacific (Waterhouse & Norris, 1987).

Biology

Adults of *A. albus* are grey, elongated and mussel-shaped (2-3 mm long). *P. pentagona* has a white, roughly circular scale (2-2.5 mm in diameter) with a reddish-yellow nipple towards one side. *A. albus* females produce an average of 47 eggs deposited beneath the scale (Vargas, 1978). Eggs hatch in 4 days; the first instars (crawlers) are mobile and can disperse to other leaves and stems of the same or adjacent plants, or to distant plantings by wind. Once the crawlers have settled, their stylets are inserted into the plant, where they remain throughout the feeding period of the immature stages. The total life cycle is 22-25 days. *P. pentagona* females moult twice and produce an average of 140 eggs during their life span of 27-35 days. The total developmental period ranges from 24-27 days. Male scales have eyes, long antennae, legs and a pair of forewings (Waterhouse & Norris, 1987).

Alternative hosts

Important pests of a wide range of other economic plants and weeds.

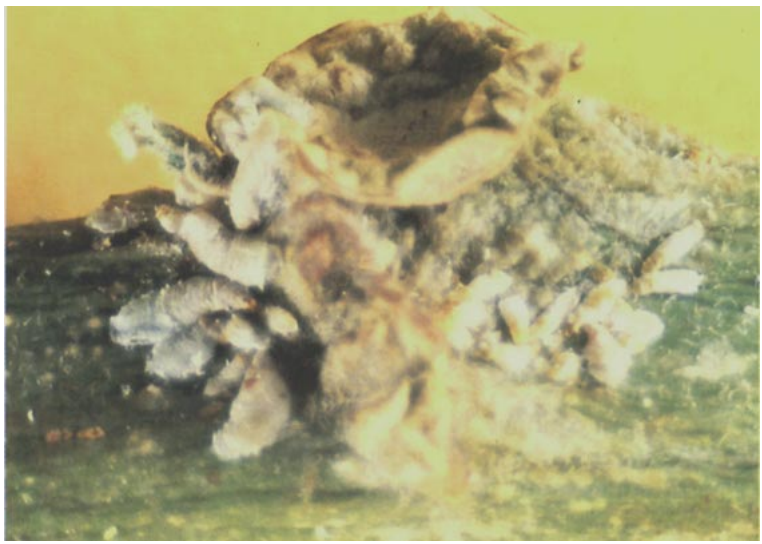

Fig. 24. Cassava white scale, *Aonidomytilus albus*, feeding on stem buds. (Dr A.C. Bellotti, CIAT, Cali)

References

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5. Stemborers

Coelosternus spp. (6 species)
Lagochirus spp. (3 species)
Chilomima clarkei

Damage

Coelosternus spp. and *Lagochirus* spp. are coleoptera, whereas *C. clarkei* is a lepidopteran. Larvae of all species damage cassava by penetrating the stern and tunneling into the pith; this weakens stems and branches which may eventually wither and break.

Geographical distribution

Coelosternus species are confined to the Americas, except for *C. manihot* which is reported from West Africa. *Lagochirus* species are primarily reported from the Caribbean, Central America and northern South America. *C. clarkei* has been reported from Colombia, Paraguay and Venezuela.

Biology

Coelosternus oviposits on various parts of the plant but mostly in succulent tissues.

Eggs of C. *granicollis* are white and larvae are curved, with a yellowish white to pale brown body. The larval period ranges from 30 to 60 days. Adults are light to dark brown. Adults of *Lagochirus* spp. oviposit 2.5 mm below the bark and eggs hatch in 5-6 days. The larvae which take about 2 months to develop, measure up to 29 mm and feed at the base of the plant. The pupal period, which lasts about 1 month, takes place in the larval chamber in the stem. Adults are brown, about 17 mm long and feed on leaves and bark. *Chilomima clarkei* lays eggs on the stems around the lateral buds of leaves that have already fallen. The larva, during its first four instars, is found feeding under a fine web around the buds. After the fifth instar it penetrates the stem and completes its life cycle in galleries. The duration of the life cycle depends on the variety and varies from 62 to 68 days.

Alternative hosts

Stemborers appear to be highly host specific and few alternative hosts are reported.

References

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Fig. 25. Cassava stem damage and presence of a protective web under which larvae of the stemborer *Chilomima clarkei* feed. (Dr A.C. Bellotti, CIAT, Cali)

6. Thrips

Frankliniella williamsi and other species.

Damage

F. williamsi damages the terminal bud of the plant. Leaflets are deformed and show irregular chlorotic spots. Brown wound tissue appears on stems and petioles, and internodes are shortened. Growing points may die, causing growth of lateral buds which may also be attacked, giving rise to a witches' broom appearance (Bellotti &van Schoonhoven, 1978).

Geographical distribution

F. williamsi is reported on cassava only from the Americas and Hawaii (Bellotti & van Schoonhoven, 1978). It is common on grasses in North America and Southeast Asia (Indonesia, Philippines) (Baltazar & Salazar, 1979; Kalshoven, 1981). *Retithrips syriacus* is reported from India and Australia. *Euthrips manihoti* is reported only from Brazil (Bellotti & van Schoonhoven, 1978).

Biology

Eggs are laid in the midrib of the leaf undersurface. Larvae and adults of *E. manihoti* and *F. williamsi* live in the terminal buds and on young leaves. Both are golden yellow and about 11 mm long. Thrips can fly short distances or may be dispersed by wind and carried on cuttings (Bellotti & van Schoonhoven, 1978). Thrips attack is more frequent during dry periods.

Fig. 26. Adult thrip *Frankliniella williamsi* feeding on cassava leaf. (Dr A.C. Bellotti, CIAT, Cali)

Alternative hosts

F. williamsi feeds on grasses, but maize is its preferred host and it is usually found in great numbers between the husks (Kono & Papp, 1977).

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