Practical Handbook

for Managing Cassava Diseases, Pests, and Nutritional Disorders

Authors:

Elizabeth Álvarez, Anthony Bellotti, Lee Calvert, Bernardo Arias, Luis Fernando Cadavid, Benjamín Pineda, Germán Llano, and Maritza Cuervo

This handbook is complementary to the book "Cassava in the Third Millennium: Modern Production, Processing, Use, and Marketing Systems" produced by the Centro Internacional de Agricultura Tropical (CIAT) and the Latin American and Caribbean Consortium to Support Cassava Research and Development (CLAYUCA).

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This practical handbook, presented as a pocket book, is a visual complement to many chapters of the book *Cassava in the Third millennium: Modern Production, Processing, Use, and Marketing Systems*. It is an indispensable aid for its users in the fields of cassava plant pathology, entomology, and nutrition, in identifying major cassava pests, diseases, and nutritional disorders.

This handbook is intended not only for professionals, technicians, and trained farmers, but also for students and teachers in Pathology, Entomology, and Plant Nutrition programs and courses offered by Agronomy schools.

This resource is best used together with the book. The book comprises information complementary to the handbook that provides a more detailed and deeper discussion over the economic importance, biology, habits, and nomenclature of insects; a comprehensive description of cassava diseases and pathogenic agents; as well as instructions on its integrated pest and disease management (IPM). The book also includes important data about nutrient deficiency in Colombian soils and toxicity levels of other elements contained in some of those soils. The book is, therefore, a must-read complement to the handbook.

Nutritional Disorders

Luis Fernando Cadavid L.[1]

Deficiencies

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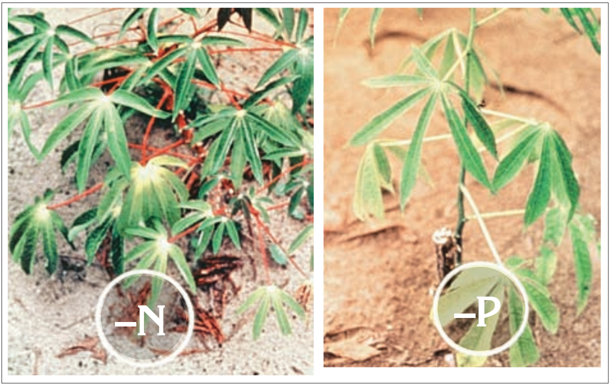

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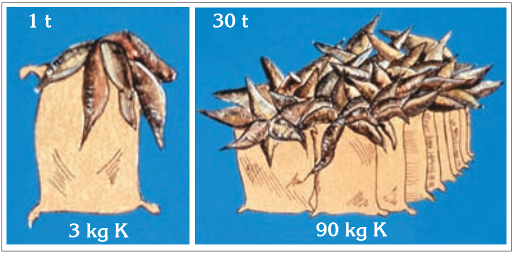

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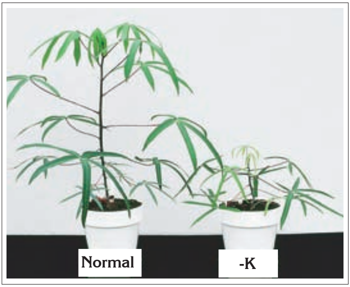

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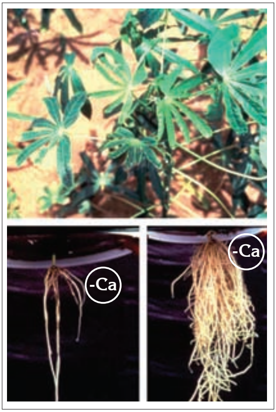

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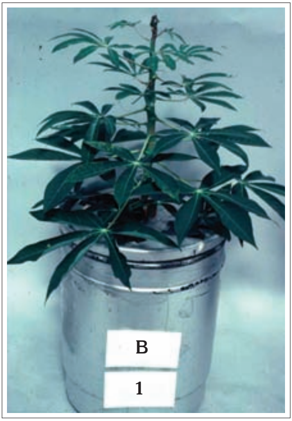

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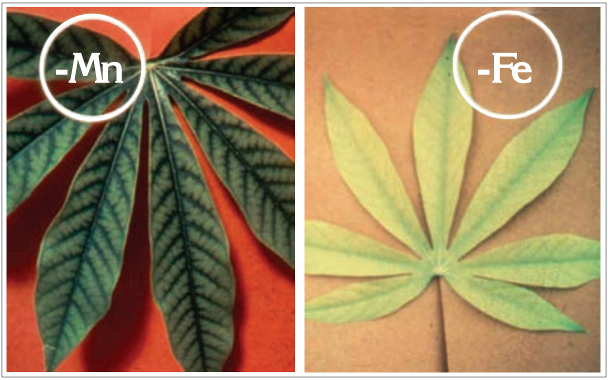

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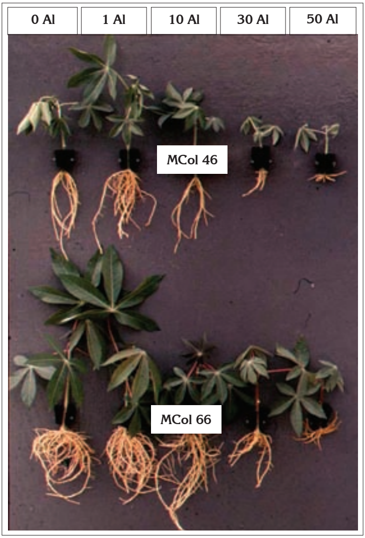

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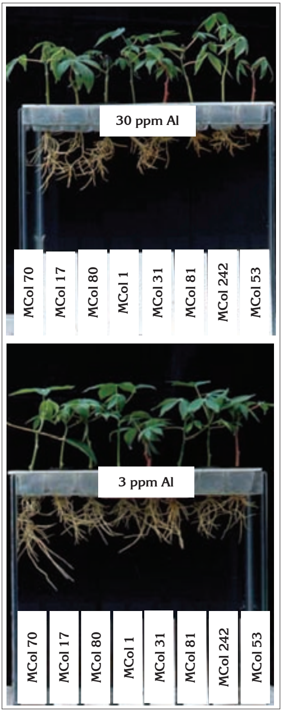

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Most common fungal and bacterial diseases in Colombia

Elizabeth Álvarez and *Germán Llano*[1]

Fungal diseases

Brown leaf spot
Cercosporidium henningsii

Brown leaf spot is usually found in warm but not very moist sites. On the upper leaf surface, brown spots appear, with well-defined and dark margins. On the leaf underside, the lesions have less-defined margins and, toward the center, the brown spots have a grayish olive cast. As these circular lesions grow, from 3 to 12 mm in diameter, their shape turns irregular and angular.

Depending on the susceptibility of the cultivar, there may appear an indefinite, yellowish, or colorless halo around the lesions. As the disease advances, the infected leaves become yellow, dry, and fall off.

1. See **About the authors** section on page iii.

It is advisable to dry out excessive moisture from the cultivated area to reduce the severity of the infection. Even though this is not an economically important disease, cuprous oxide- and copper oxychloride-based fungicides, suspended in mineral oil, provide good chemical control.

Photo E1. Lesions caused by *Cercosporidium henningsii*, causal agent of the cassava brown leaf spot.

Photo E2. Foliar lesions caused by *Cercosporidium henningsii*; a halo around each lesion can be observed.

White leaf spot
Phaeoramularia manihotis

White leaf spot is commonly found in cold, humid cassava-growing regions. Lesions are white and, sometimes, yellowish brown, and their shape may change from round to angular, ranging from 1 to 7 mm in diameter. Lesions are sunken on both leaf surfaces and extend to about half of the thickness of a healthy leaf blade.

White spots are visible to the naked eye. On the leaf underside, lesions often show diffusely colored margins. In some cases, margins may appear as a purplish brown irregular line surrounded by a yellowish brown halo. The spots' centers may have a velvety grayish aspect, especially on the leaf underside. Control practices are similar to those used for the brown leaf spot.

Photo E3. Cassava leaf affected by the white leaf spot, disease caused by *Phaeoramularia manihotis*. Municipality of Caicedonia, Department of Valle del Cauca, Colombia.

Blight leaf spot
Cercospora vicosae

Blight leaf spot appears during the rainy season in warm cassava-growing areas. It is characterized by the presence of large spots with undefined margins. Each spot may cover one fifth, or more, of the leaf lobe. On the upper surfaces of leaves, the spots are uniformly brown, whereas, on the lower surfaces, spots also have olivish gray centers due to the presence of fungal fruiting bodies.

Defoliation may occur in susceptible cultivars, being more severe at the end of the rainy season and/or vegetative cycle. As the disease advances, leaves turn yellow, dry, and fall off. It is recommended to dry out excessive moisture from the cultivated area to counteract the infection.

Photo E4. Cassava leaf lobes affected by the blight leaf spot caused by *Cercospora vicosae*.

Concentric-ring leaf spot
Phoma sp.

Concentric-ring leaf spot occurs during the rainy season, in cultivated areas with temperatures below 22 °C. It is characterized by large leaf spots, ranging from brown to black, with undefined margins. These spots are commonly found at leaf tips, margins of leaf lobes, or along the midrib and secondary leaf veins. At their early stage, lesions appear as concentric rings on the leaf upper surface, formed by the fungal fruiting bodies (pycnidia). Because old lesions do not show these rings, they may look like the lesions caused by *Cercospora vicosae*. On the leaf underside, lesions are dark brown; veins and veinlets necrose forming black thread-like filaments that emerge from the spots.

Photo E5. Concentric-ring leaf spot caused by *Phoma* sp. in a cassava leaf. Municipality of La Cumbre, Department of Valle del Cauca, Colombia.

The fungus invades the leaf, then the petiole and the green section of the stem, producing defoliation and progressive dieback or death of the affected plant. Disease-control practices include providing an appropriate sowing density and planting healthy cassava stakes by the end of the rainy season.

Photo E6. *Phoma* sp. attacking stems and petioles in cassava plant.

Cassava ash
Oidium manihotis

Erysiphe manihotis is the sexual stage of this fungus. This disease usually occurs during the dry season in warm areas. A white mycelium that grows on the leaf surface is the earliest symptom manifested by this disease. The infected tissue becomes chlorotic and forms indefinite yellowish lesions, which inside often show angular necrotic areas forming pale brown spots of different sizes. In some cassava varieties, the disease stops at the stage of indefinite yellowish lesion.

Photo E7. Cassava leaf affected by *Oidium manihotis,* causal agent of cassava ash.

Symptoms may be confused with damages caused by insects and mites. Mature leaves seem to be the most susceptible to the pathogen attack, even though young leaves in some varieties show as well symptoms of the disease. Specific control practices for this disease are deemed unnecessary.

Superelongation disease
Sphaceloma manihoticola

The fungus *Sphaceloma manihoticola* is the causal agent of this disease. The pathogen produces distortion or curling in young leaves, and cankers on nervures (on the leaf underside),

Photo E8. Symptoms of superelongation in cassava leaves, caused by *Sphaceloma manihoticola.*

Photo E9. Symptoms of superelongation in stems, caused by *Sphaceloma manihoticola.*

petioles, and stems. These cankers are lens-shaped and show different sizes. The affected leaves also show white irregular spots. The exaggerated elongation of the stem internodes is a characteristic symptom of this disease. The affected stem is thin and weak; the diseased plants are much taller than

Photo E10. Stem elongation induced by *Sphaceloma manihoticola,* causal agent of cassava superelongation. Municipality of Puerto López, Department of Meta, Colombia.

the healthy ones and, sometimes, spindly. The disease causes progressive dieback of the plant and partial or total necrosis of the leaf blades, resulting in severe defoliation.

The superelongation disease requires an integrated approach, starting by selecting resistant cultivars, e.g., ICA-Catumare or ICA-Cebucán (ICA is the Spanish acronym of the Colombian Agriculture and Livestock Institute). Healthy stakes should be planted, previously treated by immersion for 5 minutes in a Difolatan (captafol) or copper-oxychloride solution at concentrations of 3 to 5 g/L of commercial product. It should also be grown in rotation with grasses and planted with rainfall at its lowest levels. Spraying copper oxychloride (1 kg/ha) directly onto the foliage has shown good results.

Cassava anthracnose
Glomerella manihotis Chev.,
Colletotrichum manihotis Henn.

Cassava anthracnose disease is characterized by sunken leaf spots of up to 10 mm in diameter, similar to those spots associated to *Cercosporidium henningsii*, emerging near the leaf base, subsequently resulting in leaf total necrosis. The pathogen attacks twigs, causing their shriveling and progressive dieback. It also attacks mature stems, producing cankers. Pinkish areas can be observed in the center of these lesions, formed by fruiting bodies of the causal fungus.

Leaves newly sprouted at the beginning of the rainy season are the most susceptible. The disease tends to disappear with the beginning of the dry season. Discarding diseased plants and planting healthy stakes by the end of the rainfall stage are two practices recommended in managing this disease.

Photo E11. Stem cankers induced by *Glomerella manihotis*. Municipality of La Cumbre, Department of Valle del Cauca, Colombia.

Photo E12. Cassava stem necrosis caused by *Colletotrichum gloeosporioides*. Municipality of Santander de Quilichao, Department of Cauca, Colombia.

Cassava rust
Uromyces spp.

Even though it has been reported in Brazil and in Colombia, this disease holds little economic importance. It breaks out toward the end of the dry season causing, in some cases, some kind of ramulosis or witches' broom disease in stem apices. It is characterized by the formation of pustules on the veins, petioles, or green branches, ranging from light to dark brown depending on the age of the pustule or the kind of fungal fructification. Severe parasitism of *Darluca filum* is observed in mature pustules, which are occasionally surrounded by a yellowish halo and, in general, induce distortion of the affected parts.

Photo E13. Rust pustules in leaf, caused by *Uromyces* spp. Municipality of La Cumbre, Department of Valle del Cauca, Colombia.

Photo E14. Rust pustules in stem, caused by *Uromyces* spp. Municipality of La Cumbre, Department of Valle del Cauca, Colombia.

Stem necrosis
Diplodia manihotis

This disease attacks both cassava propagation material (stakes) during storage and discarded stakes left in the field, by inducing a black discoloration of vascular bundles which extends from stem lesions (entry point for the infection), resulting in final necrosis of the affected tissues. Blisters are developed in the epidermis and, underneath, the inner stem tissues are discolored black or dark brown. The blisters break, showing confluent masses of black pycnidia. A relatively high temperature may trigger the disease.

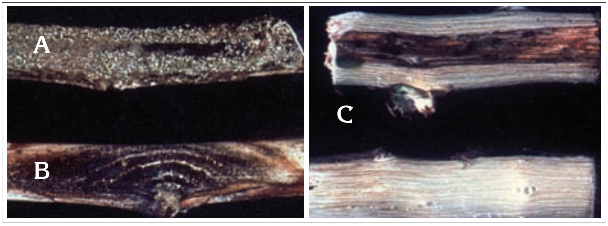

Photo E15. Cassava stem necrosis caused by the following pathogens: **(A)** *Colletotrichum gloeosporioides* and **(B)** *Diplodia manihotis*; **(C)** symptoms caused by *D. manihotis* in stem marrow. Municipality of Santander de Quilichao, Department of Cauca, Colombia.

Root rot
Phytophthora spp. and *Pythium* spp.

This kind of rot is induced by different pathogens, including *Phytophthora drechsleri*, *P. cryptogea*, *P. erythroseptica*, *P. capsici*, *P. melonis*, *P. tropicalis*, *P. sinensis*, *P. nicotianae* var. *parasitica,* and *Pythium* sp. The fungus genus *Phytophthora* is a typical soil inhabitant that may affect the crop at any stage. The fungus development is boosted by waterlogged or fast-drying or low-nutrient soils. The pathogen attacks mainly plants near drainage ditches, causing sudden wilting and severe soft root rot. Infected roots often exude a liquid of a repulsive odor and then decompose completely into the soil.

Photo E16. Root rot caused by *Phytophthora tropicalis*. Municipality of Caicedonia, Department of Valle del Cauca, Colombia.

Management measures to control this disease include the following: selecting appropriate soils of medium depth; draining the land and planting stakes on ridges; rotating cassava with grasses whenever the disease has affected 3% of the plantation area; keeping soils drained for 6 months or more if needed; eradicating diseased plants; selecting healthy

Photo E17. Tissue disintegration in cassava root, caused by *Phytophthora melonis*. Manaos, Brazil.

Photo E18. Plant wilting caused by *Phytophthora melonis*. Palmira, Department of Valle del Cauca, Colombia.

plants to obtain stakes for sowing; and using clean planting material. When the disease attacks the crop, it is advisable to apply Aliette (fosethyl-Al) or Ridomil (metalaxyl) onto the plant's basal part. Also, the stakes can be applied Ridomil (metalaxyl) in concentrations of 3 g/L. To keep the stakes clean, it is also recommended to treat them using hot water at a maximum temperature of 49 °C, during 49 minutes.

Root rot
Rosellinia sp.

This disease has been reported in many cassava-growing regions whose soils show a high content of organic matter, and in cassava plantations where forestry or woody and perennial species have been previously sown, such as coffee or cacao, on which the fungus causes the so-called Black

Photo E19. Cassava root rot induced by *Rosellinia* sp. Municipality of Fresno, Department of Tolima, Colombia.

Spot disease. Initially the root epidermis is covered with white rhizomorphs that later become black. The infected tissues inside the bulky roots are slightly discolored and exude liquid on pressure. The black mycelial bundles penetrate the tissues, where they grow, forming small cavities that contain an off-white mycelium. The infected roots have a characteristic odor of decaying wood.

Even though the disease has not been reported in young plants, still it is advisable to avoid selecting planting materials from infected crops. Other control practices include: rotating with cereal plants whenever the incidence of plant death or root rot reaches 3%; eliminating infected cassava residues and/or litter from perennial trees; planting in loose-textured soils; and improving soil drainage.

Bacterial diseases

Cassava bacterial blight
Xanthomonas axonopodis pv. *manihotis*

The causal organism of this disease is the bacterium *Xanthomonas axonopodis* pv. *manihotis*, which is systemic and penetrates the host through stomas and wounds in the plant's epidermis. The characteristic symptoms are: small, angular, aqueous-looking leaf spots found on the leaf blade underside; leaf spots merge and turn brown; leaf blight or leaf burn appears followed by wilting and dieback; gummy exudation in infected young stems, petioles, and leaf spots; necrosis of vascular bundles in petioles and infected stems, which look as if covered by brown or black bands.

To control the disease, integrated management practices should be carried out which involve selecting resistant cultivars, such as ICA-Catumare and Chiroza; planting stakes at the end of the rainy season; using healthy planting materials; treating the stakes by immersing them into a copper fungicide solution, e.g., copper oxychloride or Orthocide (Captan), in concentrations of 3–6 g/L during 5 minutes; rotating cassava with maize or sorghum; planting maize barriers to prevent dissemination by wind; controlling weeds; fertilizing adequately, mainly with potassium sources; eradicating diseased plants; preventing the movement of people, machines, and animals from infected lots to healthy lots; trimming the diseased leaves, and eliminating infected materials after harvest by burning and incorporating them into the soil. Good results have been reported when stakes that will be used as planting material are pretreated with hot water at a maximum temperature of 49 °C during 49 minutes.

Photo E20. Symptoms of angular leaf spots, induced by the bacterium *Xanthomonas axonopodis* pv. *manihotis*. Municipality of Santo Tomás, Department of Atlántico, Colombia.

Photo E21. Symptoms of leaf blight or leaf burn caused by *Xanthomonas axonopodis* pv. *manihotis*. Municipality of Santo Tomás, Department of Atlántico, Colombia.

Photo E22. Exudation in infected young stems, induced by *Xanthomonas axonopodis* pv. *manihotis.* Villavicencio, Department of Meta, Colombia.

Photo E23. Plant dieback caused by *Xanthomonas axonopodis* pv. *manihotis*. Municipality of Santander de Quilichao, Department of Cauca, Colombia.

Bacterial stem rot
Erwinia carotovora pv. *carotovora*

This disease is important for the damage it causes to the quality and germinability of planting stakes. It is characterized by an aqueous and smelly stem rot or by medullary necrosis of the plant's ligneous parts. Infected plants show bud wilt. The stem's surfaces typically show perforations made by insects of the genus *Anastrepha*, which act as vectors for the bacterium. These orifices are easy to distinguish by the presence of dry latex, discharged as the stem is perforated.

Diseased stakes used for planting will not germinate or will produce weak spindly plants, with a limited number of bulked roots. Management and control practices for this disease include using healthy planting stakes, planting varieties resistant to the insect vector, and burning infected stems.

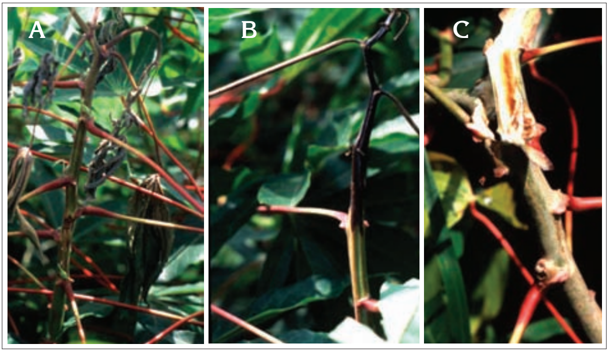

Photo E24. Cassava plant affected by *Erwinia carotovora* pv. *carotovora*. Municipality of Caicedonia, Department of Valle del Cauca, Colombia. **(A)** Apical wilting. **(B)** Necrosed young stems. **(C)** Medullary damage.

Phytoplasma-associated diseases

Benjamín Pineda L.[1]

Antholysis

Phytoplasma (previously known as mycoplasma-like organisms or MLOs)

The MLO (mycoplasma-like organism) pathogen is currently considered a phytoplasma that causes a disease reported in cassava-growing regions in the departments of Cauca, Valle del Cauca, and Tolima, in Colombia. These phytoplasmas transform the floral structures into leaf-like structures (phyllody) (Photo E25) as a result of its spreading action through the phloem (Photo E26).

The earliest symptom is virescence in the tepals whose normal creamy-pink color turns green. The next symptom is hypertrophy of the tepals. Later these tepals undergo a metamorphosis and become leaf-like structures that altogether resemble sprouts. The floral racemes lose their normal appearance, manifesting the syndrome known as “antholysis”. Fertility in both male and female flowers is lost completely, resulting in nonfunctional flowers that abort prematurely.

Symptoms of the witches’ broom disease (known as *superbrotamiento* in Spanish) have not been reported in the field, neither the loss of plant vigor nor any other developmental anomaly that could establish differences between diseased and healthy plants.

1. See **About the authors** section on page iii.

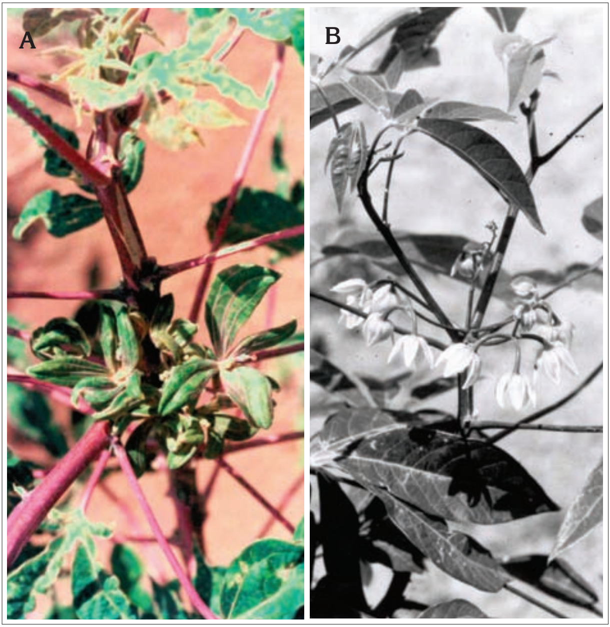

Photo E25. **(A)** Cassava inflorescence severely affected by antholysis, where flowers transformed into green leaf-like structures can be observed. **(B)** Normal inflorescence of a healthy plant.

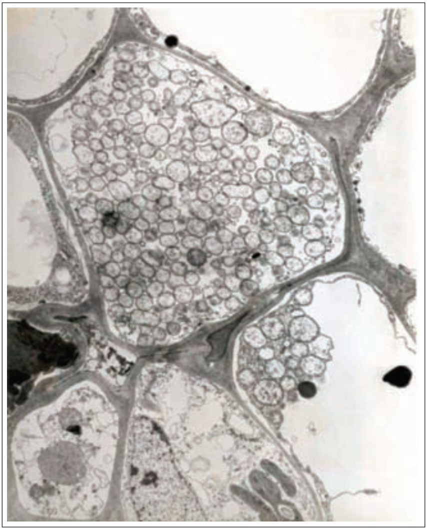

Photo E26. Cells of petiole phloem in a cassava plant showing the phytoplasmas causing antholysis.

This disease could limit plant-breeding programs or sexual-seed production programs for germplasm exchange projects.

Virus-associated diseases

Benjamín Pineda, Lee Calvert, and Maritza Cuervo[1]

Cassava common mosaic disease
CCMV (Cassava common mosaic virus)

Cassava common mosaic disease is a viral disease of relatively low incidence, mainly reported in South America. Its characteristic symptom appears in leaves as chlorotic irregular areas intermixing with dark green tissues (Photo E27).

Photo E27. Symptom of the cassava common mosaic disease, in which chlorotic to yellowish irregular areas appear intermixing with dark green tissue.

1. See **About the authors** section on page iii.

The causal agent is the potexvirus of elongated particles ('flexuous elongated') which are visible under an electron microscope (Photo E28). In severe cases, leaflets become deformed and, in many cases, plants stay short and dwarf. Symptoms observed in foliage can be easily confused with damage caused by some insects (i.e., thrips or whiteflies) or mites.

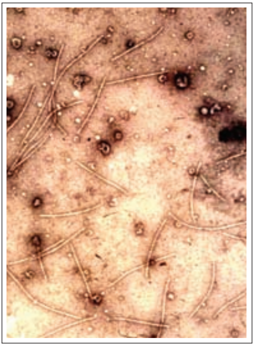

Photo E28. 'Flexuous-elongated' particles characteristic of the cassava common mosaic potexvirus CCMV, causal agent of the cassava common mosaic disease.

This disease is transmitted mainly by mechanical means, and spreads when stakes from diseased plants are used as planting material or when using contaminated machetes or other farm equipment.

It is recommended to use stakes from healthy plants as planting material, remove from the land any diseased plants and burn them, and use disinfected machetes pre-treated with detergents.

Cassava frogskin disease, also known as "*lagarto-jacaré* or caiman-lizard skin disease" (Virus only partially characterized)

This diseased is believe to harm cassava more than any other disease because it directly affects roots, resulting in yield losses near to 90% or more.

Affected plants in most varieties do not show visible symptoms in their aerial parts, and foliage looks healthy and vigorous (Photo E29). Symptoms are limited to the roots and can only be noticed when roots are thoroughly examined before or during harvest.

Photo E29. Frogskin diseased plant, even though it looks normal on the outside.

Roots in diseased plants are thin and fibrous (Photo E30) and the epidermis (shell) shows lesions or longitudinal lip-like cracks whose joined patterns resemble a net or a honeycomb (Photo E31.,A). The shell thickens and looks corky (Photo E31.,B) and brittle.

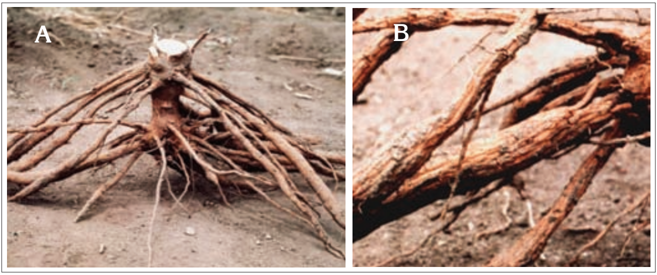

Photo E30. **(A)** Radical system of a frogskin diseased plant with a noticeable absence of bulked roots. **(B)** Close-up of the epidermis of those roots.

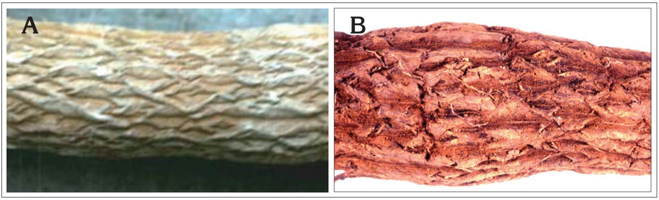

Photo E31. Roots of diseased plants. **(A)** Group of lesions resembling a net or honeycomb. **(B)** Thick epidermis and corky appearance observed in affected root.

In severely affected plants (45–60 days after being planted), characteristic longitudinal lip-like lesions can be observed at the callus and basal part of the developing pigmented roots (Photo E32). The naturally-formed cracks in the bark-like root skin, caused by the normal thickening process, are usually superficial and do not cause the formation of corky tissue (suberization).

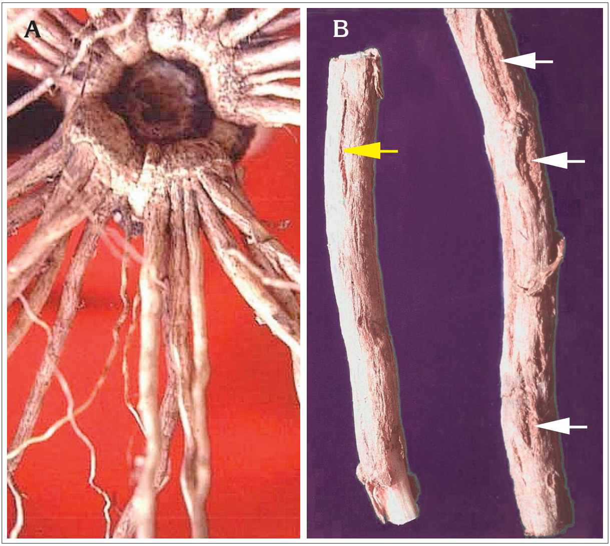

Photo E32. **(A)** Callus of a cassava stake in which pigmented roots with early symptoms of the frogskin disease can be observed. **(B)** Close-up of two rootlets: a healthy rootlet with natural cracks (see yellow arrow) and a diseased rootlet with lip-like lesions (see white arrows).

The disease symptoms may be noticeable in the overall radical system (Photo E33) or in just some few roots (affecting the entire root) or a section of the affected root. In the latter, the characteristic lesions appear in the basal, middle, or apical parts of the root (Photo E34).

Photo E33. Radical system of a cassava plant severely affected by frogskin disease.

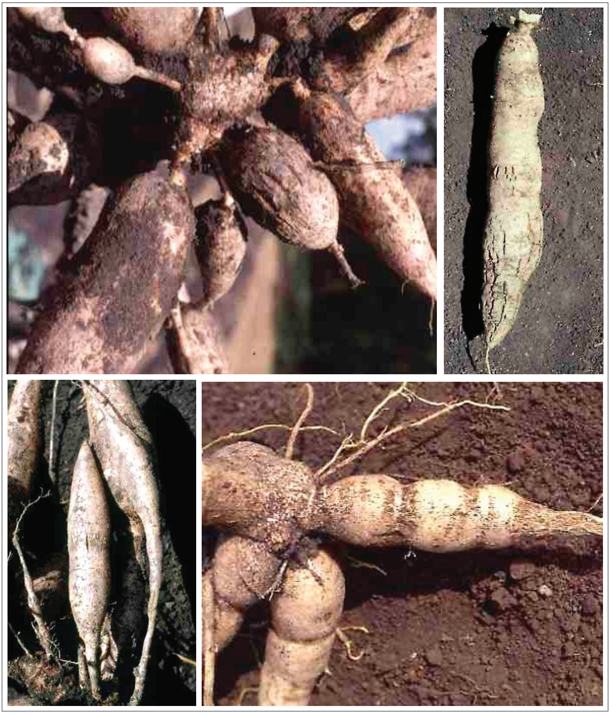

Photo E34. Cassava roots partially affected by frogskin disease. The extension and distribution of the lesions can be observed all along the roots.

Studies conducted on the disease transmission patterns in the field show that this disease propagates from plant to plant, suggesting that the disease is disseminated by an aerial vector. The whitefly (*Bemisia tuberculata*) has been more frequently associated with this disease.

The disease mainly propagates by using stakes or cuttings from affected plants. Therefore, the most effective management practice is to always use stakes from healthy plants as planting material. Whenever stakes or cuttings are intended for planting material, plants must be pulled out without cutting them, roots observed on the outside and carefully examined to detect any characteristic symptom, even minor; finally, any material that may be infected must be discarded.

Virus-like diseases

Symptoms similar to those caused by viruses are frequently observed in the plants' foliage in cases where cassava grows vigorously, the cool rainy season predominates, and there are no attacks from thrips or mites (Photo E35). These are mosaic-like symptoms accompanied by foliar distortions to either a minor or major degree, depending on varietal resistance; and they also result in plant dwarfism.

Photo E35. Symptom patterns observed in cassava, very similar to those caused by viruses.

Stakes from plants with these symptoms should not be used as planting material.

Damages Caused by Pests: Insects and Mites

Anthony Bellotti and Bernardo Arias[1]

Subterranean pests

Subterranean pests, in general, are not specific to cassava because they attack many different hosts. Some of them cause damages to planting material (stakes) while others attack roots.

The sampling process of these pests should begin while preparing the ground and continue during 'germination' or bud sprouting. These pests usually create focal points of attack, and occasionally attack the entire plantation.

White grubs
Phyllophaga sp., *Cyclocephala* sp., *Anomala* sp.

White grubs are insects that feed on the roots of several plants. In Spanish they are known as "*gallina ciega*" (blind chicken) or "mojojoy". They belong to the order Coleoptera, family Melolonthidae, and various genera, including *Phyllophaga*, *Cyclocephala*, and *Anomala*, attack cassava.

They become scarab beetles in their adult stage, and undergo a complete metamorphosis: egg, larva (grub), pre-pupa, and pupa.

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1. See **About the authors** section on page iii.

Description. Larvae are white, with a dark brown head. They are found in the soil in a C-shaped or half-moon position, and measure between 1.5 and 4 cm in length. The grubs of the genus *Phyllophaga* are the largest ones (compared to the other two genera), being about 3-4 cm long, and are the most harmful to the crop (Photo P1).

The grubs of the genus *Cyclocephala* are of medium size (2-3 cm) while the grubs of the genus *Anomala* are the smallest ones (1.5-2 mm). These genera mainly differ in the larva size.

Damage. White grubs feed on newly planted cassava stakes or cuttings (Photo P2) or on plants of 1 to 3 months old. They eat the epidermis and bark of the stakes, except for the

Photo P1. White grubs of the genus *Phyllophaga* in larva and adult stages.

ligneous part. They make tunnels in roots and stakes, affecting their viability, resulting in stakes that will not germinate or young plants that wilt (Photo P3).

Photo P2. Stake being attacked by *Phyllophaga* sp.

Photo P3. Plant wilt caused by the attack of white grubs. When they feed on roots, other pathogens enter the wounds.

Cutworms (larvae) and crickets
Agrotis ipsilon, *Spodoptera ornithogalli*, *Spodoptera frugiperda*, *Gryllus assimilis*, *Gryllotalpa* sp.

The larvae of these species live in the soil. During the evening, they cut off the buds and tender stakes from recently germinated plants or plants just a few days old. Most of these larvae are robust and show different shades, ranging from gray or brown to nearly black. In some cases, they may be found covered in dirt. They measure between 3 and 5 cm in length.

Cutworms sporadically attack cassava and appear in localized areas (foci). Their attack is seldom severe.

Surface cutworms. Black worms (*Agrotis ipsilon*) feed on the basal part of the stem near the soil surface and drop the cut-off seedlings on the ground. Larvae are gray to black in color, with barely-noticeable lighter stripes. These worms look greasy and thick (cylindrical), and coil up when disturbed (Photo P4).

Climbing cutworms. These larvae climb the stem and feed on the buds and foliage of young plants.

The larvae of *Spodoptera ornithogalli* (Photo P5) have caused the above-mentioned damage in many cassava-growing regions. They are dark gray to black, with yellow or orange stripes on their sides, separated by dotted lines.

Photo P4. Larva of *Agrotis ipsilon*.

Photo P5. Climbing larva of *Spodoptera ornithogalli*.

The species *S. frugiperda* (Photo P6) behaves similarly. The larvae of this species are light to dark brown and their cephalic capsules have an inverted Y-shaped mark.

These larvae, especially *S. ornithogalli*, are often naturally controlled by parasitoids of the order Diptera.

Photo P6. *Spodoptera frugiperda*.

Crickets. The most important species are *Gryllus assimilis* (black cricket) and *Gryllotalpa* sp. (mole cricket) (Photo P7). Cricket nymphs and adults can cause damage by cutting the shoots right after germination.

Photo P7. *Gryllus assimilis* and *Gryllotalpa* sp.

Termites
Heterotermes tenuis

The genera *Heterotermes tenuis* and *Coptotermes* sp. (Photo P8) feed on propagation material (stakes), roots, or young developing plants.

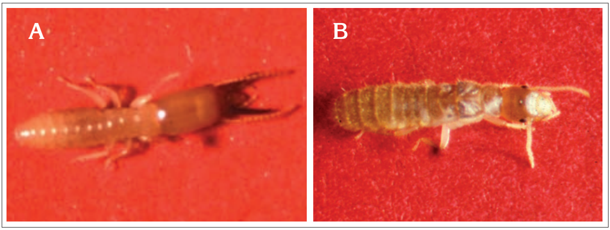

Photo P8. (A) Soldier and (B) worker termites.

The presence of termites is mainly characterized by the galleries they make in the attacked parts, such as roots or newly planted stakes (Photos P9 and P10). When plants survive or they are attacked in their maturity, termites build nests inside the stump or basal part of the plant without causing major damage. Should the roots suffer any mechanical damage or be stressed by an abiotic factor, up to 30% of the yield of the plant may be affected.

Photo P9. Root affected by termites.

Photo P10. Cassava seedling and stakes attacked by termites.

Subterranean burrower bug
Cyrtomenus bergi Froeschner

The nymphs and adults of this bug (Hemiptera: Cydnidae) feed on cassava roots, enabling the entry of pathogenic microorganisms inhabiting the soil, such as *Pythium* and *Phytophthora*, among others. Each entry point becomes a brown to black spot or mark, and these entry points altogether form the infectious complex known as root smallpox (Photo P11).

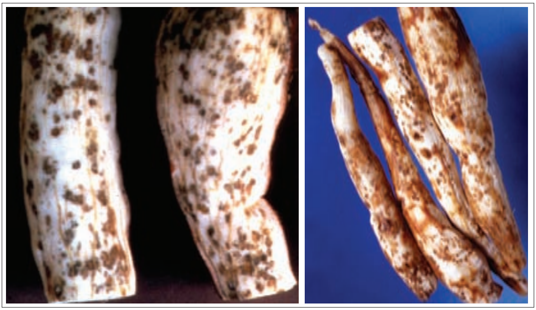

Photo P11. Damage caused by subterranean burrower bugs. viruela.

The adult female of this insect lays its eggs in the soil. Eggs are white, spherical, and measure less than 1 mm in diameter. Nymphs undergo five instars, are wingless, and their abdomen is creamy white. They have several brown quitinized structures over the thoraxic and abdominal regions. Nymphs are flat and oval-shaped, and about 1 mm long when newly hatched ("eclosioned") and up to 7 or 8 mm long during the fifth nymphal instar (Photo P12). The adult insect is black and reaches up to 10 mm in length (Photo P13).

The legs of these insects are short and strong, provided with many spines, enabling their subterranean mobilization. Their presence can be detected by the characteristic repulsive odor expelled when turning over soil near the infested plants.

Photo P12. Subterranean burrower bug nymph.

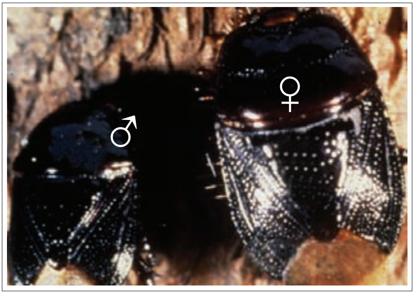

Photo P13. Subterranean burrower bug adults (male and female).

Pests that attack foliage

This group includes the pests that feed, either as suckers or chewers, directly on cassava leaves.

These pests reduce the photosynthetic area by causing chlorosis and defoliation; reduce the size of the leaves; break the apical dominance of the plant, producing re-shooting; induce the appearance of sooty mold; shorten internodes; and cause dwarfism. Some pests cause effects such as curling of stems, and rosettes in terminal buds; leaf desiccation and defoliation.

Foliage suckers

Mites
Mononychellus tanajoa, M. caribbeanae, Tetranychus urticae, T. cinnabarinus, Oligonychus peruvianus

Green mites
Mononychellus tanajoa, M. caribbeanae

Green mites develop in the apical part of plants (leaf buds, young leaves, and green sections of the stem). Damage begins as yellow stippling which spreads, and tissue takes a mottled, bronzed, mosaic-like appearance. Embryonic leaves grow deformed (Photo P14).

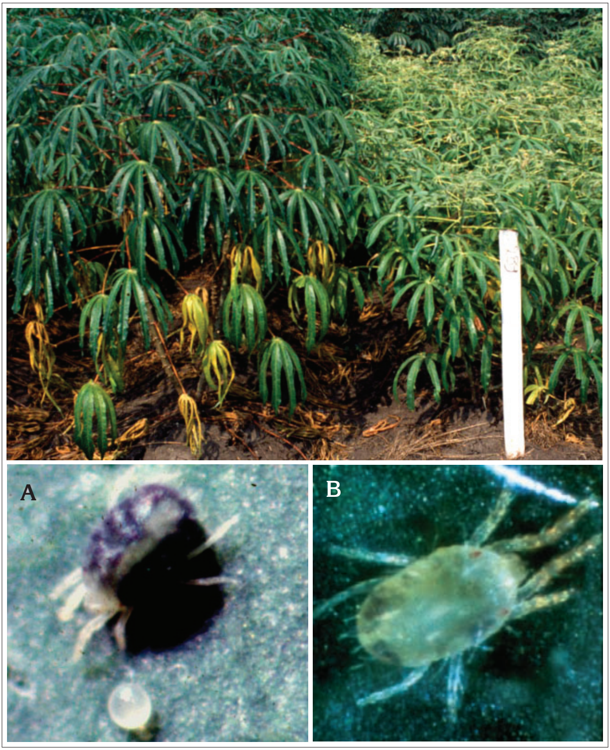

Photo P14. Damage caused by green mites. (A) *Mononychellus caribbeanae*. (B) *Mononychellus tanajoa*.

In severe cases, foliage is reduced considerably, while the stem turns rough and brown. The upper part of the plant takes a lancet-like form at its tips, with dry and leafless terminal structures (Photo P15). A characteristic of this mite species is that it does not produce webbing.

Photo P15. Severe attack by *Mononychellus* sp.

Two-spotted and red mites
Tetranychus urticae, T. cinnabarinus

Initially, damage of these mites is observed in middle and basal leaves, and then in upper leaves.

The early symptoms often appear in the leaf base, where the midribs converge; and along each midrib as the first colonies are established on the underside, in those parts of the leaf (Photo P16, left).

Defoliation occurs from bottom to top, hence the plant looks greener in the upper section and drier in the lower section.

In cases of heavy infestations, mites also affect the upper third section of the plant and a considerable amount of webbing is observed.

Mites of the species *Tetranychus urticae* have a green-coloured body with a dark spot on each side of their back, whereas mites of the species *Tetranychus cinnabarinus* have a completely red body (Photo P16, right).

Photo P16. Damage caused by *Tetranychus* sp.

Flat mites
Oligonychus peruvianus

The presence of flat mites is identified by the appearance of small web layers (looking as white spots) made by the female on the leaf underside, along the midrib and secondary leaf veins and the leaflet borders.

The adult female lays its eggs underneath the webbing (where larvae and nymphs will develop) mainly in the basal and middle leaves of the plant. The off-white spots (delimited by webbing) take a brown or dark brown coloration also noticeable on the leaf upper surface, as a result of the mites' feeding process. This effect is followed by the necrosis of tissue located underneath the webbing. In cases of prolonged drought and varietal susceptibility, plants may appear completely covered by these spots (Photo P17).

Photo P17. Leaves attacked by *Oligonychus peruvianus*.

Whiteflies

Aleurotrachelus socialis Bondar, *Bemisia tuberculata*, *B. tabaci*, *Trialeurodes variabilis*, *Aleurodicus dispersus*, *Aleurothrixus aepin*, *Tetraleurodes* sp.

Whiteflies, also known in Spanish as "*palomillas*" (Homoptera: Aleyrodidae), in their adult stage (Photo 18) are white and very small (up to 2-3 mm long). They are mainly found in the plant's terminal buds and fly quickly when disturbed. The whitefly females lay their eggs on young tender leaves. Depending on the whitefly species, eggs show different shapes: banana- or kidney-shaped (laid horizontally or obliquely) or bullet-shaped (in vertical position) (Photo P19).

Photo P18. Whitefly adult.

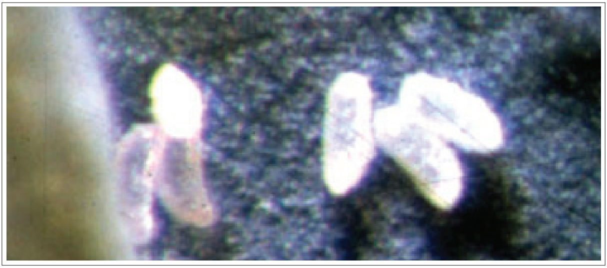

Photo P19. Whitefly eggs (*Aleurotrachelus socialis*).

Whitefly nymphs and pupae are sedentary and their color ranges from light green and amber to black. Moreover, depending on the species, they may be covered in a white powdery wax (Photos P20 and P21).

Damage caused *by Aleurotrachelus socialis.* *A. socialis* is the most economically important species in Colombia. It causes deformation, curling, and yellowish-green mottling in apical and middle leaves (Photo P22). Indirect damage is manifested by sooty mold, yellowing, and desiccation of the plant's basal and middle leaves (Photo P23).

Lace bugs
Vatiga illudens, *V. manihoti*, *Amblystira machalana*

Lace bugs (Hemiptera: Tingidae) live, throughout their entire life cycle, on the underside of basal and middle leaves of plants.

Photo P20. Different biological stages of *Aleurotrachelus socialis*.

Photo P21. Nymphs of *Trialeurodes variabilis*.

Photo P22. Direct damage caused by *Aleurotrachelus socialis*.

Photo P23. Sooty molds caused by the effect of *Aleurotrachelus socialis* feeding.

Adults. Adults are ash gray and measure about 3 mm long by 1 mm wide (Photo P24).

Eggs. Adults of *Vatiga manihoti* and *V. illudens* insert their eggs into the foliar parenchyma. The opercular pole (lid of the egg) is tiny and can be found outside the tissue (Photo P25). The egg stage lasts approximately 8.1 days.

Photo P24. Adult of *Vatiga* spp. and view of the damage it causes.

Photo P25. Eggs of *Vatiga* spp.

Nymphs. Juvenile ovoid shapes (nymphs) hatch from the eggs, crystalline or off-white in color, with numerous spinules over their body. These nymphs undergo five instars whose average duration is 16.6 days (Photo P26).

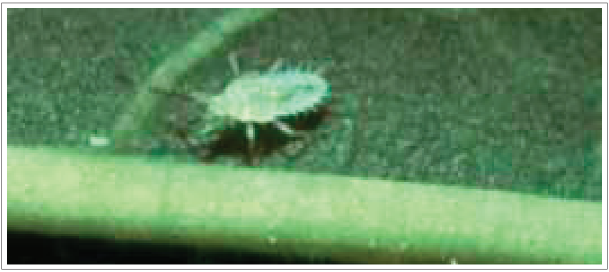

Photo P26. Nymph of *Vatiga* spp.

Damage. This insect feeds on sap from cassava leaves, and shows preference for the basal and middle leaves of plants. A high population of lace bugs causes foliar damage, such as yellow dots or spots that irradiate resembling small stars. These spots take a reddish-brown color very similar to the damage caused by the mite *Tetranychus* spp., as they spread along the midribs or central nervures and towards their central convergence point. (Photo P27). Unlike mites, the damage caused by lace bugs is characterized by the presence of black dots which are droplets of excrement left on the leaf undersides (Photo P28). In severe cases, the affected leaves have an almost white appearance.

Photo P27. Damage caused by *Vatiga* spp.

Photo P28. Excrement from *Vatiga* spp., left on leaves.

Black lace bug
Amblystira machalana, A. opaca

Eggs. Unlike *Vatiga* spp., the black lace bugs of *Amblystira* spp. lay their eggs on the leaf undersides; they are oval-shaped, measure up to 1 mm in length, and their average life cycle is 8.2 days.

Nymphs. The nymphal stage is comprised of five instars. Their body is black and ovoid. During the fifth instar, the wing pads become very noticeable. The nymph stage lasts 14.1 days on average.

Adults. The morphological characteristics of this insect are similar to those of *Vatiga* spp., but the adults have a black coloration in body and wings, with the latter having a white horizontal mark (Photo P29). The adult stage ranges between 18 and 22 days.

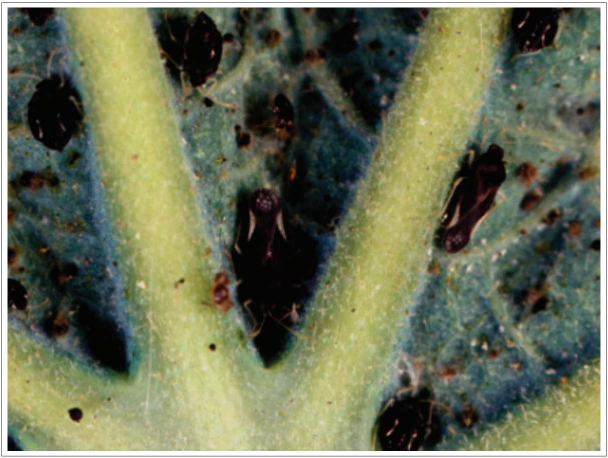

Photo P29. Nymphs and adults of *Amblystira* spp.

Damage. Damages caused by *Amblystira machalana* are identical to those caused by *Vatiga* spp. *A. machalana* individuals can be distinguished by their black coloration.

Mealybugs

This pest (Homoptera: Pseudococcidae) is comprised of the species *Phenacoccus herreni*, *P. gossypii* and *Ferrisia virgata* in Colombia; with *F. virgata* being also reported in Ecuador, *Phenacoccus grenadensis* in Brazil, and *P. manihoti* in Brazil, Paraguay, Africa, and Asia (Thailand and Cambodia).

Mealybugs are characterized by their soft body covered in a white powdery wax, as if they were dusted with flour (therefore the common name "mealybug").

Phenacoccus herreni

The adult females of this species are apterous and develop a structure called ovisac (a sac containing an ovum or ova) beneath the rear end of the abdomen, in which they carry their eggs (up to 300-500 per ovisac).

Eggs. Eggs are white, very small (about 1 mm long), and ovoid-shaped. They are deposited in the ovisac.

Nymph and adult. This insect undergoes three nymphal stages, in which its length increases from 1 mm up to approximately 3.5 mm. The fourth instar corresponds to the adult female (Photo P30).

The male sexual differentiation takes place during the third nymphal instar of *P. herreni*. The male nymph takes a pink coloration and forms a small cocoon which hatches into a very small winged adult.

Photo P30. Female nymphs with ovisac, and male adult of *Phenacoccus herreni*.

This mealybug causes two kinds of damage, one direct and the other indirect:

- The direct damage occurs when sucking the sap out of the bud leaves, causing curling, rosetting of the plant's terminal shoots, and stem deformation (Photo P31).
- This damage inhibits plant growth and induces dwarfism and, in some cases, destroys terminal shoots.
- The indirect damage is caused by the production of sooty mold (black fungus), which might extend to the leaves and petioles, thus affecting photosynthesis.

Photo P31. Damage caused by *Phenacoccus herreni*.

Phenacoccus manihoti, *P. gossypii*, *Ferrisia virgata*

The species *Phenacoccus manihoti* has morphological characteristics similar to those of *P. herreni*, but its reproduction system is parthenogenetic, that is, the females do not require males for fertilization. Plant damage is similar to that of *P. herreni*.

The populations of *P. gossypii* start causing damage at the plant's basal section and stems. The affected leaves become yellowish, which results in severe defoliation, first detected at the plant's basal section. The body of this species is much rougher than that of the aforementioned species because body segments are more noticeable and also grayish.

Ferrisia virgata differ from all of the aforesaid species in many ways, including waxy fringe-like filaments extending from the rear end of the abdomen.

Thrips
Frankliniella williamsi, Scirtothrips manihoti, Corynothrips stenopterus, Caliothrips masculinus

Frankliniella williamsi and *Scirtothrips manihoti* are the most important species. The former is golden yellow in color and about 1.1 mm long (Photo P32). They live and feed in the plant's growing points and young leaves, causing damages to the plant's terminal buds.

Photo P32. Thrip of *Frankliniella williamsi*.

The affected leaves grow abnormally. The younger leaves show deformation, yellow spots, and small irregular puncture wounds in leaflets (Photo P33). In the stem's green segment and petioles, there can be observed brown epidermic suberized (corky aspect) wounds caused by the rasping-sucking buccal apparatus of the insect.

In susceptible varieties, the plant's growing points dieback, thus inducing side shoots to grow. These shoots are affected with the same intensity and take an appearance resembling the witches' broom disease (Photo P34).

The species *Corynothrips stenopterus* is yellow with black spots on its head and last two abdominal segments. Its body is 1.5 mm long. These insects can be found mainly in the plant's middle and basal parts (Photo P35).

Photo P33. Young leaves affected by *Frankliniella williamsi* and *Scirtothrips manihoti*.

Photo P34. Plant shoots affected by *Frankliniella williamsi*.

The species *Caliothrips masculinus* is black and can be found in fully-extended leaves of young plants, especially in greenhouses. It is not commonly found in the field.

Photo P35. Thrip of *Corynothrips stenopterus*.

Leaf-eating pests

Leaf-eating pests (chewers) of cassava plants include, among others, cassava hornworms (*Erinnyis ello* L.), cassava tiger moths (*Phoenicoprocta sanguinea*), leaf-cutter ants (*Atta* sp.), and leaf-eating beetles (*Maecolaspis* sp.).

Cassava hornworm
Erinnyis ello L.

This lepidopterous insect of the family Sphingidae is the most important chewing pest affecting cassava in the Americas. It may cause defoliation of an entire plantation (100% defoliation, Photo P36).

Adults. This insect is a nocturnal moth, grayish in color with 5 or 6 black stripes on each side of the abdomen. Its forewings are gray, whereas its hindwings are rust-colored with black

Photo P36. Severe damage by *Erinnyis ello*.

borders, with the former being 34-48 mm long. Males are usually smaller than females, and have a black longitudinal stripe along their forewings (Photo P37).

Eggs. The eggs of *Erinnyis ello* are spherical and relatively large (1 to 1.5 mm in diameter); they are laid individually, and their coloration is usually green or yellow (Photo P38). Their incubation cycle lasts 3 to 5 days.

Photo P37. Adults (female and male) of *Erinnyis ello*.

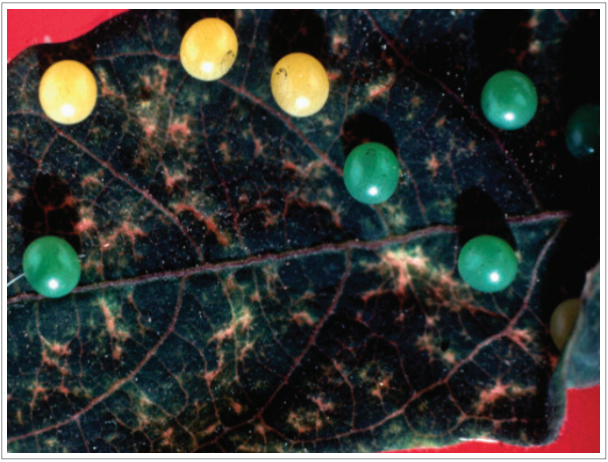

Photo P38. Eggs of *Erinnyis ello*.

Larvae. The larvae of *E. ello* exhibit a wide range of colors: green, yellow, brown or dark gray, black streaked with red, or white and orange (Photo P39,A). Larvae undergo five instars reaching a maximum length of 10 to 12 cm; subsequently they transition into prepupal and pupal stages, which take place in the soil or among fallen debris (Photo P39,B).

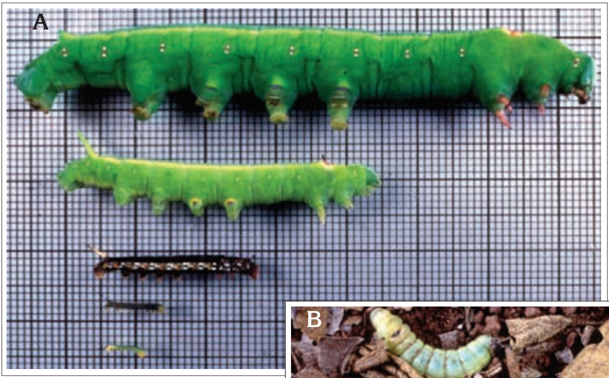

Photo P39. (A) Five larval instars of *Erinnyis ello*. (B) Prepupae and pupa of *Erinnyis ello*.

Cassava tiger moth
Phoenicoprocta sanguinea

Adults. The species *Phoenicoprocta sanguinea* belongs to the family Amatidae (or Ctenuchidae). These insects are small eye-catching butterflies whose bright colors exhibit metallic arrays of blue, red, and yellow on their body with a black background. Wings are black with transparent spots typical of the family Amatidae. Adults may reach 2.5 to 3 cm in length (Photo P40).

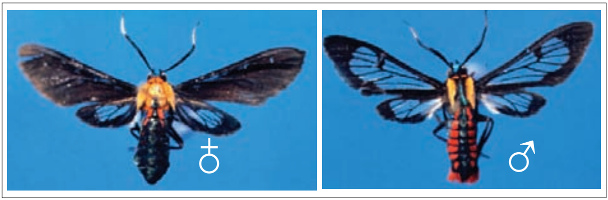

Photo P40. Adults (female and male) of *Phoenicoprocta sanguinea*.

Eggs. Eggs are semi-spherical, about 1 mm in diameter, and their color ranges from cream to light brown (Photo P41).

Larvae. They are covered in small bristles whose quantity and coloration varies between instars (Photo P42).

Photo P41. Eggs of *Phoenicoprocta sanguinea*.

Photo P42. Larval and pupal instars of *Phoenicoprocta sanguinea*.

During the first instar, larvae are light brown and turn red in the fifth instar. In early instars, feeding causes round punctures on leaflets; when they grow larger, their eating habit becomes irregular and few midribs may remain intact (Photo P43). Larvae may reach 1 mm to 1.5 cm in length.

Photo P43. Damage caused by *Phoenicoprocta sanguinea*.

Pupae. Larvae form cocoons by using their body bristles to transition into pupae inside these cocoons. Pupae are brown in color and about 1.5 cm long by up to 1 cm wide (Photo P42).

Leaf-cutter ants
Atta cephalotes, *Acromyrmex* sp.

These insects (Hymenoptera: Formicidae) are very active and live in caste-divided colonies (queen, nurses, workers, gardeners, and soldiers).

Damage. They cut out parts of the leaflets in a characteristic circular manner (crescent-shaped) and carry them in their jaws back to their nest (Photo P44). Leaf-cutter ants leave tracks behind marking their pathways to easily find the way back to their nest holes, which can be far away from the site where they cause damages. In severe cases, plants may be completely defoliated and the damage may be confused with those of hornworms.

Photo P44. Damage caused by leaf-cutter ant.

Leaf-eating beetle
Colaspis or *Maecolaspis* sp.

This pest (Coleoptera: Chrysomelidae) is a small beetle about 6-7 mm long (Photo P45). It feeds on cassava leaves and causes small irregular punctures in the leaves, starting from the lower and middle thirds of the plant (Photo P46). In susceptible cultivars, plants may appear in almost skeletal form when many punctures come together.

This beetle has green/golden-striped quitinized elytra (hard wings), characteristic to this species. Its abdomen is cream in color and its antennae are filiform. When shaking, even gently, the attacked plant or leaves where they are found, the beetles will dislodge.

Photo P45. Cassava leaf-eating beetle.

Photo P46. Damage caused by leaf-eating beetles.

Gall midges
Jatrophobia brasiliensis

This insect (Diptera: Cecidomyiidae) is known to induce galls in cassava leaves. These small midges or flies lay their eggs on the leaf surface. The larvae hatched from their eggs induce abnormal cellular growth (hypertrophy), which forms, on the leaf upper surface, greenish-yellow to red galls, narrower at the base and often curved. When the galls are opened, a cylindrical tunnel can be observed with a very small yellow larva inside (Photo P47). If galls are observed from underneath the leaf, a small hole is noticeable through which the adult midge emerges.

Photo P47. Gall midge.

Pests that attack stems

Insects attack stems in two ways:

- They settle on the stem's surface and start sucking the sap out. Initially they suck out from the buds and then continue with the rest of the plant. This category includes, among others, cassava white scales (*Aonidomytilus albus*), black scales (*Saissetia miranda*), and wax scales (*Hemiberlesia diffinis* and *Ceroplastes* sp.).

- They bore into the stem and make holes and galleries inside, where they complete their biological cycle. This group includes, among others, fruit flies (*Anastrepha* spp.) and shoot flies (*Silba pendula*); one lepidopteran (*Chilomima clarkei*); and three coleopterans (*Lagocheirus araneiformis*, *Coelosternus* sp., and *Eulecriops* sp.)

Insects that settle on the stem

White scale
Aonidomytilus albus

Cassava white scales belong to the order Hemiptera, family Diaspididae and superfamily Coccoidea.

White scales are insects protected by a white waxy shell resembling a mussel or a clam, which forms from the exuviae accumulated over the female's body in its transition from one instar into another during its life cycle. Unlike females, males have well-developed legs and wings.

They are often found around the leaf buds and later completely invade the stem (Photo P48). When this happens, they cause severe defoliation and, sometimes, dieback of the terminal bud. The attacks of these insects are more severe during dry seasons.

Black scale
Saissetia Miranda

This homopteran belongs to the family Coccidae. Its shell is black in color and larger than that of the white scale, being 4-5 mm in diameter (Photo P49). It is often found in long-established plantations where no economically-important attacks are normally reported, mostly due to good in-place biological control practices.

Photo P48. White scales invading a stem (*Aonidomytilus albus*).

Photo P49. Black scale (*Saissetia Miranda*).

Wax scale
Ceroplastes sp.

This scale is larger than *Saissetia Miranda*. It has a pale brown coloration and a brown dot on the upper surface of its protecting shell. It is found in long-established plantations, and as a pest it has little economic significance.

Stem-boring insects

Fruit fly

In Colombia, there are two species of this insect (Diptera: Tephritidae) that attack cassava, namely, *Anastrepha pickeli* and *A. manihoti*.

Adults. They have a yellowish coloration and are about 10 mm long. They have transparent wings adorned with very eye-catching brown stripes or bands (Photo P50).

Eggs. Females lay eggs in both fruit and stem. Eggs are banana-shaped, 1.2 mm long by 0.3 mm wide at their middle point of the transverse diameter. They can be found with their body inserted by one end into the soft tissue of the buds, and show at the other end a respiratory tube of about 0.8 mm long, sticking out the tissue (Photo P51).

Larvae. They are cylindrical and yellowish-white in color. They are about 8 to 10 mm long by 1 to 1.1 mm wide in their larval stage. Their head, which is not yet well defined, has two pairs of light-yellow ocelli and pronounced jaws shaped as black hooks.

Photo P50. Fruit fly adult.

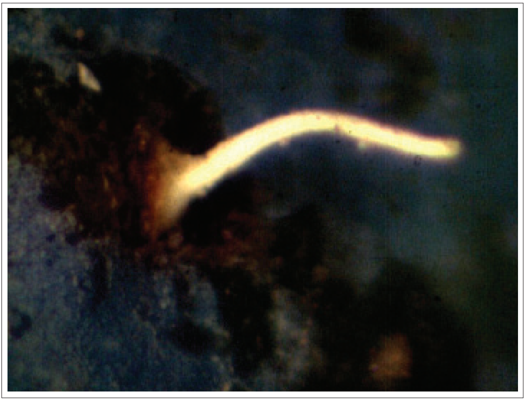

Photo P51. Fruit fly eggs.

Pupae. When larvae complete their development cycle inside the stem or the fruit, they drill a hole through which they emerge and fall to the ground to pupate. They wrap themselves up in a quitinized covering of 6.3 mm in length by 2.4 mm in diameter, on average.

Damage. When there are a few fruits in the field (or none at all), females oviposit directly into soft stems. Latex begins to flow out of the puncture made by the ovipositor and a small white hair-like filament can be observed (Photo P51), which serves to spot the egg. The stem tissue surrounding this point starts to decay. When larvae emerge, they immediately begin to bore up and down, causing rot inside the affected stem (Photo P52).

The damage caused by *Anastrepha* spp. is associated to rot caused by a bacterium (*Erwinia carotovora*). Under environmental conditions favorable to the bacterium, these rot processes may be severe, causing, in many cases, dieback of the plant's buds and terminals (Photo P53).

Photo P52. Damage caused by *Anastrepha* spp. in stakes sampled from affected stems.

Photo P53. Stem rot caused by *Anastrepha* spp.

In the field, there can be observed plants whose marrow has a light-brown or dark-brown coloration, an effect caused by the bacterium, which moves from the area affected by the insect toward the non-affected area.

Shoot fly

A number of dipterans of the family Lonchaeidae affects shoots in cassava plants, stunting growth. The most important species are *Silba pendula* Bezzi (= *Carpolonchaea pendula* = *Lonchaea pendula*), and *Lonchaea chalybea*. The species *Neosilba perezi* has also been reported in cassava.

Depending on the species, adult flies are 3 to 5 mm long. Their body is usually black in color with metallic-blue strokes, and they have a pair of transparent wings (Photo P54).

Eggs are white, about 1 mm long, shaped like a rice grain. Females lay the eggs in the plant's terminal shoots (Photo P55).

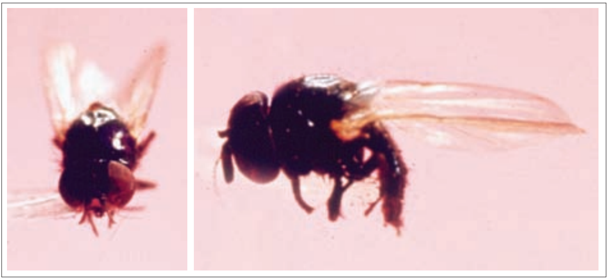

Photo P54. Shoot fly adult.

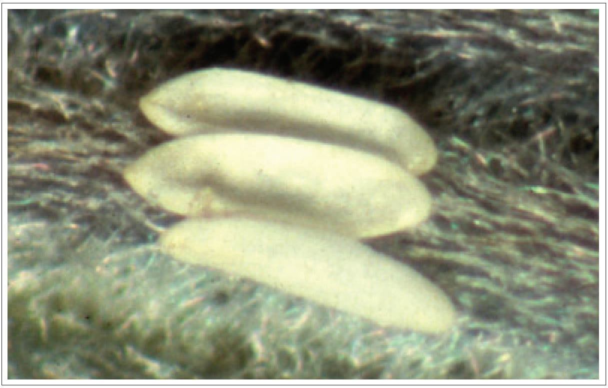

Photo P55. Eggs of *Silba pendula*.

Damage. Larvae hatch and immediately penetrate the stem. They settle within the first 5 cm of the shoot tissue. When they are ready to pupate, they emerge out of the shoot and fall to the ground, where they complete their pupation process.

Ten, fifteen or more larvae can be found inside one shoot at the same time. The larval feeding process produces a milky exudate in the shoot, that is, abundant latex that they use as covering. This exudate is initially white and turns brown or even black due to oxidation, and then dries out (Photo P56).

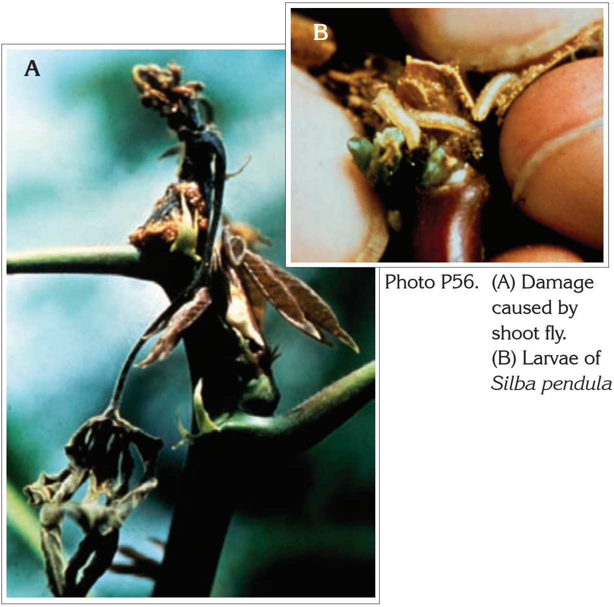

Photo P56. (A) Damage caused by shoot fly. (B) Larvae of *Silba pendula*.

Stem borer
Chilomina clarkei

Adults. The butterflies of this pest (Lepidoptera: Pyralidae) of crepuscular habit are relatively small (2.5 to 3 cm long) and cinnamon in color (Photo P57). Females lay ≈ 230 eggs on average.

Eggs. Females lay their eggs on the stem nodes, around axillary buds or close to them. They are very small and flat eggs, 1.2 mm long by 0.8 mm wide, white in color when they are newly laid, and have a pink coloration 24 hours later (Photo P58.A).

Photo P57. Adult of *Chilomina clarkei*.

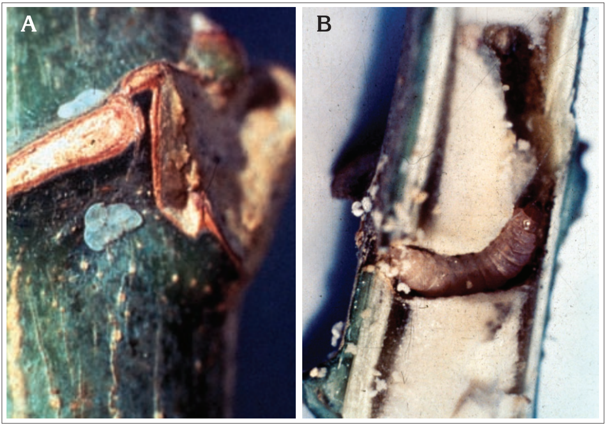

Photo P58. (A) Eggs and (B) larva of cassava stem borer (*Chilomina clarkei*).

Larvae. Stem borer larvae are apodous and creamy in color, and may undergo several instars (6 to 12). Through these instars, larvae form, where the stem is penetrated, a woven structure to protect themselves from the environment and other natural enemies or predators (Photo P58.B). Stems decay during this larval development process.

Pupae. The pupal stage takes place also in the stem. It appears as a brown capsule about 2 to 2.5 cm long by 0.5 cm wide (Photo P59.A).

Damage. Damage caused by this insect is easily detected due to the presence of webbing and fine residues of sawdust-like excrements or frass (Photo P59.B). As larvae grow larger, the size of the holes increases as well.

Photo P59. (A) Stem borer pupa. (B) Severe damage caused by *Chilomina clarkei*.

Initially the sawdust-like frass is creamy white, later it takes a brown to black coloration, when it has been days since the insect initially caused damage. Within the stem, larvae make galleries, often numerous, depending on varietal susceptibility.

Other stem borer pests

Lagocheirus araneiformis

Adults. The adult of this species (Coleoptera: Cerambycidae) is a beetle with antennae longer than its body. It has a grayish color with black spots on its coriaceous wings (upper wings). This insect is about 2 to 3 cm long by 1 cm (or more) wide (Photo P60).

Eggs. The adult females can oviposit 140 to 160 eggs, and lay them underneath the stem bark. These eggs are elliptical-shaped and initially white in color, later they turn yellow when they are close to hatch (Photo P61).

Photo P60. Adult of *Lagocheirus araneiformis*.

Photo P61. Egg of *Lagocheirus araneiformis*.

Larvae. They are apodous and spiral-shaped, and may reach up to 37 mm in length. They prefer to feed on the stem basal part, and produce thick sawdust-like residues when boring the stem (Photo P62.A). Larvae may last an average of 90.2 days in the field.

Pupae. These are exarate or free pupae, and can be found inside the stem (Photo P62,B).

Photo P62 (A) Larva of *Lagocheirus araneiformis* and the damage it causes. (B) Exarate pupa of *L. Araneiformis*.

Coelosternus sp.

This pest (Coleoptera: Curculionidae) is highly important in Brazil. The larvae of this weevil penetrate the stem and dig tunnels at the marrow or central region. Affected stems and branches may dry out or break.

Females lay several white eggs underneath the bark, inside the cavities made by their proboscis.

Larvae. Larval size may vary depending on the species. Most of the larvae are curved-shaped. Their body is yellowish white to pale brown in color, and their head is capsule-like shaped, brown with black jaws (Photo P63.A).

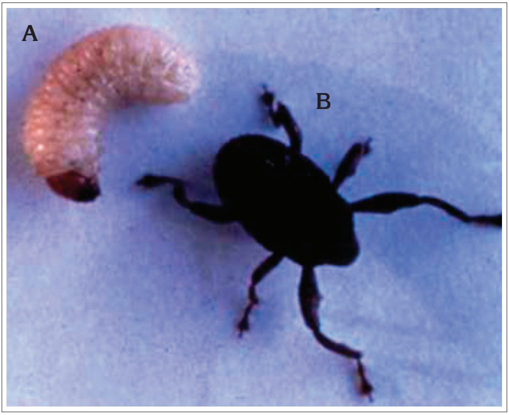

Photo P63. (A) Larva and (B) adult of *Coelosternus* sp.

Pupae. Pupae develop inside a chamber located at one of the gallery ends (Photo P64). The chamber is sealed by larval excrements (debris). The pupal stage lasts nearly a month.

Adults. They have a long proboscis; its size ranges between 6 and 12 mm depending on the species. They are dark to light brown in color (Photo P63,B).

Photo P64. Damage caused by *Coelosternus* sp. with pupae inside the stem.

Biological control

In this section, we present biological control agents of major cassava pests. Photos P65 through to P83 show either the control agent or its effect on the corresponding pest. The scientific names of these pests can be found in this handbook's previous pages.

Against the subterranean burrower bug or "smallpox bug"

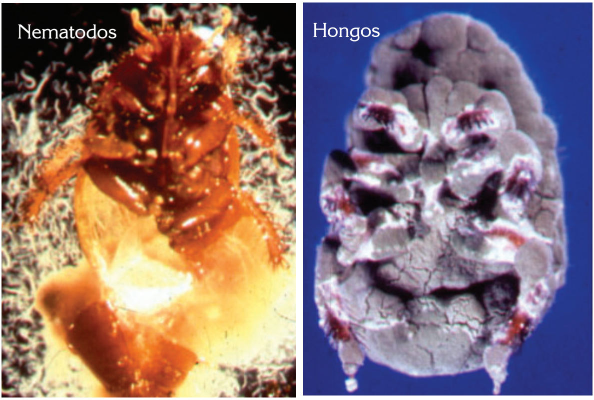

Photo P65. Nematodes (*Steinernema* sp. and *Heterorhabditis* sp.) and *Metarhizium anisopliae*.

Against mites

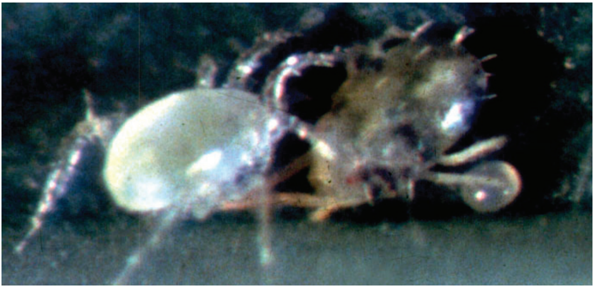

Photo P66. Predatory mites of the family Phytoseiidae.

Against whiteflies

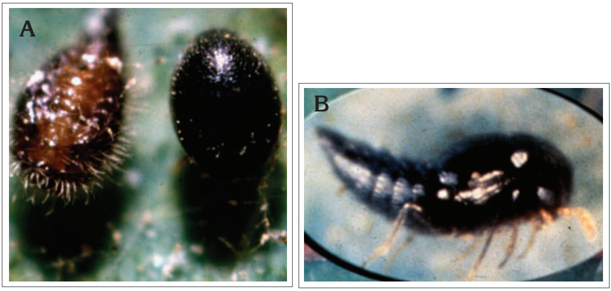

Photo P67. (A) Pupa and adult of *Stethorus* sp. (B) Adult of *Oligota* sp.

Against cassava mealybugs

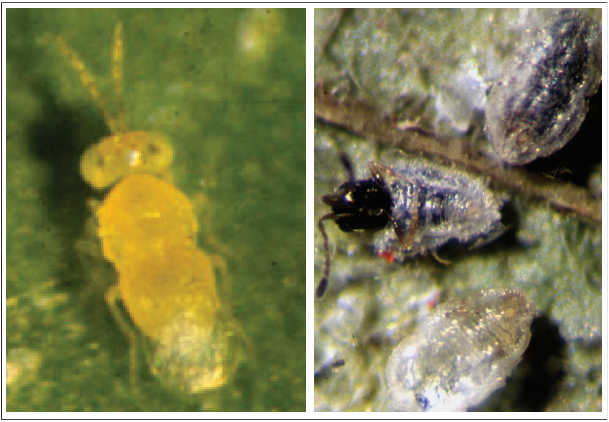

Photo P68. *Encarsia* sp. and *Amitus* sp.

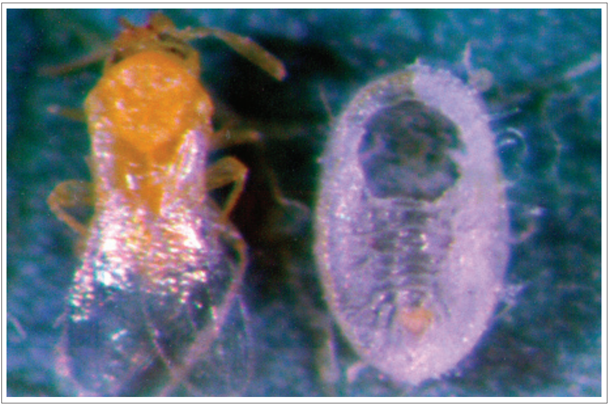

Photo P69. Parasitoid and residual pupa with operculum.

Against cassava hornworms

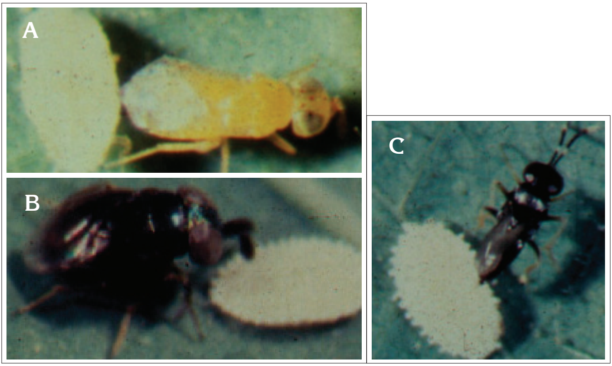

Photo P70. Parasitoids of *Phenacoccus herreni*: (A) *Acerophagus coccois*. (B) *Aenasius vexans*. (C) *Epidinocarsis* (= Apoanagyrus) *diversicornis*.

Photo P71. *Cleothera* spp. (predators).

Photo P72. *Trichogramma* spp. (egg parasitoid).

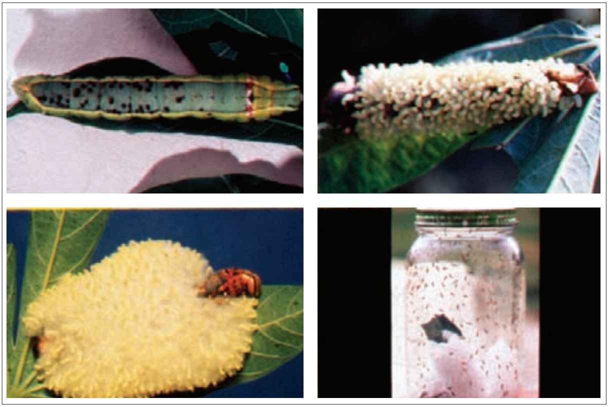

Photo P73. *Apanteles* sp. (= *Cotesia* sp.) (larva parasitoid).

Photo P74. Parasitoid dipterans of larvae and pupae of *Erinnyis ello*.

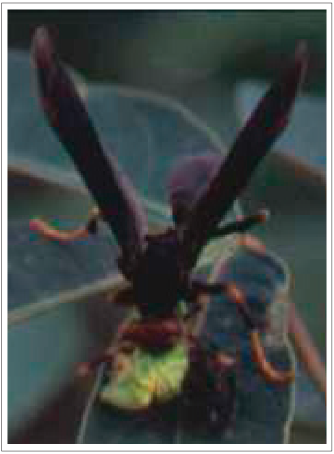

Photo P75. *Polistes erythrocephalus*, predatory hymenopteran of larvae of *Erinnyis ello*.

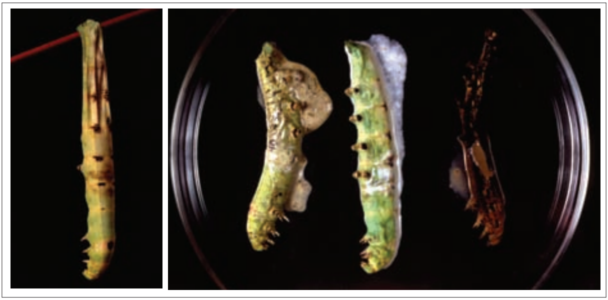

Photo P76. Hornworm larvae affected by *Baculovirus*.

Photo P77. Pupae of *Erinnyis ello* affected by the fungus *Cordyceps* sp.

Against cassava tiger moths

Photo P78. *Trichogramma* sp. (egg parasitoid).

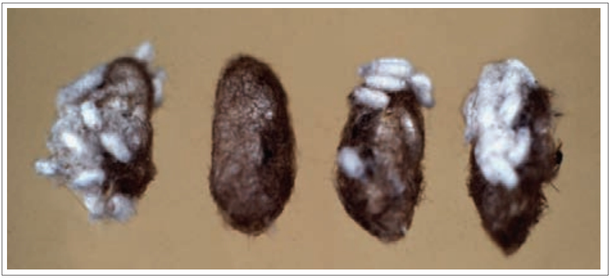

Photo P79. *Cotesia* sp. (larva parasitoid).

Against leaf-eating beetles

Photo P80. *Metarhyzium* sp. (Entomopathogen).

Against stem borers

Photo P81. *Bracon* sp. (larva parasitoid).

Photo P82. *Brachymeria conica* (larva parasitoid).

Photo P83. *Spicaria* sp., entomopathogen of larvae of *Chilomina clarkei*.

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