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# CASSAVA PESTS AND THEIR CONTROL

Anthony Bellotti
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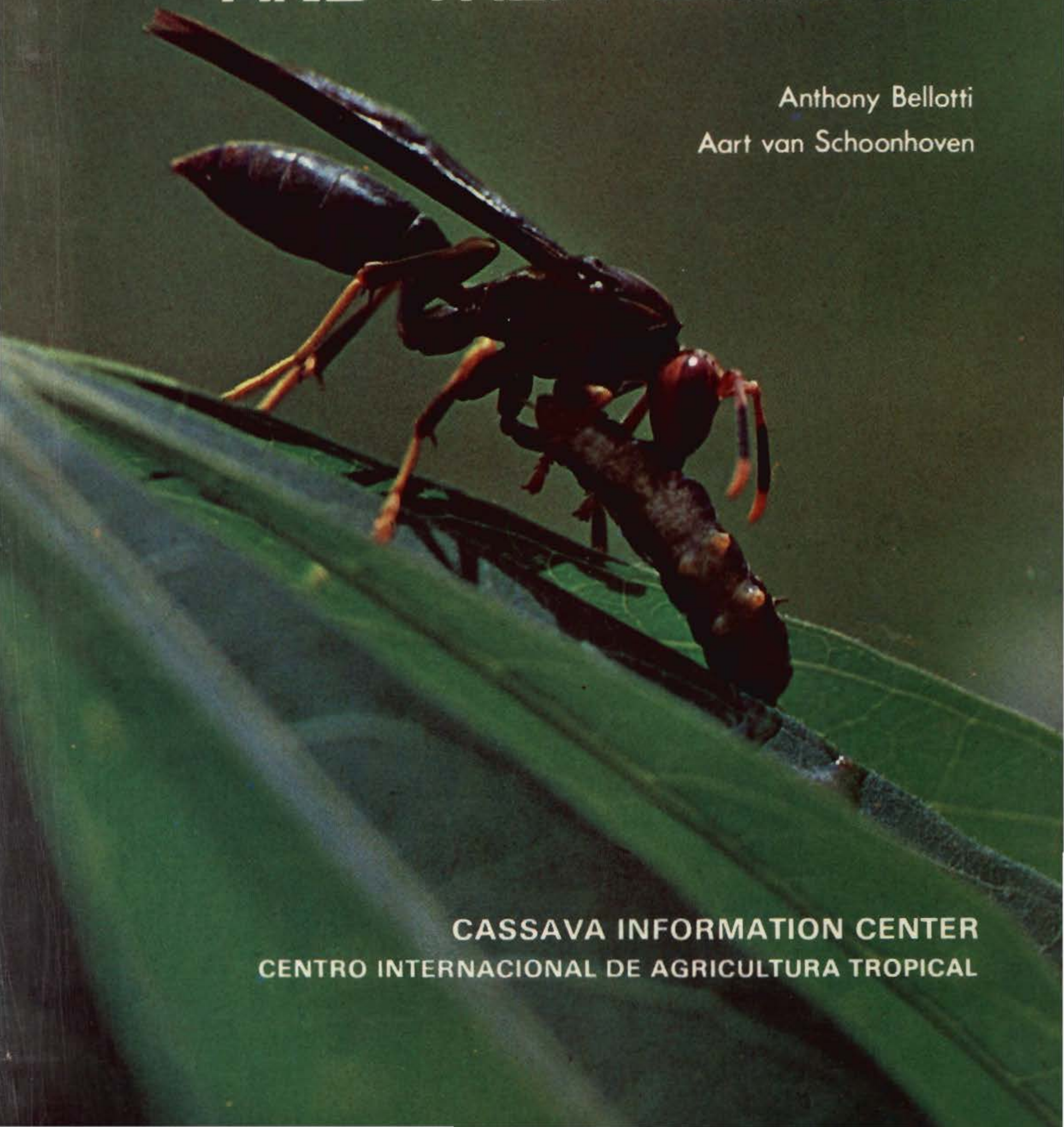

CASSAVA INFORMATION CENTER
CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL

COVER PHOTO: Larva of *Erinnyis ello* being preyed on by *Polistes* sp.



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Edited by
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CASSAVA INFORMATION CENTER - CIAT

Contents

# Cassava pests and their control*

**Anthony Bellotti**

**Aart van Schoonhoven****

## Introduction

Cassava *(Manihot esculenta)*, a major energy source for 300 to 500 million people, is grown throughout the tropical regions of the world. It is cultivated mainly in developing countries on small farms with little technology. As a result, it has received limited attention from scientists and technologists. FAO estimates for 1977 indicate an annual global production of 105 million tons on 11 million hectares, of which at least 55 million are consumed by humans. Although cassava is now cultivated in some 90 countries, 80 percent of the world's production comes from only 10; the six leading producers are Brazil (31%), Indonesia, Zaire, Nigeria, Thailand and India (98). In many parts of the world, especially West Africa, cassava appears to be the most economical, lowest risk subsistence crop for the small farmer.

The increasing world population and the limited availability of energy has prompted a recent surge of interest in cassava, not only for traditional uses as a human food and for specialized starches including tapioca but also for animal feedstuffs and industrial uses (65). There is an excellent potential for increasing both yield and area under cultivation. Two international centers for tropical agriculture, one in Colombia (Centro Internacional de Agricultura Tropical, CIAT) and another in Nigeria (International Institute of Tropical Agriculture, IITA), carry out extensive research on cassava in addition to other tropical crops (98). Emphasis is placed on developing high-yielding germplasm for low-input conditions. Present world cassava yields under small-farm conditions average only 5 to 15 t/ha. Experimental yields of 55 t in Colombia (27) and 70 t/ha elsewhere (97) have been obtained. Commercial yields with low input in Colombia have exceeded 40 t/ha. These figures indicate that undoubtedly there are several factors limiting production under farm conditions, one of which is pests.

It has frequently been reported that cassava is generally free of arthropod pests; however, present research at CIAT and other centers reveals that mite and insect damage does limit cassava production; e.g., the recent introduction into Africa and the consequent epidemic of the green mite *Mononychellus tanajoa* has caused serious crop losses (86, 104).

Cassava pests represent a wide range of arthropods; approximately 200 species have been recorded. Although many are minor pests, causing little or no economic losses, several must be classified as major pests. These include mites, thrips, stemborers, hornworms, whiteflies and scale insects.

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What little information is available on this subject—scattered in numerous journals and monographs—has been collected and made available to researchers through CIAT's Cassava Information Center. There is a paucity of data on cassava pest biology, ecology, distribution, seasonal occurrence and economic damage, often resulting in confusion as to identification, taxonomic classification, determination of synonyms and effective control measures. An attempt has been made to gather information on these pests with recent observations by the authors, whose experience has been mainly in Latin America.

## The host plant

*Manihot esculenta,* a member of the Euphorbiaceae, is a perennial shrub that originated in the Americas; it was later taken to Africa and more recently introduced into Asia. Common names include mandioca, yuca, manioc and tapioca. Because of the different levels of cyanogenic glycosides it contains in the roots, it has often been classified into "sweet" and "bitter" varieties.

Leaves are formed at active apices and consist of an elongated petiole and a palmate leaf blade. The plant exhibits apical dominance, producing a single stem; the petioles are borne on raised structures, giving the stem a characteristic nobby appearance. When the main apex becomes reproductive, apical dominance is broken; and two, three, or four axillary buds immediately below the reproductive structure become active and branching occurs. The roots accumulate carbohydrates in the parenchyma to form swollen storage organs. Depending on ecological conditions, the plant is cultivated from 8 to 24 months. Although the plant can be grown from seed, it is usually reproduced vegetatively for commercial purposes by planting stem cuttings. Cassava is grown commercially at altitudes between sea level and 2000 meters.

## Distribution of pests

The greatest diversity of insects reported attacking cassava is from the Americas. Representatives of the 17 general groups of pests described in this review are found in the Americas, 12 are reported from Africa, and only 5 are from Asia. Undoubtedly, pest distribution is more widely dispersed than the literature indicates.

Mites, whiteflies, white grubs, scales and termites are reported from all major cassava-growing areas. The green mite *Mononychellus tanajoa* is reported only from the Americas and certain parts of Africa (105), whereas the two-spotted spider mite *Tetranychus urticae (T. telarius)* is reported worldwide. The white scale *Aonidomytilus albus* is reported from Asia, Africa and the Americas whereas several other scale species are more localized. White grubs are reported damaging cassava in several regions, but no single species appears universal. The cassava hornworm *(Erinnyis ello),* shoot flies, fruit flies, lace bugs *(Vatiga manihotae)* and gall midges are reported only from the Americas. Stemborers, thrips, mealybugs and leaf-cutter ants are reported from the Americas and Africa. Grasshoppers are reported as a major pest only in Africa. Cutworms and crickets are found worldwide but have not been reported as attacking cassava in all areas.

It appears that the pest complex varies greatly over the main cassava-growing areas; therefore, careful quarantine measures should be employed to prevent their introduction into uninfested areas.

## Crop losses due to insects and mites

Insects can cause damage to cassava by reducing photosynthetic area, which results in yield reductions; by attacking stems, which weakens the plant and inhibits nutrient transport; and by

MITES

Damage by *Tetranychus urticae*

Damage by *Mononychellus tanajoa* (plant on the right)

Close-up of damage by *M. tanajoa*

Severe attack by *M. tanajoa*

attacking planting material, which reduces germination. Those mites and insects that attack the stem also lessen the quantity and quality of planting material taken from these plants, thus affecting production. Soil-borne insects attack cuttings, causing wounds or boring holes through which soil-borne pathogens can enter; they may also completely destroy the epidermis and/or buds of the cuttings. Others cut the roots and/or shoots shortly after emergence. Some insects are vectors of diseases as well.

Indications are that pests such as mites, thrips, whiteflies, scales, mealybugs, lace bugs and stemborers, which attack the plant over a prolonged period, will reduce yield more than those that defoliate or damage plant parts for a brief period; e.g., hornworms, fruit flies, shoot flies and leaf-cutter ants. This is because the cassava plant appears able to recover from the latter type of damage under favorable environmental conditions, with rainfall and soil fertility being critical factors. Cassava is often grown in regions with prolonged dry seasons and infertile soils. These additional factors of water stress and poor fertility will compound damage caused by mites, thrips, lace bugs and scales, whose populations tend to increase during dry periods.

Most of the literature reviewed did not include good economic loss data. When quantitative figures were available, they are presented in the text for each insect group.

## Mites and insects attacking foliage

### Mites

Recent research indicates that mites are one of the most serious cassava pests throughout the world. A complex of 22 species of spider mites, all belonging to the family Tetranychidae, have been identified as feeding on cassava. The criteria used for identifying these mites and their taxonomic description have been reviewed by Flechtmann (49). The more important species of the genera *Tetranychus*, *Mononychellus* and *Oligonychus* are shown in Table 1.

The two species of greatest economic consequence appear to be *M. tanajoa* and *T. urticae (T. telarius)*. *T. urticae* is found throughout cassava-growing regions of the world and is reported to cause serious losses in parts of Asia (117) whereas *M. tanajoa* is native to the Americas (16). It was possibly introduced into Africa around 1970 (86, 87) but may have been present earlier (106) and has spread quickly because of favorable environmental conditions (104, 106). *T. urticae* has a wide host range, whereas both the *M. tanajoa* and *Oligonychus peruvianus* mites appear limited to *Manihot* spp. but may attack other Euphorbiaceae. *O. peruvianus* has been identified only in the Americas (49) but *O. gossypii* has been found in Africa as well.

Yield losses as a result of mites are considerable. Nyiira (106) reports yield losses as high as 46 percent caused by *M. tanajoa* in experimental plots in Uganda. Studies in Venezuela (E. Doreste, personal communication) place losses from *M. tanajoa* in the 15 to 20% range. Field experiments at CIAT (30) involving a complex of four mite species *(M. tanajoa, M. mcgregori, T. urticae* and *O. peruvianus)* resulted in 20 to 53% loss, depending upon plant age and the duration of the attack.

#### Damage

The *Mononychellus* mite is usually found around the growing points of plants, on buds, young leaves and stems; the lower part of the plant is less affected. Upon emerging, leaves are marked with yellow spots, lose their normal green color, develop a mottled, bronzed, mosaiclike appearance and become deformed. Under severe attack, plant growth is stunted, shoots lose their green color and stems become scarified, first turning rough and brown and eventually presenting dieback. Stems and leaves necrose progressively from top to bottom (29, 106).

Table 1. **Important species of the cassava mite complex.**

| Species | Synonyms | Reported from | References |
|---|---|---|---|
| *Mononychellus tanajoa* | *Tetranychus tanajoa* | S. America | 27, 40 |
| | *Mononychus tanajoa* | E. Africa | 86-87, 104 |
| *M. caribbeanae* | *T. caribbeanae* | S. America | 115 |
| | *Eotetranychus caribbeanae* | Caribbean | 111 |
| | *Mononychus caribbeanae* | Caribbean | 111 |
| *M. planki* | *T. planki* | S. America | 111 |
| | *E. planki* | S. America | 4 |
| *M. bondari* | *Mononychus bondari* | Brazil | 87 |
| *M. chaemostetosus* | *Mononychus chaemostetosus* | Brazil | 111 |
| *M. mcgregori* | *Mononychus mcgregori* | Colombia | 28 |
| | *Mononychellus planki* (partim) | Colombia | CHWF* |
| *Tetranychus urticae* | *T. telarius* (partim) | Americas, Africa, Asia | 39, 50, 117 |
| | *T. bimaculatus* | Asia | 75 |
| *T. cinnabarinus* | *T. telarius* (partim) | Brazil, Uganda | CHWF* |
| *T. tumidus* | | Brazil, Mexico | CHWF* |
| | | Asia, Caribbean | 8 |
| *Oligonychus peruvianus* | *T. peruvianus* | Colombia | 27 |
| | *Paratetranychus peruvianus* | Colombia | CHWF* |
| | *P. trinitatis* | Colombia | CHWF* |
| *O. gossypii* | *P. gossypii* | Brazil | 50 |

*C.H.W. Flechtmann, personal communication

Damage from the *Tetranychus* mite appears initially on the lower leaves of the plant. It first shows as yellow dots along the main leaf vein, eventually spreading over the whole leaf, which turns reddish, brown or rusty in color. Beginning with the basal leaves, severely infested leaves dry and drop, and plants may die (29).

The presence of the *Oligonychus* mite is characterized by small white spots, which are webs the female spreads on the leaf undersides, commonly along the central and lateral leaf veins and

**Damage by** *Oligonychus peruvianus*

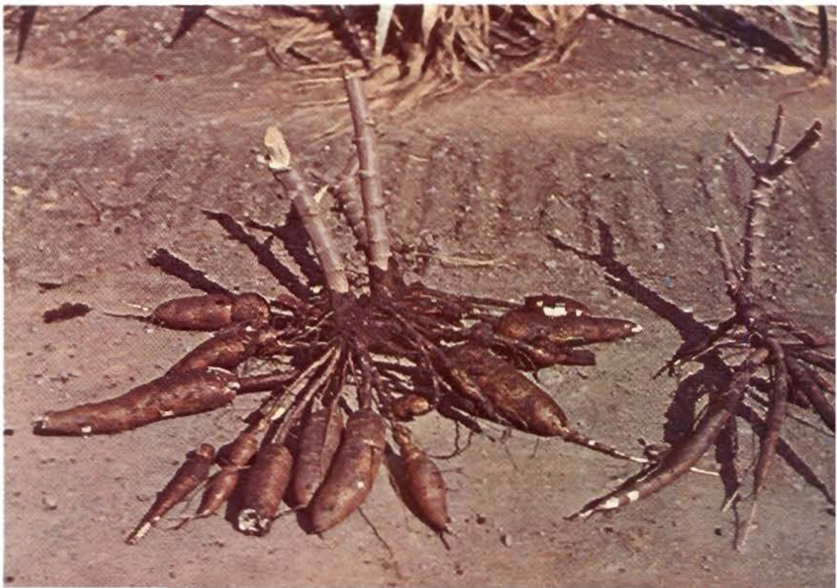
**Close-up of web formed by** *O. peruvianus* **on underside of leaf**

# THRIPS

Left, susceptible plant; right, resistant

Severe attack giving appearance of witches'-broom

Left, yield of resistant plant, right, yield of susceptible plant



margin. Eggs are deposited under this web where the immature stages develop. Corresponding yellow-to-brown dots form on the leaf upper surface. Damage is more pronounced on the lower leaves (82).

**Life history, appearance and habits**

Mites are pests primarily during the dry season when favorable environmental conditions permit populations to build up to high levels. At CIAT (29) mite populations increased during the dry season and as the plant increased in age.

The *Mononychellus* female oviposits on the leaf undersurface, along the midrib or other veins, or in leaf concavities. As the mite population increases, eggs are deposited at random. Nyiira (105) states that mite density and egg production are enhanced by dry periods, new leaf growth and high quantities of chlorophyll; they decrease during and after rains (107). Preoviposition lasts 1-3 days, with females laying from 15-111 eggs each (105). Laboratory conditions produce the following time periods for the various stages: egg, 3-5 days; larvae, 1-2 days; protonymph, 1-2 days; deutonymph, 1-2 days; and adults up to 30 days (30, 105). Laboratory studies at CIAT (30) revealed a sex ratio of 62% females and 38% males and an egg viability of 92%. The adult *M. tanajoa* is green in color and has an average body length of 350 m$\mu$. *M. mcgregori* is similar in behavior to *M. tanajoa*. We have often observed *M. tanajoa* feeding on leaves still within the bud, whereas *M. mcgregori* feeds on the young leaves after they have expanded from the bud. Both species have been found on the same plant in Venezuela (E. Doreste, personal communication) and Colombia. Laboratory studies indicate that optimal temperature for *M. tanajoa* development is 28-32°C with a relative humidity of 60% (30, 107).

Studies by Nyiira (107) and Bennett & Yaseen (8) show that wind is the primary means of dispersal for *M. tanajoa*. These mites form ballooning threads by which they lower themselves from the leaves. They are picked up and carried by air currents for long distances; thus movement of the mite is usually in the direction of the wind. Dispersal is most active on hot days (25°C), between the hours of 9-11 am and 3-5 pm. Dispersal via man, animals or other insects, as well as by walking, is also important. This mite was probably introduced into Africa via cuttings.

The two-spotted spider mite *(T. urticae)* is considered a major agricultural pest worldwide and has been studied by several workers (often as *T. telarius)* (17); however, there are few studies in relation to its association with cassava. Laboratory and screenhouse studies at CIAT (30) indicate that cassava is an acceptable host for this mite.

Oviposition is initiated on day 2 of the adult stage, on the undersides of basal leaves. Each female is capable of depositing 40-50 eggs over a 20-day period, with the peak period occurring from days 3-9. Laboratory studies (25-28°C, 60-70% RH) resulted in an egg period of 3-4 days, a larval period of 2-5 days, a protonymph period of 1-2 days, a deutonymph period of 1-3 days and an egg-to-adult period of 7-11 days; adults survived up to 22 days (30). Dispersal occurs via wind (although not by ballooning threads), walking or phoresy.

Studies of the *Oligonychus* mite on cassava are incomplete. The female spreads a small whitish web along the central and lateral veins on the undersides of basal leaves. Eggs are oviposited under this web, where larvae and nymphs develop by feeding on the leaf (28).

**Control**

The use of pesticides to control mites should be avoided. Their short life cycle enhances the development of resistance to acaricides, and predators are more adversely affected by broad-sprectrum pesticides than mites are (8). There is also some evidence that the application of pesticides can stimulate the fecundity and migration of mites. To prevent mite infestations on cuttings, pesticides such as malathion and Tamaron should be used. These products can be applied by dipping the cuttings in a solution for five minutes (84). The two primary methods of control under study are biological control and host plant resistance.

*Biological control.* Numerous predators have been reported feeding on cassava mites. These include Coccinellidae *(Stethorus* sp., *Chilomenes* sp., *Verania* sp.*)* Staphylinidae *(Oligota minuta),* Cecidomyiidae, Thysanoptera, Phytoseiidae *(Typhlodromus limonicus, T. rapax)* and Anthocoridae *(Orius insiduous). O. minuta, Stethorus* sp. and the Phytoseiidae mite complex appear to be the more common predators of *M. tanajoa* (8, 104).

Bennett & Yaseen (8) have evaluated the effectiveness of biological control of *M. tanajoa* with *O. minuta.* The development period of *O. minuta* is only 15-18 days, enabling it to react quickly to an increase in host number. Both larvae and adults feed voraciously on the mite (as many as 88 larvae and 32 adults per 75 leaf samples have been observed) and can feed on other tetranychids when *M. tanajoa* is scarce (59). Predator populations were greater during the dry season when mite density was highest and decreased during the rainy period, as did mite density. *O. minuta* populations were highest on leaves 6-10 (measured from newest leaf), coinciding with highest mite populations; its activity is therefore synchronized with that of the mite. The introduction of this predator into East Africa has begun.

*Varietal resistance.* Systematic evaluation of the CIAT germplasm bank under greenhouse and screenhouse conditions indicates only low levels of resistance to *T. urticae* and intermediate or moderate levels to *M. tanajoa* (30). Nearly 98% of the varieties were highly susceptible to *T. urticae,* as compared to 45% for *M. tanajoa.* Only 0.4% of the varieties were in the intermediate resistance range for *T. urticae,* as compared with 14% for *M. tanajoa.* These results indicate that there is a higher level of resistance to *M. tanajoa* than to *T. urticae* in cassava germplasm.

Bennett & Yaseen (8) observed large differences in population levels of *M. tanajoa* on different varieties. Nyiira (104) found the lowest *M. tanajoa* population on the varieties Kru 46, 301, 15 and K. Kawanda. During heavy attacks, he observed three times as many leaves on tolerant varieties as on susceptible ones, and leaves developed about four times more slowly on susceptible varieties. Root yield of resistant varieties was about twice that of susceptible ones. Reports from Brazil (130) and Venezuela (4) have also identified varieties resistant to *Mononychellus* and *Tetranychus.* In recent field evaluations in Colombia (31), several varieties were selected as promising for resistance.

## Thrips

Several species of thrips are pests of cassava throughout the Americas. These include *Frankliniella williamsi* (28), *Frankliniella* sp. (102, 122), *Corynothrips stenopterus* (42, 122), *Euthrips manihoti* (14, 15), *Scirtothrips manihoti* (39) and *Caliothrips masculinus* (27). Thrips attacks have also been reported from Africa (Z.M. Nyiira, personal communication) and India (*Retithrips syriacus*, Bellotti, personal observation). Yield reduction ranges from 5.6-28.4% depending on varietal susceptibility. The average reduction for eight susceptible varieties in Colombia was 17.2% (30, 123). These results are consistent with reports in literature, which estimate a 15% yield reduction (102).

### Damage

*F. williamsi,* which damages the terminal bud of the plant, is the species of greatest economic importance. Leaves do not develop normally, leaflets are deformed and show irregular chlorotic

## CASSAVA HORNWORM

(*Erinnyis ello*)

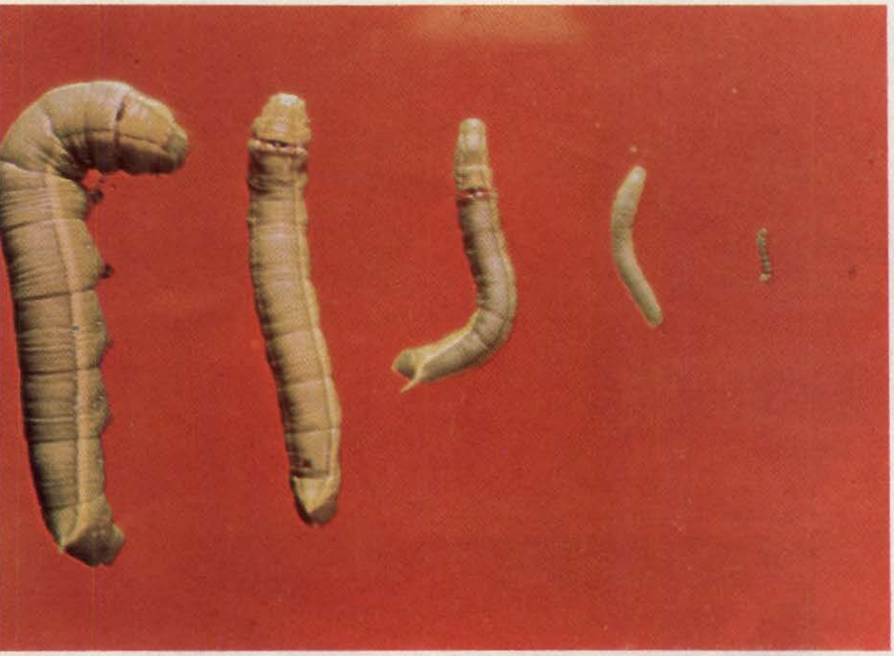
Eggs

Adult male

Fifth instar larva feeding on leaves

CASSAVA HORNWORM

Variations in larval colors



The five larval instars

Pupae

spots. Stylet damage to leaf cells during expansion causes deformation and distortion, and parts of the leaf lobes are missing. Brown wound tissue appears on stems and petioles, and internodes are shortened. Growing points may die, causing growth of lateral buds which, in turn, may be attacked, giving the plant a witches'-broom appearance (6, 102, 122, 131). Symptoms of a severe attack are similar to those for cassava mosaic (102).

**Life history, appearance and habits**

Limited information is available on the biology of thrips on cassava. Larvae and adults of *E. manihoti* and *F. williamsi* live in the growing points and on young leaves (14, 122). *Frankliniella* sp. and *E. manihoti* are golden yellow and measure about 1.1 mm in length (14). *C. masculinus*, a black species, is found mainly on expanded leaves of young plants (27). Adult *C. stenopterus* measure 1.5 mm and are yellow in color; the head and the last two abdominal segments are darkened. Thrips insert their eggs in the midrib of the leaf undersurface. The greenish colored nymphs live near the veins where they go through two nymphal and two pupal stages (46). Thrips attack is most frequent during dry periods, and plants recover with the initiation of the rainy season (131).

**Control**

The use of resistant varieties, which are readily available,is the best method of control. In the CIAT germplasm bank high levels of resistance to *Frankliniella* sp. and *C. stenopterus* exist. Approximately 20 percent of the varieties are highly resistant to thrips attack, and an additional 29 percent show only minor damage symptoms (27, 122). Resistance is based on leaf bud pilosity. Increasing pubescence of unexpanded leaves increased thrips resistance (122).

## The cassava hornworm

The cassava hornworm *Erinnyis ello* is generally considered to be one of the most serious pests because it can rapidly defoliate plants. It occurs only in the Americas, where in severe outbreaks large cassava plantations are defoliated. This pest has been reviewed in detail by Winder (134). The hornworm has been previously recorded as *Sphinx ello, Dilophonota ello* (24, 57) and *Anceryx ello* (13). A less important species *Erinnyis alope* has been reported in Brazil. Cassava is the principal host of *E. ello*, which appears to be confined to Euphorbiaceae. Additional hosts reported are *Aleuritis triloba* (24), *Manihot glaziovii*, poinsettia, rubber, papaya and milkweed (13, 36, 99). When heavy attacks occur, larvae may migrate to adjacent crops such as cotton (27, 102). Yield reductions of 10-50% have been estimated (110) depending upon plant age and intensity of attack; at CIAT yield was reduced by 18% (31). A decrease in starch content has also been suggested (52). Transmission of bacterial blight by hornworm larvae has also been reported (27, 99).

**Damage**

Hornworm outbreaks with populations of more than 90 larvae per plant have been reported (30). Populations of this magnitude will defoliate plants rapidly, and the larvae will subsequently feed on growing tips and lateral buds. Young plants may be killed. The influence of hornworm attack on the roots is severer in poor than in fertile soils (57). Damage simulation studies indicate that defoliation of young plants (2-5 months) reduces yields more than that of older plants (6-10 months). Although each larva consumes an average of 1107 $cm^2$ of leaf area during its five instars, large populations can be tolerated (28) since under favorable environmental conditions there can be up to 80% defoliation with no reduction in root yield.

**Life history, appearance and habits**

The generally gray nocturnal adult moth has five to six black bands across the abdomen, with gray forewings and reddish hind wings. The smaller males have a longitudinal dark band over the forewings. Females live 5-7 days, and the males live a few days less (24). Oviposition occurs 2-3 days after emergence, usually on the upper surface but also on the petiole, stems and leaf undersurfaces (57). A female may deposit from 30-50 eggs (30) although recent observations at CIAT (unpublished data) indicate an average of 850 eggs for individual pairs and 450 when there were 11 pairs in the cage. The eggs hatch in 3-6 days (43, 57).

The first instar larvae consume the egg shell before moving to the leaf undersurface to begin feeding. The duration of the five larval instars is from 12-15 days (57). Larvae prefer feeding on upper leaves, consuming approximately 75% of the total leaf area in the fifth instar. The hydrogen cyanide content of the leaf appears to have no effect on larval mortality but leaf age does (28). All instars show color polymorphism, but this is more common during the third instar. Colors vary from yellow, green, black, red and dark gray to tan (57).

Fifth instar larvae may reach 10-12 cm in length; they migrate to the soil where they form chesnut brown, black-lined pupae under plant debris. Larvae may crawl considerable distances prior to pupation. Pupae can diapause for several months (13, 125), but the adults normally emerge within 2-4 weeks. Hornworm outbreaks generally occur at the onset of either rainy or dry periods, but attacks are sporadic and the insect can be virtually absent for several years. In Brazil they are found all year but are most abundant from January to March; several generations may occur. In Colombia outbreaks occur mainly during the dry periods (57).

**Control**

A biological control program that combines parasitism of eggs and larvae, as well as predation, appears to be the most effective. Severe outbreaks can be reduced by applying *Bacillus thuringiensis*. Chemical control should be avoided as infestation is less frequent in nonchemically treated than in treated fields (29, 57).

Egg parasitism by *Trichogramma minutum* (99), *T. fasciatum* (27), *Trichogramma* spp. and *Telenomus dilophonotae* (57) has been reported to be as high as 94-99% (110). An average of 23 *Trichogramma* adults emerge per egg (28). Experiments at CIAT were designed to measure the effect of *Trichogramma* release on hornworm egg parasitism. Egg parasitism was measured prior to release and periodically postrelease. Results showed a 22-23% increase in parasitism four days after release (5, 31). *Trichogramma* are being released in large cassava plantations in Colombia. Egg predation by ants (*Colichorerus* sp.) and wasps (*Polibias* sp.) has also been reported (57).

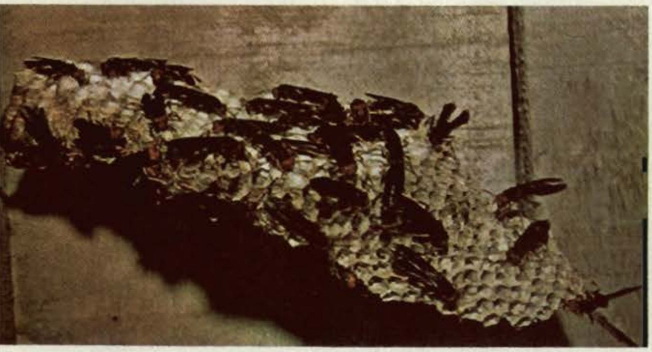
Of the reported insect and vertebrate predators of larvae, the paper wasps *(Polistes canadiensis* and *P. erythrocephalus)* appear to be the most effective (27). Each wasp requires several larvae per day, for its own consumption as well as for its brood. Control is most effective when tentlike protective shelters are provided for the wasp in the center of the cassava field (57). This practice has been successful at CIAT and on some farms in Colombia (30). Other larval predators are a pentatomid, *Alceorrhynchus grandis*, and a carabid, *Calosoma retusum* (36, 51). Predation by birds is also important in several areas of Brazil and Colombia (57, 99).

Important larval parasites in Colombia are *Apanteles congregatus* and *A. americanus* (57). These braconid parasites oviposit in the hornworm larvae where the parasite larvae develop. Mature larvae migrate from the host and pupate on the outer skin, forming a white, cottonlike

# CASSAVA HORNWORM

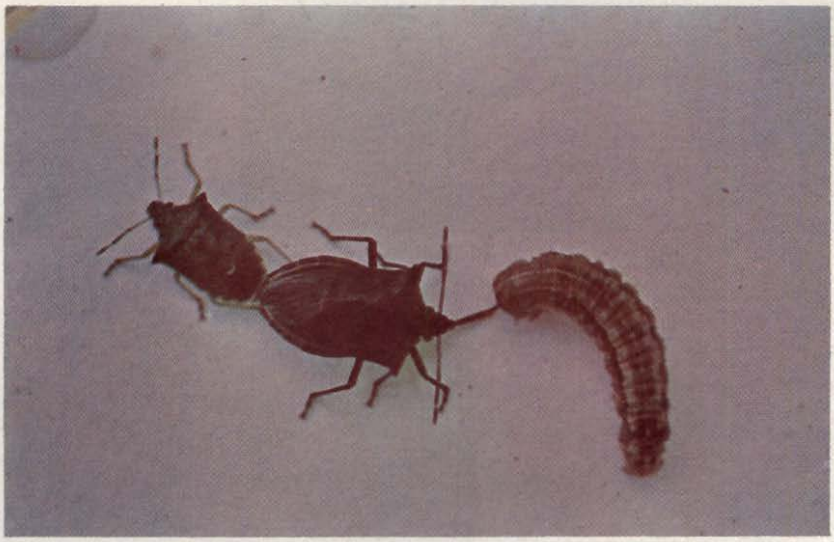
Plant defoliated by larvae

Adult *Polistes* sp. attacking larva



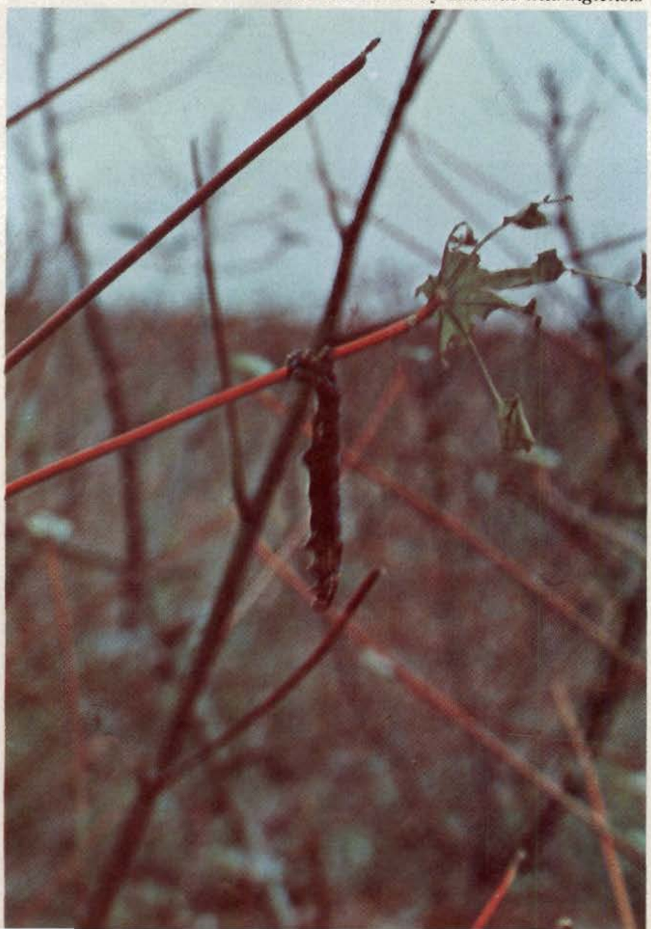
Nest of *Polistes* sp.

Larva attacked by *Apanteles* sp.



*Podisus* sp., a soldier bug that preys on larvae

Larva affected by *Bacillus thuringiensis*



mass. These cocoons are approximately 3.8 cm wide by 4.1 cm long. Each cocoon contains an average of 257 *Apanteles* pupae, of which some 80% will emerge. Liberations at CIAT resulted in an increase in parasitism of hornworm larvae (5, 31). Hyperparasitism of *Apanteles* by several hymenopteran parasites was recorded at CIAT, resulting in an average of 56% hyperparasitism (5). Similar behavior is reported for the ichneumonid wasp *Microgaster flaviventris* (24). Larval parasitism by tachinid flies is also reported (13, 24, 57, 91). *B. thuringiensis* controlled hornworm larvae effectively at CIAT. Six days after application, the larval population was 8% of the control; i.e., one per plant versus 13 on the control (30). Additional experiments show that *B. thuringiensis* is effective against all larval instars but most effective against the first (5). Studies also show that application of *B. thuringiensis* does not have an adverse effect on *Trichogramma* egg parasitism (31).

Laboratory studies at CIAT were designed to determine length of larval survival after initiating feeding of *Bacillus*-treated foliage. Results showed that larvae can survive for 1 to 4 days; however, the leaf tissue they are able to consume is reduced by 86% for the third instar, 93% for the fourth instar and 98% for the fifth instar larvae (30-31).

Cultural control practices such as plowing between rows and after harvest, as well as mechanical weed control, will destroy mature larvae and pupae. Hand-picking of larvae is recommended for farmers with small plantings.

## Whiteflies

Whiteflies (Aleyrodidae) attack cassava in the Americas, Africa and certain parts of Asia. Although they may not cause economic damage by their feeding, they are of particular importance as vectors of African mosaic disease in Africa and India (60, 80). *Bemisia tabaci* is the most important species in these areas. *B. gossypiperda* and *B. nigeriensis* are also reported from Africa. The species most frequently found on cassava in the Americas are *Trialeurodes variabilis*, *Aleurotrachelus* sp., *B. tuberculata* and *Aleurothrixus* sp. Although *B. tabaci* has been reported from the Americas, there is some doubt as to its capacity to feed on cassava (39a). African mosaic disease, reviewed by Lozano & Booth (83), is not present in the Americas.

### Damage

High whitefly populations may cause yellowing and necrosis of the lower leaves of the cassava plant. Severe infestations of *Aleurotrachelus* sp. have been observed in Colombia, where leaf damage was manifested as severe mottling or curling, with mosaiclike symptoms on susceptible varieties. A sooty mold, often found growing on whitefly excretions, may have an adverse effect on plant photosynthesis (29). Yield losses as high as 76% have been recorded at CIAT (unpublished data).

### Life history, appearance and habits

The biology of *Bemisia* spp. has been reviewed by Leuschner (80). The cycle varies with temperature; at 26°C, 17 days are required from egg to adult; within a range of mean temperatures from 12-26°, the cycle varies from 11-50 days. During hot, dry weather and low relative humidity, no eggs are laid. One generation of *B. tabaci* lasts 4-5 weeks, depending on climatic conditions; there may be up to ten generations per year (79).

Studies on the biology of *T. variabilis* (29) showed that females deposit an average of 161 eggs with 72% survival from egg to adult. Average longevity for females was 19.2 days; for males, 8.8

days. The oblong pupal stage is normally pale green, but that of *Aleurotrachelus* sp. is black, with a white waxy excretion around the outer edge (30). Heavily infested leaves are almost covered with immature stages, which gives the undersurface a glistening white effect. Infestations have been observed on upper as well as lower leaves.

Adult whiteflies are almost always found on the undersides of developing leaves, where they oviposit. Activity depends on temperature, light and rainfall; temperature and light seem to have an interacting effect on flight activity. Temperatures of 27-28°C increase activity but do not induce flight; as light becomes more intense, flight increases (80).

High populations are usually associated with the rainy season when plants are more vigorous (80, 100). Detailed population studies of *Bemisia* sp. have been conducted at IITA (79-80); possible factors involved in fluctuations of population may be a combination of ecological factors, physiological conditions of the plant, parasites and predators.

### Virus/vector relationship

Experiments conducted at IITA (80) have shown that vector density and African mosaic incidence are related. In screenhouse studies on the virus/vector relationship, Chant (32) demonstrated that whiteflies have to feed for at least 4 hours to acquire the "virus" and another 4 hours to become viruliferous; they are then able to transmit the disease after a minimum feeding period of 15 minutes. There are no results available for vector efficiency under field conditions; however, it is probably dependent on flight activity of the adults, population density and availability of young (succulent) infected leaves (80).

### Control

One way of controlling the vector is by using insecticides (23, 116, 117), but repeated treatments are necessary to maintain low populations, making this practice uneconomical. In addition, numerous wild hosts for *Bemisia* spp. would have to taken into consideration as new populations can build up quickly from these sources (80). Transmission pressure can be reduced by using resistant varieties (61). Studies at CIAT (29, 30) indicate that resistance to *Aleurotrachelus* sp. is available.

Biological control may be feasible. The coccinellid *Serangium cinctum* preys on immatures; the mite *Typholodromite* sp. feeds on adults. The wasp *Prospaltella* sp. (Encyrtidae) has been reported to parasitize whiteflies (108).

## Leaf-cutter ants

Several species of leaf-cutter ants, all belonging to the genera *Atta* and *Acromyrmex*, have been reported feeding on cassava in the Americas, especially Brazil (23, 24, 26, 42, 94, 131) and Guyana (12). The most commonly reported are *Atta cephalotes, A. sexdens, A. leavigata, A. insulans* and *A. opaciceps; Acromyrmex rugosus, A. octospinosus* and *A. diselager*.

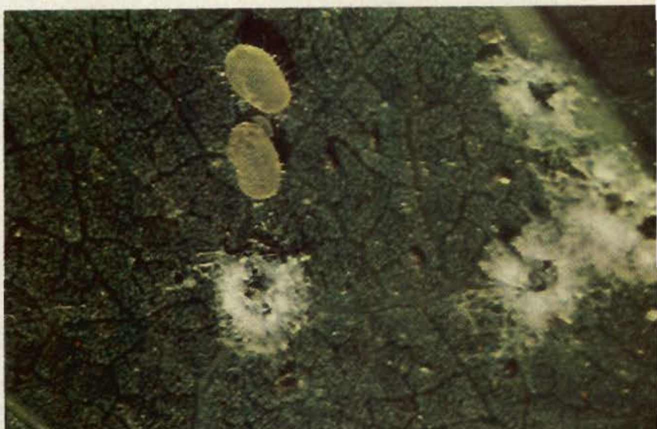
### Damage

Cassava plants can be defoliated when large numbers of worker ants move into a crop. A semicircular cut is made in the leaf; during severe attacks, the buds may also be removed. These parts are carried off to the underground nest and chewed into a paste, on which the fungus *Rhozites gongylophora* is grown (11, 12). Outbreaks frequently occur during the early months of the crop; the effect on yield is not known.

## WHITEFLIES

(*Aleurotrachelus* sp.)

Adults and eggs

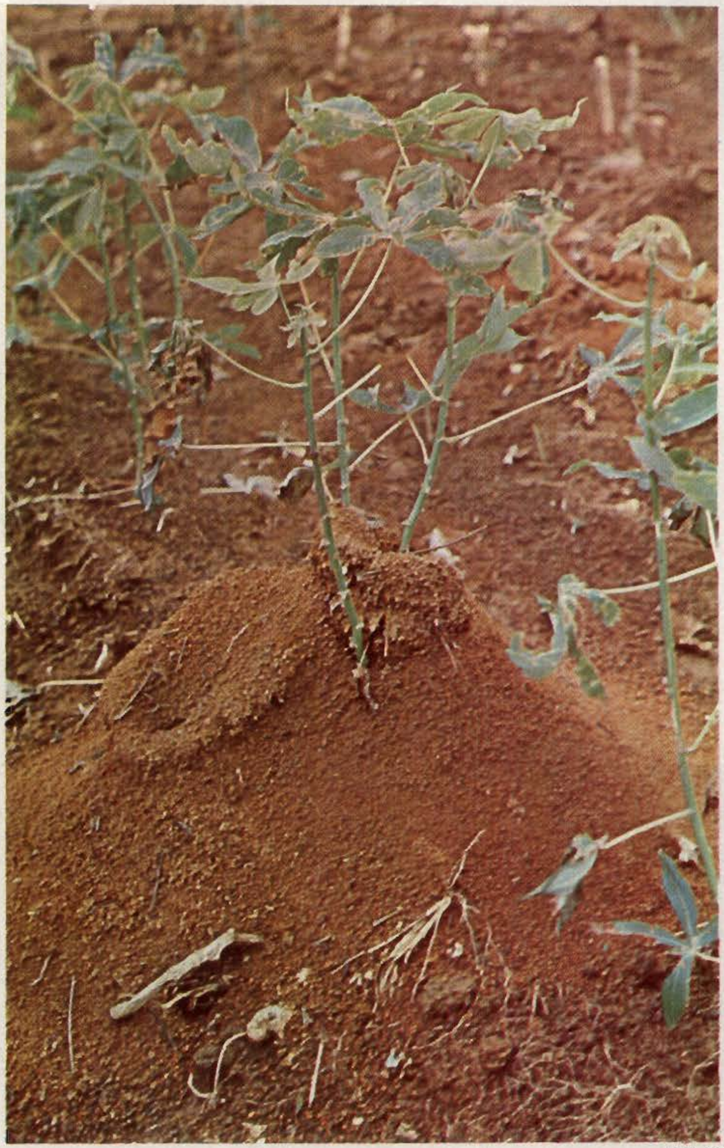


Nymphs and pupae

Severe attack

Formation of sooty mold on leaves as a result of attack

LEAF-CUTTER ANTS



**Ant hill**

### Control

Insecticides are the most effective means of control. Nests, often readily visible by the sand piles around the entrance hole (6), can be destroyed by fumigation with carbon disulfide and sulfur smoke or arsenates (24). Chlorinated hydrocarbons around the nest (26, 85) or granular Mirex baits applied along the ant trails give effective control (112). Varietal differences to ant attack are mentioned (94). Cacao, a host preferred to cassava by some of the ant species, has been planted with cassava as a protective measure (25, 131).

## Grasshoppers

Numerous species of grasshoppers are reported attacking cassava, principally in Africa (53, 67-69, 127). It is reported that resistance of cassava to the migratory locust has stimulated cassava production in many areas of Africa (88). Grasshoppers have been observed feeding on cassava in the Americas but are not considered to be a major pest there. The two species of major economic significance are *Zonocerus elegans* and *Z. variegatus* (69), both widespread in Africa between 10° north and south of the equator. Yield losses as high as 60% have been reported when younger plants are attacked (79). They may also be disseminators of cassava bacterial blight (J.C. Lozano, personal communication).

### Damage

Feeding damage is usually restricted to defoliation but can include young tender bark and seed coats (121, 127); in heavy outbreaks the bark is stripped. Immature plants are more severely affected than mature ones, which can withstand defoliation and have successful regrowth. Damage is of major importance during the dry season when cassava, which is tolerant to drought, is often the only available food source. It has been reported from some areas that the roots of defoliated plants are inedible because of excessive hardness (68).

### Life history, appearance and habits

The biology of *Z. variegatus* in Nigeria has been studied by Jerath (67) and Toye (128, 129). Adults generally lay eggs in April, placing them in eggpods a few centimeters below the soil surface; hatching occurs about 8 months later (79). The five nymphal stages last about 2 months. *Z. variegatus* is a mass migrator whereas *Z. elegans* migrates individually. Migration and feeding habits of *Z. variegatus* have been studied in Nigeria (9, 121, 127, 128) and Ghana (68). Increased cassava cultivation appears to intensify problems with *Zonocerus* (69).

Bernays et al. (9) studied the survival of *Z. variegatus* on cassava and showed that young nymphs normally reject cassava after biting it and die if they are confined on growing leaves. Later instars, if deprived of alternate food sources, will eat cassava, but adults progressively lose weight. Readiness to feed on growing cassava was associated with low HCN levels in the leaves.

### Control

Definite varietal preferences have been noted in studies of feeding habits of *Z. variegatus* (127), possibly related to acceptability of the bark of certain varieties. On the other hand, the HCN content of varieties has been linked with resistance; however, its role has not been sufficiently confirmed (121).

With regard to cultural control, planting should be done at a time that would ensure plant maturity when peak grasshopper populations occur since they prefer young, developing plants. The use of chlorinated hydrocarbons has also been recommended (79).

Biological control may also be feasible as *Z. variegatus* is parasitized by mermithid worms and the dipteran *Blaesoxipha filipjevi* (129).

## Gall midges

Gall midges (Cecidomyiidae) have been reported on cassava only in the Americas (73, 109, 131). The species *Jatrophobia brasiliensis* ( = *Eudiplosis brasiliensis, Clinodiplosis brasiliensis)* appears to be the most widespread (14, 15, 20, 21, 56).

### Damage

Gall midges are considered of little economic importance and generally do not require control. However, in Peru and Mexico, 6- to 7-month-old plants were totally deformed, measuring only 20-30 cm high as a result of a severe attack. Under high populations leaves yellow, retarding plant growth; roots become thin and fibrous (21, 73).

### Life history, appearance and habits

Adults lay from 4 to 5 individual eggs per leaf (131). When the larvae emerge, they penetrate the parenchyma tissue, causing abnormal cell growth and the formation of a gall (one larvae per gall) during the first larval instar. The second and third instars are passed here. Leaf galls generally measure 5-15 x 3-5 mm (14) and are found on the upper leaf surface; they are yellowish green to red, narrower at the base, often curved and easily noticeable. Larval duration is 15-21 days. Pupation (10-15 days) occurs in the gall; prior to pupation, the larva enlarges the exit hole, which is surrounded by a ring of elevated tissue, through which the adult emerges (73).

### Control

Varietal resistance to gall midges has been reported (130). The collection and destruction of affected leaves at regular intervals has been recommended to reduce pest populations.

Several larval parasites of gall midges have been observed, including *Tetrastichus* sp. *T. fasciatus, Dimeromicrus auriceps, Aprostocetus* sp. and *A. fidius* (21, 73, 95).

## Cassava lace bug

Lace bug *(Vatiga manihotae)* damage is reported from Colombia (23), Brazil (119) and several other countries in the Americas (119, 131). The species *V. illudens* has been reported from Brazil. High populations can cause foliar damage. Leaves have yellow spots that eventually turn reddish brown, resembling mite damage. Yield losses are not known, but observations in Brazil indicate severe defoliation in certain areas, possibly causing yield reductions.

### Life history, appearance and habits

The grayish adults, about 3 mm long, are generally found on the undersurface of the upper leaves. The whitish nymphs are smaller and are usually found feeding on the central part of the plant (27). Laboratory studies at CIAT (28) show five nymphal stages, lasting 2.9, 2.6, 2.9, 3.3 and 4.8 days, respectively (totaling 16.5 days). The egg stage is about 8 days; females deposit an average of 61 eggs. Adult longevity averages about 50 days. Prolonged dry periods were

**Defoliation of plant in northeastern Brazil**

GALL MIDGES

(*Jatrophobia brasiliensis*)

**Leaf galls**

favorable for increased lace bug populations, which were highest during the first 3 months of plant growth (29). ).

## Insects attacking stems

### Stemborers

Numerous insect species have been reported to feed on and damage stems and branches of cassava (Table 2). Although nearly worldwide in distribution, they are of particular importance

Table 2. **The common stemborers of cassava.**

| Family and species | Reported from | References |
|---|---|---|
| CURCULIONIDAE | | |
| *Coelosternus rugicollis* | Brazil | 22, 26, 43, 48, 77, 92, 119 |
| *C. tarpides* | Mexico, Central America, Caribbean | 22, 78 |
| *C. granicollis* | Venezuela, Brazil | 22, 26, 43, 48, 58, 63, 77, 119 |
| *C. manihoti* | Brazil, W. Africa | 22, 26, 43, 48, 77, 92, 119 |
| *C. notaticeps* | Brazil | 26, 43, 48, 77, 92, 119 |
| *C. alternans* | Brazil, Caribbean | 22 |
| *Eulecriops manihoti* | Brazil, Colombia | 22, 23, 48, 92, 119 |
| *Eubulus* sp. | Colombia | 23 |
| CERAMBICIDAE | | |
| *Lagochirus obsoletus* | Cuba, Nicaragua, Indonesia | 24, 101, 114 |
| *L. rogersi* | Colombia | CIAT |
| *Lagochirus* sp. | W. Indies, Florida | 24 |
| *Acanthoderes nigricans* | Colombia | 23 |
| *BOSTRICHIDAE* | | |
| *Sinoxylon brassai* | W. Africa | 76 |
| *Heterobostruchus brunneus* | Africa | 76,77 |
| PYRALIDAE | | |
| *Chilozela bifilalis* | Venezuela | 47 |
| *Chilomina clarkei* = *Pyrausta clarkei* | Venezuela,Colombia | 47, CIAT |
| *Phlyctaenodes fibilialis* | Colombia | 23 |

in the Americas, especially in Brazil (93). They generally cause sporadic or localized damage, and none can be classified as universal pests.

The most important stemborers belong to the orders Coleoptera and Lepidoptera. The dipterans *Anastrepha* spp. (fruit flies) and *Silba* spp. (shoot flies), which may also bore into the stem, are described separately in this report. Stemborers appear to be highly host specific, and few are reported to feed on alternate hosts. Two species, *Megasoma elephas* and *Sylepta gordialis*, are reported to feed on swollen roots in Venezuela (63). Several lepidopteran and coleopteran stemborers are identified from Africa (76, 77, 114); the only one reported from Asia is *Lagochirus* sp. (114) from Indonesia. Seven species of *Coelosternus* are reported attacking cassava in the Americas (22, 24, 26, 48, 58, 63, 77, 78, 92), and *C. manihoti* is reported as a pest in Africa (22). Only *Coelosternus* spp. and *Lagochirus* spp. are discussed in detail here.

*Coelosternus* spp.

*Damage.* Larvae of the *Coelosternus* weevils cause damage by penetrating the stem and tunneling into the center or pith region, which weakens the plant; stems and branches may eventually dry and break reducing the quantity and quality of planting material (22, 63). Although larvae of *C. sulcolutus* have been observed feeding on underground parts of the stem, they have never been found attacking roots (92), but they can reduce root production (78). Frass and exudate from the stem wood, ejected from burrows by feeding larvae, can be found on infested branches or on the ground below the plants (22). Adults also feed on the tips of young shoots or stems, which may retard growth (77, 92, 93).

*Life history, appearance and habits.* Females may oviposit on various parts of the plant but prefer the tender parts (35). In *C. alternans*, oviposition has been observed near broken or cut ends of branches or beneath the bark in cavities made by the proboscis (22). Oviposition by *C. granicollis* begins 3 days after copulation; the female penetrates the stem, depositing up to several white eggs, often no more than one per day (93).

Larvae vary in size depending upon the species. Fully grown larvae of *C. alternans* are 16 mm in length, with a maximum width of 4 mm, whereas those of *C. tarpides* are 9 x 2.5 mm (22). Most larvae are curved, with a yellowish white to pale brown body, a reddish brown head capsule and black mandibles (78). In *C. rugicollis* only a single larva is found in each stem, whereas in the other species there may be several (22). The larval period ranges from 30-60 days (93). The fully grown larvae of all species pupate within a cell constructed in the pith region. The pupa is held securely in place in its chamber at one end of the burrow with larval frass; duration of the pupal period is about 1 month (22, 78). After emerging from the pupal case, the adult may remain in the chamber for several days before leaving the stem. Adults range in size from 6 mm in length for *C. granicollis* to 12 mm for *C. alternans* and *C. rugicollis*. Adults are light to dark brown and may be almost completely covered with yellowish scales (22, 92). They are active throughout the year, but activity may decrease during cooler months in some areas (93).

*Lagochirus* spp.

Larvae of *Lagochirus* spp., long-horned beetles, cause damage similar to that of *Coelosternus*.

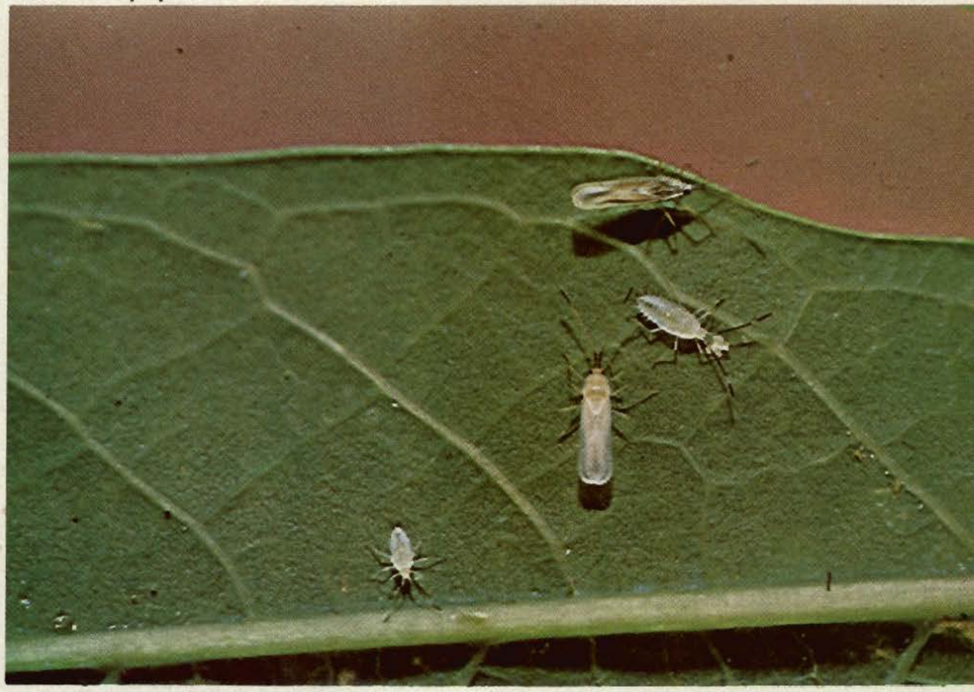
*Life history, appearance and habits.* Adults oviposit in stems and branches about 2.5 cm below the bark; eggs hatch in 5-6 days. The larvae, which take about 2 months to develop, measure up to 29 mm; they feed at the base of the plant and many can be found in one plant. The pupal period, which lasts about 1 month, takes place in the larval chambers in the stem. Adults are

## LACE BUGS

(*Vatiga manihotae*)

Typical leaf damage

Adults and nymphs on underside of leaf



## STEMBORERS

Larvae, pupae and adults of *Coelosternus* sp.

Larva of *Chilozela bifilalis*

Larva of *Lagochirus* sp.

Damage caused by *Lagochirus* sp.

nocturnal, rapid fliers, active throughout the year. They are brown in color, about 17 mm long and feed on leaves and bark (24).

### Control

Since adult stemborers are difficult to kill and larvae feed within the stems (22, 103), pesticidal control is impractical. Resistance to *Coelosternus* spp. has been found in the lines 103 Brava de Itu and 192 Itu (103). Cultural practices that will reduce pest populations include removal and burning of infested plant parts (22, 24, 89, 93). Only uninfested and undamaged cuttings should be used for propagation (24).

## Fruit flies

Two species of fruit flies, *Anastrepha pickeli* and *A. manihoti* (Tephritidae) have been identified attacking cassava in Colombia. The fruit fly was originally reported attacking the fruit, where it causes no economic losses (71, 136). We have observed fruit flies causing severe damage to stems in Colombia, Venezuela and Central America.

### Damage

When oviposition occurs in the fruit, the larvae bore throughout the fruit, destroying the developing seed. The infested fruit will shrivel and become soft, turning yellow green in color (30). Larval tunneling in the stem results in brown galleries in the pith area.

A bacterial pathogen *(Erwinia carotovora* var. *carotovora),* often found in association with fruit fly larvae, can cause severe rotting of stem tissue (29). A white exudate may flow from the larval tunnel and exit holes. As a result of severe attacks, growing points may collapse and die, retarding plant growth and encouraging growth of lateral buds. This secondary rotting may cause a reduction of yield and a loss of planting material. Damaged stems have a rotted pith area, and germination of cuttings from this material can be reduced by as much as 16% and may be delayed by several weeks (30-31). In experiments at CIAT, as many as 84% of the plants have been attacked (29).

Root losses are suspected but not known. It appears that plant age at the time of attack is important; younger plants (2-5 months) suffer more damage. Cassava plants can apparently recover rapidly from fruit fly damage, given adequate, well-distributed rainfall. Plants that had severe rot at 3 months, with dead or rotted growing terminals, were compared to healthy plants over a 6-month period. Plant height measurements showed that within 5 months the damaged plants had recovered and attained the same height as the nondamaged ones (30).

Investigations were carried out at CIAT to determine germination and yield losses due to the use of *Anastrepha*-damaged planting material. Cuttings were separated into five groups, based on damage grades ranging from 0 (no damage) to 4 (severe rotting and tunneling throughout the pith area). Results showed a decrease in cutting germination, ranging from 5% for grade 1 to 16% for grade 4, an average of 9% reduction in germination for damaged cuttings. In addition, plants from damaged cuttings yielded 17.4% less than those from undamaged cuttings; this means a loss of nearly 7 t roots/ha (31).

### Life history, appearance and habits

The yellow- to tan-colored female inserts the egg in the succulent part of the stem, about 10-20 cm from the tip, so that about one third of the egg with a slender white rod protudes. After hatching, the white to yellow larvae bore up- or downward in the stem pith regions. Since numerous eggs may be deposited in one stem, several larvae may be found per stem.

The fruit fly/bacterium association is not fully understood (30). It appears that the bacterium is present on the stem, where it can live epiphytically. Although it is probably not transported by the fly, the boring action of the larvae under high humidity conditions provides the wound needed for bacterial entrance into the stem. Under favorable environmental conditions of adequate rainfall and high humidity, rotting develops (29). Rotting does not seem to favor larvae; inspection of rotting stems showed 40% larval mortality. Thus major fruit fly population increases may result from infestations of the cassava fruit or alternate hosts rather than from stem infestations.

Mature larvae leave the stem or fruit and pupate on the ground. The larval exit hole is clearly visible in the stem. Adults emerge in about 17 days. High fruit fly populations occur year round, but extensive damage is usually associated with the rainy season.

### Control

Since severest damage coincides with the rainy season, rapid plant recovery is facilitated and control measures may not be required. An evaluation of CIAT's germplasm bank indicated varietal differences in degree of larval attack. Larval parasitism, as high as 16%, by a braconid *Opius* sp. has also been observed in the fruit (30); however, parasitism of larvae in the stem has not been found. Hydrolyzed maize was the most successful attractant used in traps for adults. As regards chemical control, it was found that fenthion, applied as a foliar systemic, gave nearly 100% control of the larvae in the stem (30).

## Shoot flies

Shoot fly damage has been observed in most of the cassava-growing regions of the Americas (10, 136). This pest has not been reported from Africa or Asia. Several species, all belonging to Lonchaeidae, have been described, but *Silba pendula* (10) and *Lonchaea chalybea* (10) are the most important. *S. pendula* [= *Carpolonchaea pendula* (136). *Lonchaea pendula* (103, 136), *L. batesi* (73), *L. glaberrina* ] is known to attack several other hosts including *Mammea americana, Mangiera indica, Inga feullei, Eugenia* sp., *Atrus* sp. and *Capsicum frutescens* (72, 136). Other shoot flies are *Silba perezi* (118), *Antherigona excisa* (103), *A. excelsa* (45), *Euxesta eluta* (103) and *Neosilba perezi* (133). Only *S. pendula* will be discussed in detail, the behavior of which is similar to that of *L. chalybea* and *S. perezi*.

### Damage

Larval feeding damage is manifested by a white to brown exudate flowing from the growing points, which eventually die. This retards plant growth, breaks apical dominance and causes germination of side buds, which may also be attacked. These symptoms resemble witches'-broom disease (102). In some cases only part of the tip is killed, and the shoot continues to grow.

Younger plants are more susceptible to attack; repeated attacks may cause plant stunting (30, 103, 131). During severe outbreaks, 86% of the plant population has been reported affected (24). At CIAT (27, 28) simulated damage studies, removing 50 and 100% of the shoots on plants 2-5 and 6-9 months of age, showed that the degree of economic damage is dependent upon plant variety and age. The late-branching variety Mecu.150 was more susceptible than Llanera at early stages (2-5 months), and yield was reduced by about 30%. Shoot removal from 6-9 months did

FRUIT FLIES

(*Anastrepha* sp.)

Adult female

Stem section showing larvae and rot caused by *Erwinia* sp.

Typical symptomatology of attack, showing apical rot and latex exudate

Propagation material affected by *Erwinia* sp. as a result of fruit fly attack

not affect yields of either variety. On an individual plant basis, there was a 15.5, 16.7 and 34.12% yield reduction when natural attack occurred at 4.5, 5.5 and 6.5 months, respectively. Affected plants were shorter and may have been shaded by healthy neighbors; hence these yield losses may be overestimated (30).

Studies in Costa Rica showed that shoot fly attack resulted in increased branching, foliage and production (120). Simulated damage studies in Florida (133) resulted in reduced height of damaged plants (159 cm vs. 241 cm) and an increased number of terminals for plants attacked once a month. However, there were no significant yield differences. Damaged plants had approximately the same number of leaves as undamaged ones.

#### Life history, appearance and habits

The dark metallic blue adult of *Silba pendula* oviposits between the unexpanded leaves in the growing points or in a small cavity made in the tissue by the ovipositor (136). As many as 22 eggs per shoot have been observed but 3-8 eggs per shoot is average (24). The eggs hatch in about 4 days, and the young larvae tunnel in the soft tissue, eventually killing the growing point (24, 131). Several whitish larvae may be found in the affected tip. It is claimed that the larval exudate gives protection against parasites and insecticides (24). The larval period is about 23 days; larvae pupate in the soil and the adult fly emerges about 26 days later (131). The fly is especially active on sunny days.

Development of the immature stages of *N. perezi* appears similar to *S. pendula*, but the adult of *N. perezi* lives 3-5 times longer than that of *S. pendula* (133).

Attacks may occur throughout the year (66); but in many areas they are seasonal (24, 35, 103), often at the onset of the rainy season (131). At CIAT (30) the dry period was favorable for higher shoot fly populations.

#### Control

The lack of data showing significant yield losses due to shoot fly damage indicates that control measures may not be necessary. Insecticide applications should be avoided since they are costly and their effectiveness, in terms of increased yields, has not been proven.

*Cultural practices.* Destruction of infested shoots at weekly intervals has been recommended but is not believed effective since there are alternate hosts (136). Planting dates can be adjusted so that the younger growing stage is passed during low shoot fly populations (27, 30, 103).

*Resistance.* Distinct varietal differences in susceptibility to shoot flies have been observed, but no extensive screening has been done (100, 101). In Guadeloupe, the varieties Petit Bel Air 4, Rais Blanc, Campestre 10 and Gabela were more resistant to *L. chalybea* (66). In Brazil, the varieties IAC 1418 and Ouro do Vale showed some resistance to *S. pendula* (19).

*Chemical control.* Larvae are difficult to control. Systemic organophosphates have been used during early attacks when populations are high (23, 101). Insecticides and a sugar solution sprayed on plants act as a bait for adult control (96, 101). Fly traps with insecticide, using decomposing fruits, casein or yeast as attractants, are also effective (136, 137).

### Scale insects

Several species of scales have been identified attacking stems in many cassava-growing regions of the Americas (24, 27, 29, 38, 109), Asia (44, 53, 88) and Africa (33, 53, 126) (Table 3).

Table 3. **Scale insects reported attacking cassava.**

| Family and species | Reported from |
|---|---|
| DIASPIDIDAE | |
| *Aonidomytilus albus* | Americas, Africa, Asia |
| = *Coccomytilus dispar* | Asia (Taiwan, India) |
| = *Lepidosaphes dispar* | Africa |
| = *Lepidosaphes alba* | Cuba |
| *Pinnaspis minor* | Peru |
| = *Hemichionaspis minor* | Peru |
| COCCIDAE | |
| *Saissetia hemisphaerica* | Madagascar |
| = *Lecanium hemisphaerica* | Mauritius |
| *S. nigra* | Madagascar, Malaya, Indonesia |
| *S. coffeae* | Madagascar |
| *S. miranda* | Colombia |
| *Coccus viridis* | Madagascar |
| *Mytilaspis dispar* | Madagascar |
| *Eurhizococcus* sp. | Brazil |
| *Monophebus* sp. | Brazil |

The most important scales appear to be *Aonidomytilus albus* (34) and *Saissetia* sp. (44, 53). *A. albus* has been observed on cassava throughout most of the cassava-growing regions of the world. This scale, which may have been disseminated from one continent to another on planting material, is now the most widely distributed cassava pest.

### Damage

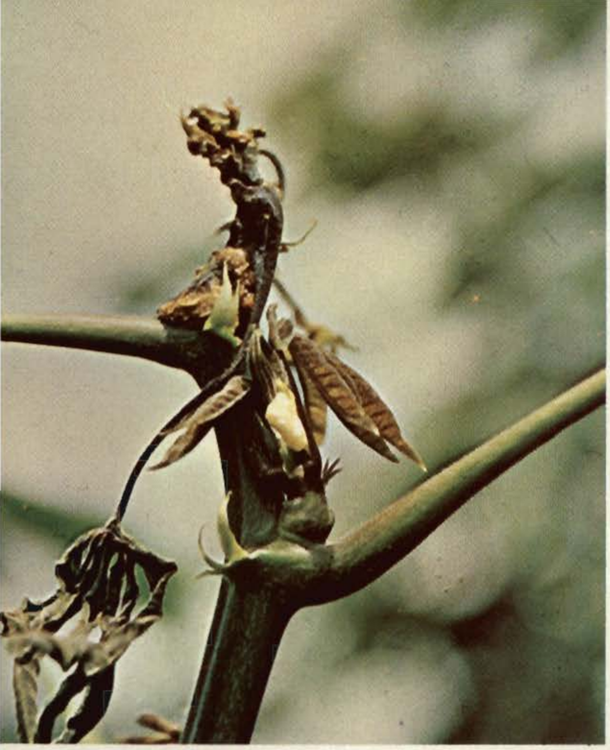
Leaves on attacked stems yellow and fall; in severe attacks the plants are stunted, the terminal bud can be killed and stems can dessicate, causing plant mortality. Heavy scale populations may cover the stem and lateral buds. *Saissetia coffeae* is reported attacking leaves, causing leaf curling (44). Scale damage appears to increase when cassava is planted continually on the same land. Outbreaks are severest during the dry season, thus aggravating drought stress.

The greatest damage from scale attack appears to be the loss of planting material as a result of the death of lateral buds. Studies at CIAT (27) with cuttings heavily infested with *A. albus* resulted in 50-60% loss in germination. Stored cuttings can also be lost because of scales (117).

Recent studies at CIAT showed that yield losses due to *A. albus* can reach 19% on a susceptible variety when the stem is almost completely covered with scales, causing severe defoliation and occasionally death of the terminal bud (31). Reduction in yield (53) and root quality (126) have been reported.

# SHOOT FLIES

(*Silba pendula*)

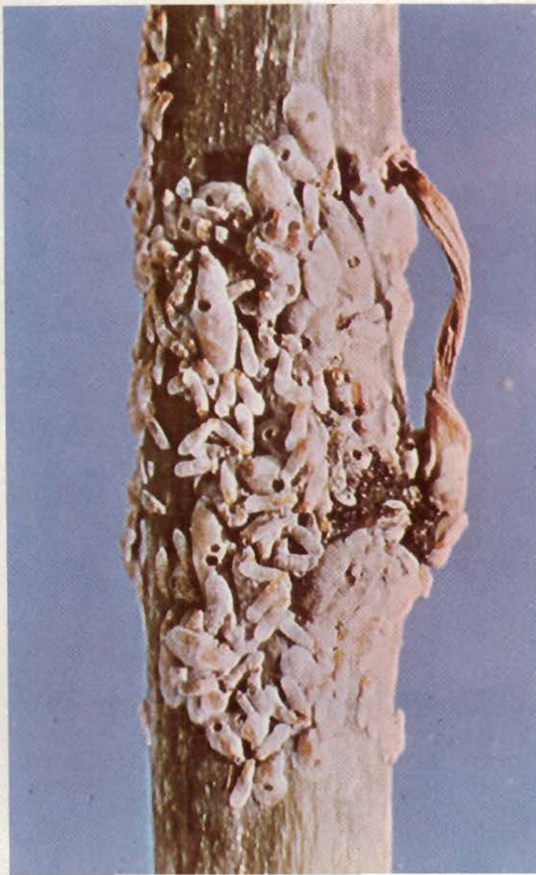


**Typical damage**

**Close-up of damage; note cream-colored exudate**

**Interior of shoot showing larvae**

Severe attack by the white scale *Aonidomytilus albus*



Close-up of *A. albus;* note exit holes on scales, made by parasites

**Life history, appearance and habits**

The biology of *A. albus* has been studied in detail by Swaine (126). The female scale of *A. albus* is mussel shaped and covered with a white waxy excretion. The cast skins of the first and second nymphal stages are incorporated in the scale. Unlike the females, males have well-developed legs and wings. The female produces an average of 47 eggs, depositing them between the upper scale covering and the lower cottony secretion. During oviposition the female shrinks and shrivels up. Eggs hatch in 4 days; the first nymphal instars (crawlers) are locomotive and can disperse. These crawlers become fixed in 1-4 days, cover themselves with numerous fine threads, molt in 11 days and become immobile. After 4 days the adult female appears and commences oviposition in 1-2 days. One female generation is passed in 22-25 days.

In laboratory studies at CIAT (31) on excised cassava stems, male scales pass through two nymphal stages, averaging 10 and 6.5 days, respectively, and a prepupal and pupal stage of 4.5 days in total. Adults live from 1-3 days and the male life cycle is about 23 days. There are three female nymphal instars, averaging 10, 5 and 9 days, respectively. The third instar is the adult stage. Eggs are oviposited under the scale and nymphs emerge during a 7-day period, with peak emergence occurring from the 3rd to 5th day. Each female produces an average of 43 nymphs.

Females of *Eurhizococcus* sp. are described as very mobile; they enter the soil and in 5-7 days, the ootheca with eggs appears on the soil surface. There are three nymphal instars, totaling 28 days, before the female appears. No males were observed (38).

Dispersal occurs by wind, active crawling or infested cuttings. The most important means of dissemination is by storing infested cuttings with healthy ones (126).

**Control**

The most effective means of control is through the use of uninfested planting material and cutting and burning infested plants to prevent the spread of infestation (84).

*Chemical control.* Chemical control may be reqüired during the dry season. Measured in percentage of adults killed, systemic insecticides and parathion were most effective (3, 124). As for chemical control of cuttings, dipping those that are infested with crawlers in DDT emulsions for 5 minutes reduces infestation; however, heavily infested cuttings still germinate poorly (27, 126). The insecticides malathion 4% (1 g/liter), Hostathion (1 cc/liter), Tamaron (1 cc/liter) and Triona + malathion (2 cc + 1 g/liter) all prevented a rapid increase of scale populations after planting (31, 84)

*Biological control.* Heavy predation of *A. albus* by a coccinellid, *Chilocorus distigma*, is reported (76). Hymenopterous parasites, *Aspidoiphagus citrinus* and *Signiphora* sp., are reported in Cuba (24).

We have observed heavy parasitism and predation of *Saissetia miranda* in the field, but the species have not been identified. We have also found a brown, spongelike fungus, *Septobasidium* sp., growing on *A. albus*.

## Mealybugs

Mealybug damage to cassava has been reported from Colombia (28, 30), Brazil (2, 64) and parts of Africa (88). The species at CIAT has been identified as *Phenacoccus gossypii*, the Mexican mealybug; and *P. gossypii* and *Phenacoccus* sp. are reported from Brazil (64). *P.*

*manihoti* has recently been reported from Africa (Zaire) and South America (7). Other mealybugs reported from Africa are *Pseudococcus virgatus* (= *Ferrisiana virgata, Dasiulopius virgatus*), *Pseudococcus citri* and *Pseudococcus adonidum* (88).

**Damage**

There is no record of economic losses in cassava resulting from mealybug attack; observations indicate that this pest is capable of causing crop losses. Albuquerque (2) reported a severe attack of mealybugs causing plant mortality at the Centro de Pesquisa Agropecuária do Trópico Umido in Belém, Brazil in 1975. This was the first time this pest was reported from the Amazon region. All 150 cassava varieties at the center were susceptible. High mealybug populations cause defoliation and drying of stem tissue, resulting in a loss of planting material. Leaves will turn yellow and dry, and defoliated plants form new buds, which are also attacked (30).

In Africa, *P. manihoti* first attacks the terminal points of the shoots, then the petioles and expanded leaves. Internodes are shortened, there is leaf curling and reduced new-leaf growth. As population density increases, all green parts of the damaged shoot eventually die. Infestation of the lower leaves, together with natural leaf fall during the dry season, gives the plant a "candlestick" appearance (81).

**Life history, appearance and habits**

*P. gossypii* has a wide host range, including food crops as well as many ornamentals (90). Females deposit sacks containing a large number of eggs around the axil of branching stems or leaves, on the underside of the leaf where the leaf petiole joins the leaf, or around the buds on the main stem. The young nymphs, shortly after initiating feeding, exude a white, waxy material from their bodies, which forms a cover over the insect. High populations give a cottony appearance to the green or succulent portion of the stem and on the leaf undersurface. They do not remain fixed but move slowly over the plant surface (2, 30). Adults measure about 2.4 by 1.5 mm.

Life cycle studies of *P. gossypii* were conducted on excised cassava stems and leaves in the laboratory (temperature 26-28°C, RH 75-85%) at CIAT (31). There are three female nymphal instars averaging 8.6, 5.7 and 6.3 days, respectively. Adult females are able to survive for up to 21 days; oviposition occurs over a 5-day period, with an average of 328 eggs per female. Eggs are located in an egg pouch which the female carries on the posterior end of her body until the nymphs hatch. Nymphs are mobile throughout their life cycle but may remain feeding in one area for several days. The female remains wingless whereas the male develops wings, enabling flight. Males pass through two nymphal stages (8.5 and 6.0 days, respectively), a prepupal (2.1 days) and pupal (2.1 days) stage before adults emerge. Adult males live from 1-3 days. There is a sex ratio of one male to three females.

Leuschner (81) describes *P. manihoti* as probably being parthenogenetic since no males have been observed in the field or laboratory populations. He reports that the female lays about 440 eggs during its life span. Eggs hatch in about 8 days. The duration of the nymphal stages is about 25 days at 25°C and the female adult life span is about 29 days. The dry season appears to favor mealybug population buildups.

**Control**

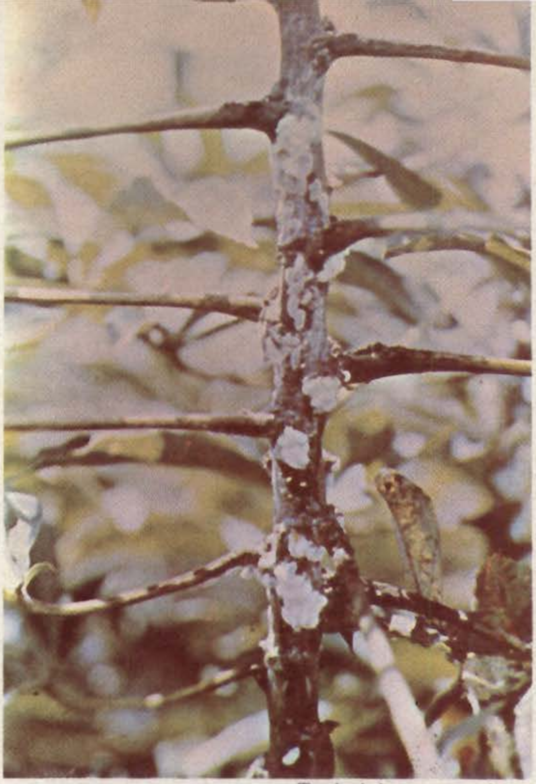
Reports indicate that this pest may be difficult to control. Albuquerque (2) states that no

*Ceroplastes* **sp., a scale that attacks the stem**

**The black scale** ***Saissetia*** **sp.**

# MEALYBUGS

(*Phenacoccus gossypii*)



Typical damage to plant

**Adult *Cleothera onerata*, a coccinellid predator**

**Larva of *Ocyptamus* sp. (Diptera), preying on mealybug nymph**

**Pupa and adult of *Ocyptamus* sp.**

insecticide gave complete control but that parathion was most effective. Biological control and host plant resistance studies have been initiated. Several predators and parasites of *P. gossypii* have been collected at CIAT (31). Predators include *Cleotera onerata, Cleotera* sp., *Scymnus* sp., *Coccidophilus* sp., a Coccinellidae; the neuropterans *Chrysopa arioles* and *Sympherobius* sp.; the dipteran *Ocyptamus* sp. (*stenogaster* Will. complex) and the lepidopteran *Pyroderces* sp. The only natural enemy of *P. manihoti* found in Zaire was the predator lycaenid butterfly *Spalgis lemolea* (7, 81).

## Insects that attack roots, cuttings and seedlings

### Grubs

Grubs are pests of cassava all over the world and are reported as a serious problem in Indonesia (74). Although several species are mentioned in the literature, *Leucopholis rorida* (Indonesia) and *Phyllophaga* sp. (Colombia) appear to be the most important. The adult stage of the grub is a beetle, usually of the family Scarabaeidae or Cerambycidae. Those reported in literature (29, 44, 74, 114) include *Leocopholis rorida, Lepidiota stigma, Euchlora viridis, E. nigra, E. pulchripes, Anamala obsoleta, A. atcharalis, Phyllophaga* sp., *Heteronychus plebejus, Opatrum micans, Corphopilus margirellus, Dactylosternum* sp., *Inesida leprosa, Petrognatha gigas* and *Sternotomis virescens*.

#### Damage

White grub damage is characterized by the destruction of the bark and buds of recently planted cuttings and the presence of tunnels in the woody part. These cuttings may rot and die. When young plants (1-2 months) are attacked, they suddenly wilt and die. Larvae will feed on bark of the lower stem just below the soil, roots and swollen roots (6, 74).

Studies with *Phyllophaga* sp. at CIAT (29) show that germination could be reduced by 95% in experimental plots; losses of 70% have been reported from Madagascar (44).

#### Life history, appearance and habits

The biology of *L. rorida* on cassava has been described in Indonesia (74). Adults become active after the rains have started, and the most severe damage occurs about 4-6 months later. The adult beetles initiate oviposition about 9 days after mating, laying up to 37 pearly white eggs singly, 50-70 cm deep in the soil. Larvae hatch in about 3 weeks. The larval stage is about 10 months, with the 4- to 6-month-old larvae being the most destructive. Larvae live about 20-30 cm deep in the soil where they feed on roots. Pupation takes place at a depth of about 50 cm. The prepupal stage is 14 days and the pupal stage is about 22 days. Additional hosts include maize, rice and sweet potatoes.

Observations of *Phyllophaga* sp. in Colombia indicate that there is a one-year cycle, with heaviest damage occurring at the onset of the rainy season. Attacks often occur if cassava is planted in land previously used for pasture or in a weedy, abandoned field. High populations can often be detected at the time of land preparation.

#### Control

*Biological control.* Several larval parasites of the grub have been identified (74) including several species of *Dielis (D. lectuosa, D. tristis, D. thoracica, D. javanica, D. formosa* and *D. annulata).* Parasitism in one study reached 26% (74). A muscardine fungus *Metarhizium* *anisopliae* is pathogenic to the grub, and recent experiments at CIAT indicate that this may be an effective control method (30). Diseased grubs have been found under natural conditions (30, 74).

*Chemical control.* White grubs were controlled with aldrin and carbofuran as a dust or in granular form applied below the cutting in the soil (29); insecticidal dip treatments for cuttings were not as successful.

## Cutworms

Cutworms, a universal pest, have been reported to attack cassava in the Americas (28, 37) and Madagascar (53). The species reported are *Prodenia litura* [ = *Hadema littoralis* (53)] , *P. eridania* [ = *Xylomyges eridania* (37)] and *Agrotis ipsilon* (28).

### Damage

Cutworm damage to cassava can be grouped into three categories: (a) Surface cutworms, such as *A. ipsilon* and *P. litura,* chew off plants just above, at, or a short distance below the soil surface, leaving the plant lying on the ground (6, 53). Plants will recover and continue to grow. A similar type of damage by crickets is reported (1). The larvae of *A. ipsilon* are greasy gray to brown, with faint, lighter stripes (6, 28). (b) Climbing cutworms ascend the stem, feeding on buds and foliage; they may also girdle the stem, causing the upper part of the plant to wilt and die. Larvae of the southern armyworm *P. eridania* have been reported to cause this type of damage in cassava-growing areas (37). They are dark gray to black in color, with lateral yellow stripes. (c) Subterranean cutworms remain in the soil, feeding on roots and underground parts of the stem, causing a loss of planting material. The bark and buds may be completely stripped. We have also observed *A. ipsilon* attacking cuttings in Colombia (6).

Losses of young plants as a result of cutworm damage may reach 50%, making it necessary to replant. In simulated damage experiments at CIAT (28), shoot removal of recently germinated cuttings showed that some varieties and shorter cuttings are more susceptible to this damage.

### Life history, appearance and habits

The biology of the cutworm species that attack cassava is similar. Eggs are laid in masses on the undersides of leaves near the soil. Eggs hatch in 6-8 days and develop in 20-30 days. The pupal stage (8-11 days) is passed in the soil or under plant debris. Oviposition is initiated about one week after adults emerge. A generation lasts about 2 months; under favorable environmental conditions, several generations will occur in one year (37, 53).

### Control

Cutworm attacks are sporadic but occur more frequently when cassava follows maize or sorghum, or is planted adjacent to these crops. Longer cuttings (30 cm) will allow plants to recover from surface cutworm attack. Cutworms attacking plants at or above ground level may be controlled effectively with poison baits (10 kg of bran or sawdust, 8-10 liters of water, 500 g of sugar or 1 liter of molasses, and 100 g of triclorfon for 0.25-0.5 ha). Underground cutworms can be controlled by applications of aldrin or carbofuran around the cuttings.

## Termites

Termites attack cassava mainly in the tropical lowlands. They are reported as pests in several areas of the world but primarily in Africa (53). *Coptotermes voltkowi* and *C. paradoxis* have

**Larva of *Sympherobius* sp. (Neuroptera) attacking mealybug ovisac**

**Adult *Sympherobius* sp.**

**Adult *Chrysopa* sp. (Neuroptera), a predator**

**Larvae and adult *Pyroderces* sp. (Lepidoptera), predator and pest of crops such as sorghum**

WHITE GRUBS

(*Phyllophaga* sp.)

Larvae attacking propagation material

Cuttings showing different degrees of damage

Death of seedling due to attack

been identified from Madagascar (53). They feed on propagation material roots, swollen roots or growing plants. Principal damage appears to be loss of cuttings; plant establishment can also be affected severely, especially during prolonged dry periods (33, 53).

In Colombia termites have been observed causing considerable losses in germination, as well as death of young plants, in several cassava-growing areas, especially where soils are sandy. In studies done at CIAT (31) nearly 50% of stored propagating material was lost due to termite feeding, and germination losses of 15-30% have been recorded. We have also observed swollen root damage by termites with subsequent root rot.

#### Control

Propagation material can be effectively protected by dusting with aldrin, Clorvel or Sevin. Aldrin, applied as a dust at the rate of 1 g per cutting at the time of planting, prevented termite attack of germinating cuttings (31).

### Crickets

Crickets damage plants by clipping recently emerged young shoots or feeding on the base of the plant, making it more susceptible to lodging (55). *Gryllotalpa africana*, reported from West Africa, is described as cutting and piercing roots and basal parts of the stem (1). *Brachytripses ackatimes* has been reported from Malaya (62). Poison baits such as those described for cutworms appear to give effective control.

## Storage pests of dried cassava

Approximately 38 insects, mainly Coleoptera, are reported as found on dried cassava chips or products (54, 113, 132, 135). Many are polyphagous; only those able to reproduce on dried cassava are important. These include *Stegobium paniceum* (113), *Araecerus fasciculatus* (54, 113, 132, 135), *Rhizopertha dominicana* (54, 113, 135), *Dinoderus minutus* (132), *Tribolium castaneum* (113, 132) and *Latheticus oryzae* (132). Most damage is reported from Asia (113) and Africa (1, 54), and on imported dried cassava in Europe (132).

No data are available on losses in dried cassava resulting from insects. Cassava chips were reduced to dust in 4-5 months in India (113). Recent studies at CIAT indicate that *A. fasciculatus*, the coffee bean weevil, and *D. minutus*, the bamboo powderpost beetle, can cause considerable losses.

### Life history, appearance and habits

Cotton (41), among others, gives detailed references and information on the biology of many of these storage pests. Indications are that dried cassava roots are not a good nutritional medium for insects because they lack protein, vitamins and micronutrients (132, 135).

### Control

Proper sanitary measures, such as cleaning and disinfecting warehouses prior to restocking and rapid removal of infested material, are the most effective control measures (1). Bitter varieties of cassava are reported to be more resistant to weevils than sweet ones (70); however, this needs confirmation. Standard grain fumigations also give effective control of these pests (113).

## Crop protection

The recent interest in cassava as an energy source for human, animal and industrial needs is bringing about an increase in production of this crop, as well as a change in production technology. The need for a relevant and sound crop protection program takes on added importance. As previously stated, cassava has historically been cultivated on a small scale with several varieties being grown in one region or even on one farm. The genetic variability in this system has helped to safeguard against major epidemics of pests and diseases. In recent years there has been a shift in this system toward large cassava plantations, employing a limited number of high-yielding hybrids or varieties. These varieties or hybrids are often ideal plant types; that is, efficient plants that will not produce excessive foliage as many traditional varieties do at present. The reasonably stable equilibrium that presently exists between pest and genotype in subsistence agriculture will be almost impossible to maintain in modern agricultural systems.

The major objective of a cassava pest management program is to suppress insect pests and maintain populations below their economic threshold. This should be done with a minimal use of costly inputs, especially pesticides. The accomplishment of this goal requires greater knowledge than we now possess of the biology and ecology of many of these pests. Advantage should be taken of the favorable factors involving the insect/plant/environment interaction and socioeconomic considerations that make a cassava pest management system an attractive and practical goal. These factors include:

1. Cassava is cultivated from 8 to 24 months, making the continual use of pesticides costly.

2. Being a long-season crop, cassava is ideally suited for a biological control program, especially in areas where there is considerable acreage and continual planting of cassava. Biological control agents have been identified for many of the major pests.

3. The cassava plant is often able to recover from insect damage. During periods of adequate rainfall, high levels of defoliation can result in little or no yield reduction.

4. Many pests are not widely distributed and pest incidence is often seasonal. The dry periods favor population buildup of many pests, but the plant's ability to withstand long periods of drought will usually result in its recovery at the onset of rains.

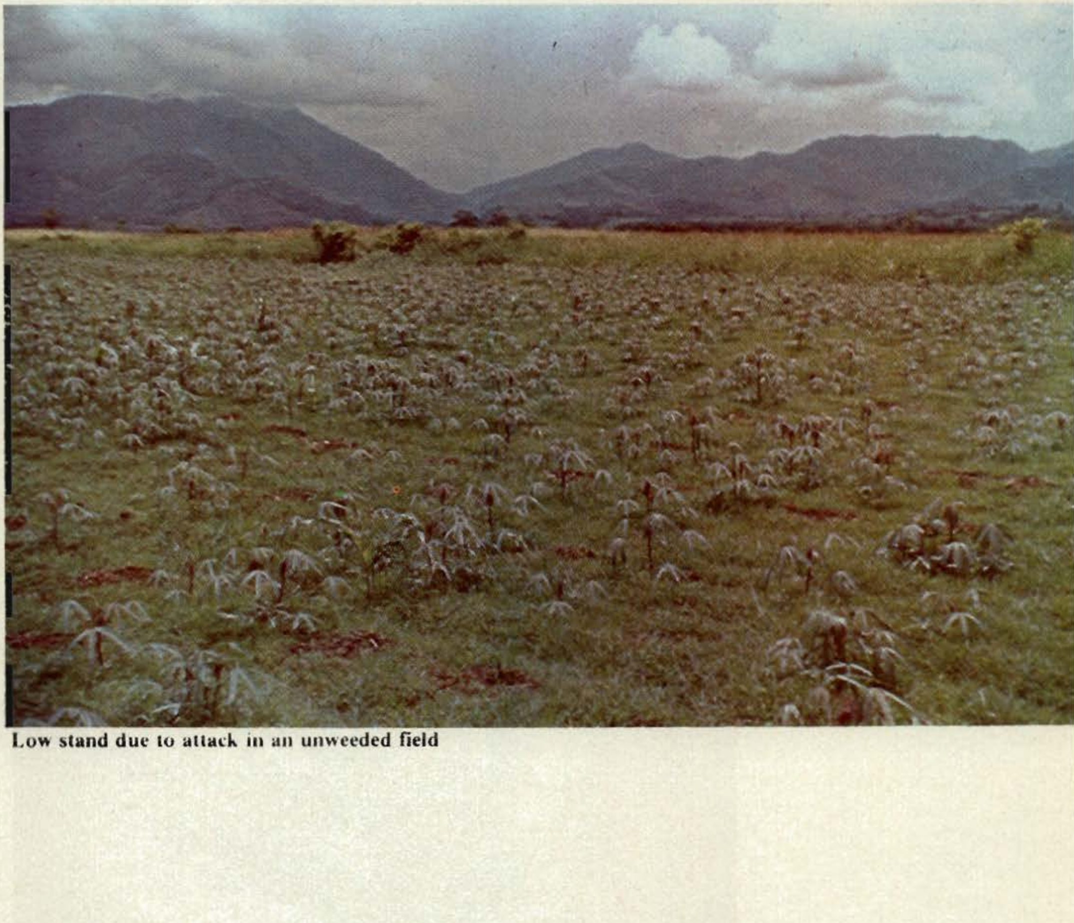
5. Cassava has a high economic threshold; vigorous varieties can lose considerable foliage (40% or more), and there are periods when the plant can undergo much higher defoliation with no significant reduction in yield. However, the new varieties developed may have a lower tolerance to defoliation.

6. Few, if any, pests will actually kill the plant, enabling it to recover from damage and produce edible roots.

7. The selection of healthy, vigorous planting material, combined with a low-cost fungicidal and insecticidal treatment, initiates rapid and successful germination, ensuring early plant vigor during this important phase and ultimately increasing yield.

8. Studies have shown that there are sources of pest resistance in cassava which, although often low levels, may be adequate to prevent serious crop losses.

9. Cassava is often grown on small farms and under multicropping conditions; this system not only reduces pest incidence but also ensures against pest outbreaks over extended areas.



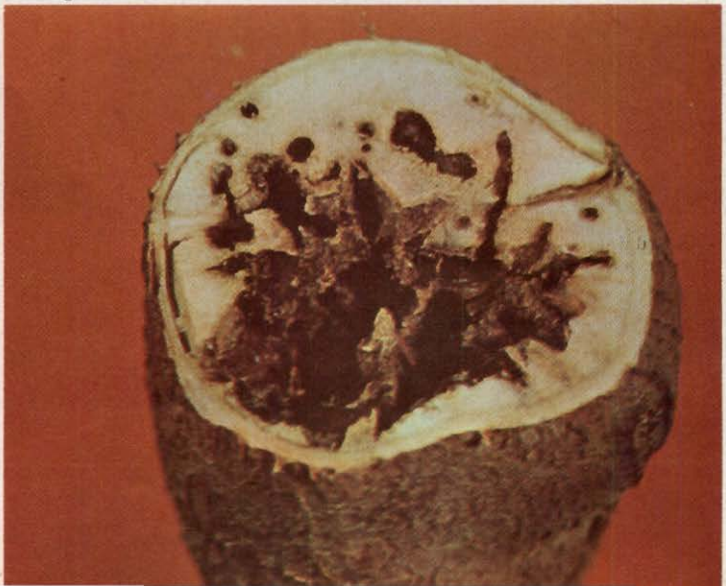
Low stand due to attack in an unweeded field

TERMITES

Infested planting material

Galleries made in stems

Damage to thickened roots



10. Evidence is that insects can cause yield reductions during specific periods in plant development. These periods should be identified so that control practices can be intensified during this time.

Since cassava pest control has received only limited attention until recently, few, if any, real trends or practices have become established over a wide area. Cassava is a low-value crop in most areas, so the use of costly pesticides has not become a common practice as is the case with cotton. The use of pesticides does not appear economically justifiable; therefore, their application should be limited. The mention in this paper of the use of insecticides for controlling cassava pests is not necessarily an endorsement of this practice.

## The role of different control methods

There are several methods for reducing pest populations below their economic injury level. An integrated control program utilizing cultural practices, selection of planting material, resistant varieties, biological control and alternative methods such as pheromones or attractants should be developed. Insecticides will be used because they offer the most immediate and rapid means of reducing pest populations over a short period. However, it is strongly felt that no pest management program should be dependent upon pesticides and they should be used only as a last resort, on a short-time basis. Nevertheless, treating planting material with pesticides is economical and effective for certain pests.

Insecticidal applications to cassava foliage may temporarily reduce pest populations, but indications are that they are ineffective over a long period as they may also reduce parasite and predator populations (8, 57). This can lead to rapid buildups of pest populations or to secondary pests (normally suppressed by natural enemies) becoming more destructive.

There are several cultural practices that can reduce pest populations. These include the use of insect-free planting material, the destruction of plant parts containing shoot flies, stemborers and scale insects, and the planting of several varieties on a single plantation. The implementation and practicability of some of these practices may be reduced as more modern agricultural technology is applied to cassava production.

Alternate means of control such as the use of pheromones, juvenile hormones, attractants and growth regulators are future possibilities and may be economically feasible on large cassava plantations; however, their use may be prohibitive for the small grower.

Since many cassava pests are not widely distributed, especially from one continent to another, it is important that an efficient quarantine program be developed and enforced within and between continents. As new high-yielding hybrids are developed, there will be increased movement of planting material. Since cassava is vegetatively propagated, many insects and diseases can be transported from one area to another. Precautions should be taken to send only insect- and disease-free planting material, and all vegetative material should be treated with an insecticide to prevent the dissemination of insects such as scales, mites, mealybugs, thrips and other pests. Material should also be free of stemborers or fruit fly larvae.

We strongly feel that an integrated control program for cassava pests should be based on biological control and host plant resistance. These two links in an integrated control chain will play important roles in future cassava pest management programs. Extensive studies in both of these areas are being carried out for several cassava pests.

**Biological control**

Numerous natural enemies have been identified and found efficient in reducing populations of cassava pests. Concentrated biological control studies for cassava pests are a rather recent effort; three systematic studies and consequent programs have been inititated. Bennett & Yaseen (8) have evaluated the effectiveness of biological control of the mite *M. tanajoa* with the Staphylinidae *Oligota minuta*. Studies on the biological control of the mealybug *Phenacoccus manihoti* involve a collaborative program between the Commonwealth Institute of Biological Control in Trinidad, IITA and CIAT.

A program studying the biological control of the cassava hornworm, *E. ello*, has been in effect for nearly six years at CIAT (28-31). This program combines egg and larval parasitism, larval predation and larval diseases.

Several other cassava pests offer the possibility of being controlled effectively by natural enemies. There are several parasites or predators of scale insects, whiteflies, the gall midge and fruit flies that have been identified and require further study. Prelimanary studies at CIAT on control of the white grub (*Phyllophaga* sp.) using the muscardine fungus *Metarhizium anisopliae* are promising.

There is excellent potential for implementing biological control as a low-cost, environmentally sound and compatible component of a cassava pest management program.

**Host plant resistance**

Host plant resistance offers the most economical and environmentally sound means of controlling cassava pests. Resistance to pests attacking cassava is not reported extensively in the literature; most reports deal only with field observations. Ongoing systematic evaluation of germplasm for pest resistance has been initiated at CIAT, IITA and several national research centers. Varying degrees of varietal resistance have been reported for mites (4, 29-31, 104), thrips (122), whiteflies (30, 31, 61), stemborers (103) and shoot flies (19, 100). Cassava germplasm is presently being evaluated for resistance to mites, thrips, scales, mealybugs, whiteflies, fruit flies and lace bugs.

The decision to identify and utilize host plant resistance for specific cassava pests depends upon various criteria that should be taken into consideration when establishing a program of this nature. These criteria include:

1. The level of economic damage being caused by a particular pest should be significant.
2. Resistance should be sought only for those pests where it is considered feasible.
3. The availability of adequate, low-cost alternative methods of control of certain pests could negate the need for entering into an extensive resistance breeding program.
4. The levels of resistance needed to reduce pest populations below an economic injury level should be considered. Since some cassava varieties have a high economic threshold, high levels of resistance may not be necessary.
5. Low levels of resistance can be combined with other control methods (i.e., biological control or cultural practices), to maintain insect populations below economic damage levels.

6. Multiple cropping systems may require lower levels of resistance since these systems may have reduced insect populations.

Cassava is a leafy, highly heterozygous naturally cross-pollinated, woody perennial. It has a long growth cycle and is easily propagated by seed or cuttings. It is grown in a scattered cultivation pattern with many traditional varieties that have various degrees of susceptibility to insects and diseases. These characteristics indicate that there is a minimum of selective pressure being exerted by pests in cassava cultivation. Vertical resistance in terms of the gene-for-gene theory would probably not evolve within such a system; therefore, resistance is probably of the horizontal type, inherited multigenically. Resistance to major cassava diseases appears to confirm this assumption. Since horizontal resistance is more stable and entails less risk as to the development of biotypes, cassava insect resistance studies should have horizontal resistance as their goal.

A cassava pest management program should place emphasis on combinations of three fundamental tactics: (1) host resistance, (2) biological control and (3) cultural control. It is important to note that pest damage to the cassava plant does not neccessarily result in a yield reduction or loss of quality of the harvested crop; therefore, control methods need not be applied unless there is an estimation of yield reduction. The ability of the cassava plant to recover from pest injury is an important criterion that should always be taken into consideration.

## The status of cassava entomological research

Concentrated research in cassava entomology is recent. At CIAT, for example, the research program is less than 7 years old, and a full-time entomologist has been assigned only for the last 4 years. Few national governments have cassava research programs, and entomology seldom occupies a significant role in any program that might exist.

We are presently confronted with an extensive range of studies that needed to be done before an effective pest management program can be developed. These studies should be oriented towards a minimal use of pesticides and the development of alternative control methods that will not destroy the ecological balance between pests and parasites found in cassava plantations. Emphasis should be placed on the following aspects: determination of yield losses and levels of economic injury for the major pests or combination of pests; the role of the environment and the influence of plant age on pest incidence and severity of damage; studies on the biology and ecology of all important pests, determining the most feasible control methods (host plant resistance for mites, whiteflies, thrips, mealybugs; biological control for hornworms, scales, white grubs, mites; cultural practices for cutworms, fruit flies, shoot flies); studies on potential pest problems that could occur if cassava acreages increase and monocultures and continuous planting of cassava are practiced; investigation of the danger of major or secondary pests becoming increasingly important as high-yielding varieties are released; studies into alternate control practices such as attractants, pheromones, or insect-growth regulators; investigating pest problems during the storage of planting material and the establishment phase of the plant; and production of insect- and disease-free planting material (as the basis for an effective quarantine program, a worldwide survey should be undertaken to identify cassava pests accurately and establish their true distribution).

Since cassava entomological research is concentrated in only a few institutions, it is feasible to establish guidelines and recommendations for future research goals and the implementation of a pest management program. The time to do this is now while cassava entomological research is still in its infancy. In November 1977, a Cassava Protection Workshop, sponsored by CIAT brought together researchers and pest management specialists from all over the world to consider these problems (18).

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# APPENDIX

## Indices for classifying pest damage

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**Octavio Vargas H. ***

Thus far little attempt has been made to standardize procedures for evaluating pest impact on cassava. Based on our observations in the screenhouse as well as in the field, we have drawn up the following scales with the hope that they will be used by cassava entomologists and agronomists in order to obtain standardized reports, which is basic for comparing results from one country to another. We would also welcome an interchange of experiences in this regard.

| Pest | Level of damage | Type of damage and/ or level of infestation |
|---|---|---|
| Thrips *(Frankliniella williamsi, Corynothrips stenopterus, Caliothrips masculinus, Scirtothrips manihoti)* | 0 | No damage |
| | 1 | A few yellow spots on terminal leaves |
| | 2 | Shoots and/or adjacent leaves slightly deformed and with yellow spots |
| | 2.5 | Shoots and/or leaves with moderate deformation (reaching the veins) |
| | 3 | Severe deformation of leaves and/or shoots |
| | 3.5 | Same as in 3, plus great reduction in leaf area |
| | 4 | Shoots completely deformed or dead; no adjacent leaves |
| | 5 | Witches'-broom appearance; death of terminal and lateral growing points |
| White scales *(Aonidomytilus albus)* | 0 | No scales present |
| | 1 | A few scales found around lateral or terminal buds |
| | 2 | Same as in 2; some internodes attacked |
| | 3 | Scales completely covering growing points and 50% of internodes; loss of lower leaves |
| | 4 | Approx 75% of stem and branches covered with scales; loss of intermediate leaves |
| | 5 | Scales completely covering stem and branches; desiccation of terminal shoots |
| Termites *(Coptotermes spp.)* | 0 | No damage |
| | 1 | Tunnels in $<$25% of the cuttings; viable plant |

* Entomologist, Visiting Scientist and Research Associate, respectively, Cassava Program, CIAT

| Pest | Level of damage | Type of damage and/or level of infestation |
|---|---|---|
| | 2 | Tunnels in 26-50% of the cutting; viable plant |
| | 3 | Tunnels in 51-75% of the cutting; leaves wilt and plant begins to die |
| | 4 | Tunnels in > 75% of the cutting; plants die |
| Shoot flies *(Silba pendula, Lonchaea chalybea)* | 0 | No damage |
| | 1 | Up to 25% of shoots attacked |
| | 2 | 26-50% of shoots attacked |
| | 3 | 51-75% of shoots attacked; plant growth retarded |
| | 4 | 76-100% of shoots attacked; plant growth retarded |
| Cassava hornworm *(Erinnyis ello)* | 0 | No damage |
| | 1 | Up to 10% defoliation |
| | 2 | 11-25% defoliation |
| | 3 | 26-50% defoliation |
| | 4 | 51-75% defoliation |
| | 5 | 76-100% defoliation and/or growing points and stem attacked |
| Fruit flies *(Anastrepha pickeli A. manihoti)* | 0 | No damage |
| | 1 | Larval tunneling in stem; plant appears normal |
| | 2 | Tunnels and white exudate or latex in stem; plant appears normal |
| | 3 | Same as in 2; deformation of shoots |
| | 4 | Shoots die, rot and terminal collapses |
| Mealybugs (*Phenacoccus gossypii)* | 0 | No nymphal stages or adults present |
| | 1 | Nymphs found on undersides of lower leaves |
| | 2 | Same as in 1; chlorotic spots begin to appear on these leaves |
| | 3 | Adults, nymphs and ovisacs present; partial chlorosis of basal leaves |
| | 4 | Adults, nymphs and ovisacs on petioles and/or stems; total chlorosis of lower leaves and/or necrosis of their margins; sooty mold on petioles and leaves |
| | 5 | Death of growing points and new lateral buds attacked; leaf necrosis and fall, desiccation of stem |

| Pest | Level of damage | Type of damage and/or level of infestation |
|---|---|---|
| Lace bugs (*Vatiga manihotae, Vatiga* spp.) | 0 | No lace bugs present |
| | 1 | A few yellow spots on lower leaves |
| | 2 | Many spots on lower leaves; leaves turn yellowish |
| | 3 | Many yellowish red spots on leaves; lower leaves curl |
| | 4 | Lower leaves curl and dry up; intermediate leaves curl |
| | 5 | Defoliation of basal and intermediate leaves; apical leaves turn yellow |
| Whiteflies (*Aleurotrachelus* sp., *Bemisia tuberculata, Trialeurodes variabilis*) | 0 | No infestation by adults/no pupae present |
| | 1 | $<$ 20% infestation of leaves/ $<$5 pupae per leaf |
| | 2 | 20-40% infestation of leaves/5-10 pupae per leaf |
| | 3 | 41-60% infestation of leaves/11-25 pupae per leaf |
| | 4 | 61-80% infestation of leaves/26-50 pupae per leaf |
| | 5 | 81-100% infestation of leaves/ $>$ 50 pupae per leaf |

Mites (*Tetranychus urticae, Mononychellus tanajoa*) *

Because of the variations in severity of damage caused at different levels of infestation, a scale was established for each of these species, based on level of food preference and symptoms observed on cassava plants grown in pots under isolation (screenhouse and glasshouse) in order to establish favorable conditions for the development of high mite populations.

*T. urticae* prefers the lower and intermediate leaves; when infestation is high, they reach the apical region of the plant. Initial symptoms are generally in the form of yellowish spots at the base of the leaves or yellowish spots forming small patches on the leaf surface. The number of spots increases as the mite population increases; there are a large number of webs that may cover the whole plant. Total defoliation finally occurs.

*M. tanajoa* develops on the shoots and terminal growing points of the plant. Embryonic leaves do not develop normally. In some cases the shoot does not develop, remaining completely closed; in other cases the embryonic leaves develop, but are deformed. Initial symptoms are found on the leaves of the shoots in the form of small translucent spots, scattered over the whole leaf or at the base of it. As the level of damage increases, there is a widespread mottling of leaves. Heavily attacked plants lose their leaves progressively, from top to bottom.

| Pest | Level of damage | Type of damage and/or level of infestation |
|---|---|---|
| *T. urticae* | 1 | Initiation of yellowish spots on some of the lower and/or intermediate leaves |

* Prepared by David H. Byrne, Visiting Research Associate and José M. Guerrero, technician of the Cassava Program at CIAT

| Pest | Level of damage | Type of damage and/or level of infestation |
| --- | --- | --- |
| | 2 | Fairly abundant yellowish spots on lower and/or intermediate leaves |
| | 3 | Damage manifest; many spots, small necrotic zones and curling of leaves, especially the basal and intermediate ones; yellowing and loss of some leaves |
| | 4 | Severe damage, heavy defoliation of basal and intermediate parts of plant; a large number of mites as well as webs can be observed |
| | 5 | Total defoliation of plant; shoots reduced in size, with a great number of webs; death of plant |
| *M. tanajoa* (field evaluations as well) | 1 | Shoot and/or adjacent leaves with a few faint yellowish spots |
| | 2 | Some leaves have a few yellowish spots that stand out |
| | 2.5 | Shoot and/or nearby leaves with many yellowish spots |
| | 3 | Shoot and/or adjacent leaves affected with a slight yellowing; yellow spots spread over the entire leaf surface; a slight reduction in shoot size can be seen |
| | 3.5 | Considerable deformation of shoot or reduction in size; yellowish spots are easily seen |
| | 4 | Shoot severely deformed or reduced in size; many yellow spots; heavy mottling; widespread yellowing |
| | 4.5 | Shoot totally affected; no leaves on shoot; yellowing and defoliation of the intermediate part of the plant |
| | 5 | Shoot dies; plant does not develop |

The cassava mite and insect complex.

| Common name | Important species | Reported from | Alternate hosts | Yield losses | Type of damage |
|---|---|---|---|---|---|
| White grubs | *Leucopholis rorida* *Phyllophaga* sp. | All regions but mainly Americas and Indonesia | Numerous | 95% loss germination | Feed on planting material and roots |
| Termites | *Coptotermes voltkevi, C. paradoxis* | All regions but mainly Africa | Numerous | Unknown | Tunnel in planting material roots, stems and swollen roots |
| Cutworms[1] | *Prodenia litura, Agrotis ipsilon* | Americas and Madagascar | Numerous | Unknown | Feed on planting material, girdle stems and consume foliage |
| Scales [1,3] | *Aonidomytilus albus, Saissetia* sp. | All cassava-growing areas | Unknown | (a) 20%, (b) 50-60% loss in germination | Attack stems, which dry, causing leaves to fall. (b) Use of infested stems reduces germination of planting material |
| Fruit flies [1,6] | *Anastrepha pickeli, A. manihoti* | Americas | Unknown | (a) Unknown; (b) 20-30% | (a) Boring of fruit (seed) and stems; causes rotting of pith area. (b) Use of infested stems for planting material results in yield loss. |
| Cassava hornworm[2] | *Erinnyis ello* | Americas | *Manihot glaziovii* poinsettia, rubber, papaya, milkweed | 20% single attack | Foliage, tender stems and buds consumed |
| Grasshoppers[2] | *Zonocerus elegans, Z. variegatus* | Mainly Africa | Numerous | Unknown | Defoliation and stripping of bark |

*Cont.*

| Common name | Important species | Reported from | Alternate hosts | Yield losses | Type of damage |
|---|---|---|---|---|---|
| Leaf-cutter ants[2] | *Atta* sp., *Acromyrmex* sp. | Americas | Numerous | Unknown | Remove foliage e |
| Mites[3] | *Mononychellus tanajoa* | Americas and Africa | *Manihot* sp. | Up to 46% | Leaf deformation and defoliation; heavy yield reduction or death |
| | *Tetranychus urticae* | All regions | Numerous | Unknown | Leaf necrosis and defoliation |
| | *Oligonychus peruvianus* | Americas | *Manihot* sp. | Unknown | Leaf spotting and defoliation |
| Whiteflies[3] | *Bemisia tabaci* | Africa, Asia | Numerous | Unknown | Vector of African cassava mosaic |
| | *Aleurotrachelus* sp. | Americas | Unknown | Up to 76% | Severe mottling or curling of leaves, presence of sooty mold |
| Mealybugs[3] | *Phenacoccus gossypii*, *P. manihoti* | Americas Africa | Numerous | Unknown | Foliage and stems attacked, causing stem drying and leaf fall |
| Lace bugs[3] | *Vatiga manihotae* | Americas | Unknown | Unknown | Leaves with yellow spots that turn reddish brown |
| Thrips[4] | *Frankliniella williamsi*, *Corynothrips stenopterus*, *Caliothrips masculinus* | Mainly in Americas but also in Africa | Unknown | 6-28% | Deformation of foliage, death of buds and browning of stem tissue |
| Gall midges[4] | *Jatrophobia brasiliensis* | Americas | Unknown | Unknown | Yellowish green to red galls formed on upper leaf surface |
| Stemborers[5] | *Coelosternus* spp., *Lagochirus* spp. | All regions but mainly Americas | Unknown | Unknown | Boring into and tunneling into stems and possibly swollen roots |

*Cont.*

| Common name | Important species | Reported from | Alternate hosts | Yield losses | Type of damage |
|---|---|---|---|---|---|
| Shoot flies[5] | *Silba pendula*, *Lonchaea chalybea* | Americas | *Mammea americana*, *Mangifera indica*, *Inga feullei* *Eugenia* sp., *Atrus* sp. | Up to 34% | Larvae bore into and kill apical buds, causing plant deformation and stunting |

[1] Insects attacking planting material

[2] Insects attacking the growing plant; foliage consumers

[3] Sap-sucking insects and mites

[4] Leaf deformers

[5] Bud and stem borers