

## CHAPTER 11

# Insects and Mites Causing Yield Losses in Cassava\*

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### Introduction

Farmers in the tropics frequently cultivate cassava for subsistence. This crop is regarded as hardy, as it is usually free of arthropod pests. Crop yields have exceeded 70 t/ha in experiments at the Centro Internacional de Agricultura Tropical (CIAT)<sup>5</sup>, whereas commercial production in regions of Colombia reaches 40 t/ha. World average, however, is 10 to 15 t/ha. These figures indicate that several factors limit production, including pests as a significant constraint.

Cassava pests include a broad range of arthropods (Bellotti and Schoonhoven 1978a). According to the crop's stage of development in which they attack (crop phenology), pests can be divided into four categories:

- Those that attack planting materials, affecting plants in the field and stored stakes (fruit flies, stemborers, scale insects, white grubs, and cutworms).
- Those that attack the plant during vegetative development (leaf eaters, sap suckers, leaf deformers, and borers that attack stems, branches, and buds).

- Those that attack fresh roots, damaging their culinary and industrial qualities (subterranean burrower bug, mealybugs, and white grubs).
- Those that attack stored dried cassava (weevils attacking flour, cassava chips, and cassava starch).

At CIAT, studies on yield losses have been conducted for over 25 years to help identify research priorities in the Cassava Program. This research has helped determine the true potential that key or primary pests have for causing losses, while at the same time, evaluate the susceptibility, resistance, or tolerance of many cultivars to pest attack. This research was developed in different ecosystems, particularly in sites where the targeted pest is endemic, as in the case of mites in the Atlantic Coast, whiteflies in the Department of Tolima, and mealybugs in the Eastern Plains. This research also confirmed that less important pests, such as fruit fly and shoot fly, do not cause significant production losses even though they may cause noticeable plant damage.

This paper discusses those results and analyzes the possible physiological causes of such reductions. Although pest damage is emphasized, some results on losses caused by poor quality planting materials are also presented. Pests that defoliate or cause other damage over a short period (hornworm, fruit fly, and shoot fly) are compared with long-term pests (mites, thrips, whiteflies, and scale insects) and those that directly attack roots.

### Distribution of Significant Pests

The widest diversity of cassava (*Manihot esculenta* Crantz) occurs in the Americas (Bellotti and Schoonhoven 1977; Bellotti 1978), the crop's center of origin. The cassava pests most often reported in the

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Americas are hornworm (*Erinnyis ello* L.); thrips (*Frankliniella williamsi* Hood and *Scirtothrips manihoti*); lace bugs (*Vatiga manihotae* Drake, *V. illudens* Drake, and *Amblystira machalana* Drake); whiteflies (*Aleurotrachelus socialis* Bondar, *Bemisia tuberculata*, and *Trialeurodes variabilis*); and fruit fly (*Anastrepha pickeli* Costa Lima). None of the aforementioned pests has been reported in Asia or Africa.

So far, few specific cassava pests have been disseminated to other areas. However, more than 20 years ago, two important pests, the cassava green mite (*Mononychellus tanajoa* Bondar), and the mealybug (*Phenacoccus manihoti* Matile-Ferrero), were accidentally introduced into Africa, where they caused serious losses in yield (Nyiira 1976; Leuschner and Nwanze 1978). The mealybug is subjected to high levels of natural control in the Americas, which is why it is not reported there as causing high yield reductions.

The white mussel scale, *Aonidomytilus albus* Cockerell, is found in almost all cassava-growing regions of the world. It can cause losses in planting materials, thus reducing stake germination and, hence, yields.

## Relationships between Pest Damage and Yield Loss

The damage that cassava suffers is usually indirect, as most arthropod pests feed on leaves or stakes, thus reducing leaf area, longevity, and rate of photosynthesis. Field studies indicate that pests that attack the crop for prolonged periods (3 to 6 months), such as mites, mealybugs, thrips, whiteflies, and lace bugs, can cause severe reductions in root yield because they feed on the cellular fluids of leaves, thus reducing photosynthesis (Table 11-1). Many attacks can induce premature defoliation and death of apical meristems (Bellotti 2000).

The potential these pests have for reducing yields is greater than that of cyclic pests such as the cassava hornworm and leafcutting ants, which cause sporadic defoliation. However, such visible pests usually induce farmers to apply insecticides (Bellotti 2000).

The subterranean burrower bug (*C. bergi*; Hemiptera: Cydnidae) is one of the few pests that directly damage cassava roots. The perforations of the stylet into roots during feeding enable pathogenic fungi to penetrate roots, thus reducing their quality (García

Table 11-1. Losses in cassava yields caused by major pests.

Pest	Yield loss	References
Hornworm ( <i>Erinnyis ello</i> )	In farm fields, natural attacks resulted in losses of 18%. Studies, using simulated damage, resulted in losses ranging from 0% to 64%, depending on the number of attacks, plant age, and soil fertility.	Arias and Bellotti 1984; Bellotti et al. 1992
Mite ( <i>Mononychellus tanajoa</i> )	Yield losses of 21%, 25%, and 53%, with attacks lasting 3, 4, and 6 months, respectively; 73% for susceptible cultivars versus 15% for resistant cultivars; and 13% to 80% in Africa.	Bellotti et al. [1983b]; Byrne et al. 1982; Herren and Neuenschwander 1991
Whitefly ( <i>Aleurotrachelus socialis</i> )	1, 6, and 11 months of attack resulted in 5%, 42%, and 79% losses, respectively, in field trials in Tolima, Colombia.	Bellotti et al. [1983b], 1999; Vargas and Bellotti 1981
Mealybugs ( <i>Phenacoccus herreni</i> , <i>P. manihoti</i> )	In Colombia, 68% to 88%, depending on the cultivar's susceptibility. In Brazil, up to 80% of farms reported. In Africa, losses of 80% were reported.	Bellotti et al. 1999; Vargas and Bellotti 1984; Herren and Neuenschwander 1991
Subterranean burrower bug ( <i>Cyrtomenus bergi</i> )	Dark brown to black lesions make roots commercially unacceptable. Starch content in roots reduced by more than 50%.	Arias and Bellotti 1985; Bellotti et al. 1999
Lace bugs ( <i>Vatiga manihotae</i> , <i>Amblystira machalana</i> )	Field trials with <i>A. machalana</i> and <i>V. manihoti</i> resulted in yield losses of 39%.	CIAT 1990
Stemborer ( <i>Chilomima clarkei</i> )	In Colombia, root yield losses increase from 45% to 62% when stem breakage is more than 35%.	Lohr 1983
Thrips ( <i>Frankliniella williamsi</i> )	In susceptible cultivars (no pubescence on apical buds or leaves), yield drops from 17% to 25% or more.	Schoonhoven 1974; Bellotti and Schoonhoven 1978a

SOURCE: Bellotti 2000.

and Bellotti 1980). Centipede larvae and termites are occasionally reported to feed on roots and, although they damage roots and cause losses, they are usually minor pests (Bellotti 2000).

### Biological and Physiological Bases of Yield Losses

The physiological bases that explain yield losses in cassava as caused by insects and mites have been explored by Cock (1978). He established that cassava may tolerate pest attack more than other crops, because it has no critical periods during production. Once the plant is established, its growth may be completely determined in almost any stage of development without affecting the formation of the organs responsible for yield, that is, bulked roots.

Pests can reduce yields indirectly by (1) consuming and thus reducing leaf area and therefore the photosynthetic rate; (2) attacking and thus weakening stems and preventing nutrient transport; and (3) attacking planting materials, thus reducing their germination rates. Direct attacks to roots may cause a cosmetic effect ("cassava smallpox"), which may affect yields and, nevertheless, makes the product unacceptable to fresh-root markets and for industrial uses. Cutworms, which attack stakes, produce lesions or holes through which soil pathogens may enter. These insects may also completely destroy the stakes' epidermis or buds. Other insects cut through roots or buds of recently germinated stakes.

In general, arthropod pests are more damaging to cassava crops during dry seasons than during the rains (Bellotti et al. 1999). The cassava plant is well adapted to long dry periods and takes advantage of short rainy seasons by reducing evapotranspiration from leaves by partly closing their stomata. Thus, water-use efficiency increases (Cock et al. 1985; El-Sharkawy et al. 1992). In plants suffering water stress, both the rapid defoliation of old leaves and the notable loss of photosynthetic activity enable young leaves to play a key role in acquiring carbon for the plant. Because several pests

prefer young apical leaves, dry seasons tend to cause major yield losses in cassava. Once the crop enters in a humid cycle (rain or irrigation), new leaves sprout in apical parts, thus increasing the photosynthetic rate. This represents potential for recovery and compensates for yield losses caused by pest attack in the dry season (Bellotti 2000).

### Economically Significant Pests

#### Mites

Mites constitute a major cassava pest throughout the world. The economically most important species include *Mononychellus tanajoa*, *Tetranychus urticae* Koch, and *Oligonychus peruvianus* McGregor. Bellotti and Schoonhoven (1977, 1978a) detail the damage they cause, principally during dry periods, when environmental conditions favor their development and permit populations to reach high levels. The duration of an attack depends on the length of the dry periods and the amount of available food. Continuous feeding by mites may lead to defoliation, which then reduces the photosynthetic rate. In experiment plots in Uganda, losses in yield caused by *M. tanajoa* were as high as 46% (Nyiira 1976; Cock 1978).

Four species of mites (*M. tanajoa*, *M. macgregori* [Flechtmann & Baker], *T. urticae*, and *O. peruvianus*) were evaluated for their effect on yields. Depending on plant age and duration of attack, yield was reduced by 21% to 53% at CIAT (Table 11-2). A 3-month attack reduces yield by 21%; 4 months, by 25%; and 6 months, by 53%. Damage led to necrosis and defoliation of the lower leaves, but complete defoliation did not occur.

On the Atlantic Coast (Colombia), Byrne (1980) found that prolonged damage caused by mites (e.g., *Mononychellus* sp.) to susceptible or resistant varieties has a differential effect on leaf size, rate of leaf formation, plant weight, and root yield. Yield losses ranged between 43% and 87%, with an average of 73% for susceptible and 16% for resistant varieties.

Table 11-2. Effect of populations of the mites *Mononychellus* spp., *Oligonychus peruvianus*, and *Tetranychus urticae* on the yield of cassava variety M Col 22. Artificial infestations of *T. urticae* were made.

Planting code	Artificial infestations	Plant age (months)	Duration of infestation (months)	Production (t/ha)		Mites (no./leaf)		Yield loss (%)
				Treated	Untreated	Treated	Untreated	
I	1	6	3	110	425	21.8	17.3	21
II	2	4 and 10	4	77	349	16.4	12.3	25
III	3	2 and 8	6	60	263	27.9	13.1	53

Production of vegetative “cuttings” (stakes) was reduced by 67% for susceptible and 16% for resistant varieties.

### Thrips

Thrips are cassava pests mainly in the Americas. Their attacks are more frequent during the dry season but plants recover as the rains start. *Frankliniella williamsi* and *Scirtothrips manihoti* appear to be the most economically important species. The insects attack the plants' terminal buds. Leaves do not develop normally: the folioles become deformed and present deep clefts from the margins to the leaves' central nervures. Irregular chlorotic spots appear. Buds may die, thus destroying the apical dominance and stimulating lateral shooting. These, at their turn, may also be attacked, giving rise to a witches'-broom appearance (Bellotti and Schoonhoven 1977). Thrips attack does not result in defoliation, even though the photosynthetic area is greatly reduced.

*Corynothrips stenopterus* prefers to attack the plant's lower and central parts and therefore does not affect apical dominance. As a result, its importance is less significant.

At CIAT, thrips attacks reduced yields between 5.6% and 28.4%, depending on the variety's susceptibility (Schoonhoven and Peña 1976, 1978). One consequence of a 3-months' thrips attack was an average 17.2% reduction of yield for eight varieties.

Highly susceptible varieties such as 'Chiroza Gallinaza' can be totally destroyed by thrips in ecosystems such as those found at CIAT (Valle del Cauca) and Santander de Quilichao (northern Cauca), where varieties must be continually sprayed with insecticides so they may develop. In ecosystems such as that found in Quindío, although the variety is attacked by thrips, their effect on yield is not significant (B Arias 1978, pers. comm.).

### Scale insects

Several species of scale insects that attack cassava stems and branches have been identified in many regions of the Americas, Asia, and Africa (Bellotti and Schoonhoven 1978a). The most important and widespread species is *Aonidomytilus albus*.

The leaves on branches become yellow and fall. In severe attacks on young plants, when the stem is invaded, plant stunting occurs, the terminal may die, and stems may dry, causing plant death. Scales may be

present throughout the year, but their attacks are more severe during summer, which exacerbates conditions by intense dryness. Although the main damage caused by scale attack appears to be the loss of planting materials, studies carried out at CIAT have shown yield reductions when populations are continuously high. For an evaluation, a classification system was developed, as follows:

- 0 = plants have considerable foliage; scales on stems are absent or scarce
- 1 = reduced foliage; scales cover less than 50% of stem surfaces
- 2 = severe defoliation with death of terminal buds; scales completely cover stem surfaces

One hundred plants, corresponding to each level of damage, were harvested and root weight measured. Damage was correlated with reduced yields. According to results, loss of yield was 4% for plants scoring 1, and 19% for those scoring 2, with the latter representing a loss of 3 t/ha.

Other species such as black scale, *Saissetia miranda*; gray scale, *Hemiberlesia diffinis*; and *Ceroplastes* sp. do not have economic importance, as they appear only in sporadic isolated attacks on old plants. *Saissetia miranda* is subject to natural and effective biological control.

### Whitefly

In the cassava crop, several whitefly species of variable importance are distributed in the Americas, Africa, and certain parts of Asia.

The family Aleyrodidae has 126 genera that include 1156 species, of which the most important for the cassava crop are *Aleurotrachelus socialis*, *Bemisia tuberculata*, and *Trialeurodes variabilis* in Colombia; *Aleurothrixus aepim* (Goeldi), in Brazil; and *B. tabaci* (Gennadius) in Africa and Asia.

*Bemisia tabaci*, so far, has not established well on cassava in Colombia. Yet, it is of particular importance, as it is the vector of the virus African cassava mosaic disease found in India and Africa, where it has caused yield losses of up to 80%.

Recent studies conducted by scientists of the National Cassava & Fruits Research Center (CNPMPF) with farmers in Bahia, Northeast Brazil, demonstrated that high populations of *A. aepim* can cause losses of more than 40% of root production.

In the last 6 years of the 1990s, in Colombia, large outbreaks of *A. socialis* has alarmed farmers in northern Cauca, southern Valle del Cauca, Tolima, and parts of the Atlantic Coast (Arias 1995). In some regions, the pest occurs throughout the year, obliging farmers to resort to pesticide use for control.

Damage in susceptible varieties manifests as a mottling or rolling-up of leaves, symptoms very similar to those of the African mosaic mentioned above. Leaf yellowing and deformation of growing points may also occur. Furthermore, *fumagina*, a black sooty fungus (*Capnodium* sp.) and a sooty-colored complex of fungi and other pathogens, may develop on the insect's sugary excretions, affecting the photosynthetic rate. In severe infestations, lower leaves are defoliated.

Vargas and Bellotti (1981) mention that, before 1978, no records existed on yield losses caused by the whitefly's feeding action on the cassava crop.

The effect of whitefly attack was evaluated on three cassava varieties (CMC 57, CMC 40—also called M Col 1468—and M Mex 59), which were treated with monocrotophos every 10 days until harvest. Whitefly populations appeared throughout the year. The treated plants showed lower densities of whitefly populations, both adults and pupae, and a higher yield than did untreated plants (Table 11-3). Reductions in yield were 33.6% for M Mex 59, 52.0% for CMC 40, and 76.7% for CMC 57. These percentages indicate considerable damage to the crop.

In another trial, whiteflies were permitted to attack cassava over increasingly prolonged periods until plants were 11 months old. Correlation ( $r = 0.9$ ) between the duration of attack and yield reduction was significant,

with a negative correlation ( $r = 0.8$ ) occurring between duration of attack and number of stakes produced per plant. The effect of duration of attack became significant after 3 months of plant growth (Table 11-4).

### Hornworm

*Erinnyis ello*, in its larval stages, is a voracious consumer of foliage and is usually considered as a highly significant cassava pest in the Americas. Its ability to cause rapid defoliation of crops alarms cassava farmers.

The larval stages (five instars) last about 15 days, during which time the insect consumes 1107 cm<sup>2</sup> of leaf area. However, 75% of this area is consumed during the last instar, that is, in the last 3 or 4 days.

A Colombian commercial crop was planted with the variety Chiroza, which has a high yield potential. A very severe attack occurred when the plants were 3 months old, with four plots being completely defoliated. At harvest, when the crop was 12 months old, the attacked plants were compared with an equal number of those plants that had escaped attack. The average yield of unattacked plants was 4.58 kg/plant, while the defoliated plants yielded 3.75 kg each. This 18% loss was equivalent to 6 t/ha on that farm.

Taking into account that the intensity of attack may be severe at any age of the crop, the effect on production varies with plant age, number of attacks, soil type, and ecosystem in which the crop is grown. CIAT recently conducted research on crops with 100% defoliation across two sites: one in Santander de Quilichao (Cauca) that had poor soil and the other in CIAT-Palmira that had fertile soil. Results showed that, in the poor soil, yield losses could be as high as 64% with two continuous

Table 11-3. Yield of three cassava varieties reduced by whitefly (*Aleurotrachelus* sp.) attack in Espinal (Tolima, Colombia), 1978. Average of four replications.

Variety <sup>a</sup>	Treated (T) <sup>b</sup>			Untreated (NT)			Yield loss (%)	(T-NT) × % per infestation	
	Yield (kg/plant)	Infestation		Yield (kg/plant)	Infestation			In leaves <sup>c</sup>	With pupae <sup>d</sup>
		In leaves <sup>c</sup>	With pupae <sup>d</sup>		In leaves <sup>c</sup>	With pupae <sup>d</sup>			
CMC 57 (SE)	3.31 (0.41)	0.57 (0.19)	0.28 (0.12)	0.77 (0.27)	3.92 (0.27)	3.17 (0.23)	76.7	85.5	91.2
CMC 40 (SE)	5.35 (0.60)	0.82 (0.23)	0.21 (0.10)	2.57 (0.43)	4.75 (0.17)	4.87 (0.08)	52.0	82.7	95.7
M Mex 9 (SE)	3.63 (0.74)	0.71 (0.21)	0.17 (0.07)	2.41 (0.67)	4.70 (0.16)	4.65 (0.10)	33.6	84.9	96.4

a. SE = standard error.

b. Monocrotophos: 1.5 cc a.i./L water.

c. Population: percentage of leaves infested by adults, nymphs, and pupae, where 0 = no infestation; 1 = <20%; 2 = 21% to 40%; 3 = 41% to 60%; 4 = 61% to 80%; 5 = 81% to 100%.

d. Pupae per leaf, where 0 = no pupae; 1 = <5; 2 = 6 to 10; 3 = 11 to 25; 4 = 26 to 50; 5 = >51.

Table 11-4. Relationship between the duration of whitefly (*Aleurotrachelus socialis*) attack and yield loss in cassava variety CMC 305-122.

Duration of attack (months)	Insecticide applications (no.) <sup>†</sup>	Yield of fresh roots (t/ha) <sup>‡</sup>	Reduction in yield (%)	Starch contents <sup>‡</sup>
0	22	42.1 a		29.6 a
1	20	40.1 ab	4.8	29.5 a
2	18	36.1 abcd	14.3	28.7 a
3	16	37.8 abc	10.2	29.4 a
4	14	30.6 bcde	27.3	30.7 a
5	12	29.8 cde	29.2	28.7 a
6	10	24.5 ef	41.8	27.7 a
7	8	26.7 de	36.6	29.4 a
8	6	16.4 fg	61.0	27.8 a
9	4	14.3 g	66.0	27.9 a
10	2	11.5 g	72.7	28.3 a
11	0	8.6 g	79.6	27.6 a

<sup>†</sup> Dimethoate was applied at 0.8 g a.i./L of water.

<sup>‡</sup> The values within the same column followed by the same letter are not significantly different at 95%.

attacks, and as high as 46% with one attack on the crop. In the fertile soil, these losses were, respectively, as high as 47% and 25.5% (Arias and Bellotti 1984).

Severe attacks may also affect the production of planting materials: 1- and 2-month-old crops attacked in each month may lose as much as 72%, and 1-month-old crops attacked only once may lose as much as 62% (Arias and Bellotti 1984).

### Mealybugs

Throughout the tropics, the mealybug constitutes one of the cassava crop's worst pests, causing serious damage to crops in the Americas and Africa. The principal species attacking cassava in the Americas are *Phenacoccus herreni* and *P. manihoti* Matile-Ferrero. In Africa, only *P. manihoti* causes economic losses.

The mealybug attacks both stems and leaves in cassava. *Phenacoccus herreni* and *P. manihoti* prefer buds, deforming and crinkling both leaves and buds, and giving the plant a rosette appearance. In severe attacks, these buds are filled with *fumagina* and finally dry up. When attacked early, plants become dwarfed, severely affecting root production.

Cassava varieties M Col 22 and CMC 40, evaluated at CIAT, respectively lost 88.3% and 67.9% of their yields. Plant height was reduced by as much as 33%, thus affecting stake number and quality. Depending on variety, as much as 74% of planting materials (stakes) may be lost (Vargas and Bellotti 1984).

### Fruit fly

Fruit flies *Anastrepha pickeli* and *A. manihoti* were originally reported because they attacked the fruit. Although the flies do not cause economic damage by attacking fruit, in crops that are too young to fruit, they deposit their eggs on the stems' tender terminal buds. The larvae then damage the growing points by tunneling into them. A bacterial pathogen (*Erwinia carotovora* var. *carotovora*) is frequently found associated with the larvae, entering the tunnels and causing tissue rot. Severe attacks can retard and kill terminal buds, thus delaying plant growth and favoring lateral bud development (Bellotti and Peña 1978).

However, cassava plants can recover rapidly from fruit-fly damage, especially when rains are well distributed. For example, plants that were severely attacked at 3 months old were compared with healthy plants over 6 months. Measurements of plant height showed that, at 5 months old, the attacked plants had grown little (CIAT 1977), but no significant differences in yield were found between attacked and unattacked plants. However, stake quality was significantly different (CIAT 1980, unpublished data). Treated plots produced between 40% and 50% more stakes of good quality than the untreated plots.

### Shoot fly

Damage caused by shoot fly has been found in most cassava-growing regions of the Americas, but has not been reported in Africa or Asia.

Several *Lonchaeidae* species have been described but *Silba pendula* Bezzi and *Lonchaea chalybea* Wiedemann are the most important (Bellotti and Schoonhoven 1978a, 1978b). The larval stage may last from 20 to 25 days, depending on the temperature (Bellotti and Schoonhoven 1978a; Waddil 1978). Hence, the duration of the attack is relatively short. However, successive attacks may occur, when damage by larval feeding manifests as a white to coffee-colored discharge that flows from the terminal buds, which finally die. Plant growth is therefore delayed and apical dominance is broken, inducing the germination of lateral buds, which may then be attacked. Studies conducted in Costa Rica (Saunders 1978), Florida, USA (Waddil 1978), and at CIAT (1975) have demonstrated that such attacks do not cause yield loss.

Arias and Bellotti (1982) simulated damage in 100% of buds, with continuous damage from 1 to 5 months in clone M Col 22, and at different crop ages. Results were similar to those observed in Costa Rica. No critical period exists for pest attack from the viewpoint of yield. However, attacks during the crop's first and second months diminished planting-material quality by 51% to 71%.

### **Stemborers**

A complex of stem-boring arthropods includes species of Coleoptera and Lepidoptera that feed on the interiors of cassava stems, causing damage (Bellotti 2000).

**Lagocheirus araneiformis.** The longhorn beetle is found throughout the world. Its attack does not severely damage crops in the field. These stemborers are most important in the Neotropics, especially in Colombia, Venezuela, and Brazil. Seven species of the *Coelosternus* genus (Coleoptera: Curculionidae) have been reported as reducing cassava yields and the quality of planting materials in Brazil. However, such damage tends to be sporadic and does not imply significant reductions in yield (Bellotti 2000).

**Chilomima clarkei.** Populations of this stemborer (Lepidoptera: Pyralidae) have recently been increasing dramatically in Colombia and Venezuela, currently constituting an important cassava pest (Vides et al. 1996). Females oviposit more than 200 eggs on stems during the night, usually near an internode or bud. The egg stage lasts about 6 days at 28 °C. After hatching, the first instars feed on the stem's cortex or epidermis.

These larvae are highly mobile and usually locate themselves near axillary buds, where they form a protective capsule in which they live until the fifth instar. From there they penetrate the stem to complete their cycle to adult emergence (Lohr 1983). The larval stages last from 32 to 64 days (Bellotti 2000).

Populations of *C. clarkei* may be present the year round, but are higher during the rainy season. As the pest, and therefore the damage, increases, control becomes more difficult. When larvae make a sufficient number of perforations (i.e., >20 per stem) in the stems, these break, reducing the quality and quantity of planting materials. Field studies indicate that fields with more than 35% of broken stems suffer significant reductions (45% to 62%) in root yield (Lohr 1983). In the Colombian Caribbean Region, 85% of planted cassava is attacked by *C. clarkei* (Vides et al. 1996).

The mobility of the first-instar larvae makes them vulnerable. They can be controlled by using *Bacillus thuringiensis*. Given its rapid generational increase, several applications will be needed, thus, increasing production costs. Field research (Gold et al. 1990) indicates that crop rotation with maize reduces stemborer populations until the maize is harvested (Bellotti 2000).

### **Termites**

In Colombia, *Heterotermes tenuis* Hagen has been identified as the most important termite species determined by attacking cassava. In the 1980s, CIAT evaluated the importance of this pest in the Atlantic Coast and found that it can cause losses of 46% to 100% of unprotected planting materials in storage. In the field, production may decline by 40%. These studies also showed that no direct relationship exists between the percentage of plants attacked at the neck of the root (stump) and the percentage of damaged roots. Over 30 treatments, the percentage of attacked plants was high (64% to 95%) at harvest. However, the percentage of damaged roots was low at 0% to 1.7% (Arias et al. 1979). When introduced cultivars were evaluated, the average level of damage in roots increased between 16.5% (ecosystem trial) and 25.5% (pest complex trial).

Termites penetrate roots through wounds or through cracks caused by climatic effects on the soil. The insects form galleries in the root parenchyma, which then fill with sand.

### Subterranean burrower bug

This cydnid is another root pest, although it does not directly affect root yields, but attacks the roots' culinary and commercial qualities. The bug feeds on the root, using its stylet (beak) to penetrate the cassava peel to reach the parenchyma. When the affected roots are peeled, a series of small colored spots can be seen on the surface. The spots range from light to dark brown or almost black, giving this type of damage the Spanish name, meaning "cassava smallpox". These perforations correspond to fungal pathogens of the soil, which penetrate through the wounds. Roots in such conditions are rejected by traders and consumers alike, obliging farmers to keep back production and suffer the consequent economic losses. These roots are usually fed to farm animals. Trials at CIAT have shown that starch production may be affected by as much as 50%, can effect-lower starch content depending on the magnitude of the attack.

### Other pests

Although many other pests attack cassava, little or no data are available on their effects on yields (Table 11-5). Many insects attack planting materials, causing losses in germination, thus reducing yields if as many as 30% of plants are destroyed. Such pests include white grubs (*Phyllophaga* sp. and *Leucopholis rorida* [Fabricius]); and cutworms (*Prodenia* spp., *Agrotis ipsilon*, *Spodoptera frugiperda* (J.E. Smith), and *Lagocheirus araneiformis*). Pests attacking foliage include ants, lace bugs (*Vatiga manihotae* and *V. illudens*), and leafhoppers.

## Discussion

Cassava is a crop with a growing period that may take 8 to 24 months to complete, according to variety and environmental conditions. It can suffer a high level of economic damage. Under certain conditions, even vigorous varieties may lose more than 40% of their foliage but, in certain periods, the plant may tolerate higher levels of defoliation without suffering significant reductions in yield. These two factors are important in the relationship between damage by pests and yield reductions in cassava. The long growing period implies that plants are subject to continuous attack from pests that cause different types of damage. The most severe attacks usually occur in summer, when damage by pests is combined with intense dryness. Although some pests do attack the crop during the rainy season, the plant usually recovers in this period and grows vigorously.

The experiments presented in this chapter show that some arthropod pests reduce yields (e.g., whitefly, Table 11-4). The magnitude of reductions is influenced by environmental conditions, soil fertility, plant age, type of damage, and duration of attack.

Pests that attack the plant's aerial parts over prolonged periods reduce yield more than those that defoliate or cause damage over short periods (Table 11-6). Cock (1978), using field data and computer simulations, suggests that "relatively minor losses in yield result from a small reduction in leaf area". However, when yield is severely reduced, causes relate to reductions in leaf longevity and the photosynthetic rate.

The results of the experiments presented tend to support the following conclusions:

- Attacks by pests such as fruit fly and shoot fly, which destroy the plant's apical parts but have little or no effects on the photosynthetic rate, do not result in losses of yield (Table 11-5).
- The damage done by the hornworm through consumption of foliage reduces leaf area but, as the attack occurs over a brief period, the plant produces new foliage (Figure 11-1).
- In a field study, when the photosynthetic rate was artificially interrupted for 1 to 2 weeks over the plant's entire vegetative cycle, yield was reduced by 18% after the experiment. This loss was predicted (20%) by a simulated model in computer for this type of damage (Cock 1978).
- Thrips reduce leaf area over about 3 months, with yield dropping by 17%.
- Scale insects cause considerable injury to the principal stem and branches because of their continual feeding. At CIAT, yield loss was 19%, supporting Cock's (1978) conclusions that severe damage to stems will reduce yield.
- Reduced photosynthetic rate throughout the vegetative cycle appears to have the most negative effect on yield (Table 11-1).
- Mites and whiteflies attack foliage over long periods, in which the photosynthetic rate declines (Figure 11-2). If the duration of the attack increases, the yield decreases.



Table 11-5. Occasional and sporadic pests or less important pests of the cassava crop.

Common name	Important species	Region	Type of damage and/or symptoms	Yield losses reported	Control strategy	References
Scale insects	<i>Aonidomytilus albus</i> , <i>Saissetia miranda</i>	Almost all cassava-growing regions in the Americas, Africa, and Asia	Stems and leaves are attacked; Leaf yellowing and defoliation; Plants may wilt and die; Attacked stakes have reduced germination	<20% of fresh root yield; 50% to 60% loss of stakes	Destroy infested branches; Use only healthy stakes with no scales; Treat stakes with malathion	Bellotti and Schoonhoven 1978a; Frison and Felio 1991
Fruit flies	<i>Anastrepha pickeli</i> , <i>A. manihoti</i>	The Americas, Costa Rica, Panama, Venezuela, Colombia, Brazil, and Peru	Fruits, seeds, and apical stems tunneled; Fruits destroyed and stake quality reduced but, normally, not much economic damage is caused	0% to 30% when infested stems are used as planting materials	Damaged stakes should not be used	Bellotti and Schoonhoven 1978a, 1978b; Lozano et al. 1981; Peña and Waddill 1982
Shoot flies	<i>Neosilba perezi</i> , <i>Silba pendula</i>	Throughout most of the Americas	Larvae kill the apical buds, delay plant growth, and induce sprouting	Losses not reported for yield; Reduced stake quality	Not required	Bellotti and Schoonhoven 1978a, 1978b; Lozano et al. 1981; Arias and Bellotti 1982
Gall fly	<i>Jatrophobia (Eudiplosis) brasiliensis</i>	All the Americas	Greenish-yellow to red galls formed on upper leaf surface	None reported	Not required	Bellotti and Schoonhoven 1978a, 1978b; Lozano et al. 1981; Samways 1980
White grubs	<i>Phyllophaga</i> spp., <i>Leucopholis rorida</i> , Others	The Americas, Asia, and Africa	Feeding on stakes and roots; Possible seedling death	Up to 95% of losses in germination	Apply pesticides to soil at planting	Bellotti and Schoonhoven 1978a, 1978b; Peña and Waddill 1982
Termites	<i>Coptotermes voltkevi</i> , <i>C. paradoxis</i> , <i>Heterotermes tenuis</i>	All regions	Feeding on stakes, roots, seedlings, and stems; Wilting and/or plant death	46% to 100% of stakes lost; Up to 25.6% of roots lost in clones introduced to the Atlantic Coast	Treat stakes with pesticides; Keep fields clean	Bellotti and Schoonhoven 1978a, 1978b; CIAT 1984; Arias et al. 1979; Lal and Pillai 1981; Lozano et al. 1981

(Continued)

Table 11-5. (Continued.)

Common name	Important species	Region	Type of damage and/or symptoms	Yield losses reported	Control strategy	References
Stemborers	<i>Lagocheirus</i> sp.	All regions	Tunneling in stems, leading to breakage	None reported	Select healthy stakes	Villegas and Bellotti 1985
	<i>Coelosternus</i> spp.	The Americas, especially Brazil	Tunneling in stems and branches, leading to breakages	None reported	Select healthy stakes; Keep fields clean; Destroy infested stems	Bellotti and Schoonhoven 1978a, 1978b; Samways 1980
Leafcutting ants	<i>Atta</i> spp., <i>Acromyrmex</i> spp.	The Americas	Defoliation	Losses not reported	Fumigate nests; Introduce poisoned baits	Bellotti and Schoonhoven 1978a, 1978b; Samways 1980
Leafhoppers	<i>Zonocerus elegans</i> , <i>Z. variegatus</i>	Mainly Africa, occasionally the Americas	Defoliation, stem damage, and branches cut	Losses not reported	Use of entomopathogens is being evaluated	Bellotti and Riis 1994; Bellotti and Schoonhoven 1978a, 1978b; Lomer et al. 1990; Modder 1994
Cutworms	<i>Agrotis ipsilon</i> , <i>Prodenia eridania</i> , <i>Spodoptera frugiperda</i>	Mainly the Americas	Feeding at the stem base, buds, and cortex of stakes and roots	Loss in germination of stakes; Seedling death	Introduce poisoned baits at planting	Bellotti and Schoonhoven 1978a, 1978b

SOURCE: Bellotti 2000.

Table 11-6. Yield losses to insects and mites, according to the duration of attack on the cassava crop.

Pest or simulation	Type of attack	Duration	Reduction in yield (%)
Shoot fly	Shoot destruction	21 days	0
Fruit fly	Tunneling in branches	11 days	0 to 5
Simulation of hornworm attack	Complete defoliation (for leaf consumption by the pest)	15 days	0 to 64
Thrips	Leaf deformation	3 months	17
Scale insects	Sap suckers on stems	3 to 4 months	19
Mites	Sap suckers on leaves (reduced photosynthesis)	3 months	21
		4 months	25
		6 months	53
Whitefly	Sap suckers (reduced photosynthesis)	10 months	76

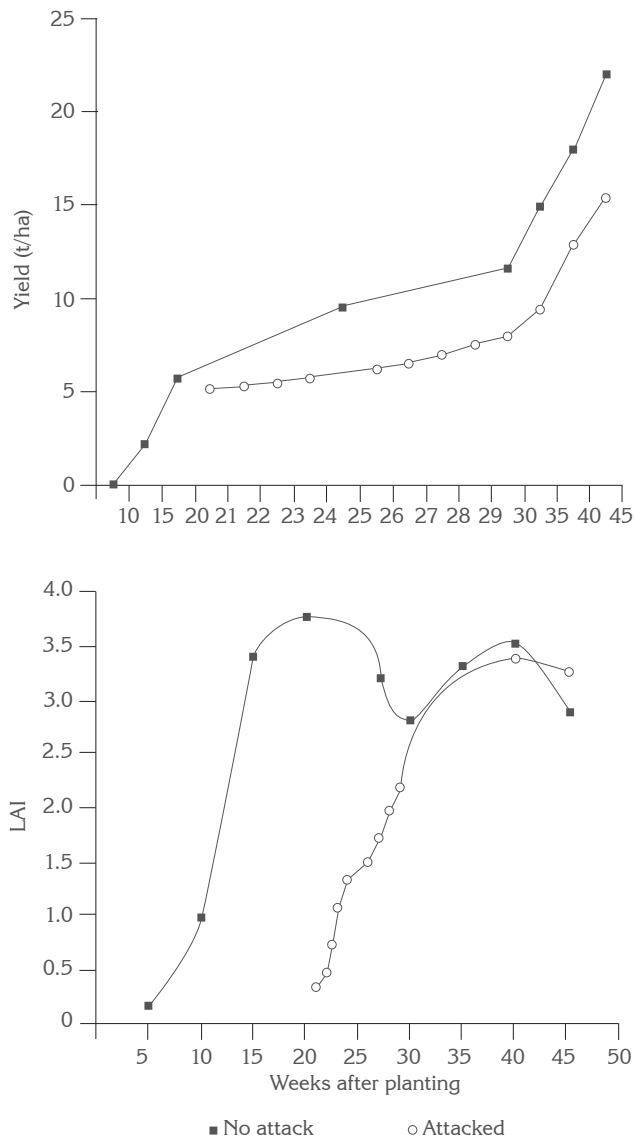


Figure 11-1. Effect of hornworm attack on yield and leaf area index (LAI) of a 20-week-old cassava crop (computer-simulated data) (from Cock 1978).

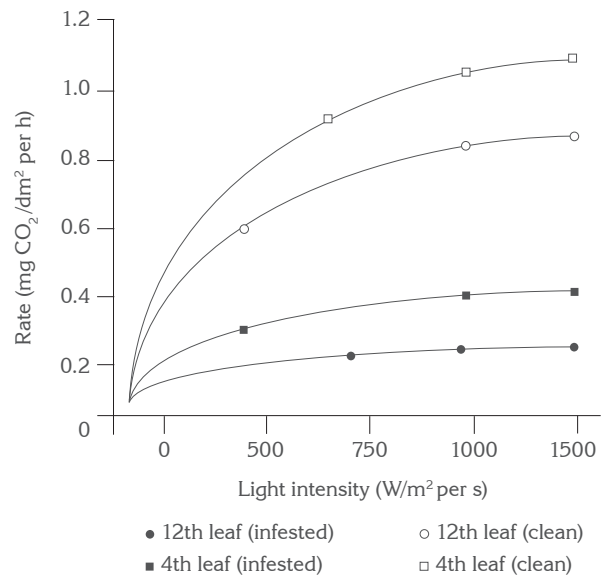


Figure 11-2. Effect of high mite infestation on the photosynthetic rate in cassava variety M Col 72 (measured in 2 leaves) (from Cock 1978).

Cock (unpublished data) suggests that computer simulations indicate that a 10% reduction in photosynthesis over the vegetative cycle of an ideal plant type will result in a 20% smaller root production. The plant seems to recover better from rapid defoliation or the death of its buds than from continuous reduction of the photosynthetic rate over a long period. In this case, pests such as the lace bug and mealybug could cause considerable yield loss (Table 11-1). However, mealybugs are known to cause as much as 88% of losses in susceptible varieties (Vargas and Bellotti 1984).

### Conclusions

Sufficient information from the field is available to demonstrate that insect and mite attacks can drastically

reduce cassava yield. Several factors seem to influence the pest-crop relation, among them environmental conditions and soil fertility. Frequently, adequate rains will permit the plant to recover from the damage with minimal reductions in yield.

The type of damage and duration of pest attack will also determine the level of reduction in yield. Pests that attack plants over prolonged periods (mites, whiteflies, thrips, and scale insects) have been proven to reduce yields more than pests that attack plants over short periods (hornworm, shoot fly, and fruit fly).

The most detrimental form of damage is that which continually reduces the photosynthetic rate.

## References

*The following acronyms are used to save space:*

CIAT = Centro Internacional de Agricultura Tropical  
SOCOLEN = Sociedad Colombiana de Entomología

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