An overview of cassava entomology

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Abstract

Research on mites and insects that attack cassava has shown that they are factors that limit yield. Furthermore, the decrease in genetic variability due to the development of genetically uniform varieties tends to increase the incidence of epidemics and epiphytotics. The mite *Tetranychus urticae*, crickets, termites, leaf-cutter ants, grubs, cutworms and the scale insect *A. albus* are considered as universal pests of cassava since they are found in almost all cassava-growing areas. Insects that attack cassava over a prolonged period cause more damage than those that attack the plant only at certain times. The degree of damage depends on various factors; but under conditions at CIAT, it was greatest from the 2nd-6th mo of growth. Insects that attack cassava can be divided into 3 categories: (1) those that attack vegetative planting material (fruit flies, stemborers, scale insects, grubs and cutworms); (2) those that attack the growing plant; foliage consumers, sap-sucking pests, leaf deformers, and bud and stem borers; and (3) those that attack stored cassava planting material and dried products (more than 38 insects, mostly Coleoptera). The status of entomological research on cassava is indicated and the areas where further research is recommended are given. The factors that should be taken into account when establishing a pest management program are presented. Biological control and host plant resistance are described in detail because of their vital importance to integrated control programs that should also include the careful selection of planting material, use of sound cultural practices, resistant varieties as well as the use of phermones, attractants and growth regulators. It is concluded that studies on resistance to diseases in cassava should aim at the development of horizontal resistance since it is stable and involves less risk in the development of biotypes. Since major characters are inherited in an additive manner, this can be an effective tool in increasing resistance in genotypes that have low levels of resistance. A table is presented on the mite and insect complex, giving data on alternate hosts, yield losses, areas where they are found, and types of damage caused.

Introduction

Historically, cassava has received limited attention from entomologists and technologists. Cassava is a perennial shrub of the Euphorbiaceae that is often grown by subsistence farmers throughout the tropical regions of the world. It has often been reported that cassava is a "rustic crop," generally free of arthropod pests. Nevertheless, ongoing research at the international centers, as well as investigation being carried out by several other scientists, is showing that insects and mites are limiting factors in cassava production. Present world cassava yields under small farm conditions

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average only 5 to 15 t/ha. Experimental yields have exceeded 50 t/ha (11, 29) and commercial yields in Colombia have exceeded 40 t/ha. These figures indicate that there are several factors limiting production under farm conditions, one of which is pests.

In recent years there has been an increase in interest in cassava, not only for traditional uses as a human food but also for animal feedstuffs and industrial uses (19). Cassava has traditionally been cultivated by small farmers, often in association with other crops. There is considerable genetic variability in this system as each area or zone is often planted to several different varieties. However, as cassava production increases and traditional methods are replaced by larger plantations with more modern technology, pressure due to insects and diseases may increase. Genetic variability will tend to disappear as new, genetically uniform, high-yielding varieties replace the many traditional varieties presently being grown. This genetic uniformity is an invitation to disaster from pest epidemics and epiphytotics. Since the role of entomologists and pathologists in future cassava production will become more important, it is necessary that systematic entomological and pathological research be initiated in areas where it is presently lacking and the interest of scientists and institutions be sought to assist in this effort.

Distribution of cassava pests

Cassava originated in the Americas, was later taken to Africa and more recently introduced into Asia (23). As expected, the greatest diversity of cassava pests reported attacking cassava is from the Americas (Table 1). Several of these pests, such as the mite *(Mononychellus tanajoa),* the cassava hornworm *(Erinnyis ello),* the shoot fly *(Silba pendula),* the fruit fly *(Anastrepha manihoti, A. pickeli),* the cassava lace bug *(Vatiga manihoti),* the white scale *(Aonidomytilus albus),* thrips *(Frankliniella williamsi)* and certain stemborers, do not appear to have a wide host range, mainly attacking cassava or other *Manihot* species. Of these, only the green mite *M. tanajoa* (Africa) and the white scale *A. albus* (Africa and Asia) are reported attacking cassava outside of the Americas.

Those pests that are identified attacking cassava in nearly all cassava-growing areas are usually universal pests with a wide host range. These include the mite *Tetranychus urticae,* grubs, cutworms, leaf-cutter ants, crickets and termites. Because of the few entomologists working on cassava, it is difficult to get a precise picture of pest distribution, and accurate identification of many pests is lacking. Indications are that surprisingly few pests specific to cassava have disseminated to other areas. The advent of jet travel probably precipitated the movement of the *M. tanajoa* mite into Africa. The white scale *A. albus,* found in nearly all cassava-growing areas, appears to be the most universal cassava pest. The dissemination of this scale probably dates back to the initial shipment of vegetative planting material by boat to Africa and later to Asia. It is difficult to detect the presence of this grayish colored scale on vegetative planting material. It is also possible that some movement of stemborers occurred through the movement of planting material.

Crop losses due to insects and mites

Insects can damage cassava plants by attacking the buds and leaves, reducing growth and photosynthetic area and efficiency; by attacking stems, which weakens the plant, inhibits nutrient transport and reduces the quality of planting material; and by attacking planted cultivars, which leads to microbial invasion, reducing germination and yield. Some insects such as whiteflies or fruit flies are vectors or disseminators of diseases while others attack the roots, which can lead to secondary rots (3).

Depending on ecological conditions, the growing period of cassava is from 8 to 24 months. Recent studies indicate that insects that attack the plant over a prolonged period, such as mites, thrips, scales, mealybugs, whiteflies and stemborers, may reduce yield more than those that defoliate or damage plant parts for a brief period; i.e., hornworms, fruit flies, shoot flies and leaf-cutter ants. This is because the cassava plant appears to be able to recover from this type of damage under favorable environmental conditions, with rainfall being the critical factor. 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 (13).

Yield losses in cassava due to a particular pest are often difficult to measure, and most of the literature available does not include good economic loss data. Cassava is often attacked by a complex of several pests, making it difficult to determine losses due to just one. Losses due to the mite *M. tanajoa* are reported as high as 46 percent in Africa (33), while experiments at CIAT (14) with a complex of four mite species *(M. tanajoa, M. mcgregori, Tetranychus urticae* and *Oligonychus peruvianus)* resulted in a 20 to 53 percent loss, depending upon plant age and the duration of the attack. Yield losses due to thrips range from 6 to 28 percent, depending upon varietal susceptibility (13, 39). Field studies in Colombia resulted in a 15 to 20 percent reduction in yield due to a single hornworm attack. Repeated attacks over the prolonged cassava-growing season would undoubtedly result in greater losses. Scale *(A. albus)* attacks at the CIAT farm resulted in a 20 percent yield reduction of a susceptible variety. Similar attacks under less favorable environmental and soil conditions may result in greater reduction. Losses due to fruit flies, stemborers, mealybugs, lace bugs, grasshoppers and others are mentioned but often unsubstantiated.

The growing period at CIAT (Valle del Cauca) and nearby cassava-growing regions is from 10 to 12 months. Data collected from actual pest attacks and from simulated damage studies indicate that yield losses are greatest when the attack occurs between the second and sixth month of plant growth. If there is a similar critical period for pest damage under other growing systems, this knowledge would be extremely useful for pest management programs.

The cassava mite and insect complex

Cassava pests represent a wide range of arthropodal fauna; approximately 200 species have been recorded (3). Cassava appears to be the preferred host for several of these pests (Table 1), including the hornworm *(E. ello)*, the fruit fly *(A. manihoti, A. pickeli)*, the shoot fly (S. pendula), the mite *(M. tanajoa)*, the lace bug *(V. manihotae)*, and the scale *(A. albus)*.

In addition there are several universal plant feeders with a wide host range that will also attack the cassava crop. These include grasshoppers, the two-spotted mite *(T. urticae)*, cutworms, leaf-cutter ants, termites, crickets, and certain whiteflies and stemborers.

It is important to note that cassava is often grown in areas with poor soil and prolonged dry periods where many other crop plants cannot be cultivated. During these prolonged dry periods, we have observed that cassava may be one of the few plants able to survive and thus be utilized as an alternate host for insects or mites. In some instances these attacks can be severe, and we have observed plant mortality due to exotic pests during these periods. An armyworm attack in Malaysia (personal observation) caused plant girdling and a 25 percent yield reduction in a 3000-acre plantation.

We can categorize insects attacking cassava into three general groups:

Insects attacking planting material

This includes those pests that will attack stems while the parent plant is still growing, thereby affecting the germination or yield of these stems when they are used as vegetative planting material (scales, fruit flies, stemborers). In addition there are those pests that attack planting material in storage for future use; scales, termites and stemborers have been identified causing this damage. After the cutting has been planted, germination can be reduced considerably by cutworms, grubs and termites, among others.

Insects attacking the growing plant

This group can be further divided into four subgroups: foliage consumers, sap-sucking pests, leaf deformers, and bud and stem borers. Foliage consumers consist of the cassava hornworm *(E. ello)*, grasshoppers and leaf-cutter ants. Severe attacks by all three of these pests will result in complete defoliation, often of large plantations. Sap-sucking pests include mites, whiteflies, scales, mealybugs and lace bugs. Except for scales, all are

Table 1. **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, girdles stems and consumes 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[1,3]	*Anastrepha pickeli, A. manihoti*	Americas	Unknown	(a) Unknown; (b) 20-50%	(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%	Foliage, tender stems and buds consumed
Grasshoppers[2]	*Zonocerus elegans, Z. variegatus*	Mainly Africa	Numerous	Unknown	Defoliation and stripping of bark
Leaf-cutter ants[2]	*Atta* sp., *Acromyrmex* sp.	Americas	Numerous	Unknown	Consume foliage

Cont.

Table I cont.

Mites[3]	*Mononychellus tanajoa*	Americas and Africa	*Manihot* sp.	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	Unknown	Severe mottling or curling of leaves, presence of sooty mold
Mealybugs[3]	*Phenacoccus gossypii*, *Pseudococcus 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
Shoot flies[5]	*Silba pendula*, *Lonchaea chalybea*	Americas	*Mammea americana*, *Mangifera indica*, *Inga feullei*, *Eugenia* sp., *Citrus* sp.	15-34%	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

primarily leaf feeders; mealybugs will feed on both stems and leaves. At least 13 species of mites have been identified as feeding on cassava, and there are undoubtedly others that have not yet been reported. The three most important are *M. tanajoa*, *T. urticae* (= *T. telarius*) and *O. peruvianus*. Seven species of whiteflies have been reported as feeding on cassava; the most important is *Bemisia tabaci* since it is the vector of African mosaic in Africa and India. This disease is not present in the Americas; and although *B. tabaci* has been reported in this hemisphere, there is some doubt as to its capacity to feed on cassava here. The most common whitefly feeding on cassava in the Americas appears to be *Aleurotrachelus* sp.

Mealybugs have frequently been reported as attacking cassava (12, 18, 25); and in recent years they have been reported as causing considerable damage in Brazil (1) and Zaire (Leuschner, personal communication). Lace bugs *(V. manihoti)* have been reported only from the Americas. Information on this pest is limited and there is no report of yield losses.

Thrips(37-38) and gall midges (7, 20) can cause cassava leaf deformation. Thrips is the more important of these two pests and can reduce yields considerably.

Insects that bore into the buds and stems of cassava are shoot flies *(S. pendula)* (5), fruit flies and the true stemborers. Shoot flies will cause death of the growing points and plant stunting. The adult fruit fly will oviposit in the tender stems of young plants and the larva becomes a borer (13-14). The bacterial pathogen *(Erwinia carotovora* var. *carotovora* is often found in association with fruit fly larvae and can cause severe rotting of stem tissue (13).

Numerous species of true stemborers have been identified as attacking cassava, especially in the Americas but particularly in Brazil (22, 27). Seven species of *Coelosternus* are reported attacking cassava in the Americas (9, 25). *Coelosternus manihoti* is reported as a pest in Africa (9), and *Lagochirus* sp. is reported from Asia (35).

Storage pests of dried cassava

Approximately 38 insects, mainly Coleoptera, are reportedly found on dried cassava chips or products (15, 35, 40). Many are polyphagous pests; others, which are able to reproduce on dried cassava, are the most important.

The status of cassava entomological research

Concentrated research in cassava entomology is recent. Few national governments have cassava research programs, and entomology seldom occupies any significant role in any program that does exit. Insect studies at various levels are being carried out in about 15 countries. It is therefore feasible to establish guidelines and recommendations for future research goals and the implementation of a sound pest management program.

An extensive range of studies should be conducted before an effective pest management program can be developed. These studies should be oriented toward a minimal use of pesticides and the development of alternative control methods that will not destroy the ecological balance between pests and parasites or predators existing in cassava plantations. There is a lack of scientific information in the following areas: yield losses and levels of economic injury for the major pests or combinations 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; identification and importance of natural enemies. Research should be practically oriented and give emphasis to low-cost, environmentally sound control practices.

As cassava acreage increases, monoculture cropping systems will replace multiple and scattered systems. On the other hand, new high-yielding hybrids will replace the traditional varieties being grown at present; consequently, genetic uniformity will replace much of the existent variability. If we study the effects that these changes have had on other food crops, we can conclude that insect and disease problems in cassava will increase in the future. Research programs are needed in all cassava-growing areas to investigate the following: potential pest problems that could occur if cassava acreages increase and monocultures, nonrotation and continuous planting of cassava are practiced; the danger of major or secondary pests becoming increasingly important as high-yielding varieties are released; pest problems during the storage of planting material and the establishment phase of the plant; the production of insect- and disease-free planting material. In addition a worldwide survey should be undertaken to identify cassava pests accurately and establish their true distribution.

Crop protection

Anticipating that in the near future there will be an increase in cassava production as well as a change in production technology, the importance of a relevant and sound crop protection program increases. As previously stated, cassava has historically been cultivated on a small scale. The genetic variability in this system has acted as a safeguard against major epidemics of pests and diseases. In recent years we have seen a shift in this system toward large cassava plantations, employing a limited number of high-yielding hybrids in monoculture. These new hybrids will be 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.

We must therefore study the implementation and relevance of the various pest control methods available. The major objective of a cassava pest management program should be to suppress insect pests and maintain populations below their economic threshold. This should be accomplished with a minimal use of costly inputs, especially pesticides. Advantage should be taken of the favorable factors involving the insect/plant/environment interaction that makes 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 uneconomical.
2. Being a long-season crop, it 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. Vigorous cassava varieties can lose considerable foliage (40 percent or more) without reducing yields. 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 recovery at the onset of rains.
5. Few, if any, pests will actually kill the plant, enabling it to recover from damage and produce edible roots.
6. The selection of healthy, vigorous planting material, combined with low-cost fungicidal and insecticidal treatments, initiates rapid and successful germination, ensuring early plant vigor during the important establishment phase and ultimately increasing yield (24).
7. Studies have shown that there are sources of pest resistance in cassava which, although of low level, may be adequate to prevent serious crop losses.
8. Cassava is often grown on small farms and under multicropping conditions. This system not only reduces pest incidence but also insures against pest outbreaks over extended areas.
9. Evidence is that insects can cause yield reductions during specific periods in plant development. These periods should be identified for different ecological zones so that control practices can be intensified during these periods.

The role of different control methods

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

In several cases insecticidal applications have proven to be ineffective over a long period as they also reduce predator populations. Mite populations, for example, reappear rapidly whereas buildups of predator populations are much slower (4). Chemical control of the hornworm resulted in more frequent infestations in chemically treated than in untreated fields (16).

There are several cultural practices that can reduce pest populations, but the implementation and practicability of these may be reduced as more modern agricultural technology is applied to cassava production.

Alternative means of control such as the use of phermones, juvenile hormones, attractants and growth regulator are future possibilities, but their use may be economically prohibitive.

We have previously stated that many cassava pests are not widely distributed, especially from one continent to another. It is of great importance, therefore, that an efficient quarantine program be developed and enforced. As new high-yielding hybrids are developed, there will be an increase in the 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.

Biological control and host plant resistance are two links in an integrated control chain that appear to play an important role in cassava pest management. Extensive studies in both of these areas have been initiated for several cassava pests.

Biological control

The factors making cassava well suited for biological control programs are its long growing period and high economic threshold; and few, if any, pests will actually kill the plant. Concentrated biological control studies for cassava pests are a rather recent effort. A review of the literature reveals that natural enemies of many cassava pests have been observed by field workers and entomologists (6,10,21,27,29). However, only recently two systematic studies and consequent programs have been initiated to control cassava pests using biological control. Bennett and Yaseen (4) have evaluated the effectiveness of biological control of the mite *M. tanajoa* with the Staphylinidae *Oligota minuta*. This predator was introduced into East Africa, where it is being evaluated for controlling the mite.

Studies on the biological control of the cassava hornworm have been initiated at CIAT (11-13). A program is being evaluated that combines egg parasitism *(Trichogramma* spp.), larval parasitism *(Apanteles congregatus)*, larval predation by the paper wasp *(Polistes canadiensis* L., *P. erythocephalus)* and a larval disease *(Bacillus thuringiensis)*.

Several other cassava pests offer the possibility of being controlled effectively by natural enemies. Studies on the predators and parasites of the mealybug *Phenacoccus gossypii* and the scale *A. albus* have been initiated at CIAT, Trinidad and Africa. Control of the white grub *(Phyllophaga* sp.) using the muscardine fungus *Metarhizium anisopliae* in also being evaluated at CIAT. Natural enemies of whiteflies, the gall midge and the fruit fly have been identified. There is excellent potential for the implementation of biological control of cassava pests; however, a great deal of basic information is needed to initiate these programs.

Host plant resistance

Resistance to pests attacking cassava is not reported extensively in the literature; most reports deal only with field observations. On-going systematic evaluation of germplasm has been limited because until the CIAT collection was assembled, extensive germplasm was not available to cassava researchers in one site. Host plant resistance offers the most economical means of controlling many cassava pests.

Varying degrees of varietal resistance have been reported for mites (2,4, 13-14, 31), thrips (37), whiteflies (13-14, 17), stemborers (30) and shoot flies (8,29). The CIAT germplasm bank is 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. There criteria include:

1. The level of economic damage being caused by a particular pest should be significant.

2. Resistance should be sought for those pests only 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 level 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 methods of control (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 comfirm this assumption. Since horizontal resistance is stable (36) and entails less risk as to the development of biotypes (33), cassava insect and disease resistance studies should have horizontal resistance as their goal.

When breeding for insect resistance, it must be remembered that cassava is propagated vegetatively and that major characters are inherited in an additive manner; therefore, once a type is obtained, the genotype can be multiplied indefinitely. If the additive effect is equally important for resistance characters as it is for yield characters, it can be an effective tool in increasing resistance where only low levels exist in a single genotype. By crossing cultivars containing low resistance levels, the presence of additive genes could result in increased resistance.

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