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Origin and management of
Neotropical cassava pests

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ORIGEN AND MANAGEMENT OF NEOTROPICAL CASSAVA PESTS

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ABSTRACT

Cassava, one of the major food crops in the tropics, is attacked by a wide range of arthropods. Several species depress yield significantly. Four major pests in the Neotropics are mites (*Mononychellus* spp.), mealybugs (*Phenacoccus herreni*), the cassava hornworm (*Erinnyis ello*) and burrowing bugs (*Cyrtomenus bergi*). Mites and mealybugs attack cassava primarily during dry periods causing severe leaf necrosis; the hornworm will feed on cassava leaves throughout the long growing cycle of the crop, although severe attacks usually coincide with the initiation of rains. Burrowing bugs feed directly on cassava roots, rendering them unaceptable for the commercial market. Control strategies are based on host plant resistance, biological control and cultural control practices. Adequate levels of resistance have been identified for mites, moderate levels for mealybugs, and burrowing bug damage is less on high HCN varieties. Many species of natural enemies have been identified for mites, mealybugs and the cassava hornworm. A granulosis virus is effective in the management of hornworm populations. Pesticide appliction to control cassava pests is discouraged and efforts are being made to develop IPM programs which do not incorporate pesticide use.

RESUMEN

El cultivo de la yuca es una de las principales fuentes alimenticias del área tropical en el mundo. El mencionado cultivo es atacado por un amplio rango de arthropodos plagas. Varias especies afectan significativamente los rendimientos.

Cuatro especies importantes en el Neotrópico son: los ácaros (Mononychellus spp.),los piojos harinosos (Phenacoccus herreni), el gusano cachón (Erinnyis ello) y la chinche subterránea (Cyrtomenus bergi). Los ácaros y los piojos harinosos causan daño principalmente durante la época de verano causando un necrosamiento severo al follage. El gusano cachón es un consumidor de follage, el cual ataca durante cualquier época del ciclo de cultivo, aunque sus ataques más severos coinciden generalmente con el inicio de las lluvias. La chinche subterránea se alimenta directamente sobre las raíces, haciéndolas inaceptables comercialmente para el mercado. Las estrategias de control enfatizan en: resistencia varietal, control biológico y prácticas culturales.

Adecuados niveles de resistencia han sido identificados para ácaros, niveles moderados para piojo harinoso y la chinche subterránea no prefiere alimentarse sobre variedades con alto contenido de HCN. Numerosos enemigos naturales han sido identificados para ácaros, piojos harinosos y gusano cachón. El virus de la granulosis es muy efectivo en el manejo de las poblaciones de gusano cachón.

Las aplicaciones de pesticidas para el control de las plagas en la yuca son desalentadoras y se hacen esfuerzos para desarrollar programas de Manejo Integrado de Plagas sin la incorporación del uso de pesticidas.

INTRODUCTION

Cassava (Euphorbiacea: Manihot esculenta Crantz), is a perennial shrub grown throughout tropical and subtropical regions of the Americas. Its roots accumulate starch in the parenchyma, forming swollen storage organs which are harvested after 7 to 24 months. Cassava originated in the Americas; however, its exact center of origin is controversial (Renvoize 1973). The crop was introduced into Africa in the 1600s, and subsequently reached Asia. The recent introduction of two arthropod pests, mites and mealybugs, from the Americas into Africa, is causing considerable crop loss throughout the cassava belt and is the object of a massive biological control effort (Herren & Neuenschwander 1991).

Within the Neotropics, in recent decades, the introduction of previously unreported species to certain areas has led to pest outbreaks and considerable crop damage. In the mid 1970s, the mealybug *Phenacoccus herreni*, was first reported causing considerable damage to cassava in Northeast Brazil (Albuquerque 1976). Evidence from recent explorations in Venezuela suggests that *P. herreni* may have been introduced into Brazil from Northern South America. Its rapid spread, severe damage, and absence of key natural enemies are indicative of an introduced pest.

Recent studies on the Cassava Green Mite (CGM) (*Mononychellus tanajoa*) demonstrate a higher degree of morphological polymorphism in Northern South America than elsewhere in the Neotropics were CGM is found. A number of species of Neotropical *Mononychellus* are oligophagous and feed only on *Manihot*, the cassava genus. More species of *Mononychellus* occur on cassava in Northern South America than elsewhere. This diversity is associated with greater species richness within the phytoseiid complex which preys upon *Mononychellus* spp. in cassava.

Most authors agree that there are three possible centers of origin of *M. esculenta*; the Brazil/Paraguay region, Northern South America, and Mesoamerica (Renvoize 1973; Rogers 1963; Sauer 1950). Sauer (1950) strongly supports Northern South America as the area of domestication of cassava, while Renvoize (1973) proposes that sweet manioc was first domesticated in Mesoamerica and bitter manioc in Northern South America.

The genetic diversity within certain arthropod herbivores of cassava in Northern S. America as well as the richness of the associated natural enemy complexes would support Northern S. America as the center of origin of M. esculenta. More precise knowledge of the area of origin of cassava and associated arthropods could aid significantly in defining cassava pest control strategies. Genetic diversity within M. esculenta for arthropod pest resistance may be concentrated in this geographic regions, and there is evidence that key biological control agents of several pest species occur in the region north of the Amazon Basin.

Cassava Green Mite.

The tetranychid mite, Mononychellus tanajoa Bondar became internationally famous after its accidental introduction to Africa in the 1970's. M. tanajoa is native to the Neotropics and has specialized to feed on the cassava genus, Manihot. Survey and experimental data suggest that although the cassava green mite (CGM) is present throughout much of the American lowland tropics where cassava is grown, economically significant outbreaks are rare, except in Brazil.

In Colombia, over 50 phytoseiid species have been reported on cassava and 18 species have been consistently collected in field surveys. 92% of 224 cassava fields surveyed in Colombia were uninfested or had low ($\bar{X} > 25$

mites per leaf) mite densities. Only 8% of fields had intermediate ($25 \le \bar{X} < 200$ mites per leaf) and none had high ($\bar{X} > 200$ mites per leaf) mite densities. In a sample of 325 Brazilian cassava fields, 12% were uninfested and 25% had intermediate or high CGM densities. Only two species of phytoseiids were consistently collected in Brazil. Data from field experiments demonstrated that fresh and dry root yield was reduced by 30% where natural enemies were eliminated (Braun *et al*. 1989).

Multilateral strategies generally offer more stability in pest management at the farm level than single-tactic approaches. Selection of commercially acceptable cassava varieties with resistance to CGM, introduction of phytoseiid species, genetic improvement of phytoseiids to enhance tolerance to low relative humidity, deployment of fungal pathogens, natural enemy conservation and augmentation techniques, and habitat manipulation are potentially useful tactics in the management of CGM in the Neotropics, particularly in Brazil, where CGM is believed to be an introduced pest.

Cassava Mealybug

Numerous species of mealybug attack cassava; however, only *Phenacoccus herreni* and *P. manihoti* (Cox and Williams 1980) are important economically. Both are of Neotropical origin, but *P. manihoti*, a major introduced pest of cassava in Africa, is confined to Paraguay, certain areas of Bolivia and the Mato Grosso area of Brazil. Until recently *P.*

manihoti caused heavy yield losses in African cassava, and has been the objective of a major classical biological control program. The hymenopteran parasite, Epidinocarsis lopezi, has become established in Africa and is bringing the mealybug under control (Hammond et al. 1987; Herren & Neuenschwander 1991).

P. herreni causes damage similar to P. manihoti and is reported only from South America. Recent explorations have confirmed its presence in certain areas of Colombia, Venezuela and, the Guayanas. P. herreni is spreading through much of Northeast Brazil where it has caused considerable yield reductions in cassava (Bellotti, pers. obs.).

P. herreni feeding causes leaf yellowing, curling, and cabbage-like malformation of the growing points. High mealybug densities lead to leaf necrosis, defoliation, stem distortion, and shoot death. Yield reductions in farmer's fields may reach 80%, and studies in experimental plots resulted in 68 to 88% yield reduction depending on the variety grown (Vargas & Bellotti 1984).

Mealybugs extract calcium from cassava leaves during feeding. Mealybug-infested cassava leaves were analyzed for Ca, P, K, and Mg and compared to non-infested leaves. Infested leaves contained 32% less Ca than non-infested leaves. No significant reduction of N.P.K was detected (Vargas et al. 1989). Reduction in Ca may result in weakened, less rigid cell walls and may be responsible for the curling characteristic of mealybug feeding damage. Reductions in photosynthetic rate, transpiration, and mesophyll efficiency, and moderate increases in water pressure deficit, internal Co_2, and leaf temperature were found in infested plants (CIAT 1988). A positive correlation between low photosynthetic rate and lower leaf calcium content was found, suggesting that Ca-rich clones may be more tolerant of _P_. _herreni_ attack than Ca-poor clones.

_P_. _herreni_ populations peak during dry seasons (van Driesche _et_ _al_. 1990). Rains reduce pest populations and permit plant recovery. The optimal temperature range for female development is 25-30°C (Herrera _et_ _al_. 1989).

Mealybug Control: A combination of host plant resistance and biological control can result in adequate control of the cassava mealybug. Although only low to moderate levels (Porter 1988) of resistance to _P_. _herreni_ have been identified, host plant resistance can reduce populations to levels which make biological control more effective. Many species of mealybug natural enemies are generally present in cassava fields; therefore, high levels of host plant resistance may not be required in order to maintain mealybug populations below economic injury levels. The curling of cassava leaves associated with mealybug feeding may protect mealybugs from insecticides and natural enemies (IITA 1985). Selection of cassava varieties which curl less in response to mealybug feeding could result in increased exposure of mealybugs to attack by natural enemies.

Biological Control: Many successes in biological control of mealybugs in perennial systems have been reported and cassava is considered a functional perennial in the tropics. The successful introduction of *E. lopezi* to control *P. manihoti* in Africa is a recent example of effective classical biological control of mealybugs in a quasiperennial system. The recent identification of several key natural enemies of *P. herreni*, may result in introductions to areas where natural enemies are lacking or ineffective and thus improve control of this species in certain areas of the Neotropics.

Approximately 70 species of parasites and predators of cassava mealybugs have been identified in the Neotropics. Parasites of *P. herreni* identified from Colombia, include *Acerophagus coccois*, *E. diversicornis*, *Anagyrus putonophilus*, *A. insolitus* and *Apoanagyrus elgeri*. Recent explorations in Venezuela have identified *Aenasius* sp. (near *vexans*) as an important parasite of *P. herreni*.

E. diversicornis prefers 3rd instar nymphs, whereas *A. coccois* parasitizes male cocoons, adult females and 2nd instar nymphs with equal frequency. Ovipositor penetration by *E. diversicornis* caused 13.2% mortality of first nymphal instars (van Driesche *et al*. 1990.). *Aenasius* sp. prefers 2nd and 3rd instar nymphs and adult females with equal frequency (CIAT 1990).

Field studies were conducted to determine percent parasitism using trap plants with mealybug hosts set out in cassava fields (van Driesche *et al*. 1988). With Bellow method (Bellow *et al*. 1991), 54.9% mortality was estimated for the combined action of two parasitoid species present (van Driesche *et al*. 1990). *A*. *coccois* was the principal species recovered from collections of mummified mealybugs.

Survey data from South America indicate that the mealybug parasitoid and predator complex is larger in Colombia and Venezuela than in Northeast Brazil, where *P*. *herreni* populations cause severe crop damage. We speculate that *P*. *herreni* is of Venezuelan origin and was disseminated along the eastern coast of South America to Northeast Brazil where it appears to be an introduced pest. The first reports of severe damage from *P*. *herreni* in Northeast Brazil date from the early 1970's. (Albuquerque 1976). Classical biological control could stabilize P. herreni below economic levels in the Brazilian Northeast.

The Cassava Hornworm

The cassava hornworm, *Erinnyis* *ello* (L) (Lepidoptera: Sphingidae) is a serious pest in nearly all cassava growing regions of the Neotropics (Bellotti Schoonhoven 1978) *E*. *ello* has a broad geographical range and is polyphaguous with at least 35 recorded food plants, including 21 species of Euphorbiaceae (Winder 1976). The genus *Erinnyis* consists of several species, although *E*. *ello* is the most commonly reported species attacking cassava. The subspecies *E*.

ello ello is reported from the Neotropics and Neoartic, and *E. ello encantado* is reported from the Galapagos Islands (Carvalho 1980).

Severe hornworm attacks can cause complete plant defoliation, resulting in bulk root loss and poor root quality. Losses in root production are influenced by plant age, soil fertility, environmental factors (especially rainfall) and frequency of attack. Yield losses in fertile soils ranged from 0 to 25% for one attack, and up to 47% after two consecutive attacks. On infertile soil, losses varied between 15 and 45% for one attack and up to 64% after two attacks (Arias & Bellotti 1984). During its five instar larval cycle, each hornworm consumes approximately 1100 cm^2 of foliage; about 75% of this is ingested during the fifth instar.

Hornworm adults are nocturnal grey moths that oviposit small, round, light green to yellow eggs individually on the upper surface of cassava leaves. Eggs hatch in 3 to 5 days. Larval duration at 15, 20, 25, and 30°C averages 105, 52, 29 and 23 days respectively, suggesting that peak hornworm activity should occur in lowland to middle altitudes (800 to 1200m) in the tropics, and in the subtropics during the summer periods, (Bellotti & Arias 1988). Few horNworm attacks have been reported from high altitude (1500-2200m) areas where cassava is cultivated.

The migratory flight capacity of *E. ello* is well documented (Winder & Abreu 1976; Janzen 1986, 1987) and is probably responsible for its wide distribution throughout the Neotropics. Adults migrate en masse, and will oviposit a considerable number of eggs in cassava fields (Bellotti & Arias 1988). These "invasions" have been detected in light trap surveys in Colombia, Brazil and Mexico, and result in "explosions" of hornworms which, if not detected and controlled, result in severe crop defoliation and yield reduction.

Hornworm Control: Several pesticides give adequate control if hornworm populations are detected during the first three instars. Larval populations in the 4th and 5th instar are difficult to control with pesticides, and their use against late instars is generally uneconomical, since considerable defoliation has already occurred. In addition, pesticide use disrupts natural enemy populations and can lead to more frequent attacks (Urias et al. 1987).

A large complex of natural enemies is associated with E. ello in the Americas (Winder 1976; Bellotti & Schoonhoven 1978; Bellotti & Arias 1988; Bellotti et al. 1990). Approximately 40 species of parasites, predators and pathogens of the egg, larvae and pupal stages have been identified. Eight microhymenopteran species of the families Trichogrammatidae, Scelionidae, and Encyrtidae are egg parasites. Of these, Trichogramma and Telenomus are the most important (Bellotti et al. 1983). Numerous dipteran and hymenopteran parasites attack hornworm larvae. Tachinid flies are the most important group of dipteran parasites

(Winder 1976), and the Brachonidae, particularly _Apanteles_ spp. are the most important hymenopteran parasites.

A large group of predators attack hornworm eggs, larvae and pupae. The most common egg predators are _Chrysopa_ spp. The most important larval predators are _Polistes_ spp. (Hymenoptera: Vespidae), _Podisus_ spp. (Hemiptera: Pentatomidae) and a number of spider species. The mycelium of _Cordiceps_ sp. (Aconycetes: Clavicipitaceae) a soil-borne fungus, invades the pupal stage of the hornworm causing mortality.

A granulosis virus of the family Baculoviruiidae (Granados, Boyce Thompson Institute, Pers. Comm.) infects hornworn larvae and is useful in the management of hornworm populations (Bellotti _et al_. 1990; Arias & Bellotti 1984). Infested larvae collected from the field are macerated in a blender, filtered through cheesecloth, mixed with water and applied to hornworm infested cassava fields. In controlled field trials, 100% larval mortality was observed 96 hours after virus application.

Migration is a possible defense against the complex of natural enemies associated with _E_. _ello_. Natural enemy populations cannot increase rapidly enough to control _E_. _ello_ irruptions. Since _E_. _ello_ outbreaks are cyclic and erratic, the release of predators and parasites is difficult to synchronize with pest outbreaks. The hornworm virus is provides a management option that can be manipulated and maintained at a relatively low cost. Preparations of the virus can be refrigerated until required for application. The _E_. _ello_ virus combined with timely detection of hornworm outbreaks offers an effective and economical control of this pest.

Cassava Burrowing Bug

The burrowing bug, _Cyrtomenus_ _bergi_ Froeschener, was first recorded as a pest in Caicedonia, Valle, Colombia (Garcia & Bellotti 1980). Nymphs and adults of this subterranean sucking insect feed on cassava roots by means of a thin, strong stylet. As it feeds, the bug inoculates the roots with soil-borne pathogens such as _Aspergillus_, _Diplodia_, _Fusarium_, _Genicularia_, _Phytophthora_ and _Pythium_ spp. (Bellotti _et_ _al_. 1988). Brown or black lesions develop on the white fleshy root, rendering it commercially unacceptable.

Surveys in Colombia and Panama have revealed that onion (_Allium_ _fistulosum_), peanuts (_Arachis_ _hypogea_), maize (_Zea_ _maize_), sorghum (_Sorgum_ _vulgare_), sugar cane, coffee, coriander, pasture grasses, potatoes and numerous weed species are also hosts of _C_. _bergi_. Yield losses in peanuts and onion are considerable and require repeated pesticide applications for effective control, since other control measures are presently not available.

_C_. _bergi_ populations are present in the soil throughout the cassava crop cycle and root damage increases with plant age (Arias & Bellotti 1985). Root damage can reach 70 to 80% of total roots with more than a 50% reduction in starch content. *C. bergi* has five nymphal instars. The life cycle lasts more than one year, and cassava roots may be the only food source exploited (Garcia & Bellotti 1980). Recent studies indicate that *C. bergi* develops faster on maize than on cassava (CIAT 1990) and prefers maize over cassava in free-choice feeding tests (78 vs. 22%). Oviposition was seven times greater on maize than on cassava.

Field trials suggest resistance to *C. bergi* may be related to the HCN content of the roots. In laboratory tests adults and nymphs fed on a high HCN clone had longer nymphal development (140 vs. 70 days), reduced adult longevity (41 vs. 106 days), reduced egg production (24 vs. 234 eggs) and increased mortality (80 vs. 20%) (CIAT 1986).

Crop Management: Intercropping of *Crotalaria* sp. (sunne hemp) with cassava is a potential means of control of *C. bergi*. Trials in farmer's fields showed that intercropping with *Crotalaria* reduced the percent of damaged roots to 3.7 compared to 61% damaged roots in cassava monoculture plots (Castaño *et al*. 1985). Cassava yield is reduced by 22% when it is intercropped with crotalaria. Although alternate spacing patterns increased cassava yields, adequate control of *C. bergi* is obtained only when crotalaria is planted between every cassava row.

Pesticide use in cassava.

Throughout the Neotropics, cassava receives minimal pesticide applications. Brazil produces about 75% of the cassava in Latin America, and is a major user of pesticides on the continent, however, almost no pesticides are used on cassava (Bellotti et al. 1990). It is estimated that pesticide use will increase by more than 200% in Latin America during the next decade and Brazil is expected to increase its share of the pesticide market significantly although alternate control strategies have potential for impact throughout the country. Since little or no insecticides are used for arthropod control on cassava, every effort should be made to develop IPM programs for cassava which do not incorporate pesticide use.

Discussion

Cassava production is expanding in many areas of the Neotropics and in certain regions, where economic incentives are greater, cultivation is intensifying with a potential for increased use of agrochemical inputs. Historically in many crops, this stage of production intensification has been accompanied by increased insecticide use, and then followed by a crisis due to failure of chemical pest control (Metcalf & Luckman 1982). In some cases, production has become so uneconomical that the crop is abandoned. The implementation of integrated pest management has revived the cultivation of some crops after such a crisis. Integration of appropriate agronomic practices with biological control and host plant resistance, can result in ecologically sustainable and economically viable cassava cultivation (Bellotti et al. 1990). The role of pesticides in cassava cultivation is limited because it is rarely economically justifiable in the context of a low value, small farmer crop with an annual or biennial cycle. The disruption of natural enemies due to insecticide misuse has been documented for hornworm and cassava green mite. The elimination of mite predators with pesticides resulted in increased mite populations and lower yields than in unsprayed plots (Braun et al. 1989).

Stable host plant resistance offers, a practical long term solution for maintaining reduced pest populations. In some cases, such as with thrips in cassava (Schoonhoven 1974), resistance is adequate to maintain pest populations below economic injury levels. Sources of resistance to arthropod pests in cassava have been identified for mites, lacebugs, whiteflies, thrips, burrowing bugs, and others (Bellotti & Kawano 1980; Bellotti et al. 1985; Byrne 1984). Immunity has not been identified for any pest, but available levels of resistance, combined with other pest management tactics, can be utilized to reduce pest populations.

Host plant resistance is usually compatible with other pest management tactics in cassava pest management. Host plant resistance and biological control are complementary, especially in areas where pests and natural enemies have coevolved on land races which have been under a long process of selection by farmer-breeders.

Recent data collected from extensive surveys in the Neotropics corroborates archeological data which suggests that cassava may have been domesticated in the area north of the Amazon Basin. Mites of the genus *Mononychellus*, and mealybugs, and their natural enemy complexes exhibit greater species richness in Northern South America than elsewhere in the Neotropics. CGM populations reach their highest level of polymorphism in this area. Population densities of cassava green mite are generally higher and damage is more severe in Brazil than elsewhere in the Neotropics (CIAT 1990). Classical biological control holds considerable potential for areas where natural enemy complexes are presently inadequate, particular if deployed in conbination with augmentation and conservtion of natural enemies and if the available genetic diversity can be exploited to establish strains which are tolerant of adverse ecological conditions such as low relative humidity.

The scope for classical introductions of natural enemies of cassava pests within the Neotropics includes the deployment of pathogens. The cassava hornworm virus, used successfully for hornworm control in Southern Brazil, (Schmidt 1988) has been recorded from a number of areas (eg. Cuba, Mexico) where *E. ello* is a reported pest.

Conclusion

The challenge to crop protectionists in the future is to contribute to sustainable production systems, especially for small farmers: IPM minimizes the use of pesticides and contributes to ecological stability in agricultural systems.

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INDEX WORDS

Natural enemies, baculovirus, biological control, migration.