Observations on Cassava Mealybugs in the Americas; their Biology, Ecology and Natural Enemies

Authors: Anthony C. Belloti, Jesús A. Reyes, Ana M. Varela, CIAT, Apartado 67-13, Cali, Colombia, and IITA, Ibadan, Nigeria.

ABSTRACT

Mealybugs constitute one of the major production problems on cassava (Manihot esculenta) in Africa and the Americas. Mealybug species identified on cassava in the Americas include Phenacoccus manihoti, P. herrene, P. gossypii, and P. grenadensis. Since its introduction into Africa from the Americas, P. manihoti has caused considerable yield losses in parts of Africa, especially Zaire. In the Americas, outbreaks of P. herreni have been reported from several areas of Brazil, Colombia, and the Guianas. These two species are similar taxonomically and cause similar damage symptoms, but differ markedly in their bionomics.

The initial attack and most severe damage by both species is to the plant growing point. Apical leaves are deformed and bunched, resulting in a "cabbage-like" effect to the growing point. High mealybug populations combined with dry season stresses can cause severe defoliation, shortening of internodes, excessive branching, dwarfism, and distortion of stems and branches. The biology of the two species differ in that P. herreni is bisexual, while P. manihoti reproduces parthenogenetically. Studies of the biology of P. herreni show that the female passes through three instars before reaching the adult stage; the complete cycle of egg through adult is 49.5 days. The male passes through four instars before the winged, adult stage; the total cycle is 29.5 days.

Numerous natural enemies of mealybugs have been identified. Biological control combined with host-plant resistance offers a safe and economical means of controlling these pests.

Mealybugs are part of an extensive complex of insects and mites that attack cassava (Bellotti and Schoonhoven 1978). They constitute a major production problem of cassava (Manihot esculenta) in the Americas and Africa. The most important species are Phenacoccus herreni, P. manihoti, P. gossypii, P. grenadensis, P. cerca surinaensis and Ferrisia virgata (Yaseen and Bennett, 1979). P. grenadensis, P. cerca surinaensis and F. virgata appear to be of only minor importance. Occasionally high populations of P. gossypii are on cassava, but this is not its primary host and attacks are usually localized (CIAT 1977).

The two most important species are P. herreni and P. manihoti. Outbreaks of P. herreni have been reported from several areas of the Americas, especially

Brazil and Colombia. Since introduction into Africa, P. manihoti has caused considerable yield losses in parts of Africa, especially Zaire. These two species are similar taxonomically and in plant damage symptoms but differ markedly in bionomics (Cox and Williams 1981).

Mealybugs are a "new" pest in cassava; only in recent years have serious outbreaks been reported. A literature search discloses that prior to about 1976, reports on mealybugs attacking cassava are limited and of minor importance.

Species origin and distribution

Both P. herreni and P. manihoti probably originated in the neotropics. The exact origin in the Americas has not been determined. Silva (1977), reported a mealybug attacking cassava in Belem, Brazil, as early as 1973; Albuquerque (1976) reported a serious mealybug outbreak in 1975 in Belem, destroying about 150 varieties in the cassava collection. The most recent report of mealybug outbreaks in the Americas was in Pernambuco, Brasil (Bellotti and Reyes 1982); mealybugs were first observed in this area in 1978 (Bellotti pers. observation) and populations have continued to increase since. Also during 1978 mealybugs were found in Carimagua in the Colombian Llanos (Varela and Bellotti 1981).

Initially there was some confusion as to the taxonomic identification; the species in northeastern Brazil and the Colombian Llanos were identified as P. manihoti, the same as or similar to P. manihoti described in Africa. However, recent taxonomic studies separate them into two species, P. herreni and P. manihoti (Cox and Williams 1981). Both species are in the Americas, but only P. manihoti is described from Africa.

P. manihoti was found in Paraguay in 1980 (Belloti, pers. obs.) and surveys by Yaseen (1981a and 1981b) located this species in Brazil (Mato Groso) and Bolivia, as well as Paraguay. P. manihoti appears to have been introduced within the last 4 or 5 years into Paraguay, being found only within 50 kilometers of Caacupe, where it was originally discovered. P. herreni has been reported from Colombia, Guyana and northeastern Brazil (including states of Pernambuco, Cerá, Pará and Amapa).

The biology of cassava mealybugs

P. herreni. Biology studies of P. herreni were on greenhouse potted plants of cassava variety M Col 113. Recently emerged nymphs were placed on leaves and isolated with small leaf cages. Daily observations were made on nymphs and adult development. Oviposisional capacity was also measured.

The female is cream colored and oval shaped throughout its life cycle. It is soft-bodied and segmented, with short antennae and three pairs of legs. Upon emerging from the egg and after each nymphal molt, its body is translucent; the female later proceeds to cover herself with small waxy secretions giving a cottony appearance.

After emerging from the eggs, nymphs remain within the ovisac for a short time and then migrate rapidly in search of a feeding site. They may remain feeding at this site throughout the nymphal stage unless disturbed or if necrosis forces them to seek another feeding site.

It is impossible to distinguish sexes during the first instar; however, sexual dimorphism is manifest during the second instar. The first female instar averages 7.7 days during which the nymphs, usually called "crawlers," migrate in search of a feeding site. The second and third female instars are 5.1 and 5.6 days, respectively. Apart from increased size, no fundamental differences occur in appearance between these two instars. The fourth instar, the adult stage averages 24.8 days.

Table 1. The life cycle of Phenacoccus herreni on cassava plants (var. M Col 113) under greenhouse conditions*.

	Females				Males		
Instar	No. days (average)	Range (days)	No. observations	Instar	No. days average	Range (days)	No. observations
Egg	6.3	6-8	205	Egg	6.3	6-7	205
1st.	7.7	6-9	79	1st.	7.5	6-8	34
2nd.	5.1	4-7	81	2nd.	6.0	5-7	34
3rd.	5.6	5-7	82	3rd.	2.8	2-4	32
Adult	6.4**	6-7		4th.	3.1	2-4	32
	18.4***	15-21	47	Adult	3.8	2-4	28
Totals	49.5	42-59			29.5	23-24	

*T = 28°C to 38.20°C; RH = 66% (90%-35%)

**Preovipositional period of female

***Ovipositional period of female

The male adult is winged, soft, and fragil with reduced mouth parts. Its body is rose colored with a pair of white wings and two pairs of white, waxy, caudal filaments as long as its body. Legs are well-developed and antennae are two-thirds as long as the body. The male passes through four nymphal instars before the adult stage. The first male instar is identical to the female with an average duration of 7.5 days. The second instar is 6 days; beginning on the fourth day the nymph changes from a cream color to pink. On the fifth day it begins to form a white cottony cocoon, within which it remains until the adult emerges. No feeding takes place during the third and fourth instar within the cocoon as mouth parts atrophy and are nonfunctional. The third instar which averages 2.8 days is the prepupal stage and the nymph begins to transform into an adult. The fourth instar, or pupal stage, is 3.1 days and rudiments of wings and antennae appear. The adult, once formed, remains within the cocoon for one day before emerging then is very active for 2 to 4 days searching for females. One male may copulate with various females.

Parthenogenosis did not exist in the population studied. The male is indispensable for reproduction; if females are not fertilized there is no oviposition. Females can be fertilized immediately upon entering the adult stage. Oviposition is initiated 3 days after copulation. Before oviposition starts the female begins to form a cottony sac, the ovisac, on the posterior end of its body. Eggs are oviposited within this sac. Formation of the ovisac continues throughout the egg laying period but does not cover all of the female body. The ovipositional period averages 18.4 days but may last up to 21 days.

The average number of eggs oviposited was 773 (529-1028) during the 18.4-day period. Maximum oviposition during the third day of 80 eggs per female slowly declined to 10 eggs on the last day of ovipositon. Eggs are cream colored, measuring 0.38 mm long by 0.20 mm wide. Incubation period is 6.3 days.

When females were isolated without males, they lived up to 23 days. When males were placed with unfertilized, 15-23 day old females, the ovisac formed in 2-3 days. The average of 200 eggs per ovisac had a sex ratio of three females to one male.

Growth differs between the sexes. Females continue to increase in size until the adult stage, maintaining the same length-by-width measurements throughout its cycle. The major male growth period is during the second instar; the length-by-width relationship increasing throughout its instars resulting in an elongated adult form.

Table 2. Size and growth of _Phenacoccus herreni_ on cassava (var. M Col 113) under greenhouse conditions*.

	FEMALES				MALES			
Instar	Observations	Length mm (increase)	Width mm (increase)	Length/width relation	Observations	Length mm (increase)	Width mm (increase)	Length/width relation
Recently hatched	25	0.42	0.20	2.1	25	0.42	0.20	2.1
1st.	50	0.71 (0.29)	0.33 (0.13)	2.1	38	0.70 (0.28)	0.32 (0.12)	2.2
2nd.	50	1.1 (0.39)	0.46 (0.13)	3.4	35	1.32 (0.86)	0.46 (0.14)	2.9
3rd.	48	1.5 (0.40)	0.8 (0.34)	1.9	35	1.33 (0.01)	0.51 (0.05)	2.6
4th.		-	-		34	(-0.02)	(-0.05)	2.8
Adult	40	3.1 (1.6)	1.4 (1.4)	2.2	30	1.46 (0.15)	0.37 (-0.09)	3.9

*Temp. = 28°C to 38°C; RH = 66% (35% to 90%)

P. gossypii. The life cycle of _P. gossypii_ was studied with females placed on excised cassava stems (M Col 113) in the laboratory (temp. 26°-28°C, 75-85% RH). Three nymphal instars averaged 8.6, 5.7 and 6.3 days, respectively. Adult females survived up to 21 days. Oviposition started between the fifth and seventh day and continued for 5 days. An average of 328 eggs per female was oviposited with most eggs produced the first day, steadily decreasing thereafter. All eggs remain in an egg pouch on the posterior part of the female's body until the nymphs hatch.

Table 3. The life cycle of Phenacoccus gossypii on cassava plants (var. M Col 113) under laboratory conditions*.

	FEMALES				MALES		
Instar	No. days (average)	Range (days)	No. observations	Instar	No. days (average)	Range (days)	No. observations
Egg	7.4	6-9		Egg	7.4	6-9	
1st.	8.59	7-10	32	1st.	8.5	7-9	10
2nd.	5.71	4-7	32	2nd.	6.0	4-9	10
3rd.	6.34	5-7	32	Prepupa	2.1	2-3	10
Adult	18.9	17-21	32	Pupa	2.1	2-3	10
				Adult	2.03	1-3	
TOTAL	46.94	39-54		TOTAL	28.13	22-36	

*Temp. = 26° to 38°C; RH = 75%-85%

While nymphs in all instars are mobile they may feed in one site for several days. They prefer to feed on the underside of leaves or on tender stems. The female is wingless, whereas males have wings enabling flight. Males pass through two nymphal stages, (8.5 and 6.0 days, respectively), a prepupal (2.1 days) and pupal (2.1 days) stage before adults emerge. Adult males live up to 3 days.

P. manihoti. Studies on P. manihoti in the Americas have only recently been initiated. African results indicate that the female of this species is parthenogenetic and no males have been observed in the field or laboratory (Nwanze et al 1979). The female life cycle is similar to P. herreni with three nymphal instars before the female reaches the adult, forth instar stage. The preovipositional period averages 5.2 days and the mature adult or ovipositional period is 20.2 days. The total duration average 46.2 days (range of 27 to 56 days). The adult female oviposited an average total of 440 eggs over a 20.2 day span. Nymphs and adults are creamy-white and covered with a thin layer of white, wooly substance (Nwanze et al. 1979).

Ecology and behavior of P. herreni

Plant infestation. Natural infestation is generally initiated by first instar nymphs which usually migrate to the apical part of the young growing shoot of the plant. Initial population build-ups are usually around the growing point. The plant reaction is a rosetting effect to the apical leaves giving a cabbage-like appearance to the growing shoot that also provides some measure of protection for this initial colony. This plant reaction may occur with only a few nymphs present, indicating injection of a toxin into the plant by nymphs or female adults.

Mealybug populations growing points may increase considerably: on one shoot in Pernambuco, Brazil, 30 males and 150 females were counted. As population increases, mealybugs migrate from the shoot and disseminate to all other plant parts. Dispersion begins on stems and eventually all leaves are infested. Infestation is always on the leaf underside, beginning at the leaf/petiole juncture, along the veins and eventually covering the whole leaf.

Heavy infestation results in plant stunting, defoliation, deformation of the growing shoot, shortening of internodes and distortion of stems. Heaviest infestations occur during the dry season. Outbreaks in Pernambuco over a 3 year period coincided with an overall decrease in rainfall. Increased mealybug populations in Colombia also occur during dry periods, thus increasing drought stress.

Onset of the rainy season stimulates plant growth and mealybug populations decrease. Severe deformation of stems may be recognized upon initiation of plant growth. Stems have a corkscrew appearance, forming 360° circles with some stems turning at almost right angles. Although populations may decrease dramatically during rainy periods, mealybugs are still present in considerable numbers. Slight deformation of the shoots can still be observed and, when opened, nymphs, adults and ovisacs are found. Shoot deformation can be observed in numerous plants even during the rainy period, however, plant damage is greatly reduced. Mealybugs may also be found on stems, especially around the lateral buds, and on the underside of middle and lower leaves. Often the smallest and weakest plants are attacked most. Regrowth from basal buds also displays considerable infestation during the rainy periods.

Dissemination of *P. herreni*. Preliminary field experiments in Colombia show that wind is a major factor in dissemination of mealybug from one field to another. Cassava plots were planted about 100 meters from a heavily infested field in the Colombian Llanos. Those fields sown in the direction of the prevailing winds became rapidly infested with mealybug nymphs, while plots up-wind of the infested field remained uninfested. Dissemination from one area or country to another is facilitated by infested planting material. In recently planted fields in Pernambuco, Brazil, stakes and plant debris were infested with mealybug. Nymphs were often feeding within the lateral buds of these plant parts.

In addition, cassava stems are often stored for varying lengths of time during dry periods while waiting for rains to resume or during cold months in sub-tropical areas of southern Brazil and Paraguay). Mealybug-infested stems stored during these periods disseminate the pest from one growing cycle to another.

Behavior of *P. gossypii* on cassava

P. gossypii has a wide host range and cassava is only an occasional host. Usually populations are controlled by numerous natural enemies. Females deposit egg sacs around the axil of branching stems or leaves, on the underside of the leaf where the leaf petiole joins the leaf, or around buds on the main stem. High populations give a cottony appearance to the green or succulent portion of the stem and on the leaf undersurface. Infestations within a field are often in patches and may occur in areas where heavy use of pesticides eliminated natural enemies. Damage symptoms are significantly different than those of *P. herreni*. *P. gossypii* feeding causes leaf yellowing and eventually defoliation beginning with the basal leaves. There is no rosetting of the shoots or distortion of shoots and stems. High populations of *P. gossypii* also occur during dry periods.

Behavior of P. manihoti on Cassava

The ecology and behavior of *P. manihoti* is similar to that of *P. herreni*. Terminal points are attacked first then the petioles and expanded leaves. Internodes are shortened, there is leaf curling and reduced new-leaf growth. As population density increases, all green parts of the damaged shoots eventually die. Infestation of lower leaves through natural leaf fall during the dry season gives the plant a "candlestick" appearance (Leuschner and Nwanze, 1978). With onset of the rainy season mealybug populations drop considerably and within a month new leaves and shoots are abundant. Nymphs and adults persist on cassava plants during the wet season and serve as inoculum at the beginning of the dry season. Dissemination of *P. manihoti* is primarily by planting material and wind (Nwanze et al. 1979).

Yield losses due to mealybugs

The effect of mealybug attack on production of cassava roots in the Americas has not been quantified. Observations indicate that populations of *P. manihoti* and *P. gossypii* are not sufficiently high to cause root reduction. However, populations of *P.* herreni in northeastern Brazil are sufficiently high to reduce yields. Indications are of root reductions up to 80% while in Pernambuco, Brazil, traditional cassava farmers are replacing it with alternate crops.

Reports from Africa show measured yield losses of 45% in experimental plots (Atur and Okeke, 1981).

Natural enemies of cassava mealybugs

In general, biological control of mealybugs on agricultural crops has been successful (Debach, 1964). The potential exists for successful control of cassava mealybugs with natural enemies. Natural enemies associated with cassava mealybugs include predators, parasites and pathogens. Approximately 25 parasites of *P. gossypii*, *P. herreni* and *P. manihoti* have been registered in the Americas. Twenty-three of these are in the Encyrtidae family and include the genera *Anagyrus*, *Aponagyrus*, *Aenasius*, and *Acerophaga*. The fungal pathogen *Cladosporium* sp. has recently been identified parasiting *P. herreni* in Brazil and Colombia.

Approximately 43 predators have been reported on the above three mealybug species. Most belong to the family Coccinellidae, primarily of the genera *Hyperaspis* and *Nephus*. Insect orders represented include Neuroptera four *Chrysopa* species and two *Sympherobius* sp.), six dipteran species (including *Ocyptamus* sp. and *Kalidiplosis* sp.), five hemipteran (including *Zellus* sp.), Coleoptera (including 22 Coccinellidae and two Staphylinidae), and two lepidopteran (including *Pyroderces* sp.). One list contains some 75 natural enemies - parasites, predators, hyperparasites - of these mealybugs. Most of these species have been reported from cassava fields. Some have been found on these mealybugs, especially *P. gossypii*, feeding on other crops.

Two species of mealybugs *P. herreni* and *P. gossypii* and their potential biological control in the Americas will be further discussed. They present two distinct situations with different modes of attack and while cassava is not the preferred host of *P. gossypii* it appears to be so for *P. herreni*.

Table 4. Predation* and parasitism** of the mealybug Phenacoccus gossypii feeding on cassava by natural enemies over five consecutive weeks in field cages***.

Weeks after exposure to natural enemies	% predation of ovisacs	% predation of nymphs and adult-females	% parasitism of nymphs and adult-females
1	64.4	76.6	5.1
2	78.4	94.6	4.8
3	94.6	87.9	8.8
4	96.6	70.6	6.7
5	100	73.2	9.6

*Predators = Kalodiplosis coccidarum, Chrysopa sp.
Coccinelidae and Reduviidae.
**Parasite = Anagyrus sp.

***Field cages = 3x3x2 m.

P. gossypii has numerous natural enemies. Its mode of attack exposes populations (on the tender portion of the stems and on leaf undersurfaces) to predation and parasitism by natural enemies. In studies at CIAT (1979) cassava cultivars were infested at 45 days with six P. gossypii egg masses and protected in screened cages to prevent attack by natural enemies. Mealybug dispersal resulted in 44.9%, 41.0%, and 14.1% of the biological stages being located on the basal, middle and upper third of the plant, respectively. Effectiveness of several enemies on controlling P. gossypii were studied in field cages (CIAT, 1980). When mealybugs became numerous (about 26,000 nymphs and adults per cage) natural enemies were allowed entry. Predator and parasite populations were recorded for 6 weeks, by which time mealybug populations were almost zero.

In general, a higher percentage of predation than parasitism resulted and the latter never averaged more than 10%. Predation of ovisacs, principally by K. coccidarum, reached 100% after 5 weeks, and predation of nymphs and adults reached 96%, primarily due to Chrysopa and Reduviids. Major predators were Chrysopa, K. coccidarum and several Coccinellids and Reduviids. Anagyrus spp. were the predominant parasites. In cages where mealybugs were most numerous, K. coccidarum was the heaviest predator while Chrysopa, the Reduviids, and some Coccinellids predominated in cages with lower mealybug populations. Mealybug populations decreased steadily during 6 weeks.

High populations of the dipteran predator K. coccidarum have been observed in greenhouse colonies of both P. gossypii and P. herreni. However, field populations have been erratic. It was initially observed predating on eggs within the ovisac, but larvae have also been found predating nymphs, especially adult females, when ovisacs are not available. It remains in the ectoparasitic stage and seldom causes nymphal mortality until the ovisac is formed, then it predates eggs until completing its life cycle. Its ectoparasitic stage is important for survival when host populations are low. A female:male ratio of 2:1 was observed.

Table 5. Populations of five natural enemies observed attacking mealybug (Phenacoccus gossypii) populations on cassava over five consecutive weeks in six exposed field cages*.

Weeks after exposure to natural enemies	Average number of natural enemies per cage**				
	PREDATORS				PARASITES
	Kalodiplosis coccidarum	Chrysopa sp.	Coccinellidae	Reduviidae	Anagyrus sp.
1	492.0	33.3	61.0		17.5
2	40.5	27.8	20.7	35.7	8.3
3	50.0	30.0	28.3	10.0	2.3
4	11.7	23.8	2.3	12.0	0.2
5	2.3	18.7	3.2	7.0	0.2

*Field cages 3x3x2 m.

**Average per cage for 6 cages.

The average number of K. coccidarum per ovisac varied depending on host availability. When ovisacs were numerous, three predator larvae were found, on average, per ovisac (from 1-5) and higher predator populations resulted in 5 larvae per ovisac (range 2-8). Initial studies of K. coccidarum indicate a life cycle of 12 days (at 28°C) to 16 days (at 22°C).

In recent years, studies at CIAT have concentred on the P. herreni since this is of greater economic importance. Natural populations of this mealybug were studied in cassava fields at CIAT. During 1981 systematic evaluations of populations of its natural enemies were made by collecting infested plant parts from 13 locations and identifying emerging parasites and predators. Collections were made during July, August, and September when mealybug populations were highest. Five major enemies were identified. Ocyptamus was by far the most predominant predator accounting for 68% of the total natural enemies observed and was found in 85% of the fields surveyed. Other predators collected were of the genera Cleothera, Sympherobius, and Chrysopa. Anagyrus sp. was the major parasite observed and accounted for 19.2% of the enemies collected.

During September 1982, similar evaluations were made. A variety of natural enemies was collected. In the first sampling, 13 predator species were identified and 12 in the second sampling. The predator collected in greatest numbers was K. coccidarum which did not appear in the 1981 sampling. The most prominent parasite found was the microhymenopteran Acerophaga coccois. This parasite represented 85% of the parasites collected in the first sample and 92% of those in the second. Although this parasite was collected in previous years at CIAT, it was not collected in such high numbers. A colony of this parasite has been established and further studies are planned.

During a P. herreni outbreak in Pernambuco, Brazil, several predators and parasites were collected. Predators included the dipterans Ocyptamus sp. and a Cecidomyiidae (possibly Kalodiplosis); the Coleopterans, Hyperaspis notata, Hyperaspis sp. and Nephus sp.; a Chrysopa sp.; a Carabidae; the Reduviidae, Zellus sp. and an unidentified Anthocoridae; a Lepidopteran, Pyroderces sp.; and three

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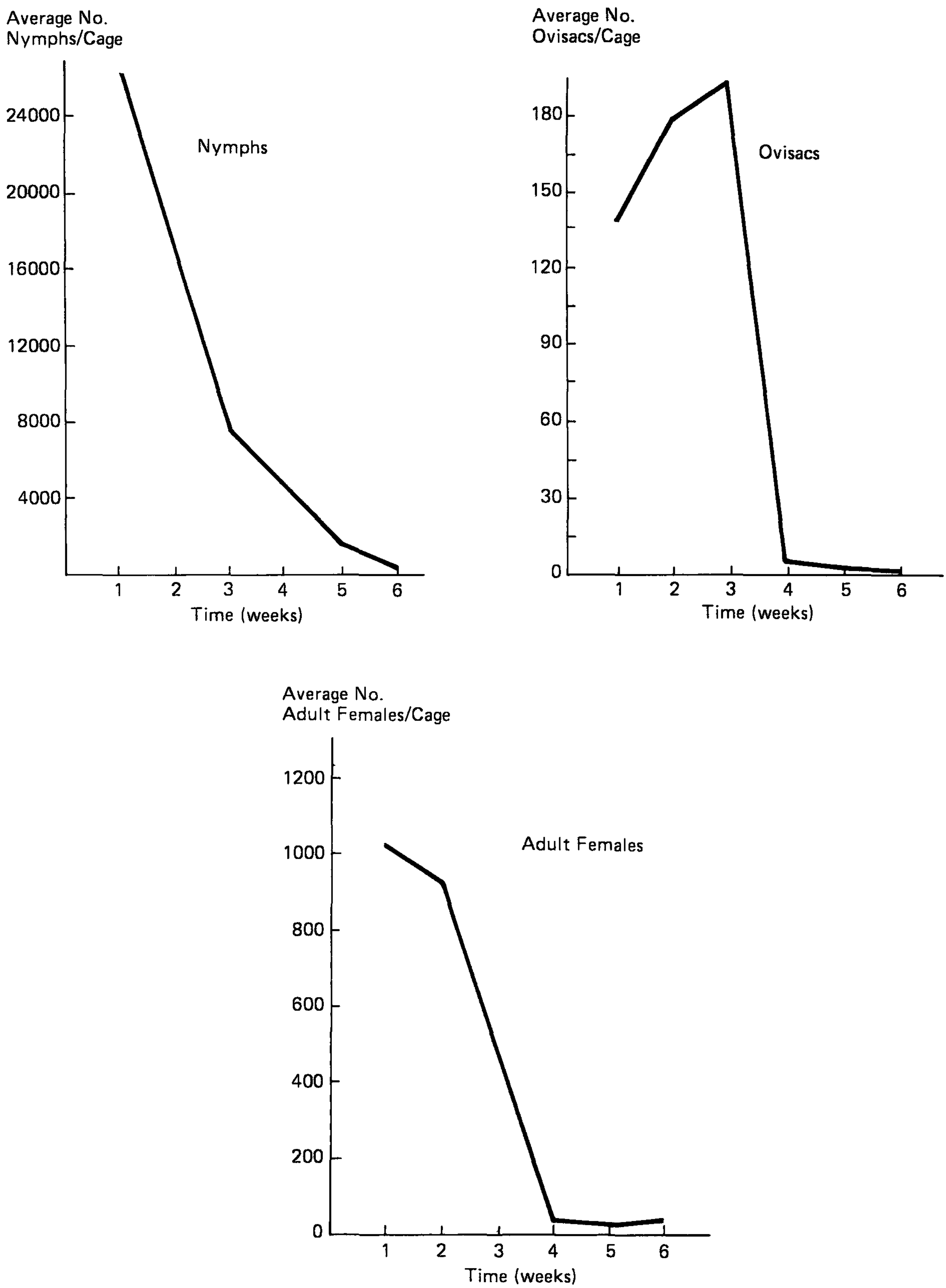

Figure 1. Reduction in number of ovisacs, nymphs and adult females of *Phenacoccus gossypii* by its natural enemies.

Table 6. Population of natural enemies of the mealybug _Phenacoccus herreni_ in 13 CIAT cassava fields.

Natural enemies	% of total enemies	% of field surveyed
Ocyptamus stenogaster	68.3	84.6
Cleothera sp.	14.6	46.1
Anagyrus sp.	9.2	61.5
Sympherobius sp.	4.4	38.4
Chrysopa sp.	3.3	30.8

Table 7. Parasites and predators collected on high field populations of _Phenacoccus herreni_ at CIAT, Palmira.

Date:	Sept. 2, 1982			Sept. 14, 1982		
	No. Species	No. Indiv.	% of total	No. Species	No. Indiv.	% of total
Parasites						
Hymenoptera						
Acerophaga	1	288	86	1	377	92
Other Hymen.	6**	19		11**	32	08
Predators						
Coleoptera	7	26	37	5	9	7
Neuroptera	2	5	7	1	1	1
Diptera	2	30	43	1*	106	84
Lepidoptera	2	9	13	3	8	6
Psocoptera				1	1	1
Hymenoptera				1	1	1

*_Kalodiplosis coccidarum_

**Includes hyperparasites

hymenopteran parasites of the family Encyrtidae, one an _Anagyrus_ sp. An Ocyptamus sp. was observed in high populations but was hyperparasitized.

At both CIAT and in Pernambuco, Brazil, the fungal pathogen Cladosporium was observed parasitizing _P. herreni_ nymphs and adults. Fungal attacks give mealybugs a sooty, dark-gray appearance. A high rate of parasitism was observed in cassava fields in Pernambuco. Observations indicate that the fungus may be most effective only under high populations. However, the fungus can be easily cultured on a medium and offers the possibility of spray applications in fields when mealybug populations are low, thereby preventing population build-ups. Further research should be directed toward this pathogen.

The search for natural enemies of *P. manihoti* recently began in Paraguay, Brazil and Bolivia. Several parasites and predators have been described. Parasites include *Apoanagyrus lopezi*, *Aenasius vexans* and *Acerophagus* sp. (all are Hymenoptera: Encyrtidae). Predators include the Coccinellidae, *Hyperaspis notata* and *Hyperaspis* notata and *Hyperaspis* sp., and the genera *Exochromus* and *Olla*. Additional predators include *Crysopha* sp., *Sympherobius* sp., *Ocyptamus* sp., and *Kalodiplosis* sp.

A problem in this mealybug/natural enemy complex is presence of several hyperparasites which can reduce populations of the natural enemies. *Ocyptamus* sp. is a frequent predator of mealybugs and appears to be an efficient one, however, as its populations build up, there is increased hyperparasitism. Since *Ocyptamus* is a fairly universal predator, it will be difficult to introduce it into areas where it does not already exist and is already accompanied by its hyperparasites. However, precautions should be taken to avoid introduction of hyperparasites of other natural enemies of the mealybug.

Summary

Mealybugs constitute a major pest problem on cassava in the Americas, causing severe losses in root yields. Current outbreaks are confined to localized areas. However, if they disseminate to other favorable cassava growing areas potentially they can cause more severe losses. Several species attack cassava but *P. herreni* appears to be most economically important. The exact origin of this species in the Americas is not known although it is reported from several countries (Brazil, Guyana and Colombia). *P. manihoti*, a closely related species causing crop losses in Africa, is reported from Brazil, Paraguay and Bolivia. Possibly these two species have a common geographic origin.

P. herreni and *P. manihoti* are taxonomically similar as is their mode of attack and the plant damage symptoms they cause. Both species attack the growing point and cause a rosetting effect to the apical leaves resulting in a cabbage-like appearance to the shoot. Heavy infestations will result in plant stunting, defoliation, deformation of the growing shoot, shortening of internodes and distortion of stems. Presence of a toxin is indicated. High mealybug populations and severe plant damage coincide with dry periods.

P. herreni and *P. manihoti* differ markedly in their bionomies. *P. manihoti* reproduces pathenogenically while *P. herreni* is bisexual. Males of *P. manihoti* have not been observed in populations studied; males of *P. herreni* are essential for reproduction and oviposition is initiated only after copulation. Females of both species have similar life cycles: *P. herreni* 49.5 days and *P. manihoti* 46.2 days. Both pass through three instars before the adult stage. Oviposition is greater with *P. herreni*, 773.6 eggs per female vs. 440 for *P. manihoti*.

Dissemination of both species is similar with wind as a major factor in movement of mealybugs from one field to another. Dissemination from one area to another is facilitated by infested planting material.

Cassava mealybugs have numerous natural enemies and considerable potential exists for biological control. Approximately 25 parasites and 43 predators of *P. gossypii*, *P. herreni*, and *P. manihoti* have been registered in the Americas.

However, the geographic origin of P. herreni and P. manihoti has not been determined, therefore the most efficient natural enemies of these two species may not yet have been observed. Exploration for the origin of these pests and their natural enemies is an essential component of a biological control program.

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