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The Ant Problems of Cocoa Farms in Brazil

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INTRODUCTION

The cocoa tree, *Theobroma cacao* L. (Sterculiaceae), is native to the Amazonian Basin. A French settler introduced the tree to Bahia from the state of Para in 1746. The first important plantation was established in 1816 near Canavieiras. As cocoa trees need shade to grow, traditional plantations used the "cabruca" system of establishment, in which the tallest, healthiest trees of the primary rainforest are selected and preserved. "Cabruca" plantations now cover about 400,000 hectares. This explains the similarities between cocoa farm and rainforest ant populations. From 1960 to the present, cocoa began to be mixed with plant species such as banana, and the following trees: *Erythrina fusca* Loureiro, *E. poeppigiana* (Walp.) Cook, *Inga spp* and *Spondias lutea* L.. This type of plantation covers approximately 200,000 hectares.

On Bahian cocoa farms, the dominant ants of the canopy are spatially distributed, in a characteristic "patchwork", or "ant-mosaic," in which each species occupies its own group of trees (Leston 1978; Winder 1978). This distribution model has been well-documented on African cocoa plantations (Majer 1972, 1976a,b; Leston 1973; Taylor 1977; Jackson 1984). In the Neotropics, the dominant ants belong to the Dolichoderinae, Ponerinae (Leston 1978) or Myrmicinae (Winder 1978) subfamilies.

Ants are an important part of the Southern Bahian cocoa agroecosystem. Leston (1978) found 130 ant species on one hectare of a secondary forest reserve, while more recent studies registered 105 soil surface species and 70 litter species on one hectare of an experimental cocoa area (Delabie, unpublished). Moreover, approximately 250 ant species have been registered for the region (Delabie, unpublished). Due to ant species diversity, interactions among themselves and other flora and fauna, the ants have enormous economic potential - both destructive and beneficial.

More than 90% of Brazil's cocoa comes from the Southern Bahian state. This paper will focus on economically-important ant species in the region, with special emphasis on current research efforts.

ANT INJURIES

Leaf-Cutting

Some fungus-growing ants (Myrmicinae, Attini) like *Atta cephalotes* (L.) and *Atta sexdens sexdens* (L.) cut young cocoa leaves - an activity particularly harmful to young plants - and flowers. Recent observations on a six year old plantation showed that continuous attacks by a mature *A. cephalotes* nest negatively affect tree development (height and trunk diameter) until the tree

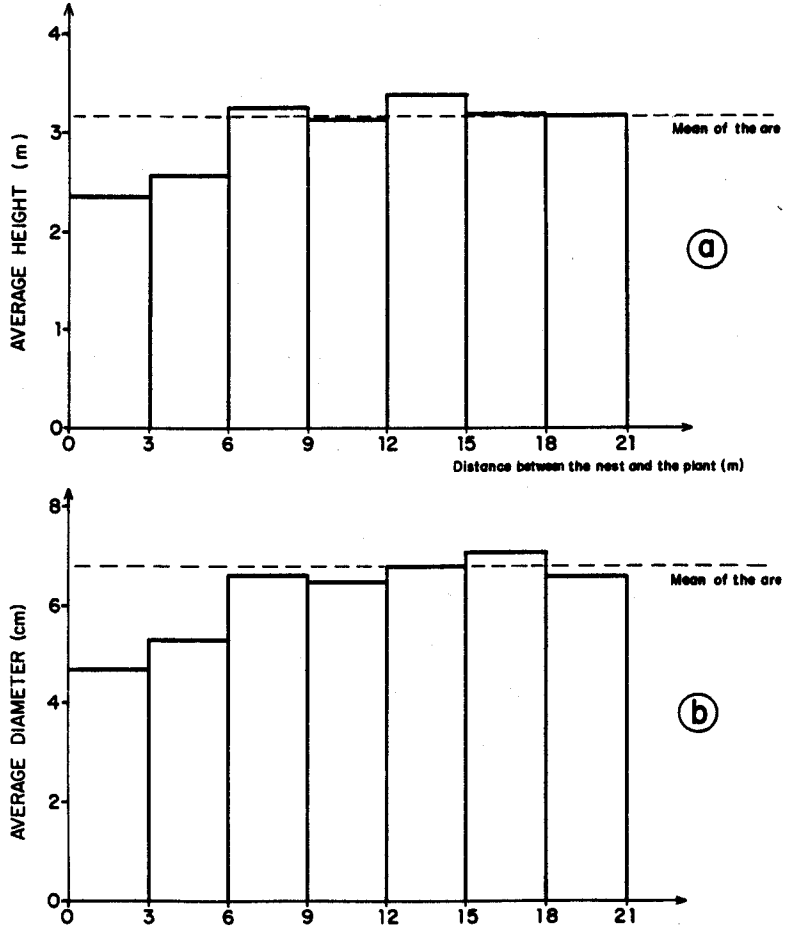

FIGURE 1. Consequences of continuous defoliation by an *Atta cephalotes* nest on the development of young cocoa trees in a 6 year old plantation.

reaches a height of six meters. Ten to 14 trees had retarded growth for two years (Fig. 1) as a consequence of the defoliation, which was inversely proportional to the tree's distance from the nest, up to about 15 meters. The results are independent of foraging trail location. In cocoa farms, nest density may reach one adult nest of *A. cephalotes* per hectare, possibly higher for *A. sexdens sexdens*, depending on vegetation type and insecticide application. *A. cephalotes* prefers dense vegetation, such as forest or well-shaded plantations, while *A. sexdens sexdens* adapts to man-made conditions, such as pasture, crop or recovering secondary forest; thus it is more frequently found on cocoa plantations. *A. cephalotes* constructs fungus-growing chambers to a depth of two meters in soils which may be flooded, while *A. sexdens sexdens* construct theirs up to five meters deep in drained areas (Abreu and Delabie, 1986).

The nests of another species--probably the most common fungus-growing ant in the region--*Acromyrmex subterraneus brunneus* Forel, are found at densities up to 150 per hectare. This often polygyne ant (Delabie, In Press) nests near the surface of the ground, at the base of trees, under rotted wood, covered by litter or beneath abandoned pieces of plants (Bondar 1923, Abreu and Delabie 1986). In addition to damaging cocoa in much the same way as *Atta* species, *Acromyrmex subterraneus brunneus* removes the skin of the pods.

Other Direct Damage to the Cocoa Tree

The gardening ant *Azteca paraensis bondari* Borgmeier (Dolichoderinae), directly damages the tree canopy by chewing or rasping buds and/or bark of the shoots above the nest, to extract gummy substances used in nest construction (Bondar 1939, Silva 1945). This action kills the branches, favors growth of associated epiphytic plants (Figure 2) and, eventually, the growth of invasor plants on the ground. Other ant species also chew the bark of buds or shoots: the "caçarema" ant, *Azteca chartifex spiriti* Forel, *Cephalotes atratus* (L.), the uncommon *Crematogaster magnifica* Santschi, (Bondar 1939), or *Solenopsis geminata* (Fabricius) (Entwistle 1972). However, except for the "caçarema" ant, the damage they cause is minimal.

The nest weight of some arboreal social insects, such as *A. chartifex spiriti* (Figure 3) or the termite *Nasutitermes spp* (Ramb.) can be damaging to cocoa (Bondar 1939, Silva and Barbosa 1948). Large and heavy, their nests may break a big branch or destabilize trees without a well-developed root system. Because of agricultural practices, a majority of cocoa pods hang on a small number of branches; these large nests can cause substantial damage.

Stinging Pests

The little fire ant, *Wasmannia auropunctata* (Roger) (Myrmicinae, Ochetomyrmicini), is among the region's most common ant species (Delabie 1988; see Ulloa-Chacon and Cherix this volume). This ant, and other, less abundant fire ants, like *Solenopsis bondari* Santschi, *S. brasiliana* Santschi and *S. geminata medusa* Mann (Myrmicinae, Solenopsidini) have the popular name of "pixixica" (Bondar 1925, 1939). All these species tend mealybugs and/or scale insects on the pods. Control of these abundant ants may be necessary to prevent harmful stings when harvesting the pods.

FIGURE 2. A nest of *Azteca paraensis bondari* with associated plants of the Gesneriaceae and Orchidaceae families.

The aggressive *Polybia versicolor* Ol. and *P. angulata* Fr. wasps must be added to this category, since they build nests near those of arboreal ants, mainly *Azteca* species (Zehntner 1917, Bondar 1939, Silva and Barbosa 1948). Aggregation of nests is common in this wasp genus (Jeanne 1978). In the presence of ants, the wasps receive a degree of protection against predators, especially birds and monkeys. The wasps probably have great utility as natural biological control agents of cocoa pests such as lepidopterous larvae. However, on cocoa plantations, field workers do not harvest pods where wasp nests are established to avoid being stung.

FIGURE 3. A nest of *Azteca chartifex spiriti*.

Homoptera-Tending

Many ants which explore and forage the canopy tend different sap-sucking insect species, such as Aleyrodoidea (genus *Aleurodicus* Douglas, *Aleurotrachelus* Quaintance and Baker and *Paraleyrodes* Quaintance), Aphidoidea (chiefly *Toxoptera aurantii* Boyer), Coccoidea (genus *Aspidiotus* Bouche, *Ceroplastodes* Ckll., *Coccus* L., *Planococcus* Ferris, *Pseudoanidia* Ckll. and *Saissetia* Depl.), and Membracoidea (genus *Aethalion* Latreille, *Bolboneta* Amyot and Serville, *Horiola* Fairmaire, *Membracis* Fabricius and *Tragopa* Germ.) (Bondar 1939, Silva 1944, 1950) on the pods, flowers or shoots. The most common tending ants belong to various subfamilies: Dolichoderinae (*A. chartifex spiriti*, *A. paraensis bondari*, *Dolichoderus attelaboides* (Fabricius), *D. decollatus* Fr. Smith and *Hypoclinea bidens* (L.)), Formicinae (*Camponotus spp* and *Paratrechina spp*), Myrmicinae (*Cephalotes atratus*, *Crematogaster spp*, *Solenopsis spp* and *W. auropunctata*) and Ponerinae (*Ectatomma tuberculatum* (Olivier) and *Odontomachus haematodus* (L.)). *E. tuberculatum* and *O. haematodus* are among the rare exceptions of

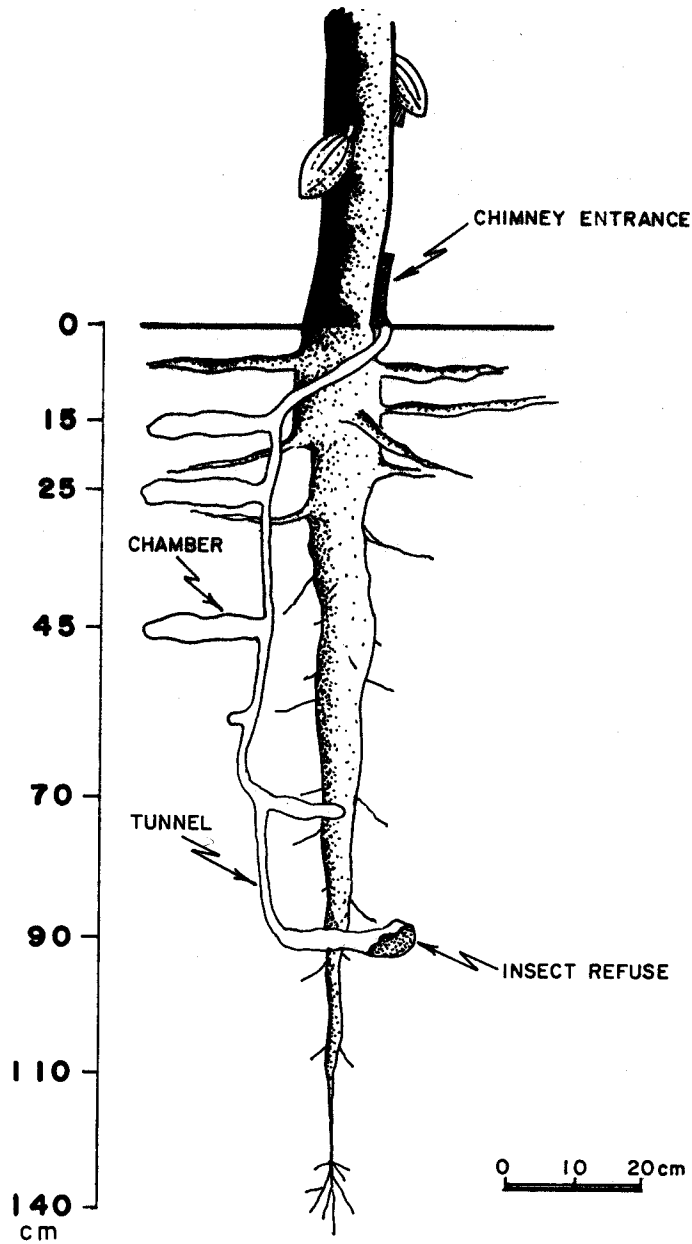

FIGURE 4. A nest of *Ectaomma tuberculatum*.

Ponerinae-tending Homoptera, since all Ponerinae were considered exclusively as predators (Bondar 1939, Weber 1946, Evans and Leston 1971, Entwistle 1972). *O. haematodus* nest in litter or rotten wood and are ground foragers. However, it occasionally nests in abandoned termite nests, shelters made of organic material or dried pods on the cocoa trees, and may tend Homoptera, chiefly treehoppers. *E. tuberculatum*, common in the cocoa agroecosystem, is a ground-nesting species. It constructs a vertical tunnel with up to five horizontal chambers near the tree tap-root (Figure 4) topped by a 10-30 cm chimney made of plant remains and applied vertically on the trunk. This ant carries excavated soil particles to the tree canopy (Bondar 1925, 1939). The colonies are polygyne and may contain several hundred workers. On some farms, 90% of the trees have a nest at their base. Some workers forage in the canopy and on the trunk, while others tend Homoptera of several families or genera, depending on the season, the tree species and the availability of flowers or fruits.

Formicinae ants (genus *Acropyga* Roger, subgenus *Rhizomyrma* Forel) rear different pseudococcid species on cocoa roots in superficial soil layers (Delabie and Mantovani, In Press), as has been reported for cocoa plantations in other countries (Wheeler 1935, Weber 1944, 1957). The association of mealybugs with these ants is obligatory. Usually, the mealybug involved is

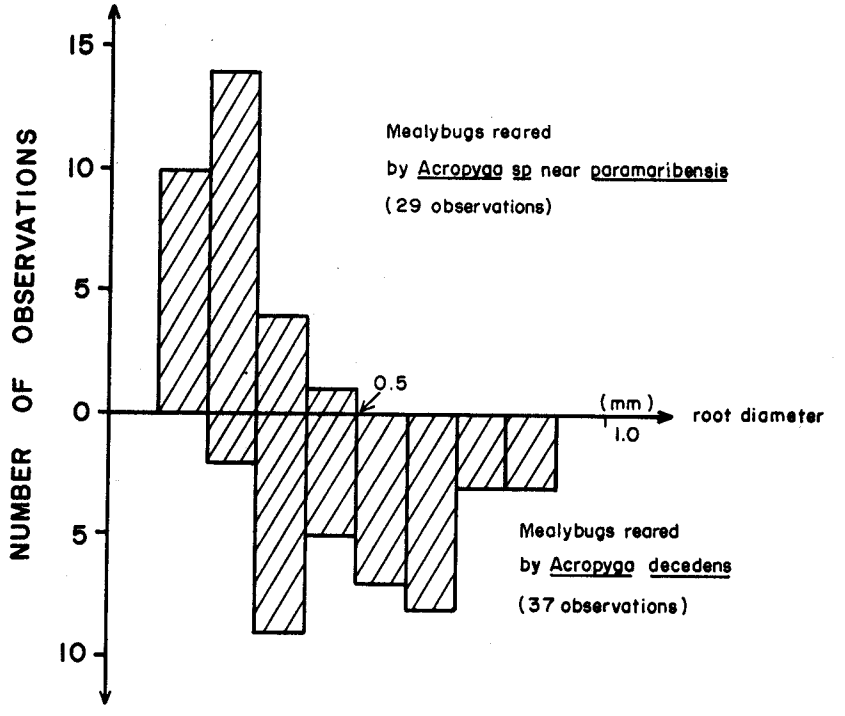

FIGURE 5. Distribution of mealybugs reared by two species of *Acropyga* in the same niche, as a function of cocoa tree root diameter.

Chavesia Balachowski (formerly referred to as *Eumyrmococcus* Silvestri), but other genera, such as *Rhizoecus* Kunckel or *Geococcus* Green may take the place of *Chavesia*. Biologically, this association is as important as that between the Attines and their fungus. Attine queens carry a mycelium fragment during the nuptial flight, while *Acropyga* female sexuals carry a fertile mealybug female (Bunzli 1935, Lima 1942, Eberhard 1978, Campos and Morais 1986). The mealybug participates in the foundation of the new ant colony, through its offspring and food flow to the ants. Colony structures have two elements: galleries which follow the plant roots where older mealybugs are established for honeydew production and "rearing-cells" where ant brood and pseudococcid young are tended by workers. It has also been noted that two *Acropyga* species coexist in the same niche by rearing mealybugs of distinct species, established on roots of different diameters (Figure 5) (Delabie and Mantovani, In Press).

There is little evidence that Homoptera tending by the ants directly affects the economics of cocoa. However, under heavy pressure by sap-sucking insects, especially coccids, the fruit buds and pods may wilt on the tree due to the high quantities of plant sap taken by the insects, e.g. *Planococcus citri* (Risso)) tended by *W. auropunctata* (Delabie 1988), tree-hoppers reared by *Dolichoderus spp* (Bondar 1939, Silva 1944) or by *Azteca spp* (Bondar 1939, Silva 1944, 1945, 1950, 1955). According to Silva (1944), cocoa tree-hoppers may destroy one-fifth of the crop.

Disease Vectors

In Africa, coccids tended by ants transmit the "Swollen-Shoot" virus disease of cocoa (Strickland 1951, 1952, Hanna et al. 1956 and Leston 1969). Although "Swollen-Shoot" and other viruses do not occur in Brazil, cocoa viruses have already been encountered in Trinidad (Posnette 1944) and other South American countries (Entwistle 1972). There is no evidence of ants participating in their propagation. *Acropyga spp* ants tending root mealybugs of cocoa are suspected vectors of root infections, as already documented for diseases coffee root diseases in Brazil (Goeldi 1892, Pickel 1927) and Surinam (Bunzli 1935).

Some African ants - in Ghana (Evans 1971, 1973) and in Nigeria (Taylor and Griffin 1981) - are directly responsible for the propagation of the "Black-Pod" of cocoa (*Phytophtora palmivora* (Butl.) Butl.), causing considerable pod losses. In Brazil, the relationship between this common disease and ants has not yet been studied, though some ant species are possible vectors of this fungus. Characteristics of ant vectors are those that use large quantities of organic material to construct their nests, such as *Azteca spp* (Silva 1955), or those which throw material originating from nest gallery excavations into the foliage, as does *E. tuberculatum*.

Flowering Inhibition

Nests with a large surface area, like those of *Azteca spp* and arboreal Termitidae, may cover important areas of the cocoa trunk and branches, preventing the development of numerous floral buds (Bondar 1939, Silva 1955, Vello and Magalhaes 1971). The two *Azteca* species build shelters made of organic material to protect their Homopteran associates (Bondar 1925,

1939, Silva 1944). These shelters are generally near the peduncule of the shoots, and may also limit the growth of new flowers.

BENEFICIAL ASPECTS OF ANTS

Biological Control

Cocoa plantation ants may control some pests by predation, repellency or by their behavior toward intruders. Efficient predators, like *Pseudomyrmex spp* (Pseudomyrmicinae) which nest in dried shoots, some Ponerinae (*Ectatomma quadridens* (Fabricius), *E. tuberculatum*, *Neoponera villosa* (Fabricius), *O. haematodus* and some Ecitoninae (especially *Labidus coecus* (Latreille) and *L. praedator* (Fr. Smith)), live on Bahia cocoa plantations. *A. chartifex spiriti*, essentially nocturnal (Benton, 1979), controls undesirable insects through its aggressive behavior or by its repellency (Silva 1955, Vello and Magalhaes 1971). Silva et al. (1982) have isolated the repellent's main component, a dialdehyde, from abdomen extracts. These ants, along with some Arachnidae species, are the main natural control agents of thrip (*Selenothrips rubrocinctus* Giard) (Zehntner 1917, Torrend 1919, Bondar 1939), as well as caterpillars of various moth species, mirid bugs (*Monalonion spp*) (Zehntner 1917, Bondar 1939), and leaf-eating beetles of the Chrysomelidae family (Ferronato 1988). For example, in *E. tuberculatum*'s lowest nest chambers (Figure 3), one meter deep, remains of arthropods caught in the cocoa environment were found--chiefly Chrysomelidae, but also Arachnidae, Gryllidae, Membracidae, Nasutermitidae and Formicidae, like *Camponotus sp* and *A. cephalotes*. The number of *A. cephalotes* workers was particularly high, however, even in an area with many *E. tuberculatum* nests, mature *A. cephalotes* colonies prospered, in contrast to Cook's opinion that the ponerines "may prevent the growth of new colonies by killing the workers as fast as they appear above ground" (in Weber 1946).

In other cocoa producing countries, ant species have been successfully utilized as biological control agents; for example, *W. auropunctata* in Cameroon (Bruneau De Mire 1969) and *Dolichoderus bituberculatus* Mayr in Indonesia (**Meer Mohr 1927, Giesberger 1983). Traditionally, some Bahian cocoa producers continue to distribute *A. chartifex spiriti* nest fragments on their plantations, knowing the pods look better on ant-infested trees. Zehntner (1917) and Torrend (1919) recommended this practice, Bondar (1925 1939) and Silva (1955) objected, mainly because of the deleterious quantities of Homoptera reared by the ants on the plants.

Pollination

For many years, until Ceratopogonidae midges were discovered to be the principal pollinators of cocoa flowers, many people believed ants or other insects with large populations in the area might have been pollinators (Harland 1925, Cope 1940, Entwistle 1972). Later, this hypothesis was rejected (Winder 1978). However, a few African ant species are responsible for a percentage of cocoa pollination (Entwistle 1972). Where *W. auropunctata* is found, its small size and high populations allow it to enter and pollinate the flowers (Billes 1941, Hernandez 1965). Moreover, studies on the productivity of cocoa trees harboring *A. chartifex spiriti* suggest that pollinating midges

are attracted to odors produced by the ant (Vello 1969, Vello and Magalhaes 1971). However, further experiments are necessary.

Fertilization

The ant can serve as a soil-fertilizing agent. However, little is known about the action of the ground-nesting ants on the recycling of cocoa agroecosystem soil nutrients. Leite's (pers. comm.) preliminary work and personal observations demonstrated the important function of fungus-growing ants like *Mycocepurus goeldii* Forel and various species of *Sericomyrmex*, which occur at high densities in some plantations; other Attines are of secondary importance. These ants usually excavate their nests to a depth of 30 to 120 cm, depending on the ant species and soil type. The mineral material resulting from the excavations is abandoned near the nest entrance, where it is rapidly incorporated into the litter, principally by rain. The great number of abandoned excavations may also improve drainage during the frequent tropical rains. This is important because the soils of cocoa plantations are never mechanically mixed; without the service performed by the ants, surface organic matter would not be blended with soil minerals as fast.

The coccid-tending ants *Acropyga*, which occur in certain plantations at high densities, are restricted to the superficial rhizosphere of the cocoa tree and the excavations made by the ants represent six percent of the soil volume at this horizon (Delabie and Mantovani, In Press). This may be an important factor for oxygen, nutrient and water circulation in this layer, where 60 to 85% of the tree's radicular system grows (Cadima Z. 1970).

RECENT ALTERATIONS OF THE ANT FAUNA IN THE BAHIAN COCOA FARMS

The "pixixica" ants, initially studied by Bondar (1925, 1930) and identified by Santschi (1925), were classified in the *Solenopsis* genus. In a recent paper, Delabie (1988) showed that the commonest "pixixica" species is *W. auropunctata*. After 60 years, this ant established a strong regional presence and a reputation for frequent and nasty stings. Studies of different cocoa plantation niches revealed that this ant is always in the litter, even if it does not appear in the canopy. *W. auropunctata*, a polygyne ant, has a high intrinsic capacity for population growth and rapidly colonizes new areas (Fabres and Brown 1978, Lubin 1984). This ant becomes dominant in the canopy only if other dominants, such as *Azteca spp*, are not present. This hypothesis may explain the effect of the intensive insecticide and fungicide use in the last few decades - sprayed on the trunk and the cocoa tree canopy - and the intensive control of social insects nesting in the canopy, such as *Azteca spp*, wasps and arboreal Termitidae, initiated after Bondar's works until 1960. To illustrate this aspect, the destruction of 8,048,019 *A. paraensis bondari* nests, 28,458 termite nests and 10,752 wasp nests from January 1944, to July 1948, in 451 farms (corresponding to ca 70,000 hectares of plantations and forest) has been documented by Silva and Barbosa (1948). Even in the 700 hectares of the Ilheus Cocoa Research Center (Centro de Pesquisas do Cacau) from March to December, 1964, 68,681 nests of *A. chartifex spiriti*, 56,141 nests

of *A. paraensis bondari* and 16,926 nests of Termitidae, were destroyed (Anonymous 1964).

Other current problems, with direct consequences for the ant fauna, include deforestation, increased number of cultivated areas and crop diversification. In the first half of the century, the cultivated areas were almost always situated near primary rainforest areas where the natural predator fauna found refuge. Until recently, regional crops were poorly diversified, which explains why *A. cephalotes*, a typical rainforest species, held on in the central cocoa production region while *A. sexdens sexdens*, which generally occurs in areas of low density vegetation, occupied the transition regions and the littoral (Silva et al. 1969, Abreu and Delabie 1986). Today, it seems that *A. cephalotes*' numbers are declining because of a successful chemical control program (Abreu and Silva 1973, Abreu and Delabie 1986), while *A. sexdens sexdens* continues its expansion, taking advantage of crop diversification and the opening of new cultivated areas and roads. Another consequence of reduced forest areas bordering the cocoa plantations is the relative disappearance of some ant genera while others flourish. Thus, plantations in the "cabruca" system when compared with rainforest areas have a lower diversity. The number of ants observed from the genera *Camponotus*, *Dolichoderus*, *Eciton* and *Pachycondyla*, common in the rainforest, decreases in the cocoa plantations, while the number of ants belonging to the genera *Crematogaster*, *Iridomyrmex*, *Solenopsis* and others, (Delabie et al. 1989) has increased. One of the most important consequences associated with the relative disappearance of the *Eciton* army ants in these areas is the disappearance of its associated fauna, principally birds (Willis and Oniki 1978, 1988). Some species of these very important predators could be preserved, if areas of native vegetation bordering the crop would be safeguarded.

CONCLUSION

Ant problems of the Brazilian cocoa farms as a whole must be analyzed with respect to possible consequences - including possible alteration of the agroecosystem - because the relationships between "cocoa ants" are fragile, dependent upon the ecological function of each species. There is no reason to discard the possible short-term human benefits of managing ant populations on the Brazilian cocoa farms, especially as programs have already been proposed and developed for other cocoa producer countries.

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