Coffee Insects: Ecology and Control

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Abstract
Coffee is one of the most important agricultural commodities in the world and is grown in more than 50 countries throughout the tropics. Several insect pests have been reported in coffee, the most important being the coffee leaf miner, the coffee berry borer, and the coffee stem borers. The basic biology of these insects is discussed.

INTRODUCTION

Endemic to Africa and now grown in more than 11 million hectares in over 70 countries in the tropics, coffee is the most important agricultural commodity in the world, with an annual estimated retail value of over $70 billion. Approximately 17–20 million families throughout the world depend on coffee for their subsistence, and total production per year is around 115 million 60-kg bags. The genus *Coffea* consists of over 90 species[1] but only two species, *Coffea arabica* L. and *Coffea canephora* Pierre ex Froehner (also known as robusta), are commercially traded, with *C. arabica* comprising approximately 65% of coffee production.[2] Several *C. arabica* cultivars are grown (e.g., Typica, Bourbon, Catuai, Caturra, Maragogipe, Mundo Novo), but their genetic base is small because of a narrow gene pool from which they originated and the fact that they are self-pollinated (i.e., self-fertile) in contrast to *C. canephora*, which is cross-pollinated (i.e., self-sterile). *C. arabica* tends to do better at higher elevations, while robusta is more suited to lower elevations. Nevertheless, both are susceptible to fungal and insect pests. More than 850 insects have been reported to attack coffee.[3,4] Of these, the most important significant throughout the world are the coffee leaf miner, the coffee berry borer, and the coffee stem borers.

THE COFFEE LEAF MINER [*LEUCOPTERA COFFEELLA* (GUÉRIN-MÉNEVILLE) (LEPIDOPTERA: LYONETIIDAE)]

Two different genera are used in the scientific literature dealing with the coffee leaf miner: *Leucoptera* and *Perileucoptera*. To address this unusual situation, we present a short summary on the systematics of this insect. The coffee leaf miner was first described as *Elachista coffeella* by Guérin-Méneville[5] using specimens collected in Martinique and Guadeloupe. Stainton[6] placed it in the genus *Bucculatrix* and later on classified it as *Cemiostoma coffeella*,[7] while Mann[8] referred to this species as *Cemiostoma coffeellum*. Walsingham[9] placed it in the genus *Leucoptera* and Silvestri[10] transferred it to the genus *Perileucoptera*. Bradley[11] remarked on differences in wing venation between the specimens used by Silvestri and the specimens he used from Trinidad and concluded that because of these differences ''this genus has not been adopted'' (by him) and used *L. coffeella*. Even though some papers state that Mey's[12] monograph recognizes *P. coffeella* as a junior synonym of *L. coffeella*, this is not an accurate statement (W. Mey, personal communication); therefore, both *Perileucoptera* and *Leucoptera* are valid until a formal phylogenetic analysis and formal synonymization is published. For many years it was thought that *L. coffeella* occurred in East Africa, but after comparing specimens from Trinidad and East Africa, Bradley[11] concluded that the East African species had been erroneously identified and should be classified as *L. meyricki* Ghesquière. Two other *Leucoptera* species are known in Africa: *L. caffeina* and *L. coma*. The area of origin of *L. coffeella* is unknown, although it has been hypothesized that it entered the American continent through plants brought from the island of Réunion.

The coffee leaf miner, a micromoth measuring approximately 2 mm in length, is the most important pest of coffee in Brazil, and is widely distributed throughout the American continent. Eggs are laid on the adaxial side of leaves, followed by larvae mining into the leaves and consuming the mesophyll eventually

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creating necrotic lesions that reduce photosynthetic area and consequently yields. Losses of up to 50% have been reported in Brazil and 40% in Puerto Rico. The insect does better in dry conditions and high temperatures and can have 7–12 generations per year. Plants in wet areas have very low infestation levels because of water entering the mine and drowning the larvae. Before pupating, the larva emerges from the mine, spins a thread, and using the wind balloons to other plants, where it spins a cocoon usually on the abaxial side of the leaf. The insect can be mass reared in vitro using detached coffee leaves.

Reliance on insecticides has had a detrimental effect on natural enemies and has resulted in the development of resistance to various organophosphates (e.g., disulfoton, ehtion, methyl-parathion, chlorpyrifos). The coffee leaf miner has at least 10 predatory wasps (Vespidae), 21 larval parasitoids (Eulophidae), and eight larval–pupal parasitoids (Braconidae). The insect is susceptible to various endotoxins produced by *Bacillus thuringiensis*, and transgenic *C. arabica* and *C. canephora* plants expressing the *B. thuringiensis cry*1Ac have been developed by French scientists. These were planted in French Guiana in 2000 and were cut down by vandals in 2005 although preliminary data indicated that 70% of the transgenic trees were completely resistant to the insect. Traditional breeding methods are being pursued in Brazil to develop varieties resistant to the coffee leaf miner.

The coffee leaf miner sex pheromones (5,9-dimethylpentadecane and 5,9-dimethylhexadecane) have been identified, and their use in the field has been proposed as a male-confusion technique. Field studies have shown that most captures in pheromone traps occur at midday. The proper management of shade and fertilization, minimizing the use of insecticides, and the conservation of natural enemies are important factors to reduce coffee leaf miner outbreaks in coffee plantations.

THE COFFEE BERRY BORER [*HYPOTHENEMUS HAMPEI* (FERRARI) COLEOPTERA: CURCULIONIDAE]

The coffee berry borer, a coffee specialist, is endemic to Central Africa and has now been reported in most coffee producing countries, with the notable exceptions of Hawaii and Puerto Rico. A phylogenetic analysis by Benavides et al.[13] using specimens from 17 countries revealed that only one species is present. Females bore a hole in the coffee berry and deposit their eggs inside; larval feeding on the endosperm greatly reduces quality and yields and can also cause abscission of the berry. Sibling mating occurs inside the berry, and 10 females are produced for every male, most likely because of the presence of the bacterium *Wolbachia*. Once adult females have emerged from the berry they are inseminated and immediately attempt to locate another berry in which to oviposit. This makes the use of insecticides very ineffective because of the short window of time during which the insect is outside the berry. Several insecticides have been used, including endosulfan, to which the insect has developed resistance. The effects of shade on the coffee berry borer are equivocal: da Fonseca[14] reported increased incidence in coffee grown under heavy shade while Soto-Pinto, Perfecto, and Caballero-Nieto[15] reported no correlation between shade/light and infestation levels. Overall, the effects of shade on insect pests and plant diseases are very complex because of their different environmental requirements for successful colonization and reproduction.[16] Classical biological control research programs have been conducted in several countries against the coffee berry borer, and parasitoids from Africa [e.g., *Prorops nasuta* Waterston, *Cephalonomia stephanoderis* Betrem (Hymenoptera: Bethylidae), and *Phymastichus coffea* LaSalle (Hymenoptera: Eulophidae)] have been introduced to other coffee growing regions. Various fungal entomopathogens, such as *Beauveria bassiana* Balsamo (Vuillemin), *Metarhizium anisopliae* (Metschnikoff) Sorokin, *Hirsutella eleutheratorum* (Nees) Petch, *Paecilomyces fumosoroseus* (Wize) Brown & Smith, and *P. lilacinus* (Thom) Samson, have been isolated from the insect. Growers in many countries grow *B. bassiana* and spray it in their plantations. Two nematodes have been reported attacking the insect: *Panagrolaimus* sp. in India, and *Metaparasitylenchus hypothenemi* Poinar et al. in Mexico.

COFFEE STEM BORERS

Several cerambycids are considered serious pests of coffee, because of larval stages boring into the trunk. These are discussed below:

Monochamus leuconotus (Pascoe)

Known as the white coffee stem borer, this insect has been a pest of coffee in eastern, central, and southern Africa for over 100 years. Eggs are laid on the trunk, and young larvae ringbark the trunk and roots, frequently causing death of the tree. Older larvae bore into the stem and feed for several months. Adult beetles, which are not attracted to light, feed on newly flushed leaf tissue but do not cause major damage to these. Eulophids, braconids, pteromalids, scelionids, and other parasitic Hymenoptera have been reported as natural enemies of this insect.

Bixadus sierricola (White)

It is an important pest in Central and West Africa. Eggs are laid on the bark; young larvae ring the bark and older larvae bore into the trunk where they feed for several months, producing large amounts of wood shavings and frass, which fall at the base of the tree under the entrance hole. Young trees usually die because of the ringbark damage, and older plants can topple over with the wind or become susceptible to termites and fungi. Adults, which feed on the bark of green shoots, are poor fliers and are strongly attracted to light. An ichneumonid and a tachinid are known to parasitize larvae of this insect.

Xylotrechus quadripes (Chevrolat)

A serious pest of coffee in South-east Asia and India. Eggs are laid on the bark, and larvae entering the bark make tunnels, which create ridges on the bark surface that are used as an indication of infestation. Adults are strong fliers, and several parasitoids have been reported attacking this insect, including bethylids, braconids, eurytomids, evaniids, and ichneumonids. Birds have also been reported as predators of larval stages, and low infestations (~2.5%) with the fungal entomopathogen *B. bassiana* have been reported in India.

Plagiohammus sp. and *Neoclytus cacicus* (Chevrolat)

Plagiohammus sp. has been reported attacking coffee trees in Mexico, Guatemala, El Salvador, Honduras, and Costa Rica. The life cycle is about 20 months, and adults typically emerge from the stems between April and June each year. Larval feeding can delay plant growth and development and in extreme cases kills the plant or makes it susceptible to falling down. *N. cacicus* has been reported attacking coffee plants in Guatemala.

COFFEE STEM BORER MANAGEMENT TECHNIQUES

Insecticides have been used in an attempt to control these insects, but because of their cryptic life cycle inside the trunk, the effectiveness of such method is doubtful. A paint containing an insecticide, which can be applied on the stem to kill the eggs and larvae as they bore, has been suggested as a possible method for control. For example, *M. leuconotus* was successfully controlled in the 1950s with 2% dieldrin paint applied to the base of the stems, but needless to say, use of methods such as this, based on highly toxic poisons, presents problems to both humans and the environment. For *B. sierricola*, fumigants have been inserted into the bores made by the insects as a control tactic. Among these, a paste containing aluminum phosphide was placed in the holes of 3200 trees attacked by stem borers in Ghana and sealed with plasticine, resulting in 100% mortality. This method relies on a highly dangerous chemical that has to be applied by hand in trees that have already been attacked. Cultural practices have been used, but these require intensive labor, e.g., collecting and killing adult insects, manually killing larvae with a wire inserted in the hole, and uprooting and burning of infested trees.

CONCLUSIONS

Owing to the low coffee prices that were prevalent in the market for several years, small coffee growers were for the most part not able to invest in pest management strategies that required inputs external to the farm, i.e., insecticides. This, on the one hand, resulted in the production of coffee that could be considered organic—even though the term ''organic'' implies more than not using pesticides—but on the other hand, led to many growers having to abandon coffee harvesting because of the severe losses caused by insect pests. The prospects, in terms of implementing innovative pest management strategies that are inexpensive and sustainable, remain bleak in great part because of scarce research funds in coffee-producing countries and the lack of an organized structure that oversees coffee research throughout the world. Research aimed at developing innovative biological control methods against coffee insects should be promoted and encouraged by major coffee companies that, after all, have a tremendous stake and interest in high quality coffee. Successful biological control of insect pests in coffee plantations could result in reduced expenses for small coffee growers who cannot fund or do this research on their own. One particularly innovative area of research involves establishing fungal entomopathogens as coffee endophytes; if successful in controlling insects, it would be a revolutionary pest management strategy.

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