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Full Length Research Paper

Traditional coffee agroecosystems in the Los Tuxtlas Biosphere Reserve, Veracruz (Mexico): a refugee for ecologically important Coleoptera

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The present study was conducted in traditional coffee agroecosystems within the buffer zone of the Los Tuxtlas Biosphere Reserve, Veracruz. The main objectives were to identify the beetles associated with this type of agroecosystems, and describe their general structure in order to know the main characteristics that provide refuge to these organisms. Two traditional coffee agroecosystems were selected, the first located at 600 m.a.s.l (meters above sea level) and the second at 900 m.a.s.l; the number of strata was visually determined. The beetles were collected every 15 days with the help of an insect net, strata by strata, within a 1000 m^2 transect. Three hundred and eighty specimens, representing 18 families, 24 subfamilies, 17 tribes and 52 genera were collected. In Site One the most abundant families were Chrysomelidae (45%) and Passalidae (13.4%); while in Site Two were Chrysomelidae (21.2%) and Passalidae (20.4%). The most abundant genera and species in Site One were *Lemma diversa* (13.4%), *Oulema melanopus* (12%) and *Passalus punctatostriatus* (9.9%); in Site Two *Passalus punctatostriatus* (15%) and different *Lemma* species (12%). *Azya luteipes* is an important component of both sites. It is the first time species from Pseudoccocidae are reported for Mexico, *Azya luteipes* was originally reported for Central and South America where is frequently used as a general biological control beetle.

Keywords: Agro-ecological matrix, structure, *Azya luteipes*, Mexico

INTRODUCTION

Biodiversity found in traditional coffee agroecosystems plays a fundamental role in sustainable production and the continued supply of goods and services. Soil fauna and microorganisms, together with roots of plants and trees, ensure nutrient cycles; predators, organisms that control pests and diseases, those who are pollinators; together

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with the genetic diversity of cultivated plants constitute a complex network that preserves the integrity of the system and contribute to water quality, climate regulation and food security. One of the most important elements in coffee agroecosystems are insects, from which the order Coleoptera is the most abundant (Morón, 2004). There are about 375,000 species of beetles in the world, of which 35,500 have been described for Mexico, representing almost 10% of the total. They live from the tropics to the polar caps, through deserts and all kinds of cultivated, rain forests and forests; they could be found in a variety of niches and have different biological functions (Bar, 2009).

The most common types of coffee agroecosystem are rustic, specialized, traditional poly-culture and commercial poly-culture. Rustic and the traditional polyculture agroecosystem types help to maintain high levels of biodiversity, because they are structured on at least four strata (herbaceous, shrubs, low tree layer and high tree layer) and they sometimes conserve between 50-80 species of the original trees, (Soto-Pinto *et al*., 2000; Villavicencio and Valdez, 2003; Cruz *et al.,* 2004; Bandeira *et al.,* 2005; Soto-Pinto *et al*., 2007; Castillo Capitán *et al*., 2014).

In many cases the size and structure of coffee agroecosystems or agricultural matrices could influence conservation of species of biological importance. Agricultural matrices could also be used as migration routes, establishment or to obtain additional resources (Brown, 1997; Muriel and Kattan 2009; Maveety *et al*., 2011). Accordingly to Maveety *et al.* (2001), beetles could be a good indicator of biodiversity as they are not only sensitive to ecological and environmental changes, but also for its morphological, taxonomic and behavioural variation. It is therefore critical to have detailed inventories of species found in each agroecosystem or ecosystem, since in many cases the changes in different species come together with sustainable management of natural resources (Brown, 1997). Poch and Simonetti (2013) found that different predator species trigger diverse beneficial effects in agroforestry systems, like the increase in productivity. Because agricultural production is just as tightly tied into the overall system function as are insect populations or soil organisms, the ecological, agricultural and economic aspects of sustainability run together with the changes in indicator groups serving as an early warning for later changes in the sustainability of the system. Preservation of natural resources is most successful when it involves the understanding of traditional knowledge and its methods of traditional resource management.

Carabidae, Staphylinidae, Scarabaeidae, Buprestidae, Tenebrionidae, Cerambycidae, Chrysomelidae and Curculionidae families, represent 68% of the species described in cloud forests and coffee agroecosystems of central Veracruz (Deloya and Ordoñez 2008). Deloya *et al* (2007), found 9,982 specimens of Scarabaeidae and Trogidae representing 21 genera and 50 species, of which 17 species were collected in shade coffee agroecosystems; 20 in coffee agroecosystems at full sun; 30 in rustic coffee agroecosystems and 20 in specialized shaded coffee agroecosystems. In 2008, these authors collected 57,052 specimens of beetles in the floor, 2,139 specimens in the understory and 218 specimens in the canopy of a fragment of cloud forest and four coffee agroecosystems with shade and full sun, which represents 61 families and 626 species. The number of families of beetles is higher in the cloud forest than in rustic coffee agroecosystems or organic coffee agroecosystems, while in polyculture coffee agroecosystems and specialized coffee agroecosystems, richness decreases 25% due to some management practices as the use of agrochemicals. According to Favila (2004), in the Los Tuxtlas Biosphere Reserve (LTBR) many studies are still needed to know the natural history and diversity of insects, the author estimates that insect richness could reach about 10,300 species. Despite extensive studies have been conducted in the Santa Marta Mountain; still do not have enough information about beetles inhabiting coffee agroecosystems and its possible ecological and productive role, in human terms. In natural areas with presence of agroecosystems, like the LTBR, it is essential to achieve an inventory, along with local people, about the best structured agricultural matrices, those more diversified, and with the best management practices that could serve not only as a refuge of indicator species, but also for the preservation of communities, biogeochemical cycles and the cultural aspects that are inextricable linked with them. Accordingly, the present study aimed to describe general structural characteristics of two coffee agroecosystems and collecting and identify the beetles presented in them.

MATERIALS AND METHODS

Site study

Research was carried out between May to December 2010 in the ejido of San Fernando, The ejido belongs to the buffer area of LTBR (Siemens, 2004) and has a volcanic origin, with igneous rocks and andesitic or alkaline basaltic lava from the quaternary period. Its physiography includes five morpho-edaphological units that were formed by mountains with slopes covered by volcanic cones (Siemens, 2004). The area is located in the sub-basin of the Huazuntlan River, within the Coatzacoalcos river basin. The vegetation includes 1) tropical pine forest, dominated by *Pinus oocarpa* and five oak species; 2) tropical semi-deciduous forest (TSF) dominated by *Brosimum alicastrum*, *Cedrela odorata*, *Inga leptoloba* and *Luehea speciosa*, among others; 3) tropical rainforest (TRF) dominated by *Omphalea oleifera*, *Quercus* sp., *Terminalia amazonia* and

Calophyllum brasiliense; and 4) deciduous forest (DF) dominated by *Alfaroa mexicana, Liquidambar styraciflua*, *Quercus* sp. and *Ulmus mexicana* (Castillo-Campos and Laborde 2004).

Sampling

Based on field trips, two coffee agro-ecosystems were chosen to describe its structure and collect the beetles found in them. Both sites are commercial polyculture systems (Franco, 2007), the first established in TSF at 674 masl between 18°16'27" N and 94°52'50" W; and the second in TRF at 915 masl between 18°18'10''N and 94°52'58''W. Before collecting insects, the number of layers of each coffee agroecosystem was determined in a visual manner; then a 100 X 10 m transect was established (Ramírez, 2006). Based on this method we proceeded to collect the beetles with an insect net crossing the transect in zigzag, hitting plants firmly; first the herbaceous layer; then the shrub layer, the lower tree layer and finally decaying plant material. All collected beetles were placed in a jar with ammonium acetate then in bottles with 70% alcohol, labelled with information of location, geographical coordinates, altitude, vegetation type, layer in which was collected and date of capture. The collections were carried out regularly every 15 days from May to December 2010. At the same time, specific data on temperature and relative humidity were taken with the help of a Kestrel® 3000 Pocket Weather Meter .

Insect identification

The identification and assembly of insects was carried out in the laboratory of the National Centre for Disciplinary Research in Conservation and Improvement of Forest Ecosystems (CENID-Coyoacán-INIFAP) in Mexico City and in the Laboratory of High Technology Xalapa (LATEX, S. C) of the Universidad Veracruzana with a stereoscopic microscope Carl Zeiss Stemi 1000 and specific taxonomic keys for families, subfamilies, tribes, genera and species (White, 1983; Borror, 1996; Domínguez, 2003) and literature available at the internet.

RESULTS

The structure of the first coffee agroecosystem at 674 masl is dominated by red cedar (*Cedrela odorata*); Mahogany (*Swietenia macrophylla*); corpo (*Vochysia guatemalensis*); chalahuite (*Inga leptoloba*), some individuals of *Inga jinicuil*; palo mulato (*Bursera simaruba*); solerillo (*Cordia alliodora*) frijolillo (*Cojoba arborea*), chocho (*Astrocarium mexicanum*), camedor palm (*Chamaedora elegans*) and chagalapoli (*Malpigia* sp.); The shrub layer is dominated by coffee plants (*Coffea arabica*) var. *Costa Rica* (Figure 1), there were observed nesting birds, orchids and also high amount of litter.

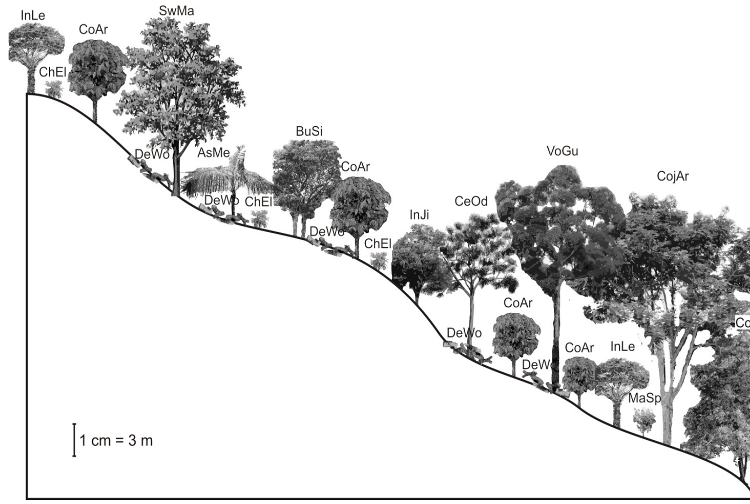

Figure 1. Idealized image of the structure of site one with the four layers observed. Acronyms mean: CojAr= *Cojoba arborea*; CoAl= *Cordia alliodora*; CeOd= *Cedrela odorata*; SwMa= *Swetenia macrophylla*; VoGu= *Vochysia guatemalensis*; InLe= *Inga leptoloba*; InJi= *Inga jinicuil*; BuSi= *Bursera simaruba*; AsMe= *Astrocarium mexicanum*; CoAr= *Coffea arabica*; ChaEl= *Chamaedorea elegans*; MaSp= *Malpigia* sp. DeWo= Dead wood.

In this site 253 individuals were collected, belonging to 17 families and 45 genera. The herb layer consist 27.67% of all collected beetles, the most important are Meloidae (1.42%), Coccinellidae (5.72%), Lycidae (5.72%), Melolonthidae (7.14%) and Chysomelidae (80%); the shrub layer includes 37.94%, the most important are Carabidae (2.08%), Scolytidae (4.16%), Melolonthidae (5.21%), Elateridae (6.25%), Cerambycidae (7.30%), Coccinellidae (7.30%), Lampyridae (7.30%), Apionidae (9.37%), Lycidae (11.45%), Curculionidae (13.54%), Chysomelidae (26.04%); the tree layer includes 16.60% of all beetles, the most important are Melolonthidae (2.38%), Cerambycidae (7.15%), Scolytidae (11.90%) and Chysomelidae (78.57%); beetles found in decay wood are 13.84% of total, from which the most important are Histeridae (2.85%) and Passalidae (97.15%); finally, beetles in leaf litter comprise only 3.95%, the most important are Erotylidae (10.00%), Tenebrionidae (30.00%) and Scarabaeidae (60.00%) (Figure 2).

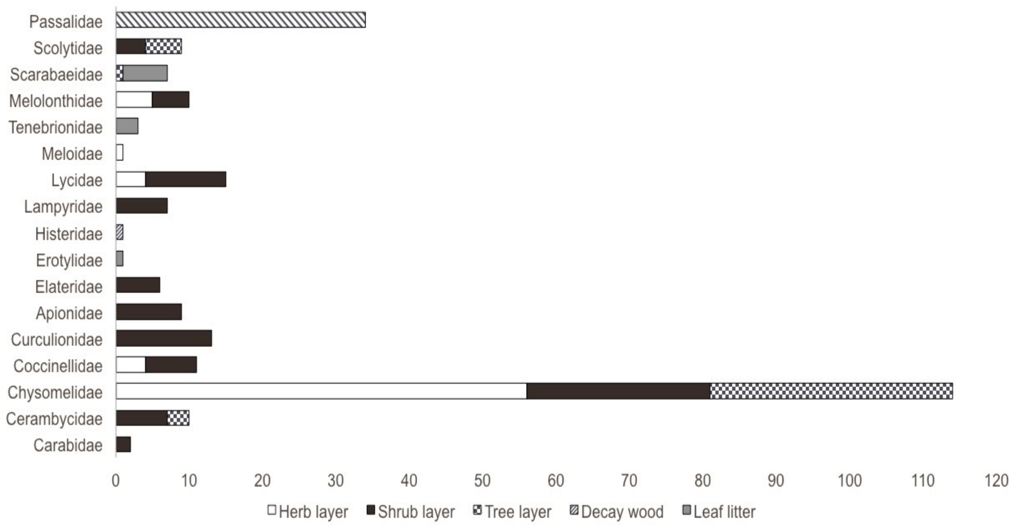

Figure 2. Abundance of beetle families by layer in site one.

The coffee agroecosystem two is located at 915 masl in an area formerly occupied by tropical rain forest (TRF), it is also a commercial polyculture. It has four layers, the tree layer is dominated by red cedar (Cedrela odorata); Mahogany (Swietenia macrophylla); corpo (Vochysia guatemalensis); Chalahuite (Inga leptoloba) and jinicuil (*Inga jinicuil*); mulatto stick (*Bursera simaruba*); pepper (*Pimenta dioica*); laurel (*Nectandra ambigens*); cojón de gato (*Tabernaemontana alba*); jobillo (*Heliocarpus appendiculatus*), carbonero (*Mosquitoxylum jamaicense*); solerillo (*Cordia alliodora*); orange (*Citrus sinensis*); lemon (*Citrus limon*); guanábana (*Annona muricata*); banana (*Musa paradisiaca*); camedor palm (*Chamaedora elegans*); hoja santa (*Piper umbellatum*) the shrub layer is dominated by coffee (*Coffea arabica*) var. *Costa Rica* as well as orchids and great amount of litter (Figure 3).

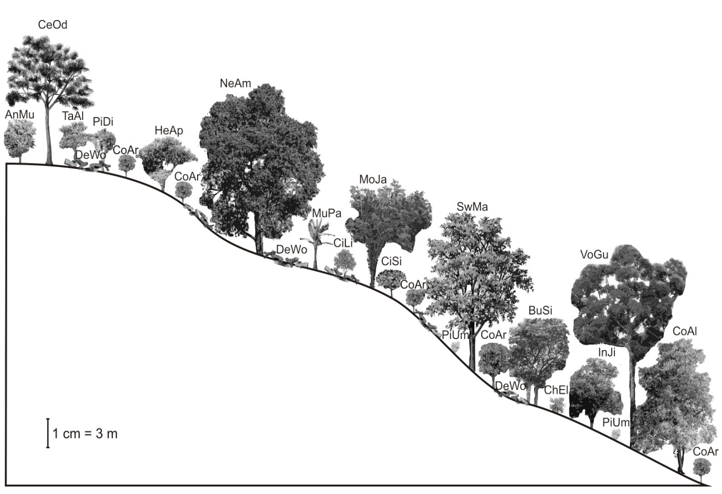

Figure 3. Idealized image of the structure of site two with the four layers observed. Acronyms mean: CoAl= *Cordia alliodora*; CeOd= *Cedrela odorata*; SwMa= *Swetenia macrophylla*; MoJa= *Mosquitoxylum jamaicense*; NeAm= *Nectandra ambigens*; VoGu= *Vochysia guatemalensis*; AnMu= *Annona muricata*; BuSi= *Bursera simaruba*; CiLi= *Citrus limon*; CiSi= *Citrus sinensis*; HeAp= *Heliocarpus appendiculatus*; InLe= *Inga leptoloba*; InJi= *Inga jinicuil*; MuPa= *Musa paradisiaca*; PiDi= *Pimenta dioica*; TaAl= *Tabernaemontana alba*; CoAr= *Coffea arabica*; ChaEl= *Chamaedorea elegans*; PiUm= *Piper umbellatum*; DeWo= Dead wood.

In this site 127 individuals were collected, they represent 16 families and 31 genera. The herb layer comprise 21.26% of all beetles, most important families are Coccinellidae (7.40%), Lycidae (11.11%), Melolonthidae (11.11%) and Chysomelidae (70.38%); beetles in the shrub layer constitute 44.88%, from which the most important are Carabidae (1.75%), Tenebrionidae (1.75%), Melolonthidae (3.50%), Cerambycidae (3.50%), Coccinellidae (5.26%), Enbomychidae (5.26%), Lampyridae (7.01%), Elateridae (8.80%), Apionidae (12.30%), Chysomelidae (14.03%), Lycidae (17.54%) and Curculionidae (19.30%); tree layer comprises only 7.87% of all collected beetles, from which the most important families are Cerambycidae (30%) and Scolytidae (70%); beetles in decay wood comprises 20.47%; the most important is Passalidae that comprises 100%; finally beetles in leaf litter constitute 5.52%, from which Erotylidae (28.57%), Tenebryonidae (28.57%) and Scarabaeidae (42.86%) are the most important (Figure 4). Table one presents families and genera identified in both sites; site one has a greater number of genera and species than site two, the most abundant were *Lemma diversa* (13.43%), *Oulema melanopus* (11.85%) and *Passalus punctatostriatus* (9.88%); in the site two *Passalus punctatostriatus* (14.96%) and *Lemma diversa* (11.81%). Both, *Lemma diversa* and *Oulema melanopus* are browsers, they are considered secondary pests, during field work some considerable damage caused by Oulema melanopus in the leaves of several species at all layers

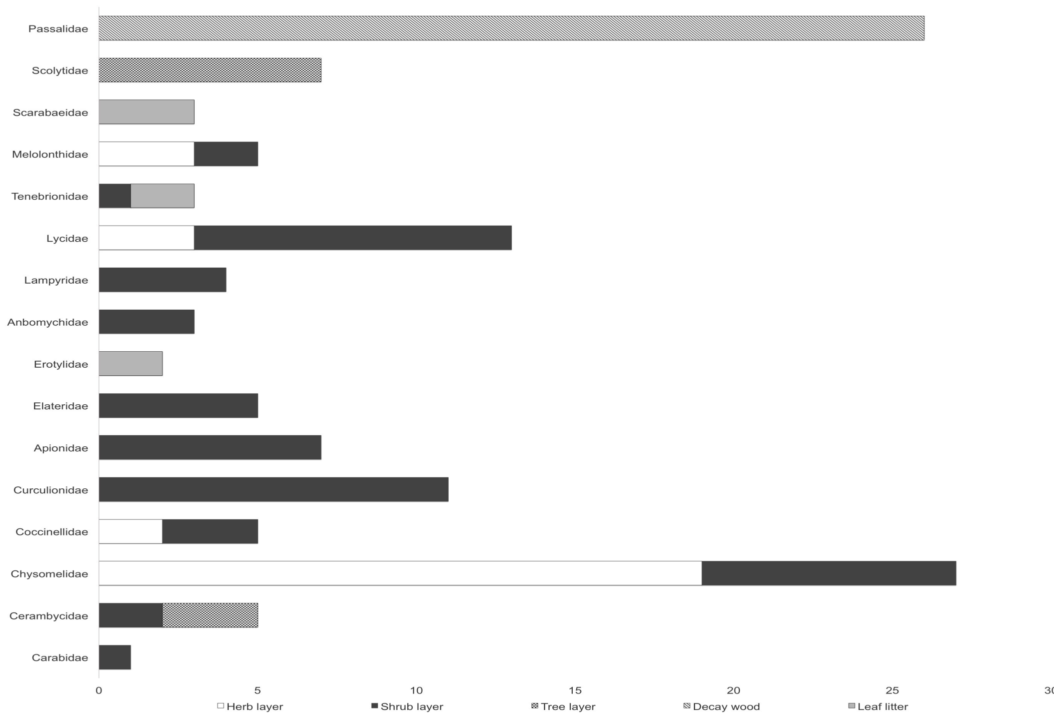

Figure 4. Abundance of beetle families by layer in site two.

Table 1. Families, genera, species and its biological function at sites one and two.

Families	Site one/species	Site two/species	Biological function
Carabidae	*Pterostichus* sp.	*Pterostichus* sp.	Predator
Cerabycidae	*Eburia quadrigeminata*	*Eburia quadrigeminata*	Borer
	Microgoes oculatus		Borer
	Monochamus sp.		Borer
Chrysomelidae	*Crepidodera* sp.	*Calligrapha* sp.	Browser
	Cryptocephalus sp.	*Charidotella* sp.	Browser
	Diabrotica sp.		Browser
	Chalepispa ignorata		Browser
	Lema diversa	*Lema diversa*	Browser
	Metachroma sp.	*Metriona* sp.	Browser
	Neobrotica sp.	*Malacorhinus* sp.	Browser
	Omophoita cyanipenis *Podagrica fuscicornis*		Browser
	Oulema melanopus		Browser
Coccinellidae	*Azya luteipes*	*Azya luteipes*	Predator
Curculionidae	*Buteo* sp.	*Buteo* sp.	Borer
	Conotrachelus psidii		Borer
	Phyllobius pomaceus		Borer
Apionidae	*Apion africans*	*Apion africans*	Browser

Table1: Continue

Elateridae	*Deilelater physoderus*	*Deilelater physoderus*	Browser
	Agriotes sputator	*Agriotes sputator*	Browser
Erotylidae	*Cypherotylus* sp.		Mycetophagous
Enbomychidae		*Epipocus puctatus*	Mycetophagous
Histeridae	*Omalodes* sp.		Predator
Lampyridae	*Cratomophus dorsalis*	*Cratomophus dorsalis*	Browser
	Photinis sp.	*Photinis* sp.	Browser
	Lampyris noctiluca	*Lampyris noctiluca*	Browser
Lycidae	*Calopteron terminale*	*Calopteron terminale*	Browser
	Lycus sp.	*Lycus* sp.	Browser
Meloidae	*Cissites maculata*		Browser
Tenebrionidae	*Tenebrio* sp.	*Tenebrio* sp.	Saprophytic
		Elodes sp.	Saprophytic
Melolonthidae	*Phyllophaga obsoleta*		Browser
Scarabaeidae			Saprophytic
Scolytidae	*Corthylus papulans*	*Corthylus papulans*	Bark
	Xyleborus sp.	*Xyleborus* sp.	Bark
Passalidae	*Passalus punctatostriatus*	*Passalus punctatostriatus*	Saproxylic
	Spurios bicornis		Saproxylic
	Odontotaenius striatopunctatus	*Odontotaenius striatopunctatus*	Saproxylic

was observed. *Lemma diversa* apparently only affects the herbaceous layer; while *Passalus punctatostriatus* are secondary decomposers of organic matter and thus contribute to the recycling of materials in the ecosystem.

In both sites the most abundant genera and species were *Lemma diversa*, *Passalus punctatostriatus*, *Oulema melanopus* was only found in site one and is the second most abundant. Of other genera, *Apion africans* was present only in the shrub layer dominated by coffee shrubs, especially on dry coffee cherries, but it is not reported in the revised literature as an insect that causes serious damages to coffee.

According with its biological role 45 genera were identified in site one, while only 31 in site two, there is a difference of 15 species between them. However, browsers predominate at both sites (55.6% in site one and 51.6% in site two) (Figure 5). Site one presents 126 more individuals than site two.

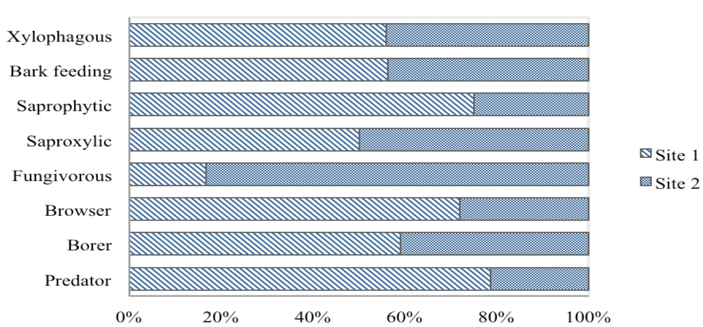

Figure 5. Functional groups of the Coleoptera collected in each of the sample sites.

Another important species, not for its abundance, but because of its status as a natural enemy of some scales of the order Hemiptera, was *Azya luteipes* (Coccinelidae) identified for the first time in Mexico through comparison of genitals (Figure 6) Woodruff and Sailer 1977: 1 not Mulsant 1850, which was previously registered as *Azya orbigera* Mulsant, 1850 and that's probably the same species, adult of size 3.0 to 4.0 mm, hemispherical body, blacks elytra and whitish pubescence, with two central black spots without pubescence; pronotum black in colour (Figure 6) (Saini and De Coll, 1996). This species was found feeding on aphids in camedor palm and scales in orange trees.

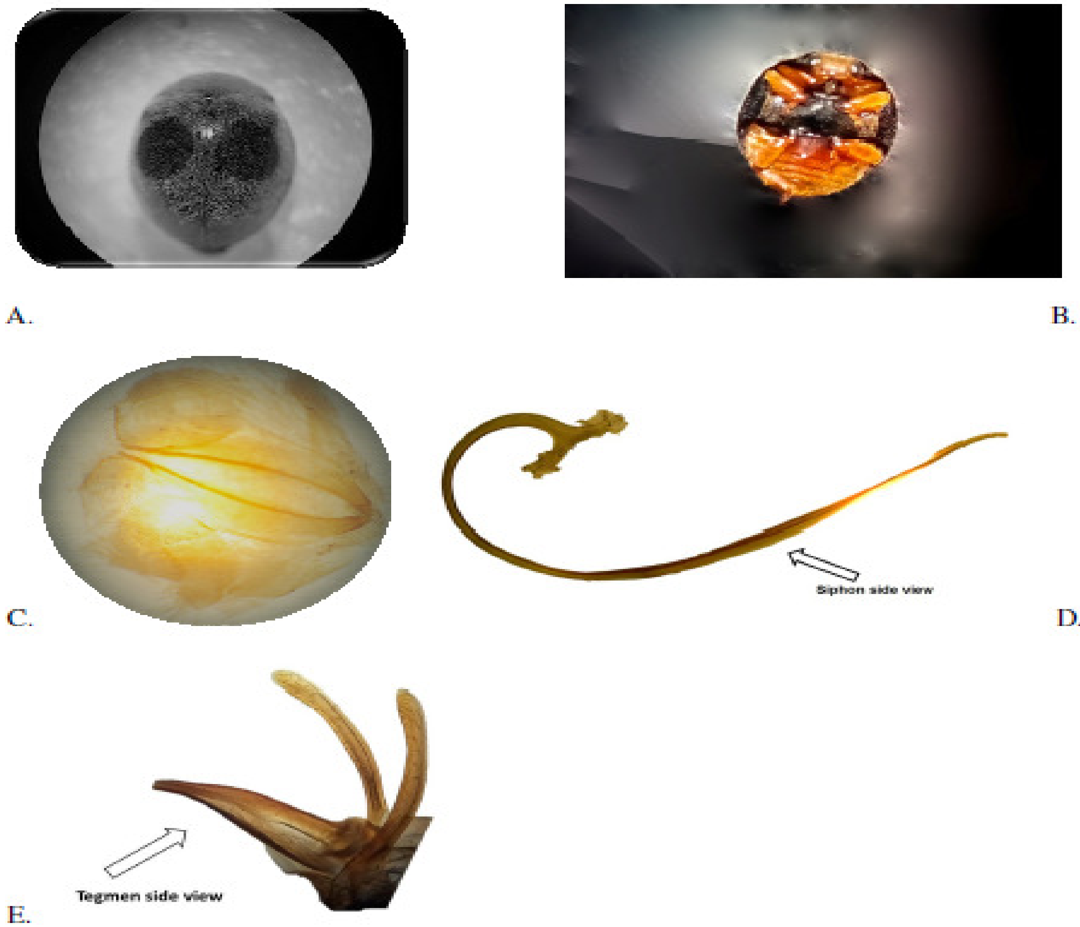

Figure 6. *Azya luteipes* in the Sierra de Santa Marta, top view (A); ventral view (B); female genitalea (B); male genitalea (D and E).

DISCUSSION

The highest abundance of individuals (253) occurs between August and September for the site one (Figure 7) and between October and November at the site two (127) (Figure 8), that is to say, a difference of almost 50% between both, the main activity of many beetles may occur from October to November (Deloya, 2008). One possible explanation is the variation of temperature and humidity between the two sites (Figure 9 and Figure 10), to find out if there are statistically significant differences between temperature and humidity of both sites, an F test was applied. Temperature shows no statistical significant differences for both sites; however, moisture did (F = 0.09; P = 0.05; M = 85.06; confidence interval = 11.00). These conditions altogether with harvest of trees, shrubs and weeds that took place in plots that limit site two during the months of monitoring might affect the development of the insects (Cepeda and Gallegos, 2008). Though, the number of families identified does not show clear differences, 15 of them are present on both sites except Erotylidae and Meloidae, exclusive of site one and Enbomychidae of both. Regarding the richness of genera some differences are important, since a total of 40 were identified at both sites, there is a difference of 17 in site one and six in site two, the others were constant at both sites. Under similar conditions Méndez L. and Moron (1985) found 13 families in a coffee agroecosystem of 50 years in Cacaohatán Chiapas. However, Deloya and Ordoñez (2008) collected 61 different families in a fragment of cloud forest, four shade coffee agroecosystems and one under full sun in central Veracruz.

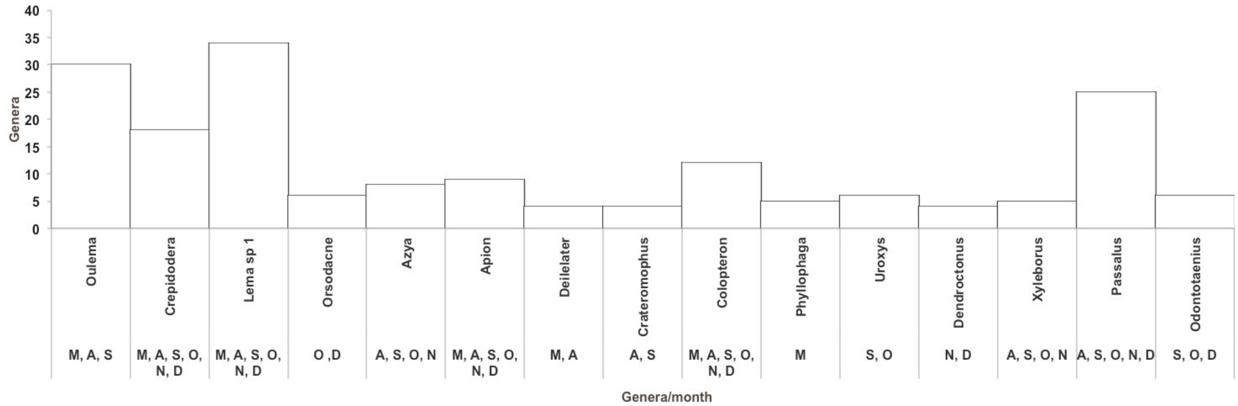

Figure 7. Most abundant genera at site one throughout sampling period.

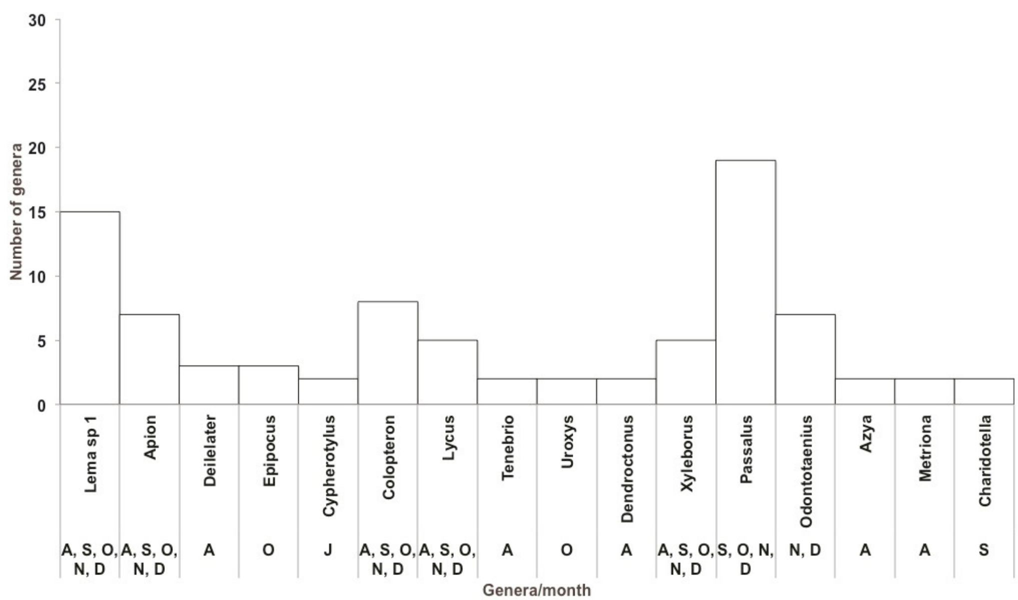

Figure 8. Most abundant genera at site two throughout the months of sampling.

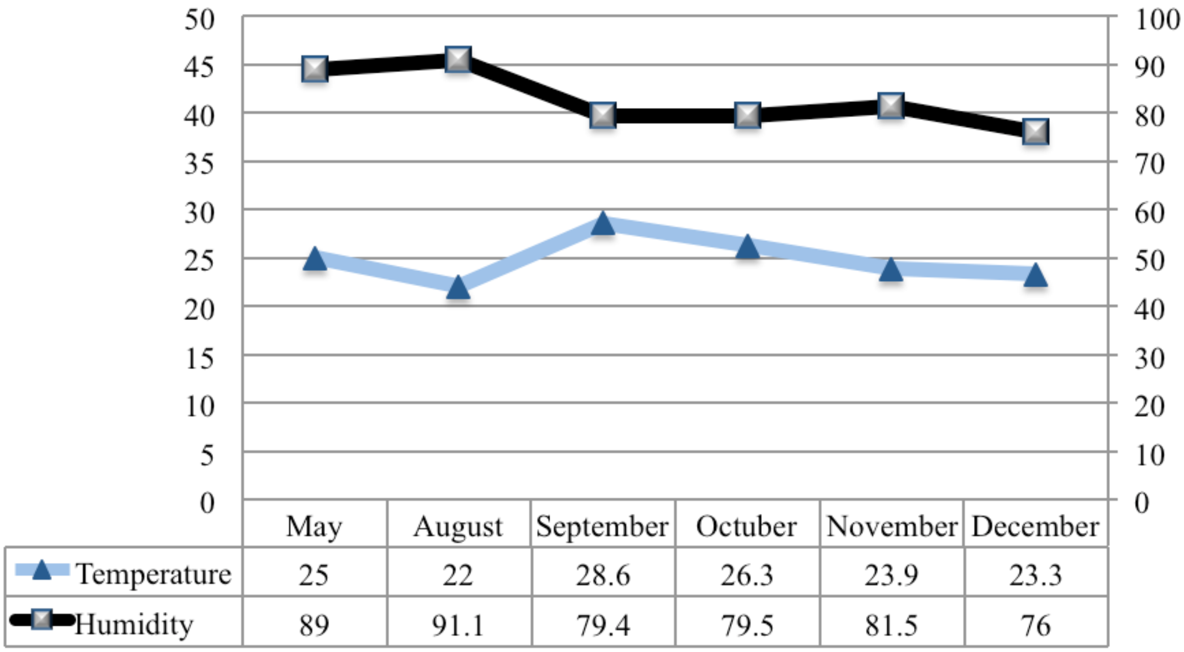

Figure 9. Composite diagram of the variation of temperature and humidity in site one.

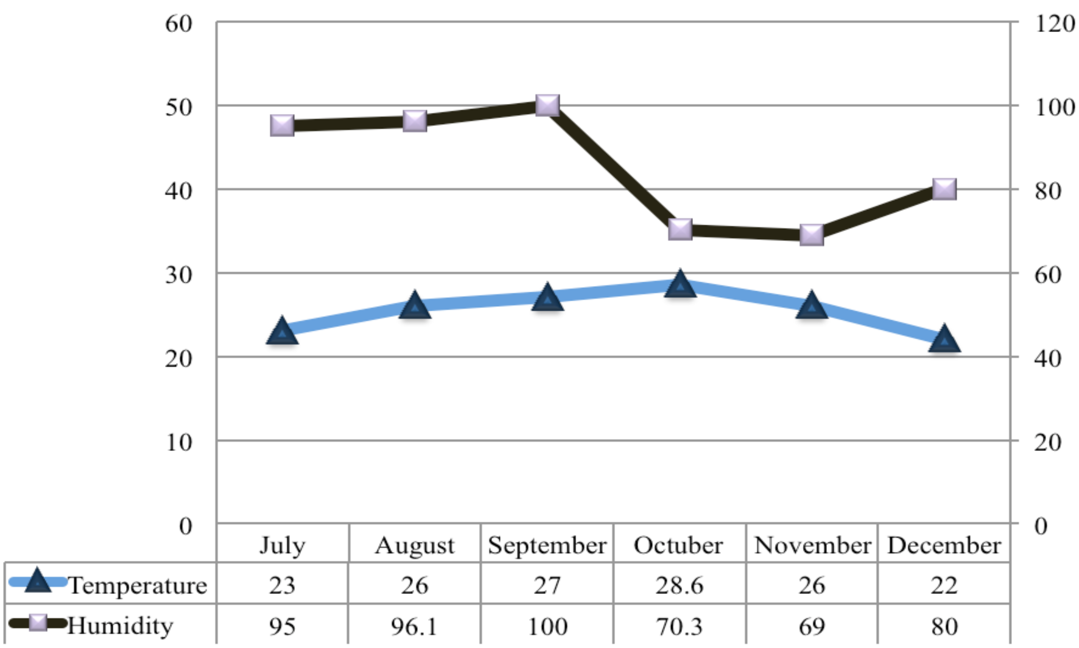

Figure 10. Composite diagram of the variation of temperature and humidity in site two.

Saprophagous and wood boring beetles disintegrate organic matter such as wood, mushrooms and fruits, among others; phytophagous control weeds and shrubs that compete for nutrients with coffee plants; the borers and bark feeding (*Dendroctonus* and *Xyleborus*) could become pests of timber trees found in coffee if strong disturbances occur. Similarly, *Passalus punctatostriatus*, *Spurios bicorni* and *Odontotaenius striatopunctatus* decompose decay wood, enabling the recycling of nutrients.

Finally, the case of *Azya luteipes* is very interesting; in the literature it is mentioned as natural enemy of *Coccus viridis* (Green) (Hemiptera) (Perfecto and Vandermeer, 2015). In Paraguay and Brazil *Azya luteipes* is used as biological control for various stages of psyllids in yerba mate fields (Nais, 2008; Barzotto and Alves, 2013).

In terms of the agro-ecological matrix paradigm (Perfecto and Vandermeer, 2008), the main contribution of traditional coffee agroecosystems of Los Tuxtlas is the conservation not just of the beetles found, but also to maintain dynamic processes in which they participate such as fragmentation of flooring materials, recycling of nutrients, as well as predation of potential insect pests. Additionally, these matrices allow the conservation of biogeochemical cycles as water, C and N. However, it is necessary further study of biological cycles of the species found, their relationship to environmental factors, human management and their ecological relationships.

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