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Rove diversity (coleoptera: Staphylinidae) in six coffee agroecosystems of Central Valley of Costa Rica

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Abstract

The family Staphylinidae is second family belonging to the Order Coleóptera, with most (47 744) described species. The rove beetles are insect ecologically significant, carrying out different roles in agroecosystems; in many cases as predators of agricultural pest. Between March of 2007 and October of 2008, samples of these coleopterans were carried out in six coffee agroecosystems belonging to Central Valley of Costa Rica. The sampling consisted in the Quadrat Sampling Method, in this method a wood quadrat (0,5 x 0,5 m) was placed around coffee plants, where litter was collected and subsequent it was sieved and placed into Berless funnels to insect extract. Analyses of the components of biodiversity for the species, were carried out, calculating biological diversity index (Shannon-Wiener), species evenness, Margalef richness, Jaccard similarity index, non-metric multi-dimensional scaling (MDS) and analysis of similarities (ANOSIM) as well.

A total of 1406 specimens were captured. Of these, 382 (27,17%) were collected in Palmares, 355 (25,25%) in Tres Ríos Sombra, 212 (15,08%) in Barreal Sol, 183 (13,02%) in Barreal Sombra, 161 (11,45%) in Tres Ríos Sol and 113 (8,04%) in Naranjo.

Ten species determined and five undetermined belonging to seven subfamilies were caught. According to the biological diversity analysis, Palmares shows the highest richness of rove beetles in the sampled places.

Staphylinidae, agroecosystems, quadrat, biodiversity.

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Introduction

The coffee industry is an activity of great economic importance in Costa Rica. Current market trends and requirements regarding the production and marketing of coffee in the world has seen the need for a more conservationist, friendly agriculture with the environment and with less use of external inputs, resulting in a coffee of highest quality and differentiated. Which is why, in recent years sustainable agriculture, has appeared as a way to maintain the productivity of agro-ecosystems, preventing the degradation of natural resources. So from an ecological perspective, there is a need to develop incentives for farmers to adopt alternative production systems that generate fewer negative effects on the environment.

Invertebrates in the fields play an important role as partners to determine the biodiversity of agro-ecosystems (Fuller et al 1995;. McCracken and Bignal 1998). The soil invertebrate fauna, including many groups of predators such as ground beetles and rove beetles, which play an important role in the natural control of pests. Increasing natural predation of pests through a more conservation farming, resulting in a reduction in pesticide use (Marasas et al., 2001).

Introducing shade trees in coffee system has a number of advantages such as improved aeration, drainage and soil fertility. According to Rice and Ward (1996) coffee cultivation associated with shade trees can act as shelter for some biodiversity and migratory and resident birds, insects, reptiles, mammals, among others.

Also Moguel and Toledo (2004), point to the importance of conserving the diversity being between 84 and 184 species of birds and 609 species of arthropod to in shade coffee.

Also, the incorporation of trees in coffee plantations may favor several groups of insects, which can achieve high levels of diversity in shaded plantations, among which highlights the Coleoptera (Nestel et al. 1993) order. In this group stands the family Staphylinidae, which is the second largest family of beetles with known number of species 47.744 (Bouchard et al. 2009). This family is distributed worldwide and is found in virtually all types of ecosystems. About half of rove beetles are found in mulch, becoming one of the most common and ecologically important insects of the soil fauna (Bohac 1999).

Staphylinidae most specific are known as predatory mites feeding on, collémbolos, nematodes and small insects and larvae; it can be used as potential drivers of some herbivorous insects (Bohac 1999; Bouchard et al. 2009). So far few studies have been developed in Costa Rica, to assess biodiversity in agro staphylinids coffee. So from the perspective of conservation agriculture, knowledge of biodiversity in the coffee agro staphylinids and functionality necessary; since some genres they might be acting as agents of biological control of pests, especially the coffee berry borer (*Hypothenemus hampei* (Ferrari).) Also staphylinids can be used as bio-indicators of environmental state and particularly of human influence agroecosystems (Bohac 1999). The objectives of this research is the identification of genres Staphylinidae species, collected in six agro coffee in the Central Valley of Costa Rica, to analyze the biodiversity present in each of the sampled sites and evaluate the possible effect of shade trees in coffee plantations staphylinids on biodiversity.

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Materials and methods

Location

The research was conducted in six different coffee agroecosystems belonging to the Central Valley of Costa Rica (Table 2). Within which they were handled entirely conventional systems and other managed alternately with different types of shade trees (Table 1).

Locality	Management	Altitude (m)	geographical coordinates	Average annual precipitation (mm)	Species shadow
three Rivers	Sun	1432	"lat 9,54836ºN", "long 83,58850ºW"	2 690,95	no
three Rivers	Shadow	1385	"lat 9,55072ºN", "long 83,59214ºW"	2 690,95	Eucalyptus deglupta, Inga sp.
Barreal	Sun	1010	"lat 9,58070ºN", "long 84,08574ºW"	1 543,35	no
Barreal	Shadow	1019	"lat 9,58010ºN", "long 84,08558ºW"	1 543,35	Eucalyptus deglupta
Palmares	Shadow	970	"lat 10,03120ºN", "long 84,25014ºW"	2 647,4	Erythrina sp., Inga sp., Gliricidia sepium, Dracaena fragrans (L) Ker-Gawl, Yucca Baker guatemalensis 1872.
Orange tree	Sun	1035	"lat 10,05381ºN", "long 84,22793ºW"	2 647,4	no

Table 1 Location of management systems and shade species used

For better understanding of the data in the following tables, the following abbreviations are used: TrSol, TrSombra, BSOL, BSombra, PSombra, nsol mean Tres Rios Sol, Three Rivers Shadow, Sun Barreal Barreal Shadow, Palmares and Naranjo, respectively.

Sampling

The samples were taken monthly from March 2007 to October 2008, so that each system was sampled a total of 20 times.

In each of the sites described above 10 different points samples they were taken. The first point was set at 100 meters from the entrance of each plot, the rest of the points are taken at random at a distance of 100-200 m between them. For sampling a combination of established methods used by Martin 1977; Bestelmeyer et al. 2000 for the study and sampling of arthropods inhabitants of litter and humus, which consisted of placing a wooden quadrant 0.5 x 0.5 m on the ground and so the coffee plants surround individually. All litter and litter located within the quadrant were collected and deposited in plastic for transport to the laboratory of Entomology at the National University of Costa Rica where they were sieved through a sieve (pore size 3 mm) bags. The resulting material was about 300 g deposited Berlese funnels for three days to extract staphylinids, which were collected in bottles of alcohol (75%).

Taxonomic identification

The specimens taken from each sample were retained and labeled. The species identification was performed at the Center of Studies in Zoology from the University of Guadalajara in Jalisco, Mexico.

Analysis of data

Shannon-Wiener index (H ') of biological diversity were calculated acording to the equation: where pi is the proportion of each species individually in the system, as well as Simpson biodiversity index according to the equation ni is calculated individuals in the species i and n is the total number of individuals.. And equity of Pielou species (J '= H' / H 'max) where H' max = ln (n). And species richness (Margalef) by the equation d = (S-1) / log N, where S = total number of species and N = total number of individuals.

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Jaccard similarity index, which is estimated based on absence-presence of species are also calculated. According to CJ equation j = (a + b - j), where j = Number of species in common between the two sites, a = No species in the first place and b = No. species at the second site. In a complementary way a multidimensional scaling (MDS) and an analysis of similarity of a road (ANOSIM) to detect differences in the structure of communities was held staphylinids.

To counteract the effect of the abundance of zeros one dummy variable is added. In the pretreatment of a square root data for processing data so that the most abundant and rare species had no influence on the analysis it is applied.

For the above software FIRST 6 (Plymouth Routines in Multivariate Ecological Research) Version 6.1.13 and PERMANOVA + Version 1.0.3 (Clarke and Gorley 2006) was used.

Results and discussion

Species composition

1406 individuals, from ten to five indeterminate certain species and seven subfamilies (Table 1) were collected. Indeterminate species could classify only to the level of subfamily. The subfamily with the highest number of species was Staphylininae 6, unlike most of the rest, which presented only two species and in the case of Paederinae, Pselaphinae and Scydmaeninae, which were only represented by a single species (Table 2).

Subfamilies with more individuals were Paederinae with 432 (30.73%), followed by Osoriinae with 333 (23.68%) and Staphylininae 261 (18.56).

Similarly Garcia et al. (2001); Garcia and Chacón de Ulloa (2005) reported 78 species grouped in eight subfamilies, of which Staphylininae Paederinae and were the most abundant and most species richness in dry forests in Colombia. Also, Jiménez Sánchez et al. (2009), an analysis of temporal variation of the diversity of rove beetles in tropical deciduous forest in Morelos, Mexico reported the second highest number of individuals within the Paederinae subfamily.

Gender	subfamily	Frequency	%
Thinocharis sp.	Paederinae	432	30,73
Aneucamptus sp.	Osoriinae	330	23,47
Lissohypnus sp.	Staphylininae	144	10,24
Coproporus sp.	Tachyporinae	123	8,75
Apocellus sp.	Oxytelinae	99	7,04
Indeterminada (Scy)	Scydmaeninae	60	4,27
Paederomimus sp.	Staphylininae	58	4,13
Indeterminada (Pse)	Pselaphinae	56	3,98
Carpelimus sp.	Oxytelinae	41	2,92
Indeterminada (St1)	Staphylininae	35	2,49
Indeterminada (St2)	Staphylininae	18	1,28
Indeterminada (St3)	Staphylininae	4	0,28
Nacaeus sp.	Osoriinae	3	0,21
Philonthus sp.	Staphylininae	2	0,14
Bryoporus sp.	Tachyporinae	1	0,07
Total		1406	100

Table 2 Total number of species, families and individuals Staphylinidae found in coffee systems studied

The distribution of the individuals species was heterogeneous, where *Thinocharis* sp. was the one who had the highest number of individuals with a total of 432 (30.73%), followed by *Aneucamptus* sp. 330 (23.47%). *Lissohypnus species* sp., *Coproporus* sp. and *Apocellus* sp., showed similar abundance between them. On the other hand species with fewer individuals they accounted for an undetermined species (St3), *Nacaeus* sp., *Philonthus* sp. and *Bryoporus* sp. each with less than 1% of all individuals.

When comparing the number of species identified for each of the systems, it shows that three of them (BSOL, BSombra and PSombra) had twelve species, followed by TrSol eleven species. On the other side they presented nsol TrSombra and only ten species each.

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A total of nine common species, *Apocellus* sp., *Carpelimus* sp., *Coproporus* sp., Indeterminate (PSE) Undetermined (SCY), *Lissohypnus* sp., Paederomimus sp. occurred in the six study sites which were *Aneucamptus* sp.. and *Thinocharis* sp. (Table 3). Moreover, the species *Philonthus* sp. and *Bryoporus* sp. they were present only in TrSol and BSombra respectively. For other systems no exclusive species was found.

The appearance of the species *Philonthus* sp. in TrSol, may be due to environmental conditions present in the system as a management system under the sun, the temperature of the soil surface and stubble this is usually higher compared to a shadow system. According to Hofmann and Mason (2006), a species belonging to the same genus as is the case *Philonthus cognatus* is an inhabitant of soils with high temperatures and high degree of compaction.

	agroecosystem											
	TrSol		TrSombra		BSol		BSombra		PSombra		NSol	
Gender	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Thinocharis sp.	65	40,37	241	67,89	21	9,91	16	8,74	73	19,11	16	14,16
Aneucamptus sp.	26	16,15	31	8,73	93	43,87	87	47,54	76	19,90	17	15,04
Lissohypnus sp.	15	9,32	17	4,79	17	8,02	37	20,22	39	10,21	19	16,81
Coproporus sp.	3	1,86	7	1,97	30	14,15	18	9,84	63	16,49	2	1,77
Apocellus sp.	13	8,07	10	2,82	15	7.08	4	2,19	31	8,12	26	23,01
Indeterminate (SCY)	9	5,59	11	3,10	12	5,66	13	7,10	7	1,83	8	7,08
Paederomimus sp.	19	11,80	18	5,07	7	3,30	1	0,55	5	1,31	8	7,08
Indeterminate (PSE)	7	4,35	7	1,97	6	2,83	1	0,55	23	6,02	12	10,62
Carpelimus sp.	1	0,62	12	3,38	5	2,36	3	1,64	16	4,19	4	3,54
Indeterminate (St1)	0	0	0	0	1	0,47	0	0	34	8,90	0	0
Indeterminate (ST2)	1	0,62	0	0	2	0,94	0	0	14	3,66	1	0,88
Indeterminate (St3)	0	0	0	0	3	1,42	1	0,55	0	0	0	0
Nacaeus sp.	0	0	1	0,28	0	0	1	0,55	1	0,26	0	0
Philonthus sp.	2	1,24	0	0	0	0	0	0	0	0	0	0
Bryoporus sp.	0	0	0	0	0	0	1	0,55	0	0	0	0

Table 3 absolute and percentage numbers Staphylinidae species found in the six coffee systems. Heredia, Costa Rica. 2009

The structure of dominance and roles staphylinids species varied depending on the type of management and the geographic location of the plantation. The most abundant species in the system and TrSombra TrSol was *Thinocharis* sp. While in the BSOL, BSombra PSombra systems and the most abundant species was *Aneucamptus* sp. Furthermore *Apocellus* sp. It was the dominant species in nsol (Table 3). These species showed a clear dominance in each system evaluated with respect to other species found within the system, in this case, it is possible that these species are mostly using available resources, compared to the rest which gives them a competitive advantage to increase their populations in the systems evaluated. Opposite situation seen in the case of PSol, where the effect of higher plant diversity of shade trees is reflected in better balance between species of rove beetles showing no clearly dominant species in the system, where the diversity of resources available within the system allows community structure more stable staphylinids. This related to other factors such as type of operation, characteristics, in situ that may have influenced the dominance and abundance of rove beetles.

	agroecosystem					
	TrSol	TrSombra	BSol	BSombra	PSombra	NSol
No. species	11	10	12	12	12	10
No. individuals	161	355	212	183	382	113
% Of individuals	11,45	25,25	15,08	13,02	27,17	8,04
Margalef richness	6,36	4,75	6,73	7,62	5,17	7,44
Equity Pielou	0,83	0,78	0,86	0,77	0,90	0,91
Shannon-Wiener	2,00	1,8	2,14	1,92	2,25	2,09

Biodiversity staphylinids

Systems with greater number of individuals were PSombra staphylinids (382) followed by TrSombra (355) and third BSOL (212). According to Shannon-Wiener index (Table 4), Pal shows the highest value of species diversity with a value of 2.25, followed by BSOL and nsol (2.14 and 2.09 respectively).

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The highest values of richness (Margalef index), which had BSombra (7.62) and nsol (7.44), presenting these two sites more functional relationship between number of species compared to the total number of individuals. The sites with greater equity corresponded to nsol (0.91) and PSombra (0.90), there being a higher proportion in terms of rove beetles species in those in the communities; It is all species in these similar sites in the number of individuals. Two of the remaining systems (BSOL and TrSol) presented intermediate values of equity analysis values of 0.86 and 0.83, respectively.

The most diverse agricultural ecosystem according to Shannon-Wiener index is PSombra, which significantly exceeded the other systems evaluated. These results may be related to a greater diversity of shade trees in this system, accompanied by high precipitation regimes since according to Buse and Good (1993), the increasing diversity of habitats, it may result in increased diversity of rove beetles.

The greatest diversity in PSombra, indicates that most of rove beetles prefer sites with high moisture content and a greater diversity of plant species and litter, which provides favorable environmental conditions and greater resources available for settlement in that system. These families of beetles are commonly found in nature, particularly in terrestrial habitats with wet conditions. (Bouchard et al. 2009).

Biodiversity values show that the resources provided by the PSombra system favors different species of rove beetles occupy these habitats and abundant display them. According to Frank and Thomas (2008) these insects prefer damp places, living on leaves, forest soils and other places with high organic matter content.

As well as several adults and larvae of rove beetles are associated with flowers. Therefore greater diversity and species composition in the coffee brings different micro habitats and different resources for the arrival of rove beetles and other organisms and insects, which could be directly related to the eating habits of this family of beetles. Also this could be due to other factors not analyzed in this research as altitude, physical and chemical soil characteristics, degree of erosion, farming practices, temperature, topography, vegetation of the area, wind), among other biotic and abiotic factors that could impact directly or indirectly on the abundance and diversity of staphylinids in coffee agroecosystems evaluated. About Jiménez Sánchez et al. (2009) mentions that at a local level, environmental variables such as altitude, slope, sunlight and water retention capacity of the soil, explaining changes in the structure and composition of vegetation. All these biotic and abiotic factors create a mosaic of microhabitats with differences in structure and composition of flora and fauna. In Mexico it has been reported that local, Staphylinidae fauna is distributed very unevenly due to variations in humidity, temperature and habitat disturbance (Jiménez-Sánchez et al. 2009).

On the other hand, the presence of high biodiversity in unshaded (BSOL and nsol) sites might be related to habitat preferences of some species.

Species similarity among sites sampled

Comparing species composition between systems, the index used shows that the most similar systems together were the TrSol and agro nsol worth 90.91 (Table 5). These were followed by BSOL and PSombra (84.62), and BSombra TrSombra, TrSombra and PSombra, BSOL and nsol, PSombra and values nsol 83.33 each.

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	Systems					
Systems	TrSol	TrSombra	BSol	BSombra	PSombra	NSol
TrSol	---------					
TrSombra	75,00	------------				
BSol	76,92	69,23	---------			
BSombra	64,29	83,33	71,43	-----------		
PSombra	76,92	83,33	84,62	71,43	-----------	
NSol	90,91	81,82	83,33	69,23	83,33	---------

Table 5 Indices of similarity (Jaccard) species of Staphylinidae in agroecosystems coffee in Costa Rica

By contrast the most dissimilar sites correspond to TrSol and BSombra (64.29), and BSOL TrSombra (69.23), and nsol BSombra (69.23) systems. There was a middle group with values between 71.43 and 76.92. Which indicates that there is a difference in the composition of communities in coffee agroforestry systems staphylinids (with and without shadow), because in most cases the sites were for similar systems under a single management, with it is the If TrSol and nsol?

The chart shows that EMD sites showed different communities staphylinids. Four of agro-ecosystems were grouped into two subgroups formed by TrSol and nsol, PSombra and Bsol. Showing these grouping similarities between peer groups. Conversely completely different sites respects others were BSombra and TrSombra (Fig. 1).

The sites showed differences in the composition of communities of rove beetles (Fig. 1), each site species selectivity.

The *Bryoporus* sp., Scy, and *Nacaeus* sp species. They were the most influential in the community of species in TrSombra staphylinids. Also *Apocellus* sp., PSE, St1, St2, St3 and *Coproporus* sp. They were shown to be most abundant in local conditions and Bsol PSombra. Species like Lissohypnus sp., *Carpelimus* sp. and *Aneucamptus* sp. They showed preference for BSombra and Psombra.

For *Philonthus* sp. and *Paederomimus* sp. They showed a slight dominance under the ecological conditions of TrSol and nsol

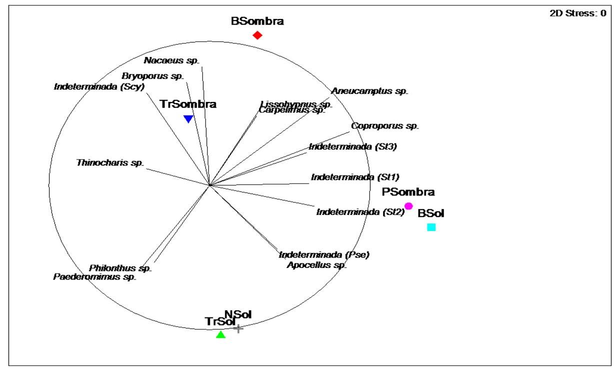

Figure 1 EMD in coffee systems studied. Heredia. Costa Rica

The results of ANOSIM one-way (Table 6) revealed that there were significant differences in the communities of staphylinids in coffee agro Central Valley Costa Rica analyzed (global R: 0.036 p <0.01).; In the individual analysis by pairs of sites only TrSol, BSOL groupings BSOL, BSombra; BSombra, nsol, showed no significant differences between them

Treatments	R Value	P Value
Pairwise		
TrSol, TrSombra	0,034	0,01
TrSol, BSol	0,022	0,02
TrSol,BSombra	0,024	0,01
TrSol, PSombra	0,022	0,01
TrSol, NSol	0,013	0,01
TrSombra, BSol	0,082	0,01
TrSombra, BSombra	0,097	0,01
TrSombra, PSombra	0,04	0,01
TrSombra, NSol	0,091	0,01
BSol, BSombra	0,002	15
BSol, PSombra	0,017	0,01
BSol, NSol	0,021	0,01
BSombra, PSombra	0,03	0,01
BSombra, NSol	0,015	0,02
PSombra, NSol	0,04	0,01

* Based on the similarity index Bray-Curtis.
Number of permutations 9999, overall R: 0.036 p <0.01%

Table 6 Analysis of similarity of a track (ANOSIM) *

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The data observed in the species similarity index, EMD and ratified in ANOSIM can see that there is a difference in the composition of communities in coffee staphylinids agroforestry systems analyzed. These results reflect the distinctive character of the fauna of rove about litter on the floors of coffee, proving that the different elements associated with the production systems, as in the case of vegetation associated with coffee, affects staphylinids communities in Costa Rica.

Understanding the different abiotic and biotic factors affecting the abundance, distribution and biodiversity in general staphylinids, it could be applied to biological control tactics within a system of integrated pest management. Since it has been shown in other crops staphylinids different species act as predators of various pests. For example Collins et al. (2002) showed that staphylinids can reduce aphid populations in cereals.

As for these living species of rove beetles on leaves, in this case the coffee mulch analyzed for their habit some identified here might be preying on larvae of the coffee berry borer, since this insect pest often develops part of its life cycle in the grains left on the ground. According to Varley and Gradwell (1971), *Philonthus decorus* (Gravenhorst, 1802) is a predator which feeds on moth pupae winter (*Operophtera brumata* (Lepidoptera: Geometridae) on the ground.

Therefore eating habits and behavior of some staphylinids identified here is to seek food in places on litter moisture and therefore compete to some degree with the development life cycle of the coffee berry borer on grain left on the floor in coffee systems, which sometimes come to suppress populations of mites and insect pests in different crops (Frank and Thomas 2008).

In general, the importance of staphylinids in relation to the competition with the coffee berry borer is unknown, which is required to conduct research to understand and quantify the significance of this family of beetles on the dynamics of these insect pest populations.

Conclusions

Regarding habits Staphylinidae in coffee systems very little is known in Costa Rica, so this study is try to measure the biodiversity of species belonging to this family and their possible use as biological control agents in these systems. Overall in this study significant differences in the sampled sites were obtained, reflecting the type of management in coffee affects the population dynamics of rove beetles in the soil. In this sense it is necessary to conduct future studies focused on the ecology of rove beetles, identifying detail abiotic and biotic factors which influence their distribution and abundance in coffee and determining which species act as predators of the coffee berry borer.

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